European Commission

Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024

Assistance to the European Commission

TASK 3 PRELIMINARY ANALYSIS OF PRODUCT GROUPS AND HORIZONTAL INITIATIVES
FINAL

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The information and views set out in this study are those of the author(s) and do not necessarily reflect the official opinion of the European Commission.

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- Oeko-Institut e.V.: Unmanned aircrafts (drones), ecological profile, durability, greenhouse covers, market surveillance, non-tertiary coffee machines, tertiary coffee machines, hair dryers, firmware and software, scarce and critical raw materials
- Van Holsteijn en Kemna BV: Professional laundry appliances, professional dishwashers, window products, low temperature emitters, water decalcifiers / softeners, lightweight design, post consumer recycled content, street lighting systems via PV

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ACRONYMS

ABS	Acrylonitrile butadiene styrene	EPD	Environmental Product Declaration
AC	Alternate current/Direct current	EPR	Extended Producer Responsibility
AI	Artificial Intelligence	EPS	External Power Supply
ASTM	American Society for Testing and Materials	EPS	Expanded Polystyrene (foam)
BAT	Best Available Technology	EPTA	(Greek consultant)
BFR	Brominated Flame Retardants	ErP	Energy related product
BLDC	Brushless Direct Current	ETFE	Ethylene Tetrafluoroethylene
bn	Billion	EU	European Union
BNAT	Best Not yet Available Technology	EVA	Ethylene Vinyl Acetate
BOM	Bill of Materials	EVA	European Vending Association
BST	Base stations	EVA-EMP	European Vending Association - Energy Measurement Protocol
CAD	Computer Aided Design	FCM	Food Contact Materials
CBI	Coffee Business Intelligence	FDM	Fused Deposition Modelling
CECED	Conseil Européen de la Construction d'appareils Domestiques (predecessor of APPLIA)	FEM	Finite Element Modelling and Simulation
CEN	Comité Européen de Normalisation	FP7	Seventh Framework Programme (European Union research and development funding programme)
CENELEC	Comité Européen de Normalisation Électrotechnique	GER	Gross Energy Requirement
CFD	Computational fluid dynamics	GHG	Greenhouse Gas
CLASP	Collaborative Labelling and Standards Program (NGO)	GJ	Gigajoules
CLC/TC	Comité Européen de Normalisation Électrotechnique/Technical Committee	GPS	Gel Permeation Chromatography
CLP	Classification, Labelling and Packaging Regulation	GPS	Global Positioning System
CO2e	Carbondioxide equivalent	GPSD	General Product Safety Directive
CoC	Code of Conduct	GRP	Glass-fiber reinforced polyester
CPR	Construction Products Regulation	GS	Geprüfte Sicherheit (Tested Safety)
CRT	Cathode Ray Tube	GWh	Gigawatthours
DC	Direct Current	ha.	Hectares
DIN	Deutsches Institut für Normung (German Standardisation Organisation)	HALE	High altitude, long endurance
DOE	Department of Energy (USA)	HDPE	High-density polyethylene
DR	Drying Rate	HEPS	High Efficiency Performance Standards
DSC	Differential Scanning Calorimetry	HFRs	Halogenated Flame Retardants
EAP	Environment Action Plan	HIPS	High Impact Polystyrene
EASA	European Aviation Safety Agency	HKI	Industrieverband Haus-, Heiz- und Küchentechnik e.V.
EC	Electricity Consumption	HORECA	Hotel, Restaurant, and Catering / Café business
EC	European Commission	ibid.	ibidem (at the same place)
EC	European Community	IC	Integrated circuit
ECHA	European Chemicals Agency	ICAO	International Civil Aviation Organisation
ECOS	European Environmental Citizens Organsation	ICP	Inductively Coupled Plasma mass spectrometry
EEC	European Economic Community	IEC	International Electrotechnical Commission
EEE	Electrical and electronic equipment	IGU	Integrated Glazing Unit
EFCEM	European Federation of Catering Equipment Manufacturers	ISO	International Standardisation Organisation
EIA	Ecodesign Impact Accounting	kton	Kilo tonnes (metric, 1000 tonnes)
EMC	Electromagnetic Compatibility Directive	kW	Kilowatts
EN	European Norm	kWh	Kilowatthours
ENAK	(Swiss association for energy efficiciency in the hospitality industry)	LASE	Low altitude, short endurance
EPA	Environmental Protection Agency (USA)	LCA	Life Cycle Assessment
EPBD	Energy Performance of Buildings Directive	LCC	Life Cycle Cost
LCD	Liquid crystal display	PRODCOM	Production Communautaire (database)

LDPE	Low density polyethelene	PS	Polystyrene
LED	Light emitting diode	PUR	Polyurethane
LIDAR	Light detection and ranging	PVC	Polyvinylchloride
LLCC	Least Life Cycle Costs	RAN	Radio Access Network
LVD	Low Voltage Directive	REACH	Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals
M	Million	RED	Radio Equipment Directive
MAV	Micro-air vehicle	RoHS	Restriction of Certain Hazardous Substances Directive
MEErP	Methodology for the Ecodesign of Energy-related Products	SCIP	Substances of Concern In articles as such or in complex objects (Products)
MEMS	Micro-electromechanical systems	SD	Smart Dust
MEPS	Minimum Efficiency Performance Standards	SEM	Scanning electron microscopy
MJ	Megajoules	SFOE	Swiss Federal Office of Energy
ML	Machine learning	SMEs	Small & medium size entreprises
MoU	Memorandum of Understanding	SVHC	Substances of Very High Concern
MSA	Market surveillance authority	SVHC	Substances of Very High Concern
MSP	Manufacturer selling price	SW	Solid Works (software)
MSW	Municipal Solid Waste	TEC plastics	Technical plastics
Mt	Million tonnes (metric)	TGA	Thermal Gravimetric Analysis
Mt CO2 eq./yr	Megatonnes of CO2 equivalent per year	TGL	Thai Green Label
MWh	Megawatthours	TOTEM	Tool to Optimise the Total Environmental impact of Materials
NAV	Nano-air vehicle	TWh	TeraWatthour
NEMS	Nano electromechanical systems	UA	Unmanned aircraft
NIR	Near Infrared Radiation	UAS	Unmanned aircraft system / Unmanned aerial system
NMR	Nuclear Magnetic Resonance	UAV	Unmanned aerial vehicle
OCS	Office Coffee Service	UK	United Kingdom
PA6	Polyamide (nylon)	USB	Universal Serial Bus
PAH	Polycyclic Aromatic Hydrocarbons	UV	Ultraviolet Radiation
PAR	Photosynthetic Active Radiation	Uw	U-value (insulation value) of window
PAV	Pico-air vehicle	VFF	Verband Fenster + Fassade
PBB	Polybromated Biphenyle	VHK	Van Hosteijn en Kemna
PBDE	Polybromated Diphenyle Ether	VOC	Volatile Organic Compounds
PC	Polycarbonate	W	Watts
PC-ABS	Polycarbonate/acrylonitrile butadiene styrene	WEEE	Waste electrical and electronic equipment
PCR	Polycarbonate recycled	WG	Working Group
PE	Poly-ethylene	Wh	Watthours
PEF	Primary Energy Factor	WP	Working Plan
PEF	Product Environmental Footprint	XRF	X-Ray Fluorescence
PEFCR	Product Environmental Footprint Category Rule	XRM	X-ray microscopy
PET	Polyethylene Terephthalate	µUAV	Micro-unmanned aerial vehicle
PJ	PetaJoules		
PMMA	Polymethyl methacrylate		
PoE	Power over Ethernet		
POP	Persistent Organic Pollutants		
PP	Polypropylene		
PPS	Polyphenylene Sulfide		

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1 INTRODUCTION

This report presents the results of Task 3 'Preliminary analysis of product groups and horizontal initiatives' of the Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024. Task 3 performs analyses of product groups and initiatives selected in Task 2 in terms of sales, trade and stock, resource consumption, technical-economic improvement potential and energy saving potential with respect to the scope of the Ecodesign Directive and the Energy Labelling Regulation. Please notice that Task 3 contains the technical assessments and does not include various other environmental aspects, policy recommendations, etc., which are assessed in Task 4.

Stakeholder comments have been taken into account when preparing this final version.

1.1 The Working Plan study

The European Commission has launched a preparatory study that will inform and assist the Commission in preparing the Ecodesign and Energy Labelling Working Plan 2020-2024 as part of the implementation of the Ecodesign Directive 2009/125/EC[1] and Energy Labelling Regulation (EU) 2017/1369[2]. The study is carried out by Viegand Maagøe, VHK and Oeko-Institut for the European Commission, DG GROW. The study started in March 2020 and is anticipated to be completed by the end of April 2021.

Formally, this is the first combined Ecodesign and Energy Labelling Working Plan to be undertaken following the changes contained in the Energy Labelling Regulation (EU) 2017/1369 (Article 15). However, it should be noted that previous Ecodesign Working Plans informally always kept in mind the possibility of combining Ecodesign and Energy Labelling, where judged appropriate on a product-by-product basis.

The Working Plan study is the first step in a process aiming at publishing implementing measures and acts in the Official Journal. Figure 1 shows a brief overview of the process.

[1] https://eur-lex.europa.eu/eli/dir/2009/125/2012-12-04 (consolidated text)

[2] https://eur-lex.europa.eu/eli/reg/2017/1369/oj

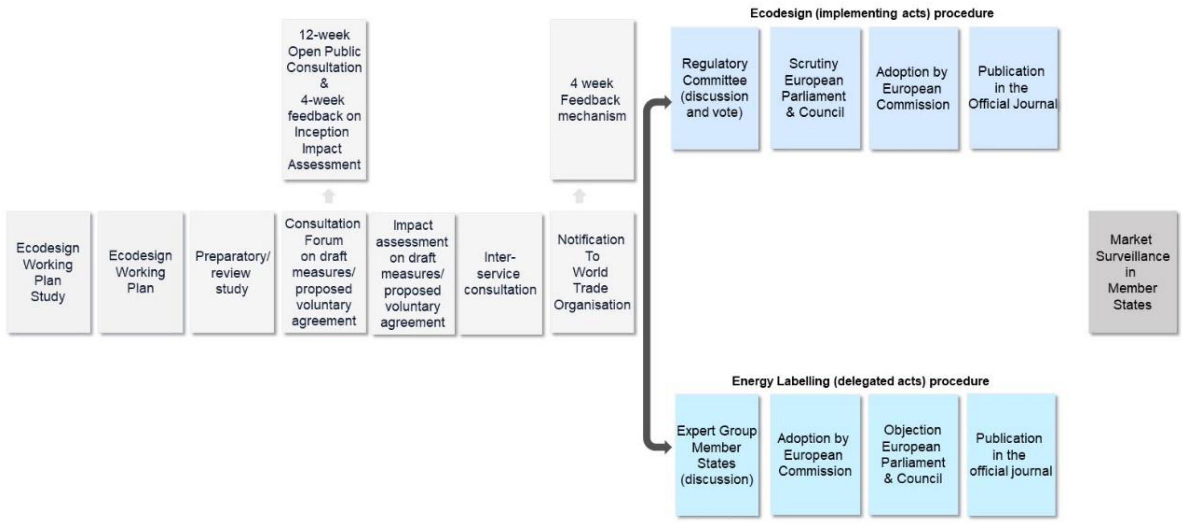

Figure 1: Process for establishing Ecodesign and Energy Labelling implementing measures and delegated acts.

1.2 Objectives

The following objectives of the Ecodesign and Energy Labelling Working Plan 2020-2024 preparatory study have been established:

1. Develop the approach for identification and prioritisation of product groups and horizontal initiatives for the working plan with a view to better take into account environmental impacts in all life-cycle stages and circular economy aspects such as products durability, reparability, recyclability and/or recycled content.

2. Analyse the product groups and horizontal initiatives regarding sales, stock, resource consumption, improvement potential, environmental impacts, regulatory coverage and feasibility, market surveillance impact and industrial competitiveness.

3. Inform and assist the European Commission in its decision-making process to compile the Ecodesign and Energy Labelling Working Plan 2020-2024 with a strong and transparent evidence base derived from scrutinising regulations and available studies, together with a thorough consultation process of relevant stakeholders.

1.3 The study team

The Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024 is carried out by a consortium consisting of:

- Viegand Maagøe A/S (lead)
- Oeko-Institut e.V.
- Van Holsteijn en Kemna BV

The collective experience of the consortium used for this study stems from involvement in European product policy & policy instruments during more than 20 years including:

- Ecodesign directive and energy labelling regulation since the preparatory phases

- Development of the MEEuP / MEErP (Methodology of Energy-using / Energy-related Products)
- Carried out more than 50 preparatory and review studies and impact assessments
- Two previous working plan studies
- EU Energy Star, Green Public Procurement, standardisation
- National Market Surveillance activities
- Ecodesign Impact Accounting
- ICT Impact Study for ENER (included in current Working Plan and a basis for the current study)
- Product design, technical knowledge, circular economy, LCA, scenario modelling, stakeholder consultations, policy instruments, etc.

1.4 Acknowledgements

The study team would like to express our appreciation to the European Commission (DG GROW and the Inter-Service Group (GROW, ENER, ENV, CNECT, JUST)) and to all stakeholders and other persons and organisations we have been in contact with during the study for all input, information and dialogue, which have been very useful for the quality of the work.

1.5 Disclaimer

The information and views set out in this study and in the study reports are those of the authors and do not necessarily reflect the official opinion of the European Commission.

All assumption, estimations, assessments and analyses have been made on the basis of data and information available and the study team's knowledge and experience, and reflecting the aim of the study i.e. to inform and assist the European Commission in its decision-making process to compile the Ecodesign and Energy Labelling Working Plan 2020-2024. Due to the amount of analyses made and the relatively limited resources available for each product group and horizontal initiative, obviously the study team had to focus on the main topics for each product and initiative and to recognise a certain level of uncertainties.

For product groups and horizontal initiatives selected for the Working Plan, detailed analyses will be carried out before any implementing measure will be established and a further policy process will be carried out.

2 PROFESSIONAL LAUNDRY APPLIANCES

2.1 Scope, policy measures and test standards

Professional laundry appliances[3] were the subject of an Ecodesign preparatory study by Bio Intelligence with Öko-Institut in 2011[4]. On the basis of that study and a preliminary impact analysis[5], the Commission discussed the results in the Ecodesign Consultation Forum (CF) 29.11.2013, concluding that there was a significant energy, carbon and water saving potential, no existing measures addressing that potential and that the product group would also otherwise eligible for measures. The main problem was the lack of appropriate measurement standards for this complex and diverse product group. A subsequent CF of 5.5.2014 decided to postpone measures until such test standards were developed[6]. The Commission issued a Standardisation Request[7]. Both CENELEC[8] and CEN[9] created appropriate working groups with a focus on clusters of the Base Cases (BC) products as defined in the preparatory study. The various working groups, monitored by Commission consultants[10], developed a total of 5 standards which have been kept up to date (see the table below).

[3] ETCT, the European Textile Care Technology association suggests “non-houdehold laundry appliances- industrial and commercial appliances”

[4] Rüdenauer, Ina e.a. (Öko-Institut e.V. Institute for Applied Ecology, Germany), Mudgal, Shailendra e.a. (BIO Intelligence Service, France), Seifried, Dieter (Büro Ö-Quadrat, Germany), Preparatory Studies for Eco-design Requirements of Energy-using Products - Lot 24:Professional Washing Machines, Dryers and Dishwashers, 2011

[5] Specific contract of VHK.

[6] May 5, 2014

[7] M/539 COMMISSION IMPLEMENTING DECISION of 11.12.2015 on a standardisation request to the European Committee for Standardisation as regards non-household washing machines, dryers and dishwashers, in support of the implementation of Directives 2009/125/EC and 2010/30/EU of the European Parliament and of the Council

[8] CLC TC59X SWG1.12 Commercial laundry machines,

[9] CEN TC214 WG05 Eco Design ENER Lot 24 Performance Measurement of Washing Machines and Dryer for industrial use

[10] VHK for Ecofys specific contract 2015-2017. From 2018 VHK specific monitoring contract.

Table 1. Base Cases and standards developed by CEN and CENELEC by appliance type

Type of appliance	CEN TC214 WG05	CLC TC59X SWG1.12	CLC TC59X WG2.1
Washing Machines			
WM1: Semi-professional washer extractor		EN 50640:2018[11]	
WM2: Professional washer extractor, <15 kg			
WM3: Professional washer extractor, 15-40 kg			
WM4: Industrial washer extractor, >40 kg	EN 17116-4:2019[12]		
WM5: Industrial washer dryer			
WM6: Industrial barrier washer in EN 17116-4			
WM7: Tunnel washer	EN 17116-3:2019[13]		

Type of appliance	CEN TC214 WG05	CLC TC59X SWG1.12	CLC TC59X WG2.1
Dryers			
D1: Semi-professional dryer, condenser			
D2: Semi-professional dryer, air vented			
D3: Professional cabinet dryer			
D4: Professional tumble dryer, <15 kg		EN 50594:2018[14]	
D5: Industrial tumble dryer, 15-40 kg			
D6: Industrial tumble dryer, >40 kg	EN 17116-2:2019[15]		
D7: Pass-through (transfer) tumble dryer			

Test standards

The test standards that are now in place will cover, as subsequent sections will show, over 90% of unit sales and environmental impact. The CENELEC standards EN 50640 and EN 50594 focus on laboratory testing of smaller sizes, whereas the CEN 17116-series deal with on-site assessment of large appliances. The latter raises questions with regards to accuracy, reliability and reproducibility of the test- and calculation methods. With the acceptance and implementation of the test standards, however, the possibility of collecting and assessing comparable data is deemed possible by stakeholders.

Further standardisation activities

CLC TC59X SWG1.12, responsible for the development of test standards for professional laundry equipment, is preparing a Round-Robin Test RRT[16].

As a response to the standardisation request (M/539) both CEN and CENELEC have put considerable effort in the development of the mentioned standards. It is expected that the working groups will complete RRTs expediently when the Commission continues its efforts in preparing Ecodesign measures.

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[11] EN 50640:2018 Household and similar electric appliances - Methods for measuring the performance of clothes washing machines intended for commercial use (successor of prEN 50640:2017)

[12] EN 17116-4:2019 Specifications for industrial laundry machines - Definitions and testing of capacity and consumption characteristics - Part 4: Washer-extractors (successor of EN 17116-4:2017)

[13] EN 17116-3:2019 Specifications for industrial laundry machines - Definitions and testing of capacity and consumption characteristics - Part 3: Continuous tunnel washer (successor of EN 17116-3:2017)

[14] EN 50594:2018 Household and similar electric appliances -Methods for measuring the performance of tumble dryers intended for commercial use (successor of prEN 50594:2017)

[15] EN 17116-2:2018 Specifications for industrial laundry machines - Definitions and testing of capacity and consumption characteristics - Part 2: Batch drying tumblers (successor of EN 17116-2:2017)

[16] CLC TC59X/SWG1.12 – meeting minutes September 13, 2017. A RRT is a test where the same product is subsequently tested by a series of different laboratories to check for reproducibility and repeatability of test results.

Lateral legislation

Since 2016, under the European Commission EMAS programme, optimised large-scale or outsourced laundry operations are part of the Best Environmental Management Practice for Tourism (BEMP).[17] EMAS-registered organisations in the tourism sector shall take the relevant sectoral reference documents into account.

2.2 Market

The table below shows estimated unit sales and stock of professional wet appliances, following data from the preparatory study[4] and the Eurostat PRODCOM statistics.
In 2010, the products in the scope represented a sales volume of ~114 000 units per year and a market of 0.65 billion euros in consumer prices. Following the preparatory study, it is assumed that sales for laundry equipment by 1% per year, which leads to sales of 126 000 units in 2020 and 139 000 units in 2030.

The 2010 installed stock of products in the scope was 1.2 million units, of which 0.86 million washing machines and 0.34 million driers. In 2020 the stock is expected to be 1.33 million units and in 2030 almost 1.5 million units. [18]

Table 2. Sales and stock (in 1000 units)

	Sales (units x 1000)					Stock (units x 1000)				
Year	**1990**	**2000**	**2010**	**2020**	**2030**	**1990**	**2000**	**2010**	**2020**	**2030**
GENERAL TOTAL	***96***	***103***	***114***	***126***	***139***	***989***	***1092***	***1207***	***1332***	***1472***
1. Non-household washing machines	**68**	**75**	**83**	**92**	**102**	**709**	**783**	**865**	**955**	**1055**
Washer-extractors < 40kg (WM1/2/3)	67.2	74.2	82.0	90.5	100.0	695	767	848	936	1034
Washer-extractors > 40kg (WM4/6)	1.0	1.1	1.2	1.3	1.4	13	14	16	17	19
Tunnel washer (WM7)	0.10	0.11	0.12	0.13	0.15	1.2	1.3	1.5	1.6	1.8
2. Non-household dryers	**28**	**28**	**31**	**34**	**37**	**280**	**309**	**342**	**377**	**417**
Condensor dryer (D1)	2.8	3.1	3.4	3.7	4.1	21	24	26	29	32
Air vented tumble dryer < 40kg (D2/4/5)	20.9	23.1	25.5	28.2	31.1	242	267	295	326	361
Air vented tumble dryer > 40kg (D6)	3.5	0.3	0.3	0.4	0.4	3.5	3.6	3.9	4.4	4.8
Pass-through dryer (D7)	1.1	1.2	1.3	1.4	1.6	13	14	16	17	19

[17] Commission Decision (EU) 2016/611 of 15 April 2016 on the reference document on best environmental management practice, sector environmental performance indicators and benchmarks of excellence for the tourism sector under Regulation (EC) No 1221/2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS) (notified under document C(2016) 2137), OJ L 104, 20.4.2016, p. 27–69

[18] Pre-corona estimates.

For the professional laundry appliances the market in manufacturer selling price (msp) was around 460 million Euros in 2018[19] with important players like Electrolux, Girbau, Kannegiesser, Miele Professional, Jensen and Primus. Extra-EU trade level for professional laundry equipment is relatively high at around 70%.
The dominant types in each category, in terms of units installed, are washer-extractors <40 kg (98% of washer units installed) and air-vented driers <40 kg (86% of drier units installed). The "design lifetime" calculated in the preparatory study[4] is in the order of 8 years for the commercial appliances and 14-17 years for the industrial appliances (>40 kg, tunnel-washers and pass-through driers).

2.3 Usage

The typical applications of laundry equipment can be identified by:

- **Coin & Card Laundry**: laundrette, camping, student dorms, etc..
- **Shared Laundry Room:** household, real estate, old people's homes etc; the users are not the owners and therefore safety, easy handling and Total Cost of Ownership are the most important issues.
- **Hospitality** hotels, restaurants, quick service restaurants etc.
- **Healthcare Laundry**: regular hospitals, nursing homes.
- **Hospitals** with very high hygiene demands
- **Nursing Homes** with hygiene demands
- **Commercial & Industrial:** service providers, textile rent cleaning, small or heavy duty laundries etc.
- **Speciality Laundry** including high-tech industries (mops, functional garments like fire and rescue service, pharmaceutical and electronic factories).

Linking customers typology directly with Base Cases is done in the preparatory study[4] as can be seen in the figures below.

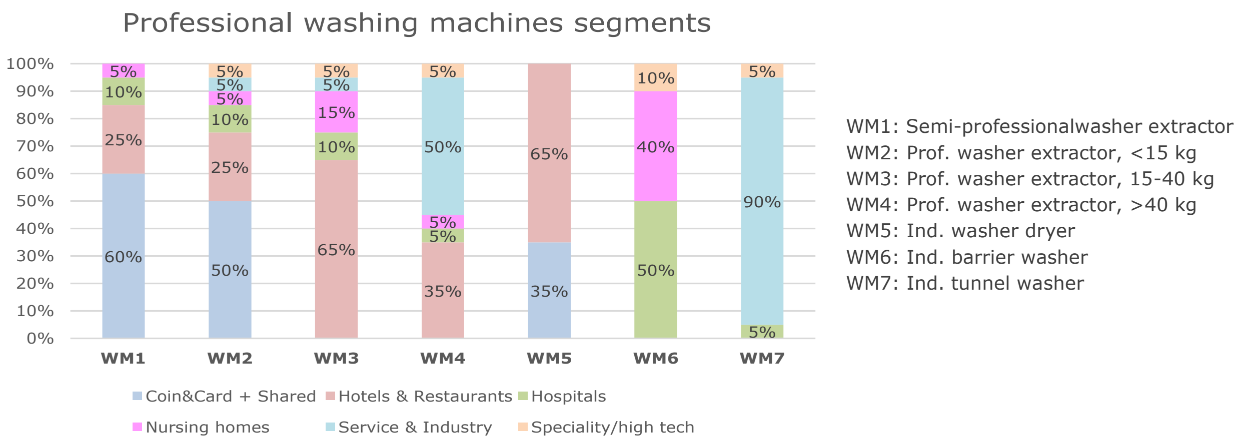

Figure 2. Professional washers segments

[19] Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data [DS-066341]: 28942230 - Household or laundry-type washing machines of a dry linen capacity > 10 kg (including machines that both wash and dry) AND 28942270 - Drying machines, of a dry linen capacity > 10 kg (PRODVAL)

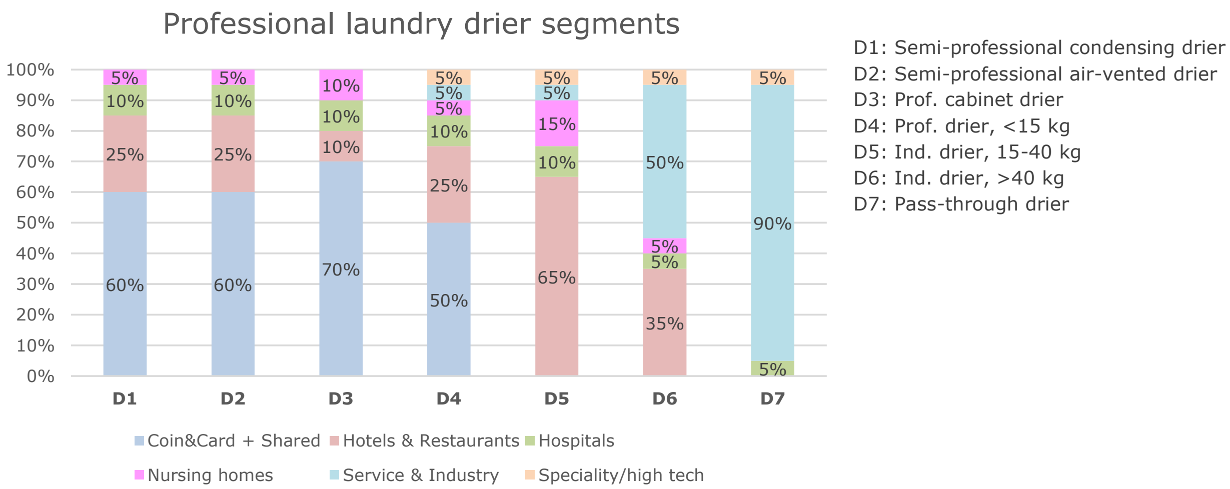

Figure 3. Professional laundry drier segments

Saving energy and water use is valued in the market of professional washing machines: the average energy consumption of professional washing machines in the EU has decreased by approximately 25 to 40% between 2000 and 2010[4].

Water consumption also decreased over the same period: the average water consumption of professional washing machines has decreased by approximately 7 to 50%[4].
Dryers show a less steep decrease in energy use over the same period: the average energy consumption of dryers sold in the EU has decreased by approximately 18 to 26%[4].

Until 2011, energy and water consumption tend to become more efficient as a result of competition in the market; companies strive to offer better products to their clients and more efficient use of water and energy make their products more attractive. On average energy consumption of state of the art products decreased with 10-40% over the 2000-2010 period[4]. The development from 2010 untill now has to be investigated. Water use tends to decrease with 15-35%[4]. On the other hand, there are many market segments where acquisition costs prevail and policy measures can move the market towards energy efficiency. Typical usage parameters for laundry equipment are summarized in Table 3[4].

Table 3. Usage parameters (tertiary sector)

Category	Cost items	Units	Value
Purchase	Purchase price	Euros/product	800–500.000
Purchase	Delivery and installation	% of product price	4 (9 for heavy duty)
Use	Electricity rate	Euros/kWh	0.090–0.138
Use	Gas	Euros/GJ	8.79–11.21
Use	Water rates	Euros/m^3	2.64
Use	Detergent	Euros/kg	2 -3
Use	Interest-inflation rate	%	4
Maintenance	Servicing and repair	% of product price	3–25
Disposal	Removal and disposal / recycling	Euros/product	0

For industrial machines the ETCT remarks that for industrial appliances the top priority is use of minimum resources and energy with as little pollutants as possible to reach highest functionality within a limited area among the three objectives: productivity, hygiene and cleanliness.

2.4 Technologies

The pictures below show several products in this group: a dryer, a tunnel-washer and a big washer-extractor.

In the laundry equipment group the smaller capacity units, e.g. up to 40 kg capacity, have a similar built and technology as top-range household machines, with a dominant use of stainless steel for housing, drum and tub. The controls have a limited number of options compared to top-range household machines but are very robust and easy-to-use. The motor is typically more robust, not a universal motor with a belt drive but a sturdy AC motor or --in the more recent models-- a brushless DC with variable speed drive. The medium to big-sized washer extractors and driers, with load-capacity of up to 100 kg, often have special provisions to enhance ergonomic loading. In a 2017 EMAS-document on optimised small-scale laundry operations in the hospitality sector also options for water re-use and heat recovery are discussed. 20

Figure 4. (From left-to-right) dryer[21], tunnel-washer,[22], big washer-extractor,[23]

A technical discussion of the <u>large</u> laundry operations like tunnel washers is given in a 2017 EMAS reference document, prepared by JRC-IPTS. [20]

[20] Styles D., Schönberger H., Galvez Martos J. L., Best Environmental Management Practice in the Tourism Sector, EUR 26022 EN, doi:10.2788/33972. Extract 5.4 Optimised small-scale laundry-operations, Extract 5.5 Optimised large-scale or outsourced laundry operations. https://ec.europa.eu/environment/emas/takeagreenstep/pdf/BEMP-5.5-FINAL.pdf

[21] https://www.danube-international.com/img/galeria//IMG_5026.JPG, retrieved May 7, 2020.

[22] https://www.milnor.com/wp-content/uploads/2014/06/20140618ARCO-MURRAY-cwww.JackRamsdale.com2481-417x600.jpg, retrieved May 7, 2020.

[23] https://www.domuslaundry.com/img/galeria/dhs-120_touch_tilt-262.jpg, retrieved May 7, 2020.

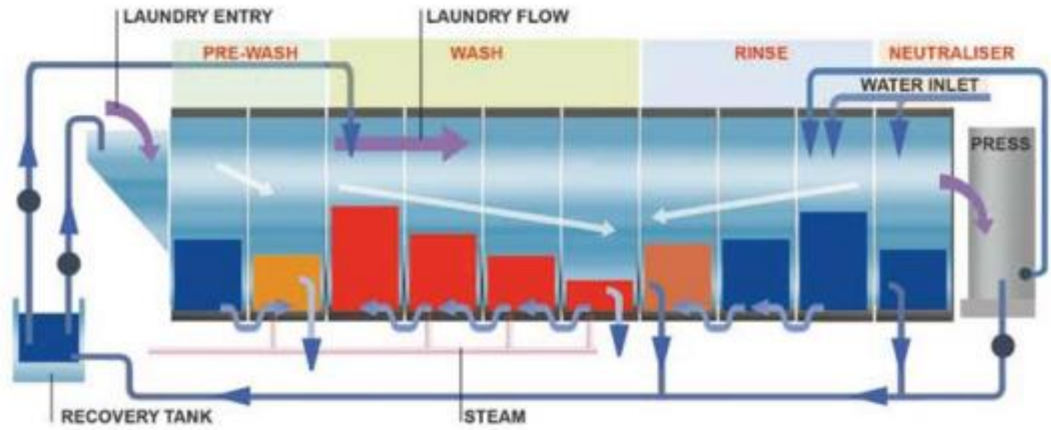

Figure 5. An example of a 10 module continuous batch washer with counter-flow water current and *steam heating (source: Girbaud in EMAS-report)*

Best practice measures are given in Table 4. The EMAS-publications confirm that there is a wide disparity between tunnel washers, which is an important criterion for eligibility regarding Ecodesign measures.

Table 4. Best practice measures for large-scale laundry operations

Stage	Measure	Description
Washing	Optimisation of continuous batch washers	Match water input to batch washing requirements and optimise water cycling through the process to achieve correct water levels and liquor ratios. Monitor and adjust machinery and dosing to minimise textile wear (Hohenstein Institute, 2010).
	Water recycling	In addition to recovery of rinse and press water, wash water may be recycled through a micro-filter system to re-inject into the prewash.
	Heat recovery	Recover heat from steam used in the drying process and waste water to heat incoming fresh water.
Drying	Optimal use	Maximise mechanical drying according to textile type, fully load dryers, and control drying times to terminate at equilibrium moisture content (~ 8 %).
	Maintenance	Ensure adequate dryer insulation, check for leaks, moisture sensor operation, duct blockages, and clean lint from filters every hour (or install automated lint cleaner).
Finishing	Ironer type	Replace old ironers with efficient new ironers (e.g. heating band design) of appropriate width for bedclothes, and ensure adequate insulation and maintenance to avoid steam leaks.
	Optimal loading	Install semi-automatic loader, adjust roller timing to achieve final textile moisture content in equilibrium with atmospheric conditions after single pass.
	Minimise energy use in tunnel finishers	Minimise heating time for textiles to reach maximum drying temperature, and decrease temperatures in subsequent zones to maintain this temperature. Recirculate hot air and ensure adequate insulation of tunnel. Aim for final textile moisture content in equilibrium with atmospheric conditions.
	Minimise chemical use for finishing	Avoid, or if not possible, minimise, the use of waterand dirt-repellent chemicals.

Entire process	Optimisation through water and heat recovery, and maintenance	Optimise the entire laundry process. Recover heat from flue-gas to heat steam feeder water, recover heat from dryer/ironer steam and waste water to heat CBW inflow. Ensure entire distribution network is insulated, inspected and maintained to prevent leaks (install automatic leak detection system).

Other EMAS recommendations are to try to encourage guests to re-use towels, set the right wash programmes, use environmentally friendly detergents, etc..

2.5 Energy, Emissions and Costs

Energy, emission and monetary costs are given in the tables below. A straightforward stock model, using the applicable estimated product life was used. Many appliances use both fuel (e.g. gas for water heating and/or drying) and electricity (e.g. drum motor, pumps, fans), both translated in primary energy equivalent for the EU[24].

Table 5. Resources input use-phase and cleaning output

Annual input and output, EU 2010	ENERGY INPUT			OTHER INPUT		OUTPUT
	elec-tri-city	**fuel**	**primary energy**	**water**	**de-ter-gent**	**clean laun-dry**
	A	B	2.5*3.6*A +B			
unit	*TWh elec*	*PJ prim*	*PJ prim*	*Mm³*	*kton*	*Mt*
GENERAL TOTAL	***4.01***	***110***	***147***	***283***	***376***	***ca. 20 Mt laundry***
						Mt
1. Non-household washing machines	**1.54**	**22**	**36**	**283**	**376**	**20.1**
Washer-extractors < 40kg	1.36	9	21	217	287	13.1
Washer-extractors > 40kg	0.12	2	4	24	28	1.3
Tunnel washer	0.06	11	12	42	61	5.7
						Mt
2. Non-household dryers	**2.47**	**88**	**111**	-	-	**20.1**
Condensor dryer	0.13	0	1.2	-	-	0.2
Air vented tumble dryer < 40kg	1.28	14	26	-	-	5.3
Air vented tumble dryer > 40kg	0.09	3	4	-	-	0.7
Pass-through dryer	0.97	71	79	-	-	14.0

[24] Note that the tables were calculated in the 2013-2014 preliminary VHK impact analysis with the primary energy factors at the time (pef 2.5 for electricity) . If this product group is selected, the preparatory/impact studies should update not only for increase in base data but also for reduction of the primary energy factor for electricity, which was recently changed from 2.5 to 2.1, and the fact that Croatia entered and the UK has left the EU28 (13% less EU-population).

The next table gives greenhouse gas emissions (in CO2 equivalent GWP-100) and NOx emissions. [25]

Table 6. Greenhouse gas and NOx emissions of products in the scope, EU 2010.

Selected Emissions EU 2010	**GHG** MtCO2 eq./a	**NOx** kton/a
Total	***9.2***	**7.9**
1. Non-household washing machines	**2.2**	**1.6**
Washer-extractors < 40kg	1.3	0.65
Washer-extractors > 40kg	0.2	0.17
Tunnel washer	0.7	0.78
2. Non-household dryers	**7.0**	**6.3**
Condensor dryer	0.1	0.00
Air vented tumble dryer < 40kg	1.6	1.02
Air vented tumble dryer > 40kg	0.2	0.21
Pass-through dryer	5.1	5.04

Other possible environmental impacts relate to the use of detergents, or in certain cases the re-use of detergents and water. As >90% of the machine-weight is made up of metals, notable stainless steel, full recycling can be expected. As far as critical raw materials is concerned, there is some niobium in electric motors, and of course the PCB, dismantled in accordance with WEEE, contains small quantities of valuable materials. There is a lively market for re-use, i.e. refurbished models are offered on specialised sector-websites.
The average acquisition value (including installation) and running costs (energy, water, detergent, maintenance) is given below. The prices for roughly the same functionality may differ a factor two. The same applies to the running costs.

The end-user expenditure in the following table is calculated with the inputs of Table 5.

Table 7. End-user expenditure

End-user expenditure, EU 2010	RUNNING COSTS	ACQUI-SITION	TOTAL

[25] For 2010 calculated with 0.41 kg CO2eq./kWh electricity. In 2020 0.38kg/kWh and 2030 0.34kg/kWh. Gas combustion 0.0561 kgCO2eq./MJ and 200mg/kWh (Gross Calorific Value).

unit	electri-city *bn euros*	fuel *bn eu-ros*	energy total *bn eu-ros*	water *bn eu-ros*	deter-gent *bn euro*	servi-cing *bn eu-ros*	acqui-sition* *bn eu-ros*	 *bn eu-ros*
GENERAL TOTAL	***0.48***	***1.48***	***1.95***	***0.75***	***0.75***	***0.05***	***0.75***	***4.26***
1. Non-household washing machines	**0.18**	**0.30**	**0.48**	**0.75**	**0.75**	**0.03**	**0.54**	**2.55**
Washer-extractors < 40kg	0.16	0.12	0.28	0.57	0.57	0.012	0.43	1.88
Washer-extractors > 40kg	0.01	0.03	0.05	0.06	0.06	0.012	0.05	0.23
Tunnel washer	0.01	0.15	0.15	0.11	0.12	0.011	0.05	0.45
2. Non-household dryers	**0.30**	**1.18**	**1.47**		-	**0.02**	**0.21**	**1.71**
Condensor dryer	0.02	0.00	0.02		-	0.000	0.01	0.02
Air vented tumble dryer < 40kg	0.15	0.19	0.34		-	0.003	0.11	0.45
Air vented tumble dryer > 40kg	0.01	0.05	0.06		-	0.002	0.01	0.07
Pass-through dryer	0.12	0.94	1.06		-	0.019	0.09	1.16

**=including installation*

2.6 Saving potential

The preparatory study has investigated the options for improvement of energy efficiency and concluded a cost-effective savings potential exists.

The technical design options that could bring about such savings were identified in the preparatory studies as follows (note: non-exhaustive):

- More efficient active components, specifically more efficient motors;
- More efficient heating, for instance through the use of heat recovery and heatpumps;
- More efficient static components such as larger air and water heat exchangers etc.;
- Improved product load, residual moisture control and other control components;
- Improved construction aimed at for instance improved air flow, insulation etc.

The technical saving potentials based on the best available technology identified in the preparatory study for non-industrial washing machines and driers says that the energy consumption of washing machines could be reduced by 19% to 35%. For driers the improvements with the best available products are some 25% reduction to 68% .
The water consumption could be reduced by 22% to 50% for washing machines.
One manufacturer remarked that any Ecodesign categorisation should not be based on capacity, e.g. have different limits below and above 40 kg capacity. [26]

[26] Comment Electrolux Professional

The policy option of choice is Ecodesign measures ('ECO' in the table below). As the buyers are professionals, the Energy Label was not considered to have additional value.

The impacts of these measures for the EU in 2030 versus a Business-As-Usual ('BAU') scenario are summarised in the table below.

Table 8. Environmental and economic improvement scenario for the EU in 2030, in a scenario with measures ('ECO') versus Business-As-Usual ('BAU')[27]

impact	**Energy primary**		**of which electric**		**Water**		**GHG**		**Acquisition**		**Expenditure**	
scenario	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU
unit	*PJ*	*PJ*	*TWh*	*TWh*	*Mm3*	*Mm3*	*MtCO2*	*MtCO2*	*bn €*	*bn €*	*bn €*	*bn €*
Total	***169***	***-41***	***4.7***	***-1.3***	***327***	***-82***	***10.4***	***-2.5***	***0.9***	***0.2***	***6.9***	***-1.3***
Non-household washing m.	**42**	**-10**	**1.8**	**-0.4**	**327**	**-82**	**2.5**	**-0.6**	**0.6**	**0.1**	**2.9**	**-0.5**
Washer-extractors < 40kg	24.6	-4.9	1.6	-0.3	251	-60.4	1.4	-0.3	0.5	0.1	2.0	-0.3
Washer-extractors > 40kg	4.1	-0.9	0.1	0.0	28	-8.4	0.2	-0.1	0.1	0.0	0.3	0.0
Tunnel washer	13.3	-4.2	0.1	0.0	48	-12.8	0.9	-0.3	0.1	0.0	0.6	-0.2
Non-household dryers	**127**	**-31**	**2.9**	**-0.9**	**-**	**-**	**7.9**	**-1.9**	**0.3**	**0.1**	**4.0**	**-0.8**
Condensor dryer	1.3	-0.5	0.1	-0.1	-	-	0.1	0.0	0.0	0.0	0.0	0.0
Air vent.tumble dryer < 40kg	29.8	-11.0	1.5	-0.6	-	-	1.8	-0.7	0.1	0.1	1.0	-0.3
Air vent.tumble dryer > 40kg	4.5	-1.5	0.1	0.0	-	-	0.3	-0.1	0.0	0.0	0.1	0.0
Pass-through dryer	91.6	-18.1	1.1	-0.2	-	-	5.8	-1.2	0.1	0.0	2.8	-0.5

Note that since the above projections were made for the EU, in 2014, there have been several events that will have diminished the positive outcome: The UK left and Croatia entered the EU (-13%), the primary energy factor for electricity decreased (from 2.5 to 2.1), not all base cases were covered by the standards and the implementation of measures was delayed by a few years due to the lack of standards.

In summary, the benefits in the year 2030 will be at least 20% less than indicated above, but still considerable:

- 33 PJ (9 TWh) primary energy saving, including 1.1 TWh electricity saving;
- About 66 Mm^3 water saving;
- 2 MtCO2eq carbon saving;
- €0.2 bn higher acquisition costs but €1.3 bn lower expenditure per annum.

These are preliminary assessments, to be refined by adding more exact numbers for the capacity (e.g. kg laundry into 24h, specific consumption in kWh/kg).[28]

[27] Pers. Comm. VHK, 2014.

[28] Comment Miele & Cie KG

2.7 Stakeholder comments

Member State experts from Germany (BAM/UBA) and the Netherlands Enterprise Agency (NEA) have expressed to be in favour of including the professional laundry appliances in the working plan.[29] If there is a choice, NEA would give it a lower priority than ICT products.

ECOS and other stakeholders like the Netherlands RVO agency point out that, even though the buyers are professionals, introducing not only ecodesign requirements but also energy label measures might be appropriate.

Industry association EFCEM asks for enough time to prepare and implement measures in view of the difficult economic times for the sector due to corona.

[29] Stakeholder comments collected by the study team Sept. 2020

3 PROFESSIONAL DISHWASHERS

3.1 Scope, policy measures and test standards

Professional laundry and dishwashing appliances were the subject of an Eco-design preparatory study by Bio Intelligence with Öko-Institut in 2011[30]. On the basis of that study and a preliminary impact analysis[31], the Commission discussed the results in the Ecodesign Consultation Forum (CF) 29.11.2013, concluding that there was a significant energy, carbon and water saving potential, no existing measures addressing that potential and that the product group would also otherwise eligible for measures. The main problem was the lack of appropriate measurement standards for this product group. A subsequent CF of 5.5.2014 decided to postpone measures until such test standards were developed[32].

The Commission issued a Standardisation Request[33]. For dishwashing CENELEC[34] created an appropriate sub-working group CLC TC59X WG2.1 on commercial dishwashers with a focus on clusters of the Base Cases (BC) products as defined in the preparatory study. The work was monitored by Commission consultants[35] and resulted in EN 63136:2019[36]. As will be shown in the next paragraphs, the base cases DW1 and DW2 that the test standard covers, represent over 95% of unit sales and up to 75% of energy- and material consumption of commercial dishwashers in the EU. The base-cases that are not covered represent small sales numbers and/or are also tailor-made and difficult to test in an accurate and reproducible way, i.e. the conveyor-type single- and multi-tank dishwashers (DW4 and DW5). There may be a future case, to be investigated, to include dedicated pot/utensil washers in policy measures, because – although sales numbers are currently small—they might represent an interesting saving option and they are produced in series. The federation of the catering equipment industry EFCEM expresses the opinion that DW1, DW4, DW5 and DW6 should be excluded a priori from the working plan.

Table 9. Base Cases and standards developed by CEN and CENELEC

Type of appliance	CLC TC59X WG2.1
DW1: Undercounter	EN 63136:2019[37]
DW2: Hood-type	
DW3: Utensil/Pot (drafts are known)	To investigate
DW4: Conveyor-type one-tank	

[30] Rüdenauer, Ina e.a. (Öko-Institut e.V. Institute for Applied Ecology, Germany), Mudgal, Shailendra e.a. (BIO Intelligence Service, France), Seifried, Dieter (Büro Ö-Quadrat, Germany), Preparatory Studies for Eco-design Requirements of Energy-using Products - Lot 24:Professional Washing Machines, Dryers and Dishwashers, 2011

[31] Specific contract of VHK.

[32] May 5, 2014

[33] M/539 COMMISSION IMPLEMENTING DECISION of 11.12.2015 on a standardisation request to the European Committee for Standardisation as regards non-household washing machines, dryers and dishwashers, in support of the implementation of Directives 2009/125/EC and 2010/30/EU of the European Parliament and of the Council

[34] CLC TC59X SWG1.12 Commercial laundry machines, CLC TC59X WG2.1 Commercial dishwashers

[35] VHK for Ecofys specific contract 2015-2017. From 2018 VHK specific monitoring contract.

[36] EN 63136:2019 Electric dishwashers for commercial use - Test methods for measuring the performance (successor of EN 50593:2017)

[37] EN 63136:2019 Electric dishwashers for commercial use - Test methods for measuring the performance (successor of EN 50593:2017)

Future standardisation activities

CLC TC59X WG2.1, responsible for development of standards for commercial dishwashers, carried out a Round Robin Test (RRT)[38] that resulted in high variations between test labs and therefore low reproducibility of specifically cleaning performance, resoiling performance and the "Pass and Fail – criteria limit". Several proposals for investigating the possibilities for improvements are planned[39].

As a response to the standardisation request (M/539), CENELEC has put considerable effort in the development of the test standard. It is expected that the working group will complete Round Robin Tests RRTs expediently when the Commission continues its efforts in preparing Ecodesign measures.

Lateral legislation

Since 2016, under the European Commission EMAS programme, optimised (professional) dishwashing is part of the Best Environmental Management Practice for Tourism (BEMP).[40] EMAS-registered organisations in the tourism sector shall take the relevant sectoral reference documents into account.

3.2 Market

Table 77 shows estimated unit sales and stock of professional design washers, following data from the preparatory study[4] and the Eurostat PRODCOM statistics.

In 2010, the products in the scope represented a sales volume of ~350 000 units per year and a market of 1.8 billion euros in consumer prices. Following the preparatory study, it is assumed that sales for laundry equipment and dishwashers are increasing by 1% per year, which leads to sales of 384 000 units in 2020 and 425 000 units in 2030.

The 2010 installed stock of dishwashers in the scope was 3.1 million units, of which 61% (1.9 million) dishwashers, 28% (0.86 million) washing machines and 11% (0.34 million) driers. In 2020 the stock is expected to be almost 3.5 million units and in 2030 approximately 3.8 million units.

In 2018 the production value of professional dishwasher market (in msp, manufacturer selling prices), with players like Miele, Electrolux, Hobart, Winterhalter, Whirlpool Commercial and Meiko, was around 820 million Euros in 2018[41]. Service is an important feature in this professional product group and thus extra-EU trade is relatively modest at 25-30%

[38] Belke, M.Sc. Lara and Stamminger, Prof. Dr. Rainer (Household and Appliance Technology Section Institute for Agricultural Technology Rheinische Friedrich-Wilhelms-Universität Bonn), Report on the Dishwasher Round Robin Test Commercial Dishwashing, 2016

[39] CLC TC59X/WG2.1 - meeting minutes March 30, 2017.

[40] Commission Decision (EU) 2016/611 of 15 April 2016 on the reference document on best environmental management practice, sector environmental performance indicators and benchmarks of excellence for the tourism sector under Regulation (EC) No 1221/2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS) (notified under document C(2016) 2137), OJ L 104, 20.4.2016, p. 27–69

[41] Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data [DS-066341]: 28295000 - Non-domestic dish-washing machines

of the manufacturing capacity in the EU for professional dishwashers. Trade margins for the EU-market are estimated at 40% of msp, resulting in a professional consumer market (excl. VAT as no VAT is due) of around €1.15 bn in 2018.

Table 10. Sales and stock (in 1000 units)

	Sales (units x 1000)					Stock (units x 1000)				
Year	**1990**	**2000**	**2010**	**2020**	**2030**	**1990**	**2000**	**2010**	**2020**	**2030**
Non-household dishwashers	**192**	**213**	**235**	**259**	**287**	**1576**	**1741**	**1923**	**2124**	**2347**
Water-change (DW1)	16.0	17.7	19.5	21.6	23.8	182	201	222	245	271
One tank (DW2/3)	167.1	184.5	203.9	225.2	248.7	1291	1426	1575	1740	1922
One tank pots/utensils (DW4)	2.2	2.4	2.6	2.9	3.2	17	18	20	22	25
One tank conveyor-type (DW5)	5.9	6.5	7.1	7.9	8.7	67	73	81	90	99
Multiple tank (DW6)	1.2	1.3	1.4	1.6	1.7	18	20	23	25	28

The dominant type is the one tank dishwasher (82% of dishwashers installed). The "design lifetime" calculated in the preparatory study[4] is in the order of 8 years for the smaller appliances and 14-17 years for the large appliances (conveyor-type dishwashers).

3.3 Usage

Dishwashers are mainly used in commercial services like restaurants and hotels (65%), hospitals and other institutional services (23%) and commercial food sales (butchers, bakeries, grocers etc.) (10%).

Energy and water consumption tend to become more efficient as a result of competition in the market; companies strive to offer better products to their clients and more efficient use of water and energy make their products more attractive. On average energy consumption of state of the art products decreases with 10-40% every 10 years[4]. Water use tends to decrease with 15-35%[42], of which the higher improvement comes with the products that handle the highest volume of dishes. Typical usage parameters for commercial dishwashers are summarized in Table 11[43].

Table 11. Usage parameters (rates apply to tertiary sector)

Category	Cost items	Units	Value
Purchase	Purchase price	Euros/product	800–500.000
Purchase	Delivery and installation	% of product price	4 (9 for heavy duty)
Use	Electricity rate	Euros/kWh	0.090–0.138
Use	Gas	Euros/GJ	8.79–11.21
Use	Water rates	Euros/m^3	2.64
Use (DISH)	Rinse	€/L	3.0
Use	Interest-inflation rate	%	4
Maintenance	Servicing and repair	% of product price	3–25

[42] Idem (p. 34)

Disposal	Removal and disposal / recycling	Euros/product	0

3.4 Technologies

A technical discussion of commercial dishwashing technologies, specifically for the tourism sector but applicable also in a broader institutional context, is the 2017 EMAS reference document, prepared by JRC-IPTS.[44]

Energy consumption is strongly related to the water consumption and dish washing, including pre-rinsing, is the most water-demanding process occurring in commercial kitchens, accounting for approximately two-thirds of their water consumption. The EMAS-report confirms that there is a wide disparity between the different models on the market, which is an important criterion for eligibility for Ecodesign measures. An average water use of 3.8 L/rack is mentioned in 2010, whereas the best performing machines use less than 2L per rack. Figure 6 below shows the energy-split of a particular model. The total energy consumption of 23 kWh per hour is dominated by heating of the final rinse water (56 %) and dryer air (26 %).

Main energy/water saving options identified in the EMAS report are :

- recycling of rinse water to wash and prewash cycles
- recovery of 20 % of wash water through filtration for rinsing
- optimised circulation of drying air
- recirculation of 65 % of drying air
- recovery of heat and moisture from vented drying air to preheat rinse water.

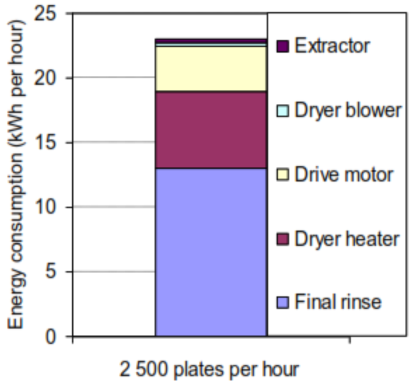

Figure 6. Operational energy consumption in an efficient dishwasher processing 2 500 plates per hour. Right: Hood-type dishwasher (source Meiko 2011 in EMAS-report [20]).

Furthermore, the EMAS-report recommends to install efficient pre-rinse spray valves (PRSV max. 6 L/minute), optimise loading, avoid prewash and use environmentally friendly (eco-labelled) chemicals.

[44] Styles D., Schönberger H., Galvez Martos J. L., Best Environmental Management Practice in the Tourism Sector, EUR 26022 EN, doi:10.2788/33972. Extract on 8.3 Optimised dishwashing, cleaning and food preparation. https://ec.europa.eu/environment/emas/takeagreenstep/pdf/BEMP-8.3-FINAL.pdf

3.5 Energy, Emissions and Costs

Energy, emission and monetary costs are given in the tables below. A straightforward stock model, using the applicable estimated product life was used. Many appliances use both fuel (e.g. gas for water heating and/or drying) and electricity (e.g. drum motor, pumps, fans), both translated in primary energy equivalent for the EU[45].

Table 12. Resources input use-phase and cleaning output

Annual input and output, EU 2010	ENERGY INPUT			OTHER INPUT		OUTPUT
	elec-tri-city	**fuel**	**primary energy**	**water**	**de-ter-gent**	**dishes out-put**
	A	B	2.5*3.6*A +B			
unit	*TWh elec*	*PJ prim*	*PJ prim*	*Mm³*	*kton*	*Mt/ 100bn dishes*
						100bn dishes
Non-household dishwashers	**12.26**	**8**	**118**	**131**	**437**	**6.5**
Water-change	0.28	0	3	6	19	0.05
One tank	8.27	0	74	94	313	4.29
One tank pots/utensils	0.01	0.01	0.1	0	0	0.02
One tank conveyor-type	2.21	4	24	18	61	1.23
Multiple tank	1.49	4	18	13	43	0.90

The next table gives greenhouse gas emissions (in CO2 equivalent GWP-100) and NOx emissions. [46]

Table 13. Greenhouse gas and NOx emissions of products in the scope, EU 2010.

Selected Emissions EU 2010	**GHG** MtCO2 eq./a	**NOx** kton/a
Non-household dishwashers	**6.6**	**0.6**
Water-change	0.1	0.00
One tank	4.1	0.00
One tank pots/utensils	0.01	0.00
One tank conveyor-type	1.3	0.26
Multiple tank	1.0	0.30

Other possible environmental impacts relate to the use of detergents, or in certain cases the re-use of detergents and water. As >90% of the machine-weight is made up of metals, notable stainless steel, full recycling can be expected. As far as critical raw materials is concerned, there is some niobium in electric motors, and of course the PCB, dismantled in

[45] Note that the tables were calculated in the 2013-2014 preliminary VHK impact analysis with the primary energy factors at the time (pef 2.5 for electricity) . If this product group is selected, the preparatory/impact studies should update not only for increase in base data but also for reduction of the primary energy factor for electricity, which was recently changed from 2.5 to 2.1, and the fact that Croatia entered and the UK has left the EU28 (13% less EU-population).

[46] For 2010 calculated with 0.41 kg CO2eq./kWh electricity. In 2020 0.38kg/kWh and 2030 0.34kg/kWh. Gas combustion 0.0561 kgCO2eq./MJ and 200mg/kWh (Gross Calorific Value).

accordance with WEEE, contains small quantities of valuable materials. There is a lively market for re-use, i.e. refurbished models are offered on specialised sector-websites.
The average acquisition value (including installation) and running costs (energy, water, detergent, maintenance) is given below. The prices for roughly the same functionality may differ a factor two. The same applies to the running costs.

The end-user expenditure in the following table is calculated with the inputs of Table 12.

Table 14. End-user expenditure

End-user expenditure, EU 2010	RUNNING COSTS						ACQUI-SITION	TOTAL
	electri-city	**fuel**	**energy total**	**water**	**deter-gent**	**servi-cing**	**acqui-sition***	
unit	*bn euros*	*bn eu-ros*	*bn eu-ros*	*bn eu-ros*	*bn eu-ros*	*bn eu-ros*	*bn eu-ros*	*bn eu-ros*
Non-household dish-washers	**1.47**	**0.10**	**1.58**	**0.35**	**1.31**	**0.03**	**1.05**	**4.32**
Water-change	0.03	0.00	0.03	0.02	0.06	0.002	0.06	0.17
One tank	0.99	0.00	0.99	0.25	0.94	0.023	0.79	2.99
One tank pots/utensils	0.00	0.00	0.00	0.00	0.00	0.000	0.03	0.03
One tank conveyor-type	0.27	0.05	0.31	0.05	0.18	0.007	0.11	0.66
Multiple tank	0.18	0.05	0.23	0.03	0.13	0.002	0.06	0.46

**=including installation*

3.6 Saving potential

The preparatory study has investigated the options for improvement of energy efficiency and concluded a cost-effective savings potential exists.
The technical design options that could bring about such savings were identified in the preparatory studies as follows (note: non-exhaustive):

- More efficient active components, specifically more efficient motors;
- More efficient heating, for instance through the use of heat recovery and heatpumps;
- More efficient static components such as larger air and water heat exchangers etc.;
- Improved product load and control components;
- Improved construction aimed at for instance improved air flow, insulation etc.

The technical saving potentials based on the best available technology identified in the preparatory study for non-industrial washing machines, driers and dishwashers differs per product group: the energy consumption of dishwashers could be improved by 8% to 37% and the water consumption could be reduced by 5% to 25%.

The policy option of choice is Ecodesign measures ('ECO' in the table below). As the buyers are professionals, the Energy Label was not considered to have additional value.

The impacts of these measures for the EU in 2030 versus a Business-As-Usual ('BAU') scenario are summarised in the table below.

Table 15. Environmental and economic improvement scenario for the EU in 2030, in a scenario with measures ('ECO') versus Business-As-Usual ('BAU')

impact	Energy primary		of which electric		Water		GHG		Acquisi-tion		Expendi-ture	
scenario	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU	BAU 2030	ECO-BAU
unit	*PJ*	*PJ*	*TWh*	*TWh*	*Mm3*	*Mm3*	*MtCO2*	*MtCO2*	*bn €*	*bn €*	*bn €*	*bn €*
Non-househ. dishwashers	**136**	**-22.0**	**14.2**	**-2.2**	**152**	**-17**	**7.2**	**-1.2**	**1.3**	**0.7**	**5.8**	**0.0**
DW1 Water-change	2.9	-0.2	0.3	0.0	7	-1	0.2	0.0	0.1	0.0	0.2	0.0
DW2 One tank	85.9	-11.2	9.5	-1.2	108	-13	4.4	-0.6	1.0	0.5	3.8	0.2
DW3 One tank pots/utensils	0.1	0.0	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
DW4 One tank conveyor-type	27.3	-6.0	2.6	-0.6	21	0	1.5	-0.3	0.1	0.1	1.0	-0.1
DW5 Multiple tank conveyor-type	20.2	-4.5	1.7	-0.4	15	-3	1.1	-0.2	0.1	0.0	0.7	-0.1

Note that since the above projections were made for the EU, in 2014, there have been several events that will have diminished the positive outcome: The UK left and Croatia entered the EU (-13%), the primary energy factor for electricity decreased (from 2.5 to 2.1), not all base cases were covered by the standards and the implementation of measures was delayed by a few years due to the lack of standards. Last but not least, the projections also assume that some of the technical improvements in the smaller machines will trickle down in the larger machines, even without specific policy measures. This effect will also have been diminished due to the current delay.

In summary, the benefits in the year 2030 are estimated to be at least 20% less than indicated above, but still significant:

- 18 PJ (5 TWh) primary energy saving, including 1.8 TWh electricity saving;
- About 17 Mm^3 water saving;
- 1 MtCO2eq carbon saving;
- For the regulated types (DW1 and DW2) €0.5 bn higher acquisition costs and €0.16 bn lower annual expenditure. At 8 year product life resulting in positive payback (~3 years) and life cycle cost saving.

3.7 Stakeholder comments

Member State experts from Germany (BAM/UBA) and the Netherlands Enterprise Agency (NEA) have expressed to be in favour of including the professional dishwashers in the working plan.[47] If there is a choice, NEA would give it a lower priority than ICT products.

[47] Stakeholder comments collected by the study team Sept. 2020

ECOS and other stakeholders like the Netherlands RVO agency point out that, even though the buyers are professionals, introducing not only ecodesign requirements but also energy label measures might be appropriate.

Industry association EFCEM asks for enough time to prepare and implement measures in view of the difficult economic times for the sector due to corona.

4 PROFESSIONAL COOKING APPLIANCES

4.1 Scope, policy measures and test standards

The energy consumption of professional kitchens represents a significant footprint - environmentally - where a the kitchen of restaurants, hotels or even office buildings could be the largest energy consumers - and financially, where energy could be the second largest expenditure to catering business after labour (and before food ingredients) [48].

Professional ovens were studied in the Ecodesign Lot 22 preparatory study on domestic and commercial ovens by Bio Intelligencee and ERA Technology in 2011. Professional hobs and grills were studied in the Ecodesign lot 23 preparatory study on domestic and commercial hobs and grills by Bio Intelligencee and ERA Technology, after which it was decided to implement requirements to domestic cooking appliances in the regulations (EU) 65/21014 and (EU) 66/2014.

The impact assessment[49] explains that commercial cooking appliances are excluded from the scope because of deficiencies in test standards and market data required to design effective and responsible measures. To solve this probably would take several years, so inclusion of commercial cooking appliances at this stage would delay the introduction of measures for domestic cooking appliances. Another conclusion in the impact assessment from stakeholder comments was that domestic and commercial cooking appliances should be handled in separate regulations.

The review clause in Article 7 of the Ecodesign Regulation (EU) 66/2014 includes an assessment of the feasibility of including professional and commercial appliances and the review study included this in the review study draft report[50]. A topic was the potential inclusion of professional cooking appliances under the project scope. The review study performed a stakeholder consultation with questionnaires and the review study draft report mentions the following considerations:

- The commercial and professional sector is potentially a high impact sector from the energy consumption point of view (initial exploratory calculations indicate it might be around half the energy consumption of the domestic market, with a significantly lower market share).
- Different user needs and significant product variability would make it particularly difficult to establish requirements which are satisfactory for all product types. Incompatibilities of definitions, formulas and energy categories are expected if domestic and commercial/professional are included under the same regulation.

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[48] Electricity Use in the Commercial Kitchen S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), [1]University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

[49] Commission Staff Working Document impact Assessment Accompanying the document Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for domestic cooking appliances (hobs, ovens and range hoods), 2013, https://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2014/swd_2014_0004_en.pdf

[50] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

Considering the reasoning above provided by relevant stakeholders, it was concluded that regulation for commercial/professional cooking appliances is necessary, since it is potentially a high impact energy consumption sector with possibilities for improvement. Regulation in the commercial/professional sector could boost innovation and be a driver for efficiency.

In order to provide appropriate ecodesign requirements, the regulation for commercial/professional cooking appliances is proposed to be specific and separated from the domestic cooking appliances regulation. This will ensure that every requirement and energy labelling category defined are suitable and meaningful, considering sector-specific user needs.

Another feedback from the stakeholders regarded potential additional information requirements where it was mentioned that the introduction an energy label also could be relevant for the commercial appliances. On the other hand, the European Federation of Catering Equipment Manufacturers EFCEM[51] states that the professional kitchens generally are too complex and integrated to get the benefit from a label.

Due to lack on reliable data on sales, stock, energy consumption and saving opportunities, the first published draft version of this report was prepared using preliminary data and assumptions. The draft version included a disclaimer stating that the calculated energy saving potential was seen as very high and probably over-estimated due to too high stock data (number of kitchens and/or number of appliances); possibly also combined with too high assumptions on the usages. After the second stakeholder meeting, the study team held an online meeting with EFCEM (European Federation of Catering Equipment Manufacturers) and HKI (industrial association of House, Heating and Kitchen Technology) discussing the data used, assumptions etc. Following this meeting, EFCEM and HKI provided more accurate estimations on the European stock of professional cooking appliances (extrapolated from the German market)[52] in addition to commenting on the assumptions made for the first version of the current task 3 study. Other stakeholders provided also useful input to be used for the final version of the report.

Due to time constraints, not all input data for the calculations have been revised. The focus was to update the calculations of the energy saving potential in Section 4.6.2. Where input data have not been updated, a note has been added.

4.1.1 Background

Studies on professional kitchens from 2018 in the Danish hospitality sector presented in Table 16 found that in restaurants, 70 % of the electricity consumption is related to the kitchens, and that in other institutions 25 – 35 % of the electricity consumption is related to the kitchens (Table 16).

[51] European Federation of Catering Equipment Manufacturers EFCEM, Stakeholder comment 26th March 2021

[52] Adrian Brändle, Estimation of the stock of food service equipment in professional kitchens on the EU 27 market, Industrieverband Haus-, Heiz- Und Küchentechnik E.V HKI (2021)

Table 16. Examples of kitchens share of electricity consumption[53].

Category	Hotel	Hostel	Camping	Restaurant
Share of the energy consumption of the institution	35 %	25 %	25 %	70 %

A study performed by University of Reading (Mudie, Essah, Grandison ad Felgate, 2013[54]) analyzed energy consumption in 14 "typical commercial kitchens" in a chain of restaurants. Of the total energy consumption in the restaurants 63 % originated from the kitchens. In the kitchens, the study found that 42 % of the total energy consumption in the kitchen originated from cooking (including for hot-holding), 10 % for lighting and 13 % for air handling including air extraction from range hoods.

A study by the Danish Association for Power Producers (Danske Elværkers Forening) investigated the electricity consumption in professional kitchens and found that 25 % of the energy consumption is for cooking appliances; ovens, hobs, cookers etc., 5 % for hot-holding, 25 % for refrigeration and cooling, 20 % for dishwashing, 10 % for lighting and 10 % for air handling[55].

The analysis is from 1993 and since then the energy efficiency of refrigeration and particularly lighting with led light has improved so the cooking appliances share of energy consumption in the kitchen must be expected to have increased in line with the numbers from Reading.

By 2010 the electricity consumption for professional kitchens in Denmark was estimated at around 1.2-1.4 TWh annually corresponding to about 15 % of private households electricity consumption for all appliances or 4 % of the total Danish electricity consumption[56].

A Czech / Austrian project by Daxbeck et al. in 2013 investigated the energy consumption in professional kitchens and the associated serving and guest areas and found that about 2/3 of the energy consumption in the investigated kitchens is from electricity. Of the electric energy consumption 8 % of the electricity consumption is for cooking appliances, 5 % for delivery (hot-holding, delivery wagons internally and out-of the house), 26 % for refrigeration and cooling, 10 % from dishwashing, 7 % from lighting, 25 % for air handling and the last 14 % for other processes and additionally energy from district heating for room and water heating was consumed. The reason for the relatively low figure on cooking is that gas used for many cooking appliances in addition to the consumed electricity and the energy consumption for guest areas. When looking at the total energy consumption cooking was responsible for about a third of it[57].

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[53] Storkøkkenvejledning 2018, Danish Energy Agency , 2018 and HORESTA (1998), sparenergi.dk/erhverv/hotel-og-restauration/storkoekken

[54] Electricity Use in the Commercial Kitchen S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), [1]University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

[55] Storkøkkenvejledning 2018, Danish Energy Agency (2018) and Danske Elværkers forening (1993)

[56] Storkøkkenvejledning 2018, Danish Energy Agency (2018) and Viegand & Maagoe (2010)

[57] Hans Daxbeck, Doris Ehrlinger, Diederik de Neef, Marianne Weineise, Ressourcen Management Agentur (RMA), Ressourcen Management Agentur (RMA), BIO AUSTRIA & Südböhmische Universität, ČR, EPOS (2011), Projekt SUKI – Energieverbrauch in Großküchen, Möglichkeiten von Großküchen zur Reduktion ihrer CO2-Emissionen, suki.rma.at/sites/suki.rma.at/files/Projekt%20SUKI%20-%20Endbericht%20Energie%20(Vers.%201.0).pdf

UK Carbon Trust and the Chartered Institute for Building Services (CIBSE) estimate according to Mudie et al[58] that the that the total energy consumption of Britain's catering industry in 2008 was approximately 22 TWh per year, at least. This corresponds to about 1,3 % of the total final energy consumption in UK (2008).[59]

The impact assessment[60] mentions that the preparatory studies found overall expected annual savings on 1.6 TWh/year (12 % of 13.3 TWh/year) for commercial ovens and hobs by 2030. As mention above the review study on other hand preliminary estimated that the savings potentials were larger and closer to the half of the savings from household cooking products; 6 – 7 TWh/year.

4.1.2 Scope

Stakeholders informed for the review study[61] that professional and commercial cooking appliances are characterized by a high level of specialization and individual costumer adaptions, tailoring, of products, higher capacities and more advanced control features and individualized automation and programming of preparation processes; i.e. higher levels of complexity. Although there is a high degree of tailorized production, review of product catalogues also show that the different product groups are typically supplied in standard measures to fit into the professional kitchen environments in modules.

In some cases the professional and commercial appliances are part of a cooking system supplied and installed in a total contract, but not more specialized than it is normally possible for the kitchen entrepreneur to combine products from different brands or "no-brands"[62] of professional cooking appliances.

Professional kitchen appliances could be covered by Machinery Directive 2006/42/EC in contrary to "Domestic appliances intended for domestic use", which are excluded from the scope. This directive defines the term "domestic use" as "use by private persons (consumers) in the home environment".

During the review study on Regulation (EU) No 66/2014 on household cooking appliances stakeholders were asked for their opinion regarding the user groups of cooking appliances[63]. It was proposed to distinguish the type of users and location where the appliance is to be used[64]:

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[58] Electricity Use in the Commercial Kitchen S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), [1]University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

[59] Annual consumption around 150 MTOE final energy (or 1700 TWh) according to: National Statistics, Energy Consumption in the UK (updated 2015), Chapter 1: Overall factsheet. webarchive.nationalarchives.gov.uk/20160512130645/https://www.gov.uk/government/statistics/energy-consumption-in-the-uk

[60] Commission Staff Working Document impact Assessment Accompanying the document Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for domestic cooking appliances (hobs, ovens and range hoods), 2013, https://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2014/swd_2014_0004_en.pdf

[61] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

[62] Interview with representative from the Danish trade organisation for professional kitchen and catering equipment, BFS.

[63] 1.st questionnaire task1-4 Cooking Household,

[64] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

- Domestic. Household appliances with an intended non-professional use.
- Commercial. Appliances to be used in an area accessible to the public (not a household) with an intended non-professional use.
- Professional. Appliances to be used in an area not accessible to the public with an intended professional use, with low scale production.
- Industrial. Appliances to be used in an area not accessible to the public, with an intended professional use, for large scale production.

A similar distinction is made on commercial and professional refrigeration appliances[65,66] and as a consequence there are two separate regulations for these products.

However, the standards on cooking appliances do not seem to make a similar distinction between commercial and professional cooking appliances. The same goes for much of the literature, which did not consequently distinct between professional and commercial cooking appliances. For the current study the terms `professional cooking appliances´ therefore will be used as in the machine directive including both professional and commercial appliances as defined above. However, the term `commercial´ is also being used in the current report will cover the same products and user groups and it is typically being used when other sources are cited.

The preparatory study ENER Lot 23 and ENER Lot 22 of "commercial cooking appliances", the Review study[67], Energy Star requirements for commercial cooking appliances[68,69,70,71], and various product standards in particular the ISO/EN standard series 60355-2 (see the section on standards) each have slightly different scopes of professional and commercial cooking appliances.

Based on these sources including the input from stakeholders for the review study regarding scope, the product categories in Table 17 are chosen as the scope of the current preliminary study on professional cooking appliances.

Table 17. Professional and commercial cooking appliances

Main category	Subcategory
Ovens	Static ovens
	Electric convection oven (forced conventional oven), full and half size[1)]
	Gas convection ovens (forced conventional oven), full and half size[1)]
	Gas steam ovens (Convection steamers)[2)]
	Electric steam ovens (Convection steamers)[2)]
	Gas combi-steam ovens (hot air convection / steam) [2)]

[65] COMMISSION REGULATION (EU) 2015/1095 of 5 May 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for professional refrigerated storage cabinets, blast cabinets, condensing units and process chillers

[66] COMMISSION REGULATION (EU) 2019/2024 of 1 October 2019 laying down ecodesign requirements for refrigerating appliances with a direct sales function pursuant to Directive 2009/125/EC of the European Parliament and of the Council

[67] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

[68] US EPA and DOE, Energy Star, 2009, Commercial Griddles Key Product Criteria, www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_products_criteria

[69] US EPA and DOE, Energy Star, 2016, ENERGY STAR Certified Commercial Fryers, www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers

[70] US EPA and DOE, Energy Star, 2009, www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens

[71] US EPA and DOE, Energy Star, 2009, www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers

	Electric combi-steam ovens (hot air convection / steam) [2)]
	Dual fuel heat source combi-steam ovens (hot air convection / steam)
	Deck ovens (bakery ovens)
	Rotatory rack ovens
	In-store bakery convection ovens
	Conveyor ovens (impingement ovens)
	Hybrid ovens with microwave function
Hobs / ranges	Gas open burners
	Gas solid tops
	Electric boiling table
	Electric hobs
	Electric infrared hobs
	Electric induction hobs
	Tilt braising pans and tilt kettles
	Pasta cookers
	Freestanding pressure cookers
	Bain-maries
Griddles[3)]	Gas griddles, single- and double-sided
	Electric griddles, thermostatically controlled, single- and double-sided
	Electric griddles, manually controlled
	Fry-top range griddles
Fryers (deep fryers)	Gas open deep-fat fryers, including standard fry pot sizes (≥ 12 inches and < 18 inches wide)
	Electric open deep-fat fryers, including standard fry pot sizes (≥ 12 inches and < 18 inches wide)
	Large gas vat (basin) fryers (18 to 24 inches wide)
	Large electric vat (basin) fryers (18 to 24 inches wide)
	Countertop fryers
	Floor type fryers
	Closed vat fryers and fryers with vats < 12 inches wide or > 24 inches wide are not suggested to be included in the scope (as they are not for energy star)
Steam cookers	Gas steam cooker
	Electric steam cooker
	Hybrid/combination products
	Pressure steamers
	Different styles: Countertop, wall-mounted models, floor-models mounted on a stand Pedestal or cabinet-style
Range hoods	Range hoods with a fan incorporated and with a horizontal length ≤ 120 cm[4)]
	Range hoods with a fan incorporated and with a horizontal length ≤ 120 cm with a recycling function[4)]
	Range hoods without a fan incorporated and with a horizontal length ≤ 120 cm[4)]
	Range hoods without a fan incorporated and with a horizontal length > 120 cm
Other	Hot cabinets, cupboards and heat lamps and similar appliances for keeping food and crockery warm.

[1)] Energy Star distinguishes between half and full size convection ovens - full size being an oven capable of accommodating standard full-size sheet pans measuring 18 x 26 x 1-inch - and between pan capacities below 6, from 6 to 20 and above 20.

[2)] Energy Star distinguishes between half, 2/3 and full size steam ovens - full size being an oven capable of accommodating two 12 x 20 x 2 ½-inch table pans per rack position - and between pan capacities below 6, from 6 to 20 and above 20.

[3)] Griddles and fryers are sometimes considered as a subcategory of hobs. For the current study they are defined as individual categories.

[4)] This is the appliance category defined as range hoods in the PRODCOM category 27511580 "Ventilating or recycling hoods incorporating a fan…"[72]

[72] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

Hot food cabinets and cupboards for keeping food and crockery warm have been left out of the scope of the current study which has focused on cooking and not on hot-holding. However, it could be relevant to study the product group of commercial and professional warm storage appliances as bain-maries as its own category to evaluate if their performance and technical characteristics based on the estimates that their energy consumption constitutes 5-10 % of the total energy consumption in the professional kitchen as presented in the introduction 4.1.1.

4.1.2.1 EU policies

Currently, professional cooking appliances is regulated under **Directive 2012/19/EU on waste electrical and electronic equipment (WEEE; category 4)**, the **Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)**, the machinery directive **Directive 2006/42/EC**, and **Regulation (EC) 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)**.

Regarding health and hygiene issues, professional cooking appliances should comply with **Regulation 1935/2004 on materials and articles intended to come into contact with food (FCM)**. Professional and commercial cooking appliances using gas as heating sources should comply with the **Regulation (EU) 2016/426 on appliances burning gaseous fuels.**[73]

More generic European legislation relevant for professional cooking appliances includes the **Low Voltage Directive (LVD) 2014/35/EU**, the **Electromagnetic Compatibility Directive (EMC) 2014/30/EU** and the **General Product Safety Directive (GPSD) 2001/95/EC**.

No European policies on energy efficiency of professional cooking appliances exist but certain **Ecodesign regulations** are also relevant for professional cooking appliances since they applies to components which may be integrated in professional cooking appliances.
Regulation (EC) No 327/2011 on fans covers fans that are driven by a motor between 125 W and 500 kW and are integrated in other products without being separately placed on the market or put into service and. However, it does not apply to the fan integrated into kitchen hoods with < 280 W total maximum electrical input for the fan(s).

REGULATION (EC) No 640/2009 on electric motors which from 1. July 2021 is repealed by **regulation (EU) 2019/1781 on electric motors.** This regulation covers electric motors that have a rated power output PN from 0.12 kW up to and including 1 000 kW. This regulation is relevant for motors for fans for range hoods and in principle it could be relevant for ovens that include forced air function and has a motor if has higher capacity the 0.120 kW.

REGULATION (EU) 2019/2020 for light sources[74]. This regulation covers from 21st September all light sources which are relevant for the lighting in kitchen hoods.

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[73] Regulation (EU) 2016/426 of the European Parliament and of the Council of 9 March 2016 on appliances burning gaseous fuels and repealing Directive 2009/142/EC, OJ L 81, 2016

[74] COMMISSION REGULATION (EU) 2019/2020of 1 October 2019laying down ecodesign requirements for light sources and separate control gears pursuant to Directive 2009/125/EC of the European Parliament and of the Council

4.1.2.2 Selected national policies

The **Energy Star** label from US Environmental Protection Agency (EPA) is applied for a number of products for restaurant and commercial use (food service)[75]. The cooking appliances with Energy Star are ovens, steam cookers, griddles, and fryers. The Energy Star does not distinguish between commercial and professional products and the products include professional products as defined for the current study.

Commercial griddles. The current specifications have been effective from 2009 with a tiers 2 from 2011 and covers gas and electric, single- and double-sided griddles including double-sided combined fuel griddles that include an electric top plate and gas bottom plate. The products must meet requirements to cooking efficiency and idle energy to comply to the requirements of the Energy Star label[76] as presented in Table 18. In 2011 when the tier 2 was first effective it also required a minimum cooking efficiency 38 % for gas griddles respectively 70 % for electric griddles. However, in 2013 the requirements on cooking efficiency were withdrawn due to problems to get the test material (beef with a standardized fat content) according to the required standard as per the ASTM F1275-03 and the F1605-97 test standards[77] and since amended so now the cooking efficiency is just to be declared[78]. Only products with thermostatic control can be Energy Star labelled.

Commercial fryers. The current Energy Star specification for fryers[79] has been effective from 2016 and covers gas and electric open deep-fat fryers, large vat (basin) fryers and countertop and floor type models.

Commercial Ovens. The Energy Star specification for commercial ovens[80, 81] has been effective from 2015 and covers electric and gas convection ovens (gas only full size), combination ovens and single and double gas rack ovens. Conventional or standard ovens, conveyor, slow cook-and-hold, deck, mini-rack, range, rapid cook and rotisserie ovens as well as 2/3-size combination ovens and dual-fuel heat source combination ovens are not in the scope.

Commercial steam cookers. The Energy Star specification for commercial steam cookers[82,83] has been effective since 2003 and covers 3-pan or larger gas and electric steam cookers including countertop models, wall-mounted and floor-models.

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[75] https://www.energystar.gov/products/commercial_food_service_equipment

[76] US Environmental Protection Agency, Energy Star, Commercial Griddles, www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles

[77] United States Environmental Protection Agency, Cover memo, www.energystar.gov/ia/partners/prod_development/new_specs/downloads/comm_griddles/Cover_Memo_V1.2.pdf

[78] ENERGY STAR® Program RequirementsProduct Specification for Commercial GriddlesEligibility CriteriaVersion 1.2, www.energystar.gov/sites/default/files/specs//private/Commercial%20Griddles%20Version%201%202%20Specification_0.pdf

[79] Energy Star, Commercial Fryers Key Product Criteria. Commercial Fryers Key Product Criteria https://www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria

[80] www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens

[81] Energy Star, Commercial Oven Key Product Criteria Version 2.2, www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria

[82] Energy Star, Commercial Steam Cookers, www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers

[83] Energy Star, Commercial Steam Cooker Key Product Criteria, www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers/key_product_criteria

Hybrid/combination products and pressure steamers are not in the scope.

Table 18 presents the product categories that are covered by Energy Star.

Table 18. Commercial cooking appliances covered by Energy Star minimum requirements.

Main category	Sub category
Griddles	Gas fuelled single- and double-sided
	Gas/electric double-sided that include an electric top plate and gas bottom plate
	Electric single- and double-sided
Fryers	Standard Open Deep–Fat Gas Fryers
	Large Vat Open Deep–Fat Gas Fryers
	Large Vat Open Deep–Fat Gas Fryers
	Large Vat Open Deep–Fat Electric Fryers
Ovens	Gas Convection Ovens (full size)
	Electric Convection Ovens - Half size - full size
	Gas combination ovens - Steam mode - Convection mode
	Electric combination ovens - Steam mode - Convection mode
	Gas rack ovens - Single - Double
Steam cookers	Electric Steam Cookers[1)] - 3-pan - 4-pan - 5-pan - 6-pan and larger
	Gas Steam Cookers[1)] - 3-pan - 4-pan - 5-pan 6-pan and larger

[1)] Tested at "Heavy load" conditions [2)] P = Pan capacity

The **Nordic Swan Ecolabel** is available for hotels, conference facilities with food services and for restaurants. The label consider a total energy consumption in kilowatt hours compared to area and number of guests and water consumption. The labels' requirements do not target the specific appliances directly and contains no specific requirements on the cooking appliances.

4.1.3 Test standards

The review study[84] addressed a lack of harmonized European standards for commercial and professional cooking products complicates as a barrier against fair comparison between products and the definition of minimum requirements and energy categories.

Although no harmonized or European standards are available for the energy efficiency and performance testing of professional gas hobs, gas ovens, electric hobs or range hoods,

[84] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

national standards in the German DIN standards, the US ASTM standards regies, the latter being used for the US Energy Star, the French NF as well as the Swiss ENAK.

For professional cooking appliances, the German test standard series **DIN 18873** *Methods for measuring of the energy use from equipment for commercial kitchens* is available for most of the equipment available in the market and for gas and electrical heated appliances[85]:

- Part 1: Convection steamers
- Part 3: Deep fat fryers
- Part 4: Convection ovens
- Part 5: Tilting frying pans and stationary frying pans
- Part 6: Tilting pressure braising pans and stationary pressure braising pans
- Part 7: Multiple deck ovens
- Part 9: Cooking zones (hobs)
- Part 12: Ovens
- Part 13: Microwave combination ovens
- Part 15: Double jacketed boiling and quick boiling pans
- Part 17: Noodle (pasta) cookers
- Part 19: Frying and grilling appliances

Further DIN standards cover other products:

- **DIN 18851** *Equipment for commercial kitchens – Ranges*. Requirements and testing
- **DIN 18858** *Equipment for commercial kitchens - Salamander broilers and giros grills*. Requirements and testing.
- **DIN 18863** on Steam cookers.

For the review study a stakeholder mentioned that CENELECT TC59X WG18 is currently developing a standard on professional ovens. Three cooking modes are under evaluation: convection, steam and combi.

SFOE[86] informs that the Swiss Topten is currently investigating product information for in-store convection bakery ovens' energy consumption. Preliminary results show that DIN 18873-4 and DIN 18873-7 are suitable for this oven type as these ovens are technically not different from convection ovens according to SFOE. However, EFCEM informs that the 18873 DIN standards series have some limits; e.g. for ovens in practice not applicable for all sizes, and they are not directly linked to the cooking, performance or to material efficiency.

[85] HKI Fachverband Großkücheneinrichtungen, 2019, Normungsarbeiten im bereich der Großküchengeräte, www.hki-online.de

[86] Swiss Federal Office of Energy SFOE, Federal Department of the Environment, Transport, Energy and Communications DETEC, Stakeholder comment 18th March 2021

Range hoods are covered by **EN 60335-2-99** on safety[87] of compete units (i.e. including the fan), by **DIN18869-1**[88] regarding design and function of built in cooker hood for ventilation for professional kitchens, including the testing, technical safety and hygienic characteristic features of range hoods, and by the standard series **EN 16282-1** and **-2**[89] regarding calculation method, design, dimensioning and safety. **EN 16282-8** covers installations for treatment of aerosols like ozone- and photocatalytic treatment. However, it seems like neither of the standards are taking care of energy efficiency[90]. EN 60335-2-99:2003 covers "the safety of electrically operated commercial hoods intended for installation above commercial cooking appliances such as ranges, griddles, griddle grills and deep fat fryers, and not intended for household use. The hoods included in this standard are used, for example in restaurants, canteens, hospitals, and commercial enterprises such as bakeries, butcheries." The scope only includes single complete units and hoods which a complete working hood, incorporating a fan and not hoods where the fan is placed on the roof or somewhere else in the duct system.

To address durability issues, the standards to support Ecodesign requirements on **material efficiency** aspects for energy-related products could be applied, covering the following aspects: extending product lifetime, ability to reuse components or recycle materials from products at end-of-life, use of reused components and/or recycled materials in products.[91]

Professional appliances are also covered by requirements to electromagnetic compatibility (EMC). The relevant EMC standards are **EN/IEC 61000-6-1**, Generic standards – immunity standard for residential, commercial and light-industrial environments and **EN 61000-6-3,** Generic standards, emission standard for residential, commercial and light-industrial environments.

EN 203-1 Gas heated catering equipment - Part 1: General safety rules. Specifies the general requirements and the constructional and operating characteristics relating to safety, marking, and the associated test methods for gas heated commercial catering and bakery appliances and applies to all professional cooking and bakery appliances using gas for preparing food and drink.

The EN 203-1 standard series does not deal with rational use of energy, but the specific requirements including test methods for energy consumption is considered in the part 2

[87] EN 60335-2-99:2003+A1:2019, Household and similar electrical appliances. Safety Particular requirements for commercial electric hoods

[88] Deutsches Institut Fur Normung E.V., 2005, DIN 18869-1:2005-03 Großküchengeräte - Einrichtungen zur Be- und Entlüftung von gewerblichen Küchen - Teil 1: Küchenlüftungshauben, Anforderungen und Prüfung + DIN 18869-1 Corrigendum 1, 2006

[89] EN 16282-1, Equipment for commercial kitchens - Components for ventilation in commercial kitchens - Part 1: General requirements including calculation method

[90] HKI Fachverband Großkücheneinrichtungen, 2019, Normungsarbeiten im bereich der Großküchengeräte, www.hki-online.de

[91] EN 45552:2020 (General method for the assessment of the durability of energy-related products), EN 45553:2020 (General method for the assessment of the ability to remanufacture energy-related products); EN 45554:2020 (General methods for the assessment of the ability to repair, reuse and upgrade energy-related products); EN 45555:2019 (General methods for assessing the recyclability and recoverability of energy-related products); EN 45556:2019 (General method for assessing the proportion of reused components in energy-related products); EN 45557:2020 (General method for assessing the proportion of recycled material content in energy-related products); EN 45558:2019 (General method to declare the use of critical raw materials in energy-related products); and EN 45559:2019 (Methods for providing information relating to material efficiency aspects of energy-related products)

for the specific products. 203-2 specifies the test methods and requirements for the construction and operating characteristics relating to the safety, rational use of energy and marking. The 203-2 standard series only covers type testing.

Below the individual products relevant for the current study that are covered by 203-2 are mentioned:

- **EN 203-2-1 Open burners and wok burners**. Only the net calorific value (Hi) and net Wobbe number (Wi) are used.
- **EN 203-2-2** Ovens. Commercial gas heated natural convection ovens, forced air ovens, multi-function ovens and steaming ovens, atmospheric or pressurised. Commercial bakery ovens, with a sole plate or a trolley and pizza ovens are also covered by this standard.
- **EN 203-2-3**. Commercial gas heated boiling pans.
- **EN 203-2-4**. Commercial gas heated fryers.
- **EN 203-2-6**. Commercial gas heated water boiling and heating appliances for beverage making.
- **EN 203-2-7**. Gas heated salamanders and rotisseries.
- **EN 203-2-8.** Gas heated brat pans and paella cookers so called after "bratt pan".
- **EN 203-2-9**. Gas heated solid tops, warming plates and griddles, the burners of which are enclosed and the flue gases of which are evacuated by a specific way.

Regarding **safety standards** applicable to professional electrical cooking appliances the review study[92] found that safety of gas and electric products is covered by the EN 60335 series on safety of household and similar electrical appliances. Generally, EN 60335-1 and EN 60335-2 are not applicable for appliances that are intended for professional uses[93], but some of the parts of the standard are specifically dedicated to commercial appliances, and apparently they are endorsed by the Machinery directive and Gas appliances regulation.

More specifically the following parts of the 60335-2 are dedicated commercial appliances ad deals with the safety of electrically operated commercial appliances intended for use in restaurants, canteens, hospitals and commercial enterprises such as bakeries, butcheries, etc (not intended for household use), their rated voltage being not more than 250 V for single-phase appliances connected between one phase and neutral and 480 V for other appliances:

EN 60335-2-36. Electrical commercial cooking and baking ranges, ovens, hobs, hob elements and similar appliances. Additional requirements for appliances with power driven moving parts are given in Annex ZE.

DS/EN 60335-2-37. Electrical commercial deep fat fryers including pressurized types. The electrical part of appliances making use of other forms of energy is also within the scope of this standard. Under revision and doughnut fryers will be included in its scope + a max volume of 200 liters product.

EN 60335-2-38. Electrical commercial griddles and griddle grills. The electrical part of appliances making use of other forms of energy is also within the scope of this standard.

[92] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

[93] webshop.ds.dk/en-gb/search/67-260-anl%c3%a6g-og-udstyr-til-levnedsmiddelindustrien/dsf-fpren-1673

FprEN 60335-2-39. Electrical commercial multipurpose cooking pans including pressurized appliances and appliances with pressurized parts.

EN 60335-2-42. Electrical commercial forced convection ovens, steam cookers, steam-convection ovens and, exclusive of any other use, steam generators.

EN 60335-2-47:2003. Electrical commercial boiling pans.

EN 60335-2-48. Electrical commercial grillers and toasters. Rotary or continuous grillers and toasters and similar appliances intended for grilling by radiant heat such as rotisseries, salamanders, etc. are within the scope of this standard.

EN 60335-2-50. Electrical commercial bains-marie.

60335-2-90:2015/prA1:2018 (Draft). Commercial microwave ovens with a cavity door including microwave ovens that have transportation means for moving the microwave load through the microwave oven. Requirements for tunnel microwave ovens and several types of microwave vending machines are covered.

EN 60335-2-99/A1. Electrical commercial hoods intended for installation above commercial cooking appliances such as ranges, griddles, griddle grills and deep fat fryers. Only single complete units and hoods supplied as separate parts which when assembled form a complete working hood, incorporating a fan, are within the scope of the standard.

EN 4855-02:2020. Aerospace series – ECO efficiency of catering equipment – Part 02: Oven equipment. This European standard describes a test procedure to identify performance characteristics and a weight rating of convection and steam ovens used on aircraft. Furthermore it describes the calculation procedure to determine an energy consumption index and a performance index. There is no direct correlation between the Eco efficiency and cooking performance in terms of food quality and appearance. The two index values represent the Eco efficiency.

ASTM test standards for US Energy Star for Professional appliances
Energy Star for Commercial Food Service Equipment is based on the following American Society for Testing and Materials (ASTM) standards for the evaluation of their energy efficiency and cooking performance**:**

ASTM F1275-03: *Standard Test Method for the Performance of Griddles* (Section 7.1)

ASTM F1275 – 14. Griddles. Thermostatically controlled, single-source (bottom) gas and electric griddles.

ASTM F1496 - 13(2019). Convection Ovens. Also applicable to convection ovens with limited moisture injection. It applies to general purpose, full-size, and half-size convection ovens and bakery ovens used primarily for baking food products. Not applicable to ovens used primarily for slow cooking and holding food product, to large roll-in rack-type ovens, or to ovens that can operate in a steam-only mode (combination ovens).

ASTM F1605 - 14(2019). Double-Sided Griddles. Thermostatically controlled, double-sided gas and electric (or combination gas and electric) contact griddles with separately heated top surfaces.

ASTM F1605-95 (2007): *Standard Test Method for the Performance of Double-Sided Griddles* (Section 7.4)

ASTM F2861 – 17. Enhanced performance of combination oven in various modes. Energy and water consumption and the cooking performance of gas and electric combination ovens that can be operated in hot air convection, steam, the combination of both hot air convection and steam modes and convection ovens with moisture injection.

ASTM F1484 – 18. Steam Cookers. High-pressure, low-pressure, pressure-less and vacuum steam cookers; convection and non-convection steam cookers; steam cookers with self-contained gas-fired, electric, or steam coil steam generators, and those connected directly to an external potable steam source.

ASTM F2140 – 11. Hot food holding cabinets. Preheat energy consumption and idle energy consumption of hot food holding cabinets.

The French standardization organization **AFNOR**, Association Française de Normalisation (NF) has issued and is in the process of issuing several standards for energy performance of professional cooking appliances:

NF D 40-020. Professional catering equipment -Griddles- Energy performance.

NF D 40-016. Equipment for mass catering Reheating and temperature maintaining appliances Energy performance.

NF D 40-050. Professional cooking and refrigerating equipment noise test code (precision class and control).

NF D 40-002. Professional catering equipment - deep fryers -Energy performance .
XP D 40-021. Professional catering equipement -Boiling pans- Energy performance (experimental standard soon to be a national French standard)

The Swiss Association **ENAK** has measurements for the professional coking appliances that are covered by the Swiss part of the **Topten** appliance efficiency ranking program (Topten.ch). In contrary to the Swiss Topten and to the situation for household cooking appliances for the Topten.eu, the EU section of the Topten program address no categories of professional cooking products.

Overall the conclusion on the standardization situation is that although no harmonized standards are applicable for the testing of energy efficiency and performance of professional cooking products, they generally seems to be well covered by standards e.g. from DIN, ASTM and ENAK. Safety and other parameters are covered by EN standards.

Range hoods are also covered by EN standards, however only performance and not energy efficiency it seems.

To address durability issues, the standards to support Ecodesign requirements on material efficiency aspects for energy-related products could be applied, covering the following aspects: extending product lifetime, ability to reuse components or recycle materials from products at end-of-life, use of reused components and/or recycled materials in products.[94]

In a possible preparatory study, further analysis will have to be made to evaluate if the standards cover all product groups decided for the scope and relevant test parameters sufficiently.

4.2 Market

4.2.1 Professional kitchens

The number of appliances in professional kitchens are linked to the number of and type of professional kitchens. Eurostat[95] SBS (structural business statistics) database provides data on the number of enterprises involved in restaurants, mobile food service, event catering (like conferences) and other food service activities (Table 19).

Table 19. Number of (commercial) enterprises EU 27 in the restaurant and catering sector. (Source Eurostat sbs[96] and own calculations).

Classification of economic activities - NACE Rev.2	2011	2012	2013	2014	2015	2016	2017
Restaurants and mobile food service activities	816,537	814,496	817,019	853,568	857,490	877,472	884,984
Event catering and other food service activities	65,807	66,801	70,725	78,191	79,734	85,169	86,310
Sum, all restaurant, mobile food service, event catering and other food service	**882,344**	**881,297**	**887,744**	**931,759**	**937,224**	**962,641**	**971,294**
Annual Change		-0.1%	0.7%	5.0%	0.6%	2.7%	0.9%
Average Growth	1.63 %						

There seems to be some country specific variations on data that has been reported to Eurostat SBS in Table 19. A sector analysis in 2009 (Pelzer and Baksyte, Eurostat[97]) found the number of restaurants including canteens and catering as well as bars, to be 1.15 million in 2006 (Table 20). Not all bars have kitchens so for the following calculations the the eurostat sbs sector of restaurants, bars, canteens and catering as presented in Table 19 is assumed to represent the number of commercial professional kitchens including commercial for cafeterias and canteens for private and public companies.

[94] EN 45552:2020 (General method for the assessment of the durability of energy-related products), EN 45553:2020 (General method for the assessment of the ability to remanufacture energy-related products); EN 45554:2020 (General methods for the assessment of the ability to repair, reuse and upgrade energy-related products); EN 45555:2019 (General methods for assessing the recyclability and recoverability of energy-related products); EN 45556:2019 (General method for assessing the proportion of reused components in energy-related products); EN 45557:2020 (General method for assessing the proportion of recycled material content in energy-related products); EN 45558:2019 (General method to declare the use of critical raw materials in energy-related products); and EN 45559:2019 (Methods for providing information relating to material efficiency aspects of energy-related products)

[95] https://ec.europa.eu/eurostat/web/prodcom/data/database

[96] Classification of economic activities - NACE Rev.2, Economical indicator for structural business statistics, Annual detailed enterprise statistics for services, (NACE Rev. 2 H-N and S95) [SBS_NA_1A_SE_R2__custom_136781], October 2020

[97] Claudia PELZER, Vaida BAKSYTE, More than 9 million persons employed in the hotels and restaurants sector in the EU, Industry, trade and services, Eurostat Statistics in focus, 101/2009

Table 20. Number of enterprises in the restaurants including canteens and catering as well as bars sector in 2006 (source: Eurostat[98] based on sbs data, sbs_na_1a_se).

	Number of enterprises)*) (1000)	Number of persons employed*) (1000)
Restaurants; bars; canteens and catering	1148	5631

*) Based on EU-27 and corrected to EU-27, 2019. Correction factor from EU-27,2006 to EU-27,2019 is 0,8, based on the numbers of enterprises in 2007 in EU-27 excl. UK and incl. HR.

In parallel to the commercial sector are non-commercial cafeterias and canteens e.g. for the constraints at military barracks, in the care sector with kitchens at residences for elderly people, hospitals, kinder gardens, schools etc. UK Carbon Trust and the Chartered Institute for Building Services (CIBSE) estimates that up to 50 % of energy consumption in Britain's catering industry originates from the non-commercial catering sector[99, 100]. Same ratio of commercial/non-commercial is found based on the number of "actors" by the CFSG (The Catering for a Sustainable Future Group) in a white paper in 2008[101] (presented in the Task 3 report in the Lot 23 preparatory study) with the number of "purely commercial" catering businesses being almost the double of hotels restaurants and guest houses.

FoodServiceEurope represents the "Contract catering" sector which they distinguish from and "Profit catering sector" or restaurant etc. as being companies to which the food service is outsourced e.g. on work places, hospitals prisons etc. The organisation informs that their members employ over 600,000 people across Europe and deliver 6 billion meals every year, serving for 67 million consumers on a daily basis. According to FoodServiceEurope the European contract catering companies serve 50 % of all meals at the workplaces, more than 25 % of the meals at schools and more than 10 % of the meals in healthcare or social sectors[102].

Based on this it is assumed that the number of public professional non-commercial kitchens in hospitals, kinder gardens etc. corresponds to the commercial kitchens. On the other hand, the Lot 22 task 2 report[103] cites the European Modern restaurants Association (EMRE) for estimating that 7.2 % of all meals served in the EU are prepared in commercial restaurants and 4.2 % in institutional restaurants corresponding to about 37 % of meals from the professional kitchens being from non-commercial professional kitchens. Based on these different input it is assumed that around 45 % of the professional kitchens are non-commercial. Therefore, that the total number of professional kitchens are around 1.8 times higher than the figures in Table 19.

The report from Pelzer and Baksyte also shows that the employment and turnover in 2006 is similar to the employment in 2009 during the peak of the financial crisis. The report

[98] Claudia PELZER, Vaida BAKSYTE, More than 9 million persons employed in the hotels and restaurants sector in the EU, Industry, trade and services, Eurostat Statistics in focus, 101/2009

[99] Carbon Trust (2008). Food preparation and catering - Increase carbon savings without compromising on quality, London

[100] CIBSE (2009). TM50 - Energy Efficiency in Commercial Kitchens. The Chartered Institution of Building Services Engineers (CIBSE) and Catering for a Sustainable Future Group (CSFG), London

[101] CFSG (2009), White paper on climate change - A sector strategy for energy efficient commercial kitchens, The Catering for a Sustainable Future Group, www.csfg.org.uk

[102] FoodServiceEurope. Dec. 2020, www.foodserviceeurope.org/en/european-industry-overview

[103] European Commission (DG ENER), 2011, Preparatory Study for Ecodesign Requirements of EuP's, Lot 22: Domestic and commercial ovens, Task 2 report

don't have the number for enterprises in the sector and their development, so for the current study it is assumed that the development in the number of enterprises follows the development in turnover and employment. The growth rate is assumed to be 1.6 %/year, similar to the growth rate found in Table 19.

Based on the above including the assumed annual growth on 1.6 % from 2017 to 2020 (zero-growth in 2020 due to Covid-19), the number of commercial professional kitchens in the EU is found to be 1.0 million and the **total number of professional commercial and non-commercial kitchens around 1.8 million in 2020** (Table 21).

Table 21. Number of professional kitchens EU 27. (Source Eurostat sbs[104], Table 19 and own calculations)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Professional kitchens	1,604,262	1,602,358	1,614,080	1,694,107	1,704,044	1,750,256	1,765,989	1,794,245	1,822,953	1,822,953

The use behaviour and number of appliances in the individual kitchens depend on the size and nature of the kitchens. Canteens for personnel at administrative businesses are typically operated during normal (office) business working time. Restaurants could be mainly evening, daytime or both, even morning, or as many hotel restaurants only morning, hospital kitchens from early morning to late evening etc.

Small mobile street food kitchen will have a limited number of smaller appliances, large food hall restaurant kitchens or event and conference centre kitchens more and bigger for large scale production.

The European hotel and restaurant sector is dominated by small independent restaurants. In 2001 more than 90% of the enterprises employ fewer than 10 people (Figure 7) and the median size in terms of employment is around 10 persons.

[104] Classification of economic activities - NACE Rev.2, Economical indicator for structural business statistics, Annual detailed enterprise statistics for services, (NACE Rev. 2 H-N and S95) [SBS_NA_1A_SE_R2__custom_136781], October 2020

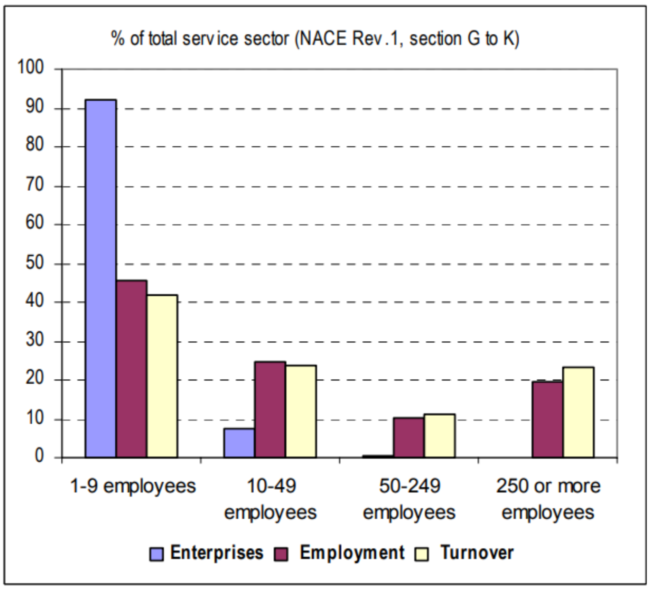

Figure 7. Share of enterprises, employment and turnover in hotels and restaurants, by size class in the EU, 2001 (source : Feas-Cannito, 2004[105]).

In spite of the domination of small enterprises in numbers, the 0.1 % of the enterprises employing more than 250 people provided 19% of jobs and accounted for 23% of all turnover in the business[106]. In 2006 the enterprises with more than 250 employed 17.6 % of jobs in the sector and accounted for 23,5 % of the turnover[107].

4.2.2 Market for appliances

Professional cooking appliances are often purchased via and installed by professional full service dealers and kitchen installers.

This section presents data based on the Eurostat[108] SBS and Prodcom concerning business structure, and production and trade data. Both the SBS and the PRODCOM statistics are the official EU-source and are based on business and product definitions that are standardized across the European Member States and thus allow comparability between the Member State data.

However, Prodcom classification is not detailed enough to cover all the products identified in task 1 as there is no specific category for professional cooking appliances covering all the relevant appliances in the PRODCOM database. Table 22 presents the product categories that can be considered or are evaluated.

[105] Franca Faes-Cannito, Statistics in focus, Industry, Trade And Services 38/2004, Hotels and Restaurants in Europe, ec.europa.eu/eurostat/documents/3433488/5316653/KS-NP-04-038-EN.PDF/a7353f7c-2364-4b56-af0b-02df997b385b?version=1.0

[106] Franca Faes-Cannito, Statistics in focus, Industry, Trade And Services 38/2004, Hotels and Restaurants in Europe, ec.europa.eu/eurostat/documents/3433488/5316653/KS-NP-04-038-EN.PDF/a7353f7c-2364-4b56-af0b-02df997b385b?version=1.0

[107] Claudia PELZER, Vaida BAKSYTE, More than 9 million persons employed in the hotels and restaurants sector in the EU, Industry, trade and services, Eurostat Statistics in focus, 101/2009

[108] https://ec.europa.eu/eurostat/web/prodcom/data/database

Table 22. PRODCOM product categories related to professional cooking appliances (Source Eurostat Prodcom[109])

Product category	Description
27511580	Ventilating or recycling hoods incorporating a fan, with a maximum horizontal side = 120 cm
28211330	Electric bakery and **biscuit** ovens
28211357	Electric infra-red radiation ovens
28931580	Non-domestic equipment for cooking or heating food

EU production and sales of professional cooking equipment.

The Prodcom category 28211330 "Electric bakery and biscuit ovens" provides data on electric bakery ovens. No Prodcom categories cover specifically ovens for professional / commercial kitchens. Table 23 presents the years 2008 to 2019. During the years 2008-2011 import and export quantity data are missing and there are extremely large variations from year to year and this could lead to some doubt about the values. At the same time it is not clear whether the Prodcom data on bakery and biscuit ovens include industrial machinery. This could explain the large year-to-year variations and the larger growth in sales value compared to sales numbers.

The numbers for `Production quantity´ in 2008-2011 that are not available are estimated (italic) by using the same average growth rate as in the years 2012-2019.

Table 23. Production import, export and EU-sales of electric bakery and biscuit ovens

PERIOD	Export Quantity	Export value	Import Quantity	Import Value	Production quantity	Production value	Total quantity sales in EU*	Total value sales in EU	Annual change, quantity	Annual change, value
2008	:	70,865,160	:	3,033,560	*59,086*	220,968,252	186,240	153,136,652		
2009	:	55,354,850	:	4,493,400	*72,008*	251,105,481	191,645	200,244,031	*2.8%*	30.8%
2010	:	61,380,530	:	3,353,310	*85,734*	286,894,018	197,207	228,866,798	*2.8%*	14.3%
2011	:	79,017,300	:	3,646,680	*84,469*	314,009,552	202,930	238,638,932	*2.8%*	4.3%
2012	78,355	80,482,010	4,420	3,549,050	282,754	434,903,163	208,819	357,970,203	*2.8%*	50.0%
2013	130,052	95,028,830	3,767	3,211,360	394,457	520,554,502	268,172	428,737,032	28.4%	19.8%
2014	68,347	93,093,410	6,911	5,155,150	343,201	478,652,746	281,765	390,714,486	5.1%	-8.9%
2015	51,523	94,999,650	33,852	6,740,330	289,635	464,156,252	271,964	375,896,932	-3.5%	-3.8%
2016	67,757	100,767,460	15,592	6,676,900	208,054	466,801,840	155,889	372,711,280	-42.7%	-0.8%
2017	61,178	105,763,550	3,241	7,274,350	198,000	475,082,147	140,063	376,592,947	-10.2%	1.0%
2018	73,070	108,715,550	39,611	7,035,340	195,888	586,007,649	162,429	484,327,439	16.0%	28.6%
2019	65,403	106,426,830	97,348	3,109,210	192,000	539,943,650	223,945	436,626,030	37.9%	-9.8%
								Average**	2.8%	11.4%

* 2008-2011: "Total quantity" is extrapolated from 2012 assuming the same average annual chance as for 2012-2019. ** Average of annual change in quantity is based on 2012-2019 since the data from previous years lacks
Source: Prodcom code 28211330, Eurostat, EU27TOTALS and own calculations

The Prodcom category 28211357 "Electric infra-red radiation ovens" only contains data from 2008 to 2010 and the data quality seems doubtful. Additionally, infrared ovens could be for industrial purposes as well and conclusively these Prodcom data Electric infra-red radiation ovens are not considered to be applicable for the current study.

[109] https://ec.europa.eu/eurostat/web/prodcom/data/database

The Prodcom category 28931580 “Non-domestic equipment for cooking or heating food” excludes non-electric tunnel ovens, non-electric bakery ovens, non-electric percolators. The data are presented in Table 24. It is not mentioned directly in the Prodcom guidance text if the electric ovens are excluded too and are considered to have their own Prodcom category (Table 22). No Prodcom data were found on gas ovens.

Table 24. Production import, export and EU-sales of non-domestic equipment for cooking or heating food.

PERIOD	Export Quantity	Export value [million Euro]	Import Quantity	Import Value [million Euro]	Production quantity	Production value [mil-lion Euro]	Total quantity sales in EU*	Total value sales in EU [million Euro]	Annual change, quantity	Annual change, value
2008	:	614	:	134	863,839	1,200	518,670	720		
2009	:	519	:	119	753,892	1,276	517,742	876	-0.2%	21,6%
2010	:	574	:	144	630,681	1,323	425,738	893	-17.8%	1,9%
2011	:	651	:	134	960,000	1,514	632,288	997	48.5%	11,7%
2012	:	681	:	146	980,940	1,472	624,281	936	-1.3%	-6,1%
2013	:	710	:	165	1,113,568	1,489	705,988	944	13.1%	0,8%
2014	:	725	:	194	1,166,893	1,510	756,396	979	7.1%	3,7%
2015	:	784	:	248	1,308,886	1,574	863,277	1,038	14.1%	6,0%
2016	:	789	:	266	1,709,845	1,582	1,145,414	1,060	32.7%	2,1%
2017	:	834	:	281	1,314,113	1,700	886,701	1,147	-22.6%	8,2%
2018	:	891	:	283	1,016,683	1,705	654,440	1,098	-26.2%	-4,3%
2019	:	895	:	343	1,197,903	1,675	803,290	1,123	22.7%	2,3%
								Avg. Change	6,4%	4,4%

* No Prodcom data on quantities of import and export. The values of total quantity are estimated assuming the same relation between "Production quantity" and "Total quantity" as for "Production value" and "Total value".
Source: Prodcom code 28931580, Eurostat, EU27TOTALS and own calculations.

Lot 22 Task 2[110] concluded that the majority of commercial ovens (> 95 %) are of the combi-steam oven type and that 82 % of the combi-steam ovens are electric. From the study the yearly market of combi-steamer also could be estimated at around 40,000 units (Table 25).

Table 25. Sales of combi-steam ovens in 2007 in the EU-27 (converted to EU27,2020, based on Lot 22 task 2).

	Electric combi-steamer	Gas combi-steamer	Total
Sales EU27,2020	33100	7400	40500
Share	82 %	18 %	100 %

However, studying the websites of dealers of professional cooking appliances shows a higher representation of convection ovens, and so does the (although limited) sample from the UK gastro-pub chain (Table 28). Similarly, public web pages which provides advices about efficient energy consumption and behavior in professional kitchens also generally seem to consider convection ovens as an important energy consumer. Consequently it is

[110] European Commission (DG ENER), 2011, Preparatory Study for Ecodesign Requirements of EuP's, Lot 22: Domestic and commercial ovens, Task 2 report

for the current study assumed that the market share of convection ovens is 10 % and with the same ratio of gas/electric convection ovens as for combi steam ovens.

For the current study it is assumed that the sales development of professional ovens used in commercial and professional kitchens follows the same trend as other "non-domestic cooking equipment as presented in Table 24 giving and average yearly sales growth of 6.4 % and annual sales in 2019 on 85,000 combi steam ovens (Table 26).

From the Prodcom data on non-domestic kitchen appliances (Table 24) an annual sales growth is found to 6.4 % resulting in estimated total sales in 2019 on 85,000 combi steam ovens for professional kitchens.

Table 26. Estimated sales of combi-steam ovens in the EU-27 in 2019.

	Electric combi-steamer	Gas combi-steamer	Total
Sales EU27,2020	69,600	15,600	85,200

Range hoods. The range hoods are defined under PRODCOM category 27511580 "Ventilating or recycling hoods incorporating a fan, with a maximum horizontal side = 120 cm^2". 27511580 is the only Prodcom category directly relevant to range hoods. However, the appliances covered by the definition would mainly be household appliances because of the size, max 120 cm - professional kitchens often will need larger hoods -, and because of the fans being integrated in the hood. For professional kitchen the extraction fan normally would be placed outside of the hood in the ventilation channel or as a roof-top exhaust fan. So conclusively the Prodcom contains no data on professional range hoods. The approach for this study is that all kitchens have ranges hood(s) for the extraction of odors, heat and humidity, and that some have more depending on the number and distribution of cooking zones. Larger kitchens will have much more than one, but as seen in later statistics the kitchen business sector primarily constitutes of small entities.

Based on this it is assumed that kitchens in average have two range hoods.

The yearly sales of range hoods are estimated from a simple calculation based on the stock (Table 34) and 10 years lifetime: Sales = stock / lifetime and are presented in Table 27.

Table 27. Sales of range hoods (1000s)

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
321	320	323	339	341	350	353	359	365	365

EU stock of professional cooking equipment

Please notice that stock data in this section have not been updated after new data from stakeholders were received – as mentioned in Section 4.1. See the adjustments in Section 4.6.2.

Not much data are available regarding data and categories of appliances in professional kitchens. A study performed by University of Reading (Mudie, Essah, Grandison and Felgate, 2013[111]) on the electricity consumption in commercial kitchens energy consumption mapped typical appliances including cooking appliances and their energy consumption in 14 professional kitchens in an English chain of "gastro-pubs". The food menu prepared is described as e.g. burgers, pies, sausages, hot sandwiches and casseroles. The study found a large variability of equipment on the models, capacities and volumes of the appliances in the kitchens in spite of the kitchens being part of the same chain and with the same menu.

The study did not consider gas appliances, except from mentioning that the average kitchens also had a large chargrill (charbroiller), a gas fired oven, and a hob with 6 burners (Table 28).

Table 28. Average number of typical professional cooking appliances in restaurant kitchens in an English chain of "gastro-pubs" (Source: Mudie et el 2013 [112])

Appliance Category	Average number of appliances per kitchen
Grill	1
Steamer	1
(Heat Lamps)	(15)
Bain-marie	1
Fryers	3
Combi steam ovens	3
Other cooking appliances	3
Gas chargrill (charbroiller)	1
Gas oven	1
Gas hob (6 burners)	1

The products in the category "other cooking appliances" use only 3 % of the energy consumption, and is assumed to be smaller appliances like mixers, kettles etc. which are not part of the statistics in Table 23 and Table 24.

The lot 23 Task 2[113] study provides some rough estimates on distribution of different commercial appliances. The study concludes that of the commercial hobs and grill products the 68 % most sold cooking appliances are boiling tops and tables (hobs) and fry tops. The study also concludes that the relative shares of products in commercial kitchens are as presented in Table 29.

[111] Electricity Use in the Commercial Kitchen S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), [1]University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

[112] Electricity Use in the Commercial Kitchen S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), [1]University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

[113] European Commission (DG ENER), 2011, Preparatory Study for Ecodesign Requirements of EuPs, Lot 23: Domestic and commercial hobs and grills, Task 2 report

Table 29. Relative share of different commercial appliances (Source: Lot 23 task 2[114])

Appliance Category	Total (relative number)	Here-of gas [%]	Electric [%]
Ovens*)	1	18	82
Hobs	0.68	60	40
Grills	0.32	50	50

*) Gas/electric share from Table 25.

This ratio corresponds relatively well with the above mentioned gastro pub study from Mudie et al. which finds 4 ovens vs. 3 grills and hobs. The number for grills and hobs (3) is lower than in the lot 23 study but it should be noted that the gas hobs in the gastro-pub study have 6 burners. This is to the large side since commercial hobs with just 1, 2, or 4 cooking zones are common.

Lot 23 Task 2 included the two subcategories charbroilers and griddles/fry tops in the category of `grills´. The ratio of the two subcategories varies in the report between 1:2.25 for sales and 1:1 for stock. For the present study a ratio of 1:1.5 on the stock is assumed. In addition to the technologies investigated in the lot 22 study, the lot 23 study and the UK gastro-pub study a number of other products are described in chapter 4.4, namely;

- other oven technologies: Impingement ovens, deck ovens (bakery ovens), rotary rack (rotisserie), microwave and hybrid ovens with microwave function (rapid cook ovens)
- tilting bratt pans / kettles and pasta cookers.

The U.S. Department of Energy (DOE)[115] has also analysed the cooking equipment in commercial kitchens and estimated the installed base of appliances in commercial kitchens as presented in Table 30. DOE finds that the around 23 % of the appliances are ovens (and additionally 17 % microwave), and that the 29 % of the appliances are in the categories broilers, griddles and ranges (corresponding to the grills and hobs categories). Fryers constitutes around 27 % and steamers around 4. Those figures confirm the assumption that the share of ovens and grills/hobs are around the 25-30%.

[114] European Commission (DG ENER), 2011, Preparatory Study for Ecodesign Requirements of EuPs, Lot 23: Domestic and commercial hobs and grills, Task 2 report

[115] W. Goetzler, M. Guernsey, K. Foley, J. Young, G. Chung (2016), Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances (2015 Update), U.S. Department of Energy, https://www.energy.gov/sites/prod/files/2016/06/f32/DOE-BTO%20Comml%20Appl%20Report%20-%20Full%20Report_0.pdf

Table 30. Cooking equipment in U.S. commercial kitchens[116]

Equipment Types	Fuel	Installed Base (1,000s)	Share (%)
Broilers	Gas	346	5.0
	Electric	34	0.5
Fryers	Gas	1,077	15.6
	Electric	780	11.3
Griddles	Gas	447	6.5
	Electric	477	6.9
Ovens	Gas	882	12,7
	Electric	722	10.4
Ranges (hobs and oven build together)	Gas	660	9.5
	Electric	65	0.9
Steamers	Gas	90	1.3
	Electric	182	2.6
Microwaves	Gas	N/A	0.0
	Electric	1,162	16.8

A Swedish supplier of kitchen ventilation (Tovenco)[117] has published a dimensioning table for kitchen ventilation with data about typical kitchen appliances, there declared power and numbers of them in professional kitchens. In these table the share of ovens is closer to 15-20 % than 25 - 30 %, but the overall picture, that combi ovens are dominating the product category, is the same.

Based on the above presented data it is for the current study concluded that the relative share of the professional cooking appliances considered in this study are as presented in Table 31. The assumptions are based on:

- Ovens, hobs, and grills: The Mudie, lot 22 and 23 data + referring to the argumentation above. Additionally, the group `other´ has been added, assuming it constitutes 10 % of the ovens.
- Microwave ovens are except from hybrid ovens not counted in the `other´ due to low improvement potentials (chapter 4.4.1) and energy consumption (e.g. seen from the `other´ group in the UK gastro pubs, Table 50).
- The share and relative number of steam cookers, Bain-marie and fryers are based on the Mudie study on UK gastro pubs but with the addition of the extra typical products not mentioned in that study.
- Tilting bratt pans and kettles as well as pasta cookers: Are widely available in the market, and from public informative web pages with advices about energy efficiency in professional kitchens and visits in professional kitchens it is found that these products should be considered.

[116] W. Goetzler, M. Guernsey, K. Foley, J. Young, G. Chung (2016), Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances (2015 Update), U.S. Department of Energy, https://www.energy.gov/sites/prod/files/2016/06/f32/DOE-BTO%20Comml%20Appl%20Report%20-%20Full%20Report_0.pdf
[117] Tovenco, Projekterings-anvisningar, http://www.visionair.dk/UserFiles/File/Dimensioneringsanvisning.pdf

Table 31. EU stock of professional appliances. Relative share of product categories (own calculations)

Product category	Sub category	Share of group	Total number of appliances in the main product category*	Number of appliance in subcategory	Relative share
Ovens	Static oven	0	3	0	0.000
	Convection oven	0.09		0.27	0.022
	Steam and combi oven	0.81		2.43	0.194
	Other; Air impingement, microwave hybrid (rapid cooker)	0.1		0.3	0.024
Hobs and grills	Grills including chargrill	0.128	4	0.512	0.041
	Fry-tops	0.192		0.768	0.061
	Hobs, gas	0.408		1.632	0.131
	Hobs, induction	0.063		0.253	0.020
	Hobs, infrared	0.075		0.301	0.024
	Hobs, electric resistance	0.134		0.535	0.043
Steam cookers		1	1	1	0.080
Bain-marie		1	1	1	0.080
Fryers		1	3	3	0.240
Bratt pans and kettles (incl. tilting)		0.667	0.5	0.334	0.027
Pasta cookers		0.333		0.167	0.013
Total			**12.5**	**12.5**	**1**

*Out of 12.5 appliances

The data from Tovenco[118] indicates that the number of cooking appliances compared to the numbers in Table 31 sums up to 8-10 for small and medium sized professional kitchens

The EU stock of professional cooking appliances could be estimated on a bottom-up approach by multiplying the number of about 1.8 million professional kitchens in 2020 from Table 21 and the assumed number of appliances per kitchen in Table 28 being 10 (excluding heat lamps and `other..´). Alternatively a top-down approach could be used, using the Prodcom data on total sales as starting point for a stock estimation. The results from both approaches are presented in Table 32.

[118] Tovenco, Projekterings-anvisningar, http://www.visionair.dk/UserFiles/File/Dimensioneringsanvisning.pdf

Table 32. Stock estimates (in 1000s) based on a top-down and a simplified bottom-up approach.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Top-down										
No. of enterprises	1604	1602	1614	1694	1704	1750	1766	1794	1823	1823
Annual sales of non-household cooking appliances on EU market excl. ovens	632	624	706	756	863	1145	887	654	803	803
Stock estimate excl. ovens (simple estimate derived from an average lifetime of 12 years)	7587	7491	8472	9077	10359	13745	10640	7853	9639	9639
Stock estimates including ovens not counted in Table 24 (25 % of total number of cooking appliances)	10117	9988	11296	12102	13812	18327	14187	10471	12853	12853
Bottom-up										
Stock estimate (derived from 10 cooking appliances in average per kitchen)	16043	16024	16141	16941	17040	17503	17660	17942	18230	18230
Difference of estimates	5926	6035	4845	4839	3228	-824	3473	7471	5377	5377
Average stock	**13080**	**13006**	**13718**	**14522**	**15426**	**17915**	**15924**	**14207**	**15541**	**15541**

Estimated stocks of individual professional cooking appliances are based on the total number of appliances from Table 32 and the following assumptions regarding share of gas and electricity as heat source:

- Ovens, hobs and grills as in Table 29
- Steam cookers are assumed having same of gas/electric ratio as steam combi steam ovens (ovens, Table 29).
- Bain-marie, tilting bratt pans and kettles, and pasta cookers are assumed having same of gas/electric ratio as hobs (hobs, Table 29).

The results are presented in Table 33.

Table 33. Stock of professional kitchen appliances and energy source (1000s, own calculations).

Product category	Sub category	Heat source	Share	Stock EU 27,2020 in 2020
Ovens	Static oven	Electricity	0.820	-
		Gas	0.180	-
	Convection oven*	Electricity	0.820	275
		Gas	0.180	60
	Steam and combi oven	Electricity	0.820	2477
		Gas	0.180	544
	Other; Air impingement, microwave and hybrid (rapid cooker)	Electricity	0.820	306
		Gas	0.180	67
Hobs and grills	Grills including chargrill	Electricity	0.500	318
		Gas	0.500	318
	Fry-tops /griddle	Electricity	0.667	637
		Gas	0.333	318
	Hobs, gas	Electricity	-	0
		Gas	1.000	2029
	Hobs, induction	Electricity	1.000	314
		Gas	-	0
	Hobs, infrared	Electricity	1.000	374
		Gas	-	0
	Hobs, electric resistance	Electricity	1.000	665
		Gas	-	0
Steam cookers		Electricity	0.820	1019
		Gas	0.180	224
Bain-marie		Electricity	0.667	829
		Gas	0.333	414
Fryers		Electricity	0.667	2488
		Gas	0.333	1242
Bratt pans and kettles (incl. tilting)		Electricity	0.667	277
		Gas	0.333	138
Pasta cookers		Electricity	0.667	138
		Gas	0.333	69
Total			1	15541

Range hoods. As mentioned above it is assumed that professional kitchen in average have two range hoods, giving the stock as presented in Table 34.

Table 34. Stock of range hoods, two per professional kitchen (1000s, own calculations).

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3209	3205	3228	3388	3408	3501	3532	3588	3646	3646

Forecast - Stock

The average growth rate is assumed to be 0 % in the years 2020-2023 due to the setbacks from the Covid-19 epidemy. From 2024 to 2030 the average growth rate is assumed at 1.6 %/year, similar to the growth rate found for commercial kitchens (Table 4). The Prodcom data on EU sales figures of professional cooking appliances (Table 22) suggest a higher growth of the appliance numbers than kitchens but for the present study the figures directly related to kitchens are used for the forecasts. It has not been considered for the forecasts if some appliances would have higher growth rates than other e.g. due to a technology shift.

The forecasts on the stock of professional cooking appliances are presented in Table 35.

Table 35. Forecasts of the EU stock of professional cooking appliances (1000s, own calculations).

Product category	Sub category	Heat source	2020	2025	2030
Ovens	Static oven	Electricity	-	-	-
		Gas	-	-	-
	Convection oven*	Electricity	275	284	308
		Gas	60	62	68
	Steam and combi oven	Electricity	2,477	2,559	2,774
		Gas	544	562	609
	Other; Air impingement, microwave and hybrid (rapid cooker)	Electricity	306	316	342
		Gas	67	69	75
Hobs and grills	Grills including chargrill	Electricity	318	329	356
		Gas	318	329	356
	Fry-tops	Electricity	637	658	713
		Gas	318	328	356
	Hobs, gas	Electricity	-	-	-
		Gas	2,029	2,096	2,272
	Hobs, induction	Electricity	314	324	352
		Gas	-	-	-
	Hobs, infrared	Electricity	374	386	419
		Gas	-	-	-
	Hobs, electric resistance	Electricity	665	687	744
		Gas	-	-	-
Steam cookers		Electricity	1,019	1,053	1,142
		Gas	224	231	251
Bain-marie		Electricity	829	856	929
		Gas	414	428	464
Fryers		Electricity	2,488	2,569	2,786
		Gas	1,242	1,283	1,391
Bratt pans and kettles (incl. tilting)		Electricity	277	286	310
		Gas	138	143	155
Pasta cookers		Electricity	138	143	155
		Gas	69	71	77
Total			**15,541**	**16,051**	**17,401**

Forecast for the stock of range hoods by based on the same principles as for cooking appliances is given in Table 36.

Table 36. Forecasts of the EU stock of range hoods for professional kitchens (1000s, own calculations).

Year	2020	2025	2030
Stock (1000s)	3.646	3.766	4.082

Forecast - Sales

A revised forecast on the sales figures, calculated from lifetime and stock estimates is presented in Table 37. These sales numbers are used for resource consumption estimates on aggregated level in Section 4.5.2.

Table 37. Sales estimates and forecast (in 1000s, own calculations)

Product category	Sub category	Heat source	Lifetime (years	2020	2025	2030
Ovens	Static oven	Electricity	12	0	0	0
		Gas	18	0	0	0
	Convection oven*	Electricity	11	25	26	28
		Gas	18	3	3	4
	Steam and combi oven	Electricity	11	225	233	252
		Gas	11	49	51	55
	Other; Air impingement, microwave and hybrid (rapid cooker)**)	Electricity	11	28	29	31
		Gas	11	6	6	7
Hobs and grills	Grills including chargrill	Electricity	10	32	33	36
		Gas	11	29	30	32
	Fry-tops / griddles	Electricity	10	64	66	71
		Gas	11	29	30	32
	Hobs, gas	Electricity	10	0	0	0
		Gas	11	184	191	207
	Hobs, induction	Electricity	10	31	32	35
		Gas	11	0	0	0
	Hobs, infrared	Electricity	10	37	39	42
		Gas	11	0	0	0
	Hobs, electric cast iron	Electricity	10	66	69	74
		Gas	11	0	0	0
Steam cookers		Electricity	12	85	88	95
		Gas	12	19	19	21
Bain Marie		Electricity	10	83	86	93
		Gas	10	41	43	46
Fryers		Electricity	10	249	257	279
		Gas	11	113	117	126
Bratt pans and kettles (incl. tilting)		Electricity	11	25	26	28
		Gas	11	13	13	14
Pasta cookers		Electricity	11	13	13	14
		Gas	11	6	6	7
Range hoods		Electricity	11	331	342	371
		Gas	11	0	0	0
Total				**1788**	**1846**	**2002**

4.3 Usage

Usage patterns and also operation modes differ for the different types of machines considered. Professional cooking appliances are used in professional kitchens in different sectors and establishments like restaurants, mobile food service, catering (parties, festivals, companies etc.), canteens for employees and schools in the public service sector like hospitals, child and elderly care, etc. The use patterns depend on the establishment where they are used – for example, the operating hours of an employer canteen for office employees typically would be morning to midday, a hospital kitchen all day round, a hotel kitchen in the morning or all day round if it service a restaurant too, restaurant kitchens midday and evening, or perhaps even evenings etc.

Professional kitchen appliances for a fully functional kitchen are costly and different purchase models could be found e.g. leasing vs. purchase and the owner of a food service establishment could rent the premises or own the kitchen him/herself.

Mudie et al[119] e.g. found that user behavior impacts the overall energy consumption in the food service sector significantly. For the cooking appliances, behavioral factors like turning appliances down/off when not required could save significant amounts of energy, in most cases 30-40 % compared to average. For grills up to 70 % of the energy consumption was saved for the most efficient use compared to the least efficient.

The study also found that this energy wise "inappropriate" behaviour was more the rule than the opposite. A conclusion could be that professional cooking appliances need to support efficient usage behaviour per default.

Generally, the daily hours of active usage of cooking appliances are estimated at 3-4 hours, based on calculation in the lot 22 and 23 preparatory studies and on the investigations from Daxbeck et al. on some Austrian and Czech professional kitchens[120].

A number of public guidelines e.g. the Danish Energy Agency guideline for professional kitchen personnel[121] and the US Environmental Protection Agency (US EPA) informs about efficient usage of cooking appliances. Advises are e.g.:

- Switch on the equipment just prior before it is being used. This is relevant for all equipment, from bain-marie and hot-holding equipment cooking zones, hobs, griddles, fryers, ovens etc. The energy consumption of the appliances is unnecessarily high when it is standing standby warm and additionally the excess energy is released to the kitchen environment.
- Be aware, that new ovens and hobs have a much shorter warm-up time than old appliances, so old habits like switching on the cooking appliances all day instead of immediately prior to its use is not necessary with new appliances.
- Reduce idle time by turning the griddle off during periods of non-use
- Turn of hobs, ovens and other equipment not in use. Use eventual timer control.
- Calibrate the griddle controls to operate at the correct temperature
- Replace missing control knobs
- For double-sided griddles, save energy by lowering the upper platen during extended periods of non-use
- Lower the temperature on the equipment during periods of low-production if a completely switch down is not suitable.
- Use a lid when possible. Use of lid on large fryers, tilting pans and kettles etc. could save up to 50 % of the energy consumption.

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[119] Electricity Use in the Commercial Kitchen S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), [1]University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

[120] Hans Daxbeck, Doris Ehrlinger, Diederik de Neef, Marianne Weineise, Ressourcen Management Agentur (RMA), Ressourcen Management Agentur (RMA), BIO AUSTRIA & Südböhmische Universität, ČR, EPOS (2011), Projekt SUKI – Energieverbrauch in Großküchen, Möglichkeiten von Großküchen zur Reduktion ihrer CO2-Emissionen, suki.rma.at/sites/suki.rma.at/files/Projekt%20SUKI%20-%20Endbericht%20Energie%20(Vers.%201.0).pdf (Table 3-3)

[121] Danish Energy Agency, *Storkøkkenvejledning,* 2018

- Use only the steam function in steam and combi ovens when necessary since the steam function increases energy consumption.
- Adjust the temperature of hot holding equipment to the lowest hygienically allowed temperature, usually 65 °C and observe the temperature regularly.
- Make sure that sealings on ovens, cookers, kettle pans etc, are tight, and change them if they are not.
- Safe energy by filling the oven, use pre- and after heat, and the least possible amount of water when cooking potatoes.
- If food prepared in an oven is not being served within 20 minutes, then use insulation to hold the oven instead of keeping the oven switched on, and do not open and close the oven unnecessarily.
- Use micro wave for small amounts of food.
- Adjust gas burner hobs to about 2 cm distance from the pan; this provides the best burner and heat transfer efficiency.

For **professional range hoods** maintenance of filters is important part of daily usages, being central for fire safety reasons, longer lifetime and thereby lover utility costs, less strain on the exhaust system motor and better performance of the exhaust system resulting in lower energy consumption and better extraction of fumes and cooling of the kitchen working environment. According to The *hood filter handbook*[122] the three common methods for cleaning hood filters are

- Hand washing with hot, soapy water and a non-abrasive scrubber or sponge which is often most effective way to remove grease and grime from hood filters. Bleach or harsh chemical can cause corrosion.
- Washing in a commercial dishwasher at its highest temperature with soap and water.
- Soak in a soak tank overnight in water and non-corrosive cleaner; a time and workforce saving method.

Harsh cleansers and bleach will corrode the filters and shorten their life and should be avoided.

Digitization. EFCEM comments that digitisation might be the most efficient measure to promote more efficient user behaviour and performance of cooking appliances without sacrificing on cooking performance. The appliances could benefit from digitisation e.g. by communication between the appliances (e.g. smart kitchen ventilation), communication of the devices with the staff to visualize the impact of different kitchen behaviour and help the staff trying out comparable cooking performance with lower energy.

4.4 Technologies

4.4.1 Ovens

Ovens and especially convection ovens are the most widely used appliances in professional and commercial kitchens and are used for nearly all types of food preparation.

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[122] Hoodfilters.com, 2016, The hood filter handbook, https://www.hoodfilters.com/flyers/Hood_Filter_Hand-Book.pdf

The main categories of ovens are:

- Static ovens
- Convection oven (forced conventional oven)
- Steam ovens and combi-steam ovens (hot air convection / steam)
- Deck ovens (bakery ovens)
- Rotatory rack ovens
- In-store bakery convection ovens
- Conveyor (impingement) ovens
- Microwave and hybrid ovens with microwave function

Most of the ovens – except microwave and hybrid ovens – are avaiable in electric, gas an some even in dual fuel heat source versions.

The lot 22 task 6 preparatory study by Mudgal et al[123] mapped a number of different potential improvements for ovens like advanced insulation, three glass layers in glass doors and power management with "sleep mode" where the oven reduces the temperature to 100 °C to be ready for operation relatively quickly but still saving energy compared to an "idle mode" on e.g. 180 or 250 °C. As presented for combi steam ovens below, improved temperature control with lower oscillation also improves energy efficiency. For gas ovens specifically a careful design of gas burners for optimized combustion in combination with sufficient level of ventilation through the oven to remove steam and combustion gasses but not cooling down the oven too much could increase operating efficiency. Also replacement of gas pilot lights with electronic ignition would save around 5,5 kWh of gas energy per day per gas oven. All the mentioned technologies are already available, but also better "not-available-technologies" were identified in the lot 22 preparatory study.

Static ovens. A static or conventional oven cooks food primarily using the naturally occurring hot air currents from the heating elements to transfer heat over the surface of the food product. A static oven operates without a fan or a blower. The burner or heat elements heat the air within the oven cavity as well as the cavity walls[124].

For gas ovens the burner efficiency influences the energy efficiency, while for electric ovens there is a 100 % heat transfer. The energy efficiency of professional static ovens could be impacted by the mass of the oven, the insulation level in walls and door and around doors, the latter influenced by the sealing lists, where e.g. double sealing lists will minimize heat losses around the door and with automatic shut-off of the convection fan during door openings.

Mudgal et al[125] informs that commercial convection ovens tends to be left on continuously to be constant ready to use. Idle energy consumption could give a significant contribution

[123] S. Mudgal, B. Tinnetti, E. Hoa Bio Intelligence Service & C. Robertson, P. Goodman, S. Pitman ERA Technology, Preparatory study for ecodesign requirements of EuPs Lot 22: Domestic and commercial ovens, European Commision DG TREN, 2011, www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task6-final.pdf

[124] Energy Star® Program requirements - Product specification for commercial ovens, Version 2.2., www.energystar.gov/sites/default/files/Commercial Ovens Final Version 2.2 Specification.pdf

[125] S. Mudgal, B. Tinnetti, E. Hoa Bio Intelligence Service & C. Robertson, P. Goodman, S. Pitman ERA Technology, Preparatory study for ecodesign requirements of EuPs Lot 22: Domestic and commercial ovens, European Commision DG TREN, 2011, www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task6-final.pdf

to the energy consumption of professional static ovens especially for older types, that are heating up slowly and where there will be a tendency from the users to keep the oven more or less heated for a longer time to avoid waiting time when it is going to be used.

Neither of the two appliance energy efficiency programmes, Topten or Energy Star, include professional or commercial static ovens.

Convection ovens. Convection ovens are general-purpose oven that cooks food by forcing hot dry air over the surface of the food product. The forced air convection displaces the cold air around the cold food. Thereby the heat transfer rate is increased and the food absorbs the heat energy more quickly.

Full- and half-size electric convection ovens, and full-size gas convection ovens can earn the Energy Star by meeting minimum cooking energy efficiency, as well as a maximum idle energy rates. Cooking energy efficiency represents the amount of energy absorbed by the food product compared to the total energy used by the oven during the cooking process. The idle energy rate represents the energy used by the oven while it is maintaining or holding at a stabilized temperature[126].

Standard gas convection ovens have a 30 % cooking energy efficiency and an idle energy rate of 18,000 Btu/h, where the minimum requirements to Energy Star certified gas convection ovens are 44 percent cooking energy efficiency and idle energy rate of 13,000 Btu/h.

Standard electric convection ovens have a 65 % cooking energy efficiency and an idle energy rate of 2 kW were Energy Star minimum requirements are 70 percent cooking energy efficiency and an idle energy rate of 1.6 kW[127].

Steam ovens and combi-steam ovens (combi-steamers). Steam ovens uses hot saturated and superheated steam to cook food[128]. They work by generating the steam either in a separate boiler or continuously within the oven. The last method is believed to be the most efficient. The steam is heating it to 100 °C or more (superheated) up to 350 °C, and releasing the steam into the cavity[129]. A common model is to combine the function of a convection oven and a steam oven in a combi-steam oven, also called convection steam oven or combi-steamer. Table 38 presents different categories of steam ovens and their heating functions from the review study.

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[126] US Environmental Protection Agency, Energy Star, Commercial ovens, Overview, 2015 https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens

[127] US Environmental Protection Agency, Energy Star, Commercial ovens, Overview, 2015, www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens

[128] Energy Star® Program requirements - Product specification for commercial ovens, Version 2.2., www.energystar.gov/sites/default/files/Commercial Ovens Final Version 2.2 Specification.pdf

[129] S. Mudgal, B. Tinnetti, E. Hoa Bio Intelligence Service & C. Robertson, P. Goodman, S. Pitman ERA Technology, Preparatory study for ecodesign requirements of EuPs Lot 22: Domestic and commercial ovens, European Commision DG TREN, 2011, www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task6-final.pdf

Table 38 Types of steam ovens[130]

Type of steam oven	Heating functions
Steam oven (solo-steam oven)	- Steam cooking
Convection steam oven (combi-steam oven, combi-steamer)	- Steam cooking - Steam cooking with fan-forced convection - Fan-forced convection
Steam-assisted oven	- Steam cooking with fan-forced convection - Fan-forced convection

Combi-steam ovens can cook with steam only, with steam and fan-forced convection, and with fan-forced convection heating only. These ovens thereby combine wet and dry cooking, with the advantages of evenly distributed heat and browning and the steam that adds moisture to prevent the food from becoming too dry.

Burlon[131] analysed the energy transfer and losses in different mechanisms within a commercial electric convection steam oven by tests of an 17 kW electric combined steam and convection oven. In this case Burlon found, that a significant part of the energy is lost through the walls in cavities and thermal bridges and through ventilation of vapours (Table 39). Note that the efficiencies of the two heating modes cannot be compared since it was performed with different test loads. It does however indicate where the energy ends up and consequently to look for improvement potentials. One of the findings was that improved temperature control with less temperature oscillation, a completely acceptable change for the users, is one of the major methods for efficiency improvements.

Table 39 Energy fluxes for steam and convection mode in a combined commercial electric convection steam oven (Source: Burlon[132])

Energy flux	Convection mode	Steam mode
Vapours	20 %	11 %
Walls	24 %	6 %
The load in the centre of the oven	35 %	79 %
Door	6	0 %
Liquids	16	1 %

Burton also applied and tested different options to improve the energy efficiency on a prototype, finding 16 % lower energy consumption heating op the structure of the oven and 29 % lower consumption for maintenance of the operating conditions (idle energy) however on the cost of the size of the oven cavity (10 % smaller). Adjusted for capacity an overall improvement above 20 % is reached.

[130] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

[131] Burlon, Fabio, Energy Efficiency of Combined Ovens, Energy Procedia, Elsevier BV, 2015

[132] Burlon, Fabio, Energy Efficiency of Combined Ovens, Energy Procedia, Elsevier BV, 2015

The lot 22 task 6 preparatory study by Mudgal et al[133] also describes some potential improvements for steam ovens specifically; heating the steam inside the cavity, heat recovery from condensate and for gas ovens the use of heat exchanger for heat transfer.

Half- and full-size gas combination ovens with a pan capacity ≥ 6; and half- and full-size electric combination ovens with a pan capacity ≥ 5 and ≤ 20 can earn the Energy Star certification by achieving both convection mode and steam mode idle and cooking energy efficiency levels as presented in Table 41Table 40. Energy Star requirements for a 12 pan steam and combi-ovens. Calculations based on [134]. No firm conclusion was reached in the study, except that products were already available that being around 25 % more efficient that standard products.

For Energy Star the maximum values of idle energy consumption for a 12 pan combi and steam oven which based on the Energy Star product information is assumed to be a standard size oven are calculated and presented in Table 40. As it can be seen the requirements are slightly stricter for combi ovens in convection mode than for "pure" convection ovens. In the steam mode the ovens are less efficient. Energy Star specification do not provide savings potentials for this product category.

Table 40. Energy Star requirements for a 12 pan steam and combi-ovens. Calculations based on [135].

	Operation	Idle Rate P = 12	Cooking-Energy Efficiency [%]
		[Btu/h]	
Gas	Steam Mode	≤ 8911	≥ 41
	Convection Mode	≤ 7225	≥ 56
		kW	
Electric	Steam Mode	≤ 2.236	≥ 55
	Convection Mode	≤ 1.459	≥ 76

Note: P = Pan capacity.

EFCEM[136] points the attention to the unique potential of combi steamers in respect of heat recovery, as the energy in combi steamers is released very concentrated at the ventilation pipe. This is not the case with other cooking appliances. Thus, the combi-steamer heat recovery from combi steamers can be done e.g. via a heat recovery integrated in the ventilation system above the appliance.

Rotatory rack ovens. Large commercial ovens that are frequently used in high volume backing facilities and other food service operations, such as supermarkets, high volume bakeries, and institutions[137]. Single and double gas rack ovens are eligible for Energy Star

[133] S. Mudgal, B. Tinnetti, E. Hoa Bio Intelligence Service & C. Robertson, P. Goodman, S. Pitman ERA Technology, Preparatory study for ecodesign requirements of EuPs Lot 22: Domestic and commercial ovens, European Commision DG TREN, 2011, www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task6-final.pdf

[134] US Environmental Protection Agency, Energy Star, Commercial ovens, Overview, 2015, https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens

[135] Energy Star® Program requirements - Product specification for commercial ovens, Version 2.2., www.energystar.gov/sites/default/files/Commercial Ovens Final Version 2.2 Specification.pdf

[136] European Federation of Catering Equipment Manufacturers EFCEM, Stakeholder comment 26th March 2021

[137] Energy Star® Program requirements - Product specification for commercial ovens, Version 2.2., www.energystar.gov/sites/default/files/Commercial Ovens Final Version 2.2 Specification.pdf

if they do not exceed energy idle rate requirements and achieve minimum baking energy efficiency criteria. Rotary rack ovens will not be considered for the scope.

Rotisserie Ovens are ovens fitted with a mechanism to move or turn food past a fixed heat source while the food is slowly being cooked on all sides[138]. Neither of the appliance energy efficiency programmes, topten or Energy Star, include professional or commercial static ovens. Rotesserie ovens will not be considered for the scope.

In-store bakery convection ovens. Convection ovens designed specifically for baking. Neither of the appliance energy efficiency programmes, topten or Energy Star, currently include professional or commercial static ovens. In-store bakery ovens will not be considered for the scope.

The Swiss Federal Office of Energy (SFOE)[139] comments however, that this oven type is rapidly increasing with shops baking bread freshly on site (often pre-baked or raw frozen dough pieces). Topten Switzerland is finalizing a study about in-store bakery convection ovens on behalf of SFOE. One subject is to gather data on energy consumption. Some manufacturers report that energy consumption is increasingly topical for their customers and they would be supportive of a uniform declaration of energy consumption values and as an example a manufacturer has highlighted efficiency improvements of 20-30% for new models comparing to previous models. These ovens are technically not different from convection ovens. The main difference is the visual design (because visible to customers), in particular featuring large glass doors (triple glazing = BAT) and therefore it could be difficult to distinguish between in-store bakery convection ovens and other convection ovens.

This indicates a potential loop-hole in a regulation on convection ovens that is excluding in-store bakery ovens.

Conveyor ovens (impingement ovens). Conveyor ovens or impingement ovens are ovens which provide rapid and controlled baking of food products by means of radiant and forced convection by jets of hot air and a conveyor band transporting the products through the oven using a pre-set time. Impingement ovens are particular useful for high volume production of relatively uniform food products like pizzas, pitas or waffles and are for the same reason also often marketed as pizza ovens. This oven type is normally rather flat and therefore it could be stabled if higher capacity is needed in the kitchen.

According to Habas[140] impingement ovens reduces the cooking time, some manufacturers informs 30-35 %, and due to the quicker cooking, less moisture is lost with impingement heating, resulting in better flavour and texture. The conveyor band and also helps the kitchen personal by transporting the food away from the cooking zone which reduces the need for direct oversight from busy kitchen staff and preventing food from burning.

Habas also describe disadvantages of this oven type which mainly are the need for a careful adjustment of the oven settings (temperature, speed of conveyor band, nozzle distance

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138 Energy Star® Program requirements - Product specification for commercial ovens, Version 2.2., www.energystar.gov/sites/default/files/Commercial Ovens Final Version 2.2 Specification.pdf

139 Swiss Federal Office of Energy SFOE, Federal Department of the Environment, Transport, Energy and Communications DETEC, Stakeholder comment 18th March 2021

140 Cathy Habas, Hunker, 2020, What Is an Impingement Oven? www.hunker.com/13409435/what-is-an-impingement-oven

from conveyor band). Consequently the ovens are not so easy to use for changing menus but would normally be dedicated to one food category. Also not all food products e.g. bread and cakes are suitable for this kind of treatment.

Conveyor ovens will not be considered for the scope.

Professional microwave ovens. Microwave ovens functions by heating up the water molecules in the food. They are for instance used for preheating, defrosting, vegetables and precooked food. Their advantage is quick heating of the ore of the heat load. Disadvantages are that the food could change its texture and that the heat could be unevenly distributed, leaving cold spots inside the product.

Typically the professional microwave ovens maximum capacities ranges from 0.8 kW and up to about 2 kW. Professional microwave ovens with capacities from about 2 to 3 kW are also found and could be characterised as heavy duty microwave ovens.

Like the Lot 22 preparatory study by Mudgal et al[141] the current study found no indication on significant improvement potentials for professional microwave ovens. Neither of the two appliance energy efficiency programmes, topten or Energy Star, include micro wave ovens. It may be relevant to look at standby consumption of professional microwave ovens.

Hybrid ovens. Hybrid ovens or rapid cook ovens combines the microwave, convection heating and air impingement ovens. Their advantages is the possibility for rapid cooking with cooking times from 20-30 seconds and up to a few minutes for smaller dishes. Rapid cook ovens will heat both the core of the heat load and give the roasted or crunchy surface appearance from a conventional oven due to the combination of the microwaves and convection oven. Typical wattages for these ovens are from about 0.8 to 2 kW for the microwave function and 2 up to 3 kW for the convection oven function but also with products having capacities up to 5 – 6 kW.

Hybrid ovens are particular relevant for small "semi-professional" kitchens like in mall kiosks, convenience stores, convention halls, delis, and food trucks. Some of the ovens have a catalytic converter system that captures grease and smoke so they can be used without a hood[142].

The lot 22 task 6 study[143] concludes that there is a high product variability and that the combination with microwave energy in any case will make these ovens relatively energy efficient. One of the conclusions from the review study was that it would be relevant to provide information also for the professional consumers regarding energy efficiency and

[141] S. Mudgal, B. Tinnetti, E. Hoa Bio Intelligence Service & C. Robertson, P. Goodman, S. Pitman ERA Technology, Preparatory study for ecodesign requirements of EuPs Lot 22: Domestic and commercial ovens, European Commision DG TREN, 2011, www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task6-final.pdf

[142] https://www.webstaurantstore.com/guide/622/rapid-cook-ovens-buying-guide.html

[143] S. Mudgal, B. Tinnetti, E. Hoa Bio Intelligence Service & C. Robertson, P. Goodman, S. Pitman ERA Technology, Preparatory study for ecodesign requirements of EuPs Lot 22: Domestic and commercial ovens, European Commision DG TREN, 2011, www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task6-final.pdf

end of life aspects for these products[144]. The Swiss Topten programme includes the rapid cooking ovens in their product register[145]. Energy Star does not.

Efficiency programmes for ovens. As mentioned above some of the commercial ovens can earn the US Energy Star. Eligible product for the rating scheme are electric half- and full-size combination ovens; and gas, single and double rack ovens. All must meet minimum requirements to idle energy rates and minimum cooking or baking energy efficiency levels. According to the US EPA are commercial ovens that have earned the Energy Star generally about 20 percent more energy efficient than standard models[146]. The specific requirements for the products covered are listed in Table 41.

Table 41. Energy Star minimum requirements to commercial ovens[147]

Appliance		Idle Energy rate	Cooking energy efficiency [%]
Ovens	Gas Convection Ovens (full size)	≤ 12,000 Btu/hr	≥ 46
	Electric Convection Ovens - Half size - full size	 ≤ 1.00 kW ≤ 1,60 kW	 ≥ 71 ≥ 71
	Gas combination ovens - Steam mode - Convection mode	 ≤ 200P + 6,511 [Btu/hr]$^{2)}$ ≤ 150P + 5,425 [Btu/hr]	 ≥ 41 ≥ 56
	Electric combination ovens - Steam mode - Convection mode	 ≤ 0.133P + 0.6400 [kW]$^{2)}$ ≤ 0.080P + 0.4989 [kW]	 ≥ 55 ≥ 76
	Gas rack ovens - Single - Double	 ≤ 25,000 Btu/hr ≤ 30,000 Btu/hr	 ≥ 48 ≥ 52

$^{1)}$ Tested at "Heavy load" conditions $^{2)}$ P = Pan capacity

Size and capacity distribution of ovens. For ovens the size distribution of small vs. standard and larger for the current study is assumed to follow a normal distribution curve with the standard ovens as the normal. Also it is assumed that the average energy consumption and saving potentials corresponds to the standard oven. These two assumptions are used for the estimation on stock and energy consumption.

Other environmental parameters than energy

Noise. Convector ovens have noise from the convector fan and it is recommended to investigate the typical sound power from professional ovens and to consider at limit on 70 dB(A), as also required in EN 60335. EFCEM[148] informs that noise is generally not considered to be a problem for cooking appliances.

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[144] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, 3.3.4 Information to consumers, Joint Research Centre, 2020

[145] topten.ch, Turbo-Öfen, www.topten.ch/business/products/turbo_ovens

[146] US Environmental Protection Agency, Energy Star, Commercial ovens, Overview, www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens

[147] US Environmental Protection Agency, Energy Star, Commercial ovens, Overview, www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria

[148] European Federation of Catering Equipment Manufacturers EFCEM, Stakeholder comment 26th March 2021

Water consumption. Steam ovens consumes water for the steaming, but in small quantities. The water could be supplied from a water treatment unit providing soft and demineralized water avoid need for decalcification of the boiler. EFCEM informs that currently no standards are available for evaluating the water consumption of ovens.

4.4.2 Hobs and griddles

Professional and commercial and hobs are also known as cook-tops, ranges (although also understood as an integrated oven and cook-top), stoves and cookers. Professional hobs are found with gas and electric hobs. The main types of electric hobs are the traditional (old fashioned) hobs with cast iron mass stoves, the glass ceramic and the induction stoves.

Gas hobs' main advantage is the good control of the heating process due to their possibility of heating the cooking vessels quickly and turning down even more quickly to allow the chef to fine tune the cooking process. Additionally gas stoves are more versatile than any electric stoves regarding the choice of cooking vessels – almost all pans and pots could be used independent of material and geometry, especially for open burners. Due to the direct conversion from gas to heat gas is generally considered as an efficient stove heating technology. However the efficiency also depends on the burners efficiency and how much of the generated heat that is lost around the cooking vessel.

Cast iron stoves / electric resistance hobs work by heating a heat element and transferring the heat to the pots and pans. Due to the higher heat capacity, there is longer reaction time and thereby higher losses of mass hobs compared to the other electric.

Glass-ceramic hobs heats up the cooking vessel by means of infra read heating e.g. from a halogen heater, through the transparent glass ceramic glass top plate.

Induction hobs provides fast heating which is comparable to gas stoves and an the highest cooking efficiency - both in respect of thermal cooking efficiency and time consumption - compared to the other two electric stove technologies. The heat generator of an induction hub is a (copper) coil placed under the top plate that generates an oscillating electric field that induces a magnetic flux, which magnetizes and thereby heats the cooking vessel. Almost all consumed energy goes directly into the heated vessel.

Induction hobs provide more consistent heating than cooking by thermal conduction and - depending on the primary energy conversion factor – the cooking energy efficiency of induction hobs more or less equals gas stoves. Induction hobs however normally require cookware of ferromagnetic materials like cast iron or stainless steel[149]. Lately induction hobs models have been introduced with the possibility to heat cookware of other metals[150]

Fry-tops (griddles). A subcategory or perhaps an add-on to professional hobs is fry-tops or griddles (US Energy Star). A fry-top is a steel sheet with splash sides and back which is layed or installled on top of a range. The plate covers the entire hob, and is used onstead of pans for frying steaks, bread, vegetables etc. The fry-top is normally polished and

[149] Wikipedia, Cooktop, 2020, en.wikipedia.org/wiki/Cooktop

[150] Panasonic, 2017, www.prnewswire.com/news-releases/panasonic-introduces-groundbreaking-new-induction-cooktop-providing-extraordinary-commercial-cooking-performance-with-all-kinds-of-metal-cookware-300404902.html

perhaps also with cromium surface to get a very smooth nonsticky surface. Instead of a plane surface it ould be riffled like a grill. It is usually possible to is drain grease and liquids of the frytop into an additional grease collection container to enable dry frying or grilling. Some ranges has the fry-top integrated permantly.

Like (other) hobs fry-top hobs are found for gas and gas and electricity as heat source. Electric fry-tops are avaiable with traditional resistance heating element or infrared heating elements mounted below the cooking surface.

An interesting category of electric fry-top is with steam, where a sealed chamber below the fry-top contains water that is super-heated and condensate on the sheet under the cooking zone. This should ensure a uniform heat distribution over the entire cooking zone up to around 200 °C and an exact temperature control since the condensation temperature depends on the pressure, and is constant everywhere in the chamber[151].

EPA defines single-sided and double sided commercial griddles for the energy specifications as an "appliance designed for cooking food in oil or its own juices by direct contact with either a flat, smooth, hot surface (…) or a hot channelled cooking surface (…) where plate temperature is thermostatically controlled." The double sided griddle can as the name says cook the food on both sides at once[152]. Griddles with channelled surface creates a similar pattern of brown lines of charring on the prepared food as a charbroiler (see the section below)

An important use factor for griddles – especially for electric griddles – is the heat-up time, which need to be short, otherwise the users are tempted to leave it on heated during the entire working day.

The US EPA also mentions other construction factors as important for energy efficiency and efficient use of griddles[153]:

- Improved thermostatic controls and strategically placed thermocouples; and only thermostatically controlled, not manually controlled griddles and fry-top ranges, are eligible for Energy Star
- Unform temperature distribution across the griddle plate
- Highly conductive or reflective plate materials.

Additionally EPA mentions that thermostatic controls "have the potential to sense the presence of cooking loads and offer better response and faster recovery when a load of fresh product is placed on the cooking surface".

General factors for improved energy efficiency for hobs. Generally for the professional kitchen temperature sensors and thermostats as well as automatic controls and temperature display, timer etc. are factors that support energy efficient cooking. For glass-ceramic hobs in particular cooking sensors for automatic shut-down of cooking zones

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[151] Accu-Steam, www.ckitchen.com/p/accutemp-egf4803a3650-t1-accu-steam-griddle.html

[152] US EPA, 2011, Energy Star, Commercial Griddles Key Product Criteria, www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_products_criteria

[153] US EPA, 2011, Energy Star, Commercial Griddles Key Product Criteria, www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_products_criteria

are important[154] but for all hobs improved thermostatic controls and strategically well placed thermocouples could improve the energy efficiency.

Efficiency programmes for hobs. Energy Star covers single- and double-sided gas and electric griddles that are thermostatically controlled. The Energy Star requirements refers to cooking energy efficiency and idle energy rate as per Table 42.

Table 42. Energy Star minimum requirements to commercial griddles[155]

Appliance		**Idle energy rate**	**Cooking energy efficiency [%]**
Griddles	Gas fuelled single- and double-sided	2,650 Btu/h/ft^2	Declared[1)]
	Gas/electric double-sided that include an electric top plate and gas bottom plate	2,650 Btu/h/ft^2	Declared[1)]
	Electric single- and double-sided	0.320 kW/ft2	Declared[1)]

[1)] Tested at "Heavy load" conditions per ASTM F1275 and F1605 test standards

The cooking efficiency is defined as the ratio of energy absorbed by the food product to the total energy supplied to the griddle during cooking. The idle Energy Rate is defined as the consumption required by the griddle for maintaining a stabilized operating condition or temperature and normalized to the area of the (bottom) cooking surface. The exact calculation formulas are found in Annex 1.1.

Neither of the appliance energy efficiency programmes, topten or Energy Star, include other categories of hobs or ranges.

4.4.3 Grills / Broilers, charbroilers

Professional and commercial charbroilers, also known as grills, barbecues, chargrills or broilers are characterized as an appliance for heating food on a "cooking devise consisting of a series of grates or ribs"[156] and with the heat provided from the top the side or below; the latter called charbroiler.

Broilers provide an alternative method for cooking flavorful foods by the process that usually takes 3 to 6 minutes and are normally used to give the food a smoked flavor - hence the traditional use of charcoals - and the characteristic brown lines from the warm ribs.

The heat source normally is below the metal ribs and could be electric (resistance or infrared), gas or charcoal (the last not in the scope of the current study). The heat could be applied directly or distributed via a heat deflector, sometimes e.g. lava rocks or other briquettes. Electric broilers using infrared heating provides a more efficient heating due to a quicker adjustment and control.

[154] Danish Energy Agency, 2018. Storkøkkenvejledning

[155] US EPA, 2011, Energy Star, Commercial Griddles Key Product Criteria, www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_products_criteria

[156] Wikipedia , 2020. Charbroiler, en.wikipedia.org/wiki/Charbroiler

Charbroilers are known for uneven temperature distribution on the cooking zone and as inefficient. The newest models of broilers increase food preparation efficiency, shorten pre-heat times and reduce excess heat loss in the kitchen[157].

4.4.4 Steam cookers

Steam cookers are used in restaurants, hospital, and catering kitchens for making soups, pasta, rice and milk dishes, for stewing meat, fish, vegetables and rapid steaming of vegetables or fish, final preparation of frozen or semi-prepared, ready-to-cook meals. The equipment is not suitable for roasting or baking. Steam cookers are related to steam ovens but as mentioned without the roasting and baking capability. This product category is not very common in Europe.

Steamers could be with electric or gaseous heat sources. Steamers with gaseous heat source also has an electricity consumption for fan motor, controls and potentially a secondary heating element, The following main technologies are found for commercial steamers according to the EPA[158]:

- Boiler-based steamer: Has a separate heating boiler that supplies steam to the cooking compartment at a pressure range from 0 to 15 psig. Generator and cooking cavity are housed in a single unit.
- Boiler-less steamer with an open steam generator. Generates steam inside the cooking cavity under atmospheric pressure. The water reservoir inside the cavity is manually accessible.
- Boiler-less steamer with a closed steam generator: Generates steam inside the cooking cavity under atmospheric pressure. The water reservoir inside the cavity is not manually accessible.

Steam cookers could improve their energy efficiency by better insulation and more efficient steam delivery systems. According to the EPA added benefits are shorter cook times and higher production rates.
Steam cookers with three pans or more could earn the Energy Star if they meet requirements to minimum cooking energy efficiency and an idle rate based on pan capacity as presesnted in Table 43. The rating is applicable for countertop and wall-mounted models, floor-models mounted on a stand, pedestal or cabinet-style base. Hybrid/combination products and pressure steamers are are not covered[159].

[157] https://www.georgiapower.com/business/save-money-and-energy/customer-resource-center/equipment/commercial-cooking/broilers.html

[158] US EPA, 2017, Component Inspection Of Energy Star® Certified Steam Cookers, Directive no. 2017-01, www.energystar.gov/sites/default/files/asset/document/Directive%20_2017-01_Component%20Inspection%20of%20ENERGY%20STAR%20Certified%20Steam%20Cookers_0.pdf

[159] US EPA, Commercial Steam Cooker, Key Product Criteria www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers/key_product_criteria

Table 43. Energy Star minimum requirements to commercial steam cookers

Appliance		Idle Energy rate	Cooking energy efficiency [%]
Steam cookers	Electric Steam Cookers[1)] - 3-pan - 4-pan - 5-pan - 6-pan and larger	 0.400 kW 0.530 kW 0.670 kW 0.800 kW	50 %
	Gas Steam Cookers[1)] - 3-pan - 4-pan - 5-pan 6-pan and larger	 6,250 Btu/hr 8,350 Btu/hr 10,400 Btu/hr 12,500 Btu/hr	38 %

[1)] Tested at "Heavy load" conditions

EPA has identified the most important components of steam cookers. Examples of components with significant influence on the energy efficiency are door gaskets (heat loss), thermal insulation and placement, steam vent and exhaust tubing design, temperature control etc.[160].

Other resources. The water consumption of steam cookers could vary significantly depending on cooker design. According to the EPA an average standard model uses about 40 gallons of water per hour (150 l/h) while an Energy Star certified steam cooker with the same capacity uses only 3 gallons of water per hour (11 l/h) or a 90 % saving[161].

4.4.5 Bain-marie

A bain-marie is a heated open container, traditionally a double container with a water bath between the two walls. It is used to heat food gently or to keep food warm at temperatures up to 90-95 °C over a period of time. In the normal bain-marie the inner container / well is heated uniformly due to the water bath.

Bain-maries are constructed with a water inlet and a tap for water drainage. Materials are normally mainly 100 % stainless steel, insulation in mineral wool and plastic for controls plus non-ferritic metals for electronics and heating element. For electric models the heating element could be an immersion heater.

A uniform temperature distribution, low heat losses through the sides and exact and quick temperature control are key elements for efficient operation.

One manufacturer[162] claim that by replacing the water bath with a constantly circulating flow of warm air flow through the containers a significantly faster preheating phase and

[160] US EPA, 2017, Component Inspection Of Energy Star® Certified Steam Cookers, Directive no. 2017-01, www.energystar.gov/sites/default/files/asset/document/Directive%20_2017-01_Component%20Inspection%20of%20ENERGY%20STAR%20Certified%20Steam%20Cookers_0.pdf

[161] US EPA, Commercial Steam Cooker, Key Product Criteria www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers/key_product_criteria

[162] Electrolux Professional (2020), Drop-in bain-marie, air ventilated, https://tools.electroluxprofessional.com/Mirror/Doc/MAD2/Electrolux%20Professional/English/341010_Drop-in%20bain-marie,%20air%20ventilated,%20with%20one%20well%20(3%20GN%20container%20capacity).pdf?version=1606360848

lower energy consumption is possible. Additionally, since the system operates without water there is no water consumption and easier maintenance with no calcification of the resistances heating elements for electric bain-maries.

4.4.6 Fryers (deep fryers)

Fryers or deep fryers have heated fry pots that are used for deep frying of food products in hot oil or fat. Fryers are used in a variety of high-volume food establishments including fast food and full-service restaurants, grocery and retail, and institutional kitchens[163].

Fryers are found both with gas and electricity as heat source. Energy Star distinguishes between fryers with standard sized pot (12 to 18 inches) vs large sized vat (18 to 24 inches wide).

The energy and cooking efficiency including the cooking time for fryers, depends on the fry-pot design and the control of the fryers. Examples of design factors improving energy efficiency are[164,165,166]:

- Frypot insulation which reduces standby losses resulting in a lower idle energy rate.
- Lid which reduces energy consumption especially during the heating phase.
- Temperature probe which is strategically mounted e.g. on the elements. This ensures precise temperature readings
- Efficient thermostat control minimizes over-temperature, maximizes oil life, and compensates for variations in cooking loads and thereby improving cooking consistency.
- Efficient burners (for gas) and heat exchanger design (gas and electric).

Standard and large sizes open deep-fat fryers for both gas and electric heat sources of both countertop and floor type models could earn the Energy Star. Closed fryers and fryers with other pot/vat measures are exempted from the scope of Energy Star.

Commercial/professional fryers from the mentioned product group could get the Energy Star if they meet the requirements to minimum cooking efficiency and maximum idle energy rate as presented in Table 44.

Table 44. Energy Star minimum requirements to commercial fryers[167]

Appliance		Idle Energy rate	Cooking energy efficiency [%]
Fryers	Standard[2)] Open Deep–Fat Gas Fryers	≤ 9,000 Btu/hr	≥ 50[1)]
	Large[2)] Vat Open Deep–Fat Gas Fryers	≤ 12,000 Btu/hr	≥ 50[1)]
	Large[2)] Vat Open Deep–Fat Gas Fryers	≤ 0.80 kW	≥ 83[1)]
	Large[2)] Vat Open Deep–Fat Electric Fryers	≤ 1.10 kW	≥ 80[1)]

[1)] Tested at "Heavy load" conditions

[163] US EPA. Energy Star, 2016, Commercial Fryers Key Product Criteria www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria

[164] US EPA. Energy Star, 2016, Commercial Fryers Key Product Criteria www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria

[165] Frymaster, Oil Conserving, 2020, www.frymaster.com/info#oil-conserving

[166] Danish Energy Agency, 2018. Storkøkkenvejledning

[167] US EPA. Energy Star, 2016, Program Requirements, Product Specification for Commercial Fryers Eligibility Criteria Version 3.0, www.energystar.gov/sites/default/files/Commercial Fryers Program Requirements.pdf

2) Standard size fry pots are ≥ 12 inches and < 18 inches wide. Large are 18 to 24 inches wide.

The Energy Star requirements refer to the ASTM test standards: F1361-07 (2013), *Test Method for Performance of Open Deep Fat Fryers* for standard fryers and F2144-09, *Test Method for Performance of Large Open Vat Fryers* for large vat fryers. Also the German standard DIN 18873-3:2018-02 specifies how to test fryers.

Other resources. The main resource consumed by fryers in addition to energy is oil/fat, and therefore fryers could be equipped with oil filter and perhaps also an oil filtration unit which includes an oil pump and might operate automatically. Such filtration functions must be expected to add to the energy consumption of the fryer but at the same time it could extend the life time of the oil or fat. This might be particular relevant for the large fryer models[168].

Correct temperature control and no overheating of oil may be possible relevant parameters to investigate to improve the conservation and reduce the break-down and oxidation of the oil in case a closer investigation proves this to be a relevant parameter.

4.4.7 Tilting braising pans (bratt pans) and kettles

Tilting braising pans are also known as tilting bratt pans or just bratt pans. The most prominent features of tilting pans and kettles are their large volume and, as the name says, that they could be tiltet. The purpose is that is should be easy and quick to fill and empty the vessels and that it is possible to handle large food volumes safely and ergonomically correct. The energy source could be gas and electricity and for the gas appliances the ignition could be automatic spark ignition or pilot flame – the latter resulting in a permanent idle / standby mode energy consumption.

Tilting brazing pans are multi-functional cooking appliance which could be used for roast-ing, pot-roasting, braising, simmering, boiling and steaming. Tilting braising pans and kettels are insulated around the cooking vessel which together with a tight lid means low losses to heat radiation and infiltration of cold ambient air. This result in high thermal cooking efficiency and low heat losses to the kitchen environment. The geometry of the vessels could both be round and rectangular.

Typical other features for tilting pans are build-in mixer (in round vessels), integrated water tap, and a pressure lid which means the tilt braising pan could be used for pressure cooking as well wit reduced cooking time. Tilting pans often are highly automatized appliances with the possibility to control annd monitor from remote as well as using automatic preparation processes e.g. overnight cooking.[169]

The public procurement advices from the Danish Energy Agency[170] regarding tilting pans and kettles are to invest in appliances with the following characteristics:

- Sufficient insulation
- Quick and efficient heating (high power)

[168] Frymaster, Oil Conserving, 2020, www.frymaster.com/info#oil-conserving

[169] Electrolux Professional, 2020, Smart Boiling Pans, (leaflet), and Firex srl, 2020, www.firex-foodequip-ment.com/catering-machinery

[170] Danish Energy Agency, 2018. Storkøkkenvejledning

- Continous (stepless) temperature control and temperature display
- A well fitting and tight lid, wich preferaly is hinged
- Timer and automatic swtich on/off watch
- Low standby consumption
- Electric (motorized) kip function

A relevant test standard for standard tilting pans and kettles DIN 18873-5:2016-02 Methods for measuring the energy consumption of commercial kitchen appliances - Part 5: Tilting frying pans and stationary frying pans. A relevant test standard for pressurized tilting pans and kettles is DIN 18873-6:2016-02 Methods for measuring the energy consumption of commercial kitchen appliances - Part 6: Tilting pressure braising pans and stationary pressure braising pans.

According to the utility company Georgia Power is the average efficiency of electric bratt pans is about 80%, while gas model efficiency is just over 50%.

Efficiency programmes for bratt pans. Topten.ch includes tilting pans. The Topten.ch test parameters for these appliances are[171]:

- Time in seconds to reach 180 °C
- Energy consumption in kWh required to heat the pan from 24 to 180 °C
- Energy consumption in kWh for keeping the temperature on 180 °C for 60 minutes
- Energy consumption in kWh for cooking a standard dish (load)
- Rated power (kW)
- Volume and area of the pan.

4.4.8 Pasta cookers

Pasta cookers are basically constructed as a fryer with a heat bath for heating food. However, due to the liquid being heated is salt water instead of oil the materials used should be more corrosion resistant. Heating elements could be gas, electric resistance or e.g. by infrared heating. In the professional kitchen quick heat up is important in order not to have the cooker boiling most of the time.

Cooking in pasta cookers could be more efficient than using hobs, probably due to the equipment being optimized for the purpose but also because of the repeated use of the same cooking water. An Italian study by Fusi et al., 2016[172] on the energy efficiency of pasta cooking suggests that cooking in pasta cookers saves up to 60% of energy and 38% of water compared to range tops.

The results suggest that cooking in pasta cookers more efficient compared to range tops. The study also compared a number of products and found based on this and literature studies the data regarding relation between capacity of water volume and power rating

[171] Topten.ch, Gastro, Flexi-Pfannen, June 2020, www.topten.ch/business/products/flexi_pans

[172] Alessandra Fusi, Riccardo Guidetti, Adisa Azapagic, Evaluation of environmental impacts in the catering sector: the case of pasta, Journal of Cleaner Production, Volume 132, 2016, https://doi.org/10.1016/j.jclepro.2015.07.074

and other data on typical efficiencies as presented in Table 45. The efficiency values however are based on two cycles quickly after each other and not taking idle mode consumption into consideration.

Table 45. Typical rated and efficiency data (final energy) for pasta cookers (source: Fusi et al. 2016[173])

	Relation power rating, y (kW) and volume, x (l)	Cooking efficiency (%)
Electric	$y = 0{,}2108x + 1{,}5947$	97,4
Gas	$y = 0{,}389x - 0{,}1533$	50

Topten.ch[174] includes professional pasta cookers and considers

- energy consumption for standby in kWh/hour
- energy consumption for 11 minutes of cooking in kWh
- speed in seconds for heating from 24 to 99 °C respectively 50 to 99 °C
- and the corresponding energy consumption in kWh.

Topten.ch requires information regarding these, but does not provide a maximum treshold value.

4.4.9 Range hoods

In a professional kitchen the primary purposes of a range hood is to extract pollutants, steam and heat from the cooking zones. A secondary purpose for many professional range hoods is to illuminate the cooking zone. Range hoods also must filter the grease and particles from the extracted air to keep and maintain a safe and functional air extraction system without deposition of grease and dirt in the ducts.

Range hoods together with the other kitchen ventilation system should ensure a good working environment with low temperatures ad without draft (air velocity around the work place < 0.4 m/s[175]).

Commercial and professional kitchens constitutes in average of two ventilation hoods according to the US Environmental Protection Agency[176]. A range hood depends on a mechanical fan which could be integrated in the range hood or placed in the duct system away from the range hood.

Definition. Based on the definitions from EN 16282-2[177] on `kitchen ventilation hood´ a professional range hood could be defined as an air terminal device which provides the facility to capture, contain and remove process pollutant and which can also provide a point of supply-air back into the room.

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[173] Alessandra Fusi, Riccardo Guidetti, Adisa Azapagic, Evaluation of environmental impacts in the catering sector: the case of pasta, Journal of Cleaner Production, Volume 132, 2016, https://doi.org/10.1016/j.jclepro.2015.07.074

[174] Topten.ch, Gastro, Pasta Cookers, www.topten.ch/business/products/pasta_cookers

[175] Danish Energy Agency, 2018. Storkøkkenvejledning

[176] Energy Star, Technology Profile: Demand Control Kitchen Ventilation (DCKV), source; interview: R. Swierczyna, Interviewee, CKV Lab Manager, Fisher-Nickel, inc.., 2013, www.energystar.gov/sites/default/files/dckv_technology_profile.pdf

[177] EN 16282-1, Equipment for commercial kitchens - Components for ventilation in commercial kitchens - Part 1: General requirements including calculation method

A hood can be equipped with lighting, can be a means of housing various types of filtration, and can be integrated in flat ceilings in accordance with EN 16282-3.
The pollutants which are being removed constitutes of airborne grease, combustion products, fumes, smoke, heat, and steam from the cooking process.

Scope. For the present study and based on EN 60335-2-99[178] the scope contains range hood for installation above commercial cooking appliances such as ranges, griddles, griddle grills and deep fat fryers, and not intended for household use, their rated voltage being not more than 250 V for single phase hoods connected between one phase and neutral, and 480 V for other hoods.

The scope covers the following units

- single complete hoods supplied with an integrated fan;
- hoods supplied as separate parts which when assembled form a complete working hood, incorporating a fan;
- hoods not incorporating a fan.

The scope does not include hoods designed exclusively for industrial purposes or for locations with conditions, such as the corrosive or explosive atmosphere or as on-of-a-kind-products.

The air flow rates are large in professional kitchens. For most professional kitchens Make-up air – the air for replacing the extracted air is supplied either by the building's heating ventilation and air-conditioning system or a ventilations system dedicated to the kitchen. For some smaller professional kitchens including e.g. food trucks, the air is replaced by natural ventilation. The replacement air – make up air (MAU) - could be heated or cooled depending on the climate, but since one of the main purposes of professional range hoods normally is to extract heat the MAU often does not need to be heated. The energy consumption resulting from the usages of professional range hoods thus is related to the movement of air and to the lighting.

As mentioned in Section 4.1.1 ventilation is one of the major energy consumers in professional kitchens.

Categories of range hoods. Professional range hood are normally found as

- wall mounted hood types with different slope angles of the front/extraction zone
- island hoods to be positioned over cooking zones that are placed in the middle of the room with no wall near. These could be single and double sided with one- or two-sided extraction.
- Back shelf hoods / Low proximity hoods Options which hang lower over the cooking equipment. This enables lower exhaust flow rates and a smaller hood than traditional wall type and could for instance be used for smaller cooking appliances like fryers.

Hoods could be constructed for specific conditions e.g.:

- to remove heat, suitable at higher or lower temperature
- for exhaust air with high level of smoke and grease

[178] IEC/EN 60335-2-99 Household and similar electrical appliances –Safety –Part 2-99:Particular requirements for commercial electric hoods

- for exhaust air with condensate from non-grease producing appliances
- or a combination of all
- for gas, electric heat source or solid fire (coal or firewood) heat source
- for food truck / food trailer.

Fans. Professional range hoods for which the air is extracted by external extraction fans the electrical input power for the fan motor almost always will exceed 125 W which is the limit of the scope of the regulation No 327/2011.

For professional range hoods with integrated fans - ether supplied as a single unit or assembled onsite - the fans are in the scope of the regulation No 327/2011 except when the total maximum electrical input power for the fan(s) is < 280 W. So for professional range hoods with fan motors below this limit there is a loophole in the current regulation regarding fan efficiency (see regulatory framework in Section 4.1.2.1).

Lighting. The light sources for professional range hoods are covered by Regulation (EU) 2019/2020 on light sources (Section 4.1.2.1).

Filtration. Filtration of the extracted air is an essential part of the function of professional range hoods. If the grease and the other pollutants is not captured, it would build up in the ventilation system and become a major fire hazard and reduce the performance of the range hood. So, for fire safety reasons appropriate filtering is a must.

First step in the filtering process is to capture grease and condensate from the vapour from the cooking process. After that, the finer and more volatile parts in the air stream like aerosols and finer particulate matter is recovered or eliminated for odour control and to further prevent deposits in the duct system and heat recovery units.

Examples of filter technologies for the condensate and grease recovery are centrifugal filters (or cyclone filters), grease filter baffles, eventually with sack filters, and metal or aluminium mesh filters. Mesh filters however generally not as the primary or sole filter and have a major disadvantage from filter clogging; the pressure losses increases significantly during use, while the performance including pressure loss of centrifugal filters is more constant[179].

Examples of aerosol recovery elements are electrostatic filters, charcoal pleated air filter. Filters for particulate matter. The above-mentioned examples all recover the pollutants, but another cleaning principle is to eliminate the pollutants. This is the principle of plasma (incl. cold plasma), UV and photocatalytic oxidation, and ozone generating - potentially also by means of UV - treatment, presented in the review study180 and in the German national annex NA 040-05-02 AA to DIN 18869-7[181]. Ozone generators are only applicable for larger systems for total extract flows exceeding 2,500 m^3/h according to EN 16282.

[179] Energistyrelsen, 2018. Storkøkkenvejledning

[180] Rodríguez Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

[181] DIN 18869-7:2010 DE, Großküchengeräte - Einrichtungen zur Be- und Entlüftung von gewerblichen Küchen - Teil 7: Anlagen zur Aerosol- und Aerosolatnachbehandlung, Anforderungen und Prüfung, NA 040-05-02 AA

The reason is that air-fed ozone generators produce too much NO_x and nitric acid (HNO_3) if the ventilation is not sufficient[182].
Additionally, range hoods could need spark filters, to prevent flames from cooking to enter the ducts risking setting the grease layers or dust and grease vapours in the ducts and grease filters at fire[183].

Depending on filter type the energy consumptions due to pressure losses or for operating the filter (plasma, electrostatic and UV and ozone generators) will impact the overall efficiency and energy consumption.

When choosing the right filter, corrosion resistance should be a primary concern. Between high heat, humidity, grease, air particles and cleaning chemicals – hood filters are under constant bombardment that leads to corrosion over time. For high volume kitchens heavy-duty material such as stainless steel or galvanized are preferred materials. Aluminum can also be an option if durability and corrosion resistance isn't important. Materials such as stainless steel or galvanized steel will resist corrosion, last longer and have to be replaced less frequently than aluminum. Appearance could also be a filter material selection criteria. If customers have visual contact with the kitchen hood, a stainless steel filter with its more shiny finish could be a preferred option.

Self-cleaning / self-washing hoods. Several manufacturers have self-cleaning systems that automatically wash down grease from the inner side of the hood and a portion of the duct with hot water spray and e.g. the grease extractors, typically on a daily basis. This should increase the general performance and safe labor time.

Make-up air. Some manufacturers claim ad have tested that strategically placed directional low velocity make-up air streams close to the cooking zone and range hood could improve the performance of range hoods by compensate for low capacity of the buildings ventilation system for the kitchen ventilation or alternatively reduce the necessary air flow for range hoods and kitchen ventilation by 20 -40 %. The principle also increases fumes capture and improves the work place environment and comfort due to better heat capture and less draft in the working zone[184,185] . The explanation of this effect is that the air stream prevents infiltration of the contaminated and heated air from the cooking into the kitchens' working environment.

This principle is also known from air extraction from other work places in industry.[186]

Demand control and sensors. Standard professional kitchen range hoods and kitchen ventilations are operated manually with an on-off switch or perhaps stepwise and often working at full capacity and speed during the entire working day. The result is too high air volumes and fan speeds too much of the working day.

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[182] https://www.ozonetech.com/sites/default/files/brochure_-_eu_standard_equipment_for_commercial_kitchens_v1.0_en-web.pdf

[183] Hoodfilters.com, 2016, The hood filter handbook, https://www.hoodfilters.com/flyers/Hood_Filter_Hand-Book.pdf

[184] Halton, Halton -Capture JetTM Technology, https://www.halton.com/wp-content/uploads/2020/08/Halton_CaptureJetBrochure_BR-004.pdf

[185] Halifax SCHP1148 Type 1 11' x 48" Commercial Kitchen Hood System with Short Cycle Makeup Air www.webstaurantstore.com/halifax-schp1148-type-1-11-x-48-commercial-kitchen-hood-system-with-short-cycle-makeup-air/421SCHP1148.html

[186] Ventilation Ståbi, 2. Ed. 2001, Nyt Teknisk Forlag - Praxis, Copenhagen

The demand depends on number of appliances being used in the kitchen generally and under a specific hood. Control systems are available where the range hoods or even the make-up air kitchen ventilation system are operated by demand control instead, meaning that the range hoods are regulated up or down depending on when a heat load is detected and one or more of the cooking zones are in use. This is called a Demand Control Kitchen Ventilation system (DCKV), and it has the potential to providing substantial energy savings, according to the US Environmental Protection Agency, EPA[187]. EPA mentions that field studies suggests that energy savings could be 60 % or more depending on the facility and type of operation[188].

The signal could come from temperature, optical, or infrared (IR) sensors that monitor cooking activity or from direct communication with cooking appliances (Figure 8)[189]. To get the full benefit, the DCKV system both should have the sensors / communication module and variable speed control of the fans in the range hood / exhaust system and for the supply air.

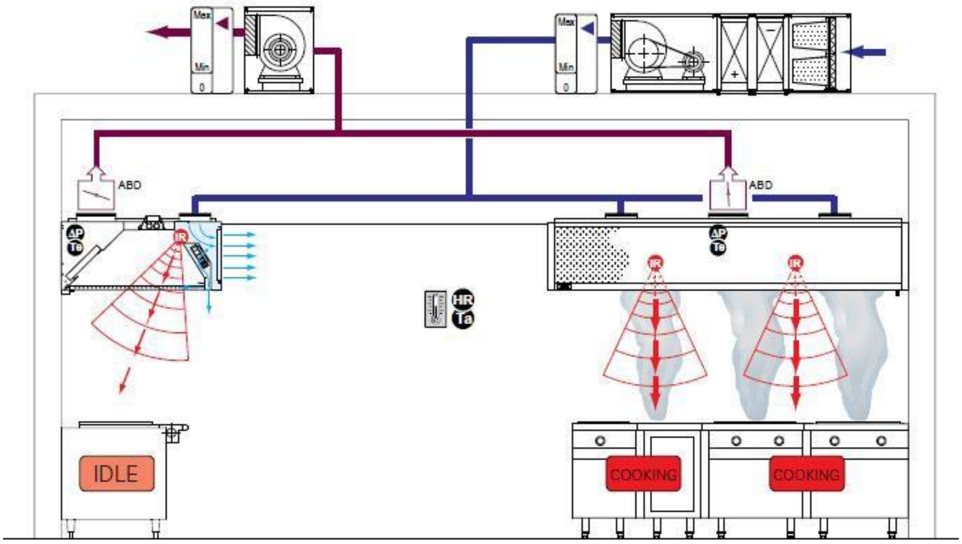

Figure 8. Demand control ventilation system with infrared sensors that remotely monitor the cooking surfaces (Source, Halton[190])

EPA mentions that optimal function of the systems also depends on how quickly the system responds. A slower respond to cooking activity may delay exhausting cooking effluent and heat, and as a consequence the minimum fan speed may be increased resulting in lower overall savings. It should be noted, that demand control of MAU and kitchen ventilation systems requires system integration, while the choice and selection and optimal placing of sensors is product specific related to the individual product

[187] US Environmental Protection Agency, Energy Star, Technology Profile: Demand Control Kitchen Ventilation (DCKV), www.energystar.gov/sites/default/files/dckv_technology_profile.pdf

[188] US Environmental Protection Agency, Energy Star, 2015 – 2016 Demand Control Kitchen Ventilation, www.energystar.gov/about/2015-emerging-technology-award-demand-control-kitchen-ventilation

[189] D. Fischer, R. Swirerczyna and A. Karas, "Future of DCV for Commercial Kitchens," ASHRAE Journal, pp. 48-54, February 2013.), mentioned in www.energystar.gov/sites/default/files/dckv_technology_profile.pdf

[190] Source: Halton, "13 Coins Case Study: Airflow and energy savings with the Halton Marvel system," Halton, 2013, www.energystar.gov/sites/default/files/dckv_technology_profile.pdf

model of range hoods, and thus could be controlled by the manufacturer of the range hood.
EPA concludes that the demand response can be optimized by one of the four methods[191]:

- Place the thermometer(s) closer to the cooking appliance
- Use optical sensor to detect fumes and steam
- Use infrared sensor to detect temperature changes remotely rather than waiting for the heat or effluent to reach the sensor in the hood
- Apply communication interphase to the cooking appliances.

Range hoods for professional kitchens are produced as standard products, particularly the smaller units but are also and often custom manufactured; the kitchen installer or owner orders a cover or hood adapted to the specific kitchen and perhaps with a specific surface treatment, filters and controls and sensors. So these products are made from standardized components but adapted for each specific installation.

4.4.10 Weight and material composition

Generally, resources to manufacture professional cooking appliances mainly include metals, and plastics, glass for oven doors, for glass ceramic and induction hobs, and for insulation.

The preparatory studies for task 22 and 23 analysed typical BOMs for professional combi steam ovens, hobs and fry tops. As no substantial change in the construction of the professional combi steam ovens, hobs and fry tops has occurred since 2011, the resource use information from the preparatory studies in Lot 22 and 23 are used for these products. For the other product group, assumptions has been made based on internet research of manufacturers' product factsheets, and comparison of bill of materials (BOM) for similar products from lot 22 and 23 as explained below.

Ovens. The BOM prepared by the Lot 22 task 4 and 5 preparatory study is adopted for the combi steam ovens. For the convection ovens it is assumed in lack of further information, that they in respect of materials used correspond with -store bakery convection ovens. However, the lot 22 study only considers the BOM for *electric* convection in-store bakery convection ovens. Sso for the gas convection oven it is assumed that the convection oven requires the same ratio of other materials for the gas heater (excluding steam generator) as the combi steamers does. The electric heating element is smaller in the convection oven than in the the combi steamer and the the gas heating element is also adjusted to be smaller in same ratio as the electric (Table 46).

[191] US Environmental Protection Agency, Energy Star, 2015 – 2016 Demand Control Kitchen Ventilation, www.energystar.gov/about/2015-emerging-technology-award-demand-control-kitchen-ventilation

Table 46. Assumed BOM of professional combi steam ovens (Source: Based on Lot 22 Task 4[192] and 5[193])

	Combi steamer, electric		Combi steamer, gas		Convection oven, electric		Convection oven, gas		Impingement rapid cook oven, electric	
	Weight (g)	Share (%)	Weight (g)	Share (%)	Weight (g)	Share (%)	Weight (g)	Share (%)	Weight (g)	Share (%)
Bulk Plastics	800	1%	800	1%	0	0%	0	0%	0	0%
Techn. Plastics, silicone polymer (e.g door seal)	2400	2%	2400	2%	60	0%	60	0%	38	0%
Techn. Plastics, other	5800	4%	5800	4%	60	0%	60	0%	0	0%
Ferro metals (incl. stainless steel)	72200	90%	50500	87%	54090	84%	53820	82%	42976	62%
Non-ferro metals	3900	3%	5900	4%	1733	1%	0	0%	4000	6%
Coating	0	0%	0	0%	0	0%	0	0%	0	0%
Electronics	1600	1%	1600	1%	800	1%	800	1%	506	1%
Silicate glass (door)	9000	7%	9000	6%	0	0%	0	0%	2500	4%
Misc. (mineral fiber, insulation)	8000	6%	8000	5%	30000	24%	30000	28%	18980	28%
Total	**135500**	**100%**	**154500**	**100%**	**122927**	**100%**	**109060**	**100%**	**69000**	**100%**

The oven categories `Other; Air impingement, microwave and hybrid (rapid cooker)´ is a rather diverse group of products. However, it is represented by an impingement and microwave rapid cook oven which weights 69 kg[194]. The BOM is assumed to be releatively close to the electric convection oven and is extrapolated from that. For the hybrid microwave oven function and glass oven door 6.5 kg of ferro metals is substituted with materials for the microwave magnetron and transformer. This is assumed to constitute of 4 kg of non ferritic metals, primarily copper and and 2.5 kg of glass.

Hobs and grills. The BOMs prepared by the Lot 23 task 5 preparatory study are adopted for the electric hobs and fry tops. The data in Table 47 regarding hobs represents a four zone freestanding hob. The data for the grills and fry tops represents a free standing 1-zone fry top or grill where the grills and fry tops are considered having the same BOM.

Since these appliances are also marketed as table top units it is suggested to evaluate the BOM of table top appliances as well in a potential preparatory study for commercial cooking appliances.

[192] European Commission (DG ENER) (2011) Preparatory Study for Ecodesign Requirements of EuPs Lot 22: Domestic and commercial ovens, Task 4 report

[193] European Commission (DG ENER) (2011) Preparatory Study for Ecodesign Requirements of EuPs Lot 22: Domestic and commercial ovens, Task 5 report, https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task5-final.pdf

[194] TurboChef Microwave/Impingement Oven, Rapid Cook, Electric, turbochef.com/product/single-batch/

Table 47. Composition of gas and electric hobs and fry tops (source: Lot 23 task 5[195]).

	Commercial electric hob		Commercial gas hob		Commercial electric grill/fry top		Commercial gas grill/fry top		Commercial electric infra-red (glass ce-ramic) hob*		Commercial electric induc-tion hob**	
	Weigh t (g)	Share (%)	Weight (g)	Share (%)	Weigh t (g)	Share (%)	Weigh t (g)	Share (%)	Weigt h (g)	Share (%)	Weigt h (g)	Share (%)
Bulk Plastics	5400	7%	5100	9%	7700	12%	5530	9%	5400	7%	5400	7%
Techn. Plastics, silicone poly-mer (door seal)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Techn. Plastics, other	1160	1%	660	1%	860	1%	860	1%	1160	1%	1160	1%
Ferro metals (incl. stainless steel)	10400 0	77%	121000	78%	78200	72%	87733	73%	64300	80%	64300	78%
Non-ferro me-tals	1200	1%	2000	3%	3430	5%	3660	6%	3100	4%	5100	6%
Coating	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Electronics	0	0%	0	0%	0	0%	0	0%	500	1%	500	1%
Silicate glass	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Misc. (mineral fiber, insula-tion)	120	0%	0	0%	170	0%	170	0%	6120	8%	6120	7%
Total	**80080**	**100%**	**58260**	**100%**	**65980**	**100%**	**64310**	**100%**	**80580**	**100%**	**82580**	**100%**

For the electric infrared (glass ceramic) hob it is assumed that the BOM corresponds to the electric hob but with 6000 g of ceramic glass cover and 1900 g of non-ferritic metals (both replacing ferro metals) for the radiant heating elements as well as 500 g of electronic, inspired from lot 23 task 4 on domestic electric hobs (which is an infrared hob).

For the electric induction hob a BOM that corresponds to the electric infrared hob is assumed but with extra 2000 g of non-ferritic metals for the induction heating element.

Bain-maries. A standard electric Bain-marie table top model with one well in the dimensions mm 360 x 614 x 290 (suitable for at GN 1/1 container), a heating capacity of 760 W, and a total weight of 10,5 kg is chosen as a representative product. The main materials are stainless steel for housing and well, some non-ferro metals heating element (electric or gas) and tap for draining the bain, electronics for controls and insulation materials.

The relative material fractions are assumed to be similar to combi steamers for electric respectively gas heat source, except a much lower levels of plastic and no glass and sealing for doors (Table 48).

Fryers and Pasta cookers. The basic function and construction of fryers and pasta cookers are relatively similar to Bain-maries, however with higher heating capacity and more sturdy construction, so parallel assumptions are made as are for Bain-marie regarding their BOMs. Pasta cookers need compared to fryers materials with higher corrosion resistance.

For the fryer here too a table top model with one well suitable for a GN 1/1 container is considered. Heating capacity is on 9 kW and the fat or oil vat volume on 15 liter

[195] European Commission (DG ENER) (2011), Preparatory Study for Ecodesign Requirements of EuPs Lot 23: Domestic and commercial hobs and grills Task 5 report,, www.eup-network.de/fileadmin/user_upload/Produktgruppen/Lots/Final_Documents/Lot_23_Task_5_Final.pdf

corresponding to a total weight (drained) on 20 kg (Table 48). Section 15.4.2 on weight and material composition also explains the selected capacity size.

For the pasta cooker a free standing model is considered with a heating capacity on 8,6 kW, a well volume on 24,5 liters with one well in the dimensions mm 250 x 400 x 300 (corresponding to two baskets), and the weight being 55 kg (Table 48).

Table 48. Assumed BOM of Bain-maries (Source: Own calculations, extrapolated and adapted from combi steamers).

	Bain-marie, electric		Bain-marie, gas		Fryer, electric		Fryer gas		Pasta cooker, electric		Pasta cooker, gas	
	Weight (g)	Share (%)	Weight (g)	Share (%)	Weight (g)	Share (%)	Weight (g)	Share (%)	Weight (g)	Share (%)	Weight (g)	Share (%)
Bulk Plastics	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Techn. Plastics, silicone polymer (e.g. door seal)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Techn. Plastics, other	60	1%	60	0%	60	0%	60	0%	60	0%	60	0%
Ferro metals (incl. stainless steel)	9241	88%	10751	88%	19419	88%	22594	88%	48628	88%	56577	89%
Non-ferro metals	347	3%	524	4%	728	3%	1102	4%	1824	3%	2759	4%
Coating	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Electronics	142	1%	142	1%	299	1%	299	1%	748	1%	748	1%
Silicate glass (door)	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Misc. (mineral fiber, insulation)	711	7%	711	6%	1494	7%	1494	6%	3741	7%	3741	6%
Total	**10500**	**100%**	**12188**	**100%**	**22000**	**100%**	**25548**	**100%**	**55000**	**100%**	**63884**	**100%**

Bratt pans and kettles. For the present study the BOMs of bratt pans and kettles are assumed to be relatively close fry tops and the BOM extrapolated from fry tops.

The BOM is calculated for a free standing on metal frame middle sized product with a deep pan with the inner pan dimensions 65 mm deep pan and W x L: 705x520 mm, two heating zones and a rated nominal heating capacity on 9 kW rated (13 kW max) and a weight of 120 kg. The calculated BOM is presented in Table 49.

Table 49. Assumed BOM of tilting bratt pans and kettles (Source: Own calculations, extrapolated from fry tops).

	Commercial electric bratt pans		Commercial gas bratt pans	
	Weight (g)	Share (%)	Weight (g)	Share (%)
Bulk Plastics	14004	12%	10058	9%
Techn. Plastics, silicone polymer (door seal)	0	0%	0	0%
Techn. Plastics, other	1564	1%	1564	1%
Ferro metals (incl. stainless steel)	97884	82%	98375	84%
Non-ferro metals	6238	5%	6657	6%
Coating	0	0%	0	0%
Electronics	0	0%	0	0%
Silicate glass	0	0%	0	0%
Misc. (mineral fiber, insulation)	309	0%	309	0%
Total	**120000**	**100%**	**116963**	**100%**

Range hoods. The review study[196] informs professional range hoods are manufactured from a combination of stainless steel, copper, bronze, nickel, zinc (e.g. for galvanizing), tempered glass, aluminum, brass and heat resistant plastics, but with stainless steel as the most dominant material for the casing.

From studies of supplier catalogues the stainless steel models definitely are the most dominant. An average example is a professional middle sized wall mounted range hood with width 1600 mm, height: 500 mm and depth 900 mm. It is supplied without internal fan and motor but could be configured with a speed variator for motors up to 1,17 kW and air extraction capacity of up to 1900 m^3/h. It is entirely constructed in 304 AISI stainless steel.

Net weight 36 kg including the stainless steel mess or labyrinth filters[197].

4.5 Energy, Emissions and Costs

4.5.1 Energy consumption

Please notice that the energy consumption data in this section have not been updated after new data from stakeholders were received – as mentioned in Section 4.1.

4.5.1.1 Product level

The energy consumption for some of the professional cooking appliances considered was measured by Mudie et al (2013)[198] (Table 50).

[196] Quintero, R., Boyano, A., Bernad D., Donatello S., Paraskevas, D., Villanueva, A. Review study of Ecodesign and Energy Labelling for Cooking appliances – European Commission, Joint Research Centre, 2020

[197] Electroluxprofessional.com (Dec. 2020)

[198] S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), Electricity Use in the Commercial Kitchen, [1]University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

Table 50. Average energy consumption (final energy, electricity) of professional cooking appliances in an English chain of "Gastro-pubs" [199]

Appliance Category	Average number of appliances per kitchen	Avg. total daily (kWh)	Avg. daily for one appliance (kWh)	Relative Standard Deviation (%)	Share of total consumption (%)	Avg. yearly energy consumption per appliance (kWh/year, final energy)	Avg. yearly energy consumption per appliance (kWh/year, primary energy)
Grill	1	37	36,9	28	21%	11510	24170
Steamer	1	12	12,0	47	7%	3741	7856
Heat Lamps	15	21	1,4	35	12%	431	904
Bain-marie	1	27	27,2	44	15%	8483	17815
Fryers	3	41	13,6	44	23%	4245	8915
Combi-Ovens	3	36	11,9	34	20%	3714	7799
Other cooking appliances	3	6	2,0	37	3%	632	1328
Total kitchen consumption for cooking	27	179		22.9	100%		

Table 51 sums up the conclusions from Section 4.4 regarding energy consumption based on various sources. Consumption figures based on Energy Star product specifications are calculated as Energy Star do not inform the yearly consumption but savings potentials in percentage and in annual energy consumption. These data are converted to the yearly consumption figures presented in Table 51.

Table 51. Average energy consumption of professional cooking appliances (Source: Own calculations based on Energy Star requirements).

Product	Fuel	Estimated yearly primary energy consumption per standard appliance [kWh/(appliance year)]
Static oven	Electricity	13860
	Gas	17584
Convection oven*	Electricity	13860
	Gas	17584
Steam and combi oven	Electricity	19459
	Gas	14639
Griddles	Electricity	24818
	Gas	35169
Fryers	Electricity	50400
	Gas	58614
Steam cookers (steamer)	Electricity	40250
	Gas	63499

The US market and products are not 1:1 similar to the products on the European market and kitchens, e.g. does the Energy Star generally consider larger cooking appliances as commercial, although ranges and hobs on the EU market are not consequently large; e.g. table top units with one or two heating zones are common.

[199] S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), Electricity Use in the Commercial Kitchen, University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

Comparing the estimated yearly energy consumptions for the steam combi oven it fits nicely. The energy consumption for fryers and steam cookers on the other hand, is three times larger.

Table 52 sums up the estimated energy consumptions.

Table 52. Primary annual energy consumption in kWh per appliance.

Product	Fuel	Lifetime [years]	Estimated yearly primary energy consumption per standard kWh/appliance
Ovens			
Static oven	Electricity	12	13860
	Gas	18	17584
Convection oven	Electricity	11	13860
	Gas	18	17584
Steam and combi oven	Electricity	11	19459
	Gas	11	14639
Other; Air impingement, and microwave hybrid (rapid cooker)	Electricity	11	
	Gas	11	
Hobs and grills, inkl. griddles and ranges			
Grills including Chargrill	Electricity	10	27300
	Gas	11	35169
Fry-tops / griddles	Electricity	10	27300
	Gas	11	35169
Hobs , gas	Electricity	10	
	Gas	11	35000
Hobs, induction	Electricity	10	20000
	Gas	11	
Hobs, infrared	Electricity	10	20000
	Gas	11	
Hobs, electric resistance	Electricity	10	20000
	Gas	11	
Steam cookers	Electricity	12	40250
	Gas	12	63499
Bain-marie	Electricity	10	17815
	Gas	10	22269
Fryers	Electricity	10	50400
	Gas	11	58614
Bratt pans (Tilting bratt pans and kettels)	Electricity	11	27300
	Gas	11	35169
Pasta cookers	Electricity	11	11573
	Gas	11	7145
Range hoods	Electricity	11	3549
	Gas	11	0

4.5.1.2 Aggregate level

The above energy consumption values have been multiplied with estimated stock data to obtain total use phase energy consumption for 2020, 2025 and 2030.

Table 53: Aggregate EU use phase energy consumption for professional cooking appliances stock (GWh, source: Own calculations)

Product category	Sub category	Heat source	2020	2025	2030
Ovens	Static oven	Electricity	0	0	0
		Gas	0	0	0
	Convection oven*	Electricity	3815	3940	4272
		Gas	1063	1097	1190
	Steam and combi oven	Electricity	48208	49791	53978
		Gas	7961	8222	8914
	Other; Air impingement, microwave and hybrid (rapid cooker)	Electricity	0	0	0
		Gas	0	0	0
Hobs and grills	Grills including chargrill	Electricity	8689	8974	9729
		Gas	11193	11561	12533
	Fry-tops / griddles	Electricity	17387	17958	19468
		Gas	11182	11549	12521
	Hobs, gas	Electricity	0	0	0
		Gas	71017	73348	79516
	Hobs, induction	Electricity	6279	6485	7030
		Gas	0	0	0
	Hobs, infrared	Electricity	7479	7725	8374
		Gas	0	0	0
	Hobs, electric cast iron	Electricity	13296	13733	14887
		Gas	0	0	0
Steam cookers		Electricity	41035	42382	45946
		Gas	14210	14677	15911
Bain Marie		Electricity	14773	15258	16542
		Gas	9220	9522	10323
Fryers		Electricity	125386	129502	140393
		Gas	72801	75191	81514
Bratt pans and kettles (incl. tilting)		Electricity	7550	7798	8454
		Gas	4856	5015	5437
Pasta cookers		Electricity	1598	1650	1789
		Gas	493	509	551
Range hoods		Electricity	12940	13365	14489
		Gas	0	0	0
Total			**512431**	**529252**	**573760**

4.5.2 Other resource consumption

Other resource consumption on product level has been described in section 15.4.2. Table 54 presents the aggregate values for selected materials, based on annual sales.

Table 54: Total annual EU-27 material consumption (t)

	Bulk Plastics	Techn. Plastics, silicone polymer (e.g. door seal)	Techn. Plastics, other	Ferro metals (incl. stainless steel)	Non-ferro metals	Coating	Electronics	Silicate glass (door)	Misc. (mineral fiber, insulation)
2020	3255	662	2056	83121	2957	0	616	2541	4550
2025	3362	684	2124	85850	3054	0	636	2625	4699
2030	3645	741	2302	93070	3310	0	690	2846	5095

Source: Own calculations

4.6 Improvement potential

The current section on improvement potential considers only energy consumption. Other aspects like consumables, including oil for fryers, and materials could be relevant to address. However, no valid information on these aspects was avaiable. Same situation is relevant for the case of potential material savings from improved durability. Before analysing the subject it is not clear if e.g. more electronics for improved controls and better insulation – e.g. three layers glass – on the material side would out outweight possible requirement on increased durability. Allready now there is a market for repair and sales of used professional cooking appliances according to stakeholders (EFCEM).

EFCEM[200] also draws the attention to the professional kitchens' potential of contributing positively to the challenges with peak power. The standard on "interface for power optimisation in commercial kitchens" (DIN 18875) may provide the frame for a Smart Readiness Indicator[201] for kitchen systems while e.g. private household kitchens cannot contribute the same way.

4.6.1 Use phase energy consumption

Ovens. Generally for ovens, the lot 22 task 6 preparatory study by Mudgal et al[202] mapped a number possible theoretical and already existing improvements for ovens (chapter 4.4.1). The prep. study also received data from stakeholder that indicates that the best commercial ovens may consume 25% less energy than average ovens. These values are from 2011 and although some technical improvements will be made, it is assumed that similar savings potentials are possible now by changing to BAT, if no other data on savings potentials are available, also assuming this improvement figure is relevant for gas and eletric ovens both.

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200 European Federation of Catering Equipment Manufacturers EFCEM, Stakeholder comment 26th March 2021

201 https://smartreadinessindicator.eu/

202 S. Mudgal, B. Tinnetti, E. Hoa Bio Intelligence Service & C. Robertson, P. Goodman, S. Pitman ERA Technology, Preparatory study for ecodesign requirements of EuPs Lot 22: Domestic and commercial ovens, European Commision DG TREN, 2011, www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task6-final.pdf

So for standard commercial *static ovens* gas as well as electric an improvement potential on 25 % is assumed. The annual energy consumption per oven is assumed to be the same as for convection ovens.

Convection ovens. According to the US EPA[203] standard gas convection ovens have a 30 percent cooking energy efficiency and an idle energy rate of 18,000 Btu/h, whereas Energy Star certified gas convection ovens must meet the specification requirements of 44 percent cooking energy efficiency and idle energy rate of 13,000 Btu/h.

Standard electric convection ovens have a 65 percent cooking energy efficiency and an idle energy rate of 2 kW; whereas Energy Star certified electric convection ovens must meet the specification requirements of 70 percent cooking energy efficiency and an idle energy rate of 1.6 kW.

The US Environmental Protection Agency claims that commercial ovens that have earned the Energy Star have savings potentials compared to standard models as listed below:

- About 20 percent more energy efficient (electric and gas overall).
- An electric convection oven saves about 660 kWh annually
- A gas convection oven saves about 18 MBTU annually

As is seen from the figures above regarding idle rate and cooking efficiency the potentials are much larger for the gas ovens and based on this the following efficiency improvement potentials are assumed; 10 % for electric and 20 % for gas.

The estimates of the ovens energy efficiency and yearly energy consumption is based on their cooking energy efficiency and idle energy rate, to which the energy star has requirements. Cooking energy efficiency represents the amount of energy absorbed by the food product compared to the total energy used by the oven during the cooking process. The idle energy rate represents the energy used by the oven while it is maintaining or holding at a stabilized temperature.

Steam ovens and combi-steam ovens. For professional steam and combi ovens EPA only defines the requirements to power consumption but do not establish potential savings by applying the Energy Star requirements.

However as presented in Section 4.4.1 Burlon[204] found that 20 % efficiency improvement on a standard electric combi oven is possible and although no firm conclusion was reached in the Lot 22, 2011 study it found that products were already available that were around 25 % more efficient that standard products. Therefore it seems realistic to assume as a conservative estimate that the same level in energy efficiency improvement is possible for steam and combi ovens as for standard convection ovens on the gas appliances and higher for electric products. That means 20 % on electric and 30 % on gas steam and combi ovens. Lot 22 task 5[205] provides (based on a daily use time on 8 hours) estimated energy consumptions for commercial electric and gas combi steamers as presented in Table 55.

[203] www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens

[204] Burlon, Fabio, Energy Efficiency of Combined Ovens, Energy Procedia, Elsevier BV, 2015

[205] Task 5 report, 2011, European Commission (DG ENER) Preparatory Study for Ecodesign Requirements of EuPs Lot 22: Domestic and commercial ovens, https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot22-23-kitchen/lot22-task5-final.pdf

Table 55. Yearly energy consumption of steam and combi ovens (source: Based on Lot 22 Task 5).

Energy source	Total yearly energy consumption (primary energy, MWh/year)
Electric	19459
Gas	14639

Grills / charbroilers. Since no other data sources have been found for charbroilers and the functionality of this product group in many ways are similar to fry tops similar, usage and improvement potentials are assumed to be similar for the present study. The potential impact of more efficient burners or technology change to infrared heating could be investigated further i a potential preparatory study.

Fry tops / griddles. According to the US EPA some of the typical constructive measures that can improve griddlees energy efficiency is using highly conductive or reflective plate materials, using improved thermostatic controls and strategically placing thermocouples[206].

The US Environmental Protection Agency claims that commercial griddles that have earned the Energy Star have savings potentials compared to standard models as listed below:

- Electric griddles are 11 percent more energy efficient and
- save about 1,300 kWh annually.
- Gas griddles are 10 percent more energy efficient and
- save about 12 MBTU annually

The Energy Star label can be found on gas and electric, single and double-sided commercial griddles that are thermostatically controlled.

For the present study 10 % improvement potential on both gas and electric fry tops is assumed.

Steam cookers. According to the US EPA[207] steam cookers typically could be improved by better insulation, tighter seals and more efficient steam delivery systems resulting in reduced heat loss as well as shorter cook times and higher production rates and significantly less water consumption.

The US Environmental Protection Agency claims that commercial steam cookers that have earned the Energy Star have savings potentials compared to standard models as listed below:

- Up to 60 percent more energy efficient and up to 90 percent more water efficient than standard models using on average 3 gallons (11 l) of water per hour for Energy Star certified steam cookers versus 40 gallons (150 l) of water per hour for standard models
- an electric steam cooker saves about 11,500 kWh annually
- a gas steam cooker saves about 130 MBTU annually.

[206] www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles

[207] www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers

A US standard steam cooker is defined as having a capacity on at least three pans. The pan size is defined at 300 x 500 x 65 mm[208] (similar to the European GastroNorm GN 1/1 on 325 x 530 mm and with 65 mm as a one of the standard hights).

Bain-maries. No exact figures on potential efficiency improvements has been found. For the present study it is assumed that from optimized temperature control and insulation compared to standard products, it is possible to save 5 % on the electric models energy consumption, and further 5 % by optimal burner design for gas heated models.

Additionally, the improvement potential from a technology change for circulating air-heating as claimed by one manufacturer (section 4.4.5) could be investigated.

Fryers. According to the US EPA[209] fryers typically could be improved through:

- advanced burner and heat exchanger designs which offer better combustion and heat transfer
- fry pot insulation which reduces standby losses and results in a lower idle energy rate.

Added benefit are also shorter cook times and higher production rates according to the EPA.

Standard sized fryers that have earned the Energy Star are up to 30 percent more energy efficient than standard models and large vat commercial fryers that have earned the Energy Star label are up to 35 percent more energy efficient than non-qualified models.

The US Environmental Protection Agency claims that commercial fryer that have earned the Energy Star have savings potentials compared to standard models as listed below:

- standard vat electric fryers are 14 percent more energy efficient
- and save about 2,390 kWh annually
- standard vat gas fryers are 30 percent more energy efficient
- and save businesses about 50 MBTU annually

A US standard vat is defined as a vat that measures 12 - 18 inches wide (30.5 – 45.7 cm) has and a capacity on 25 - 65 pounds fat (11.3 – 29.5 kg or around 12 to 33 L). This corresponds to typical European floor standing fryers. In Europe however, table top fryers are also widely used and their capacities typically are in the range 4 - 16 L per vat. Based on this a slightly more conservative assumption that the potential savings are 10 % for electric fryers and 25 % for gas fryers.

Bratt pans. It is expected that there are similar opportunities for improved temperature controls, heat transfer – particularly from gas heater -, insulation and quality of lid as has been seen for other products. The basic function and components of bratt pans are comparable with griddles. Based on this a potential efficiency improvement at 10 % at least, for electric and gas heated bratt pans is assumed and a similar energy consumption as for fry tops.

[208] Energy Star Program Requirements for Commercial Steam Cookers: Version 1.1, 2003

[209] www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers

Pasta cookers. No specific energy efficiency improvement potentials were identified. However, for the present study it is assumed that there are similar opportunities for improved temperature controls - or more precisely control of boiling intensity -, insulation, and efficient heat transfer as for fryers. One manufacturer offers a heat recovery function for preheating the fresh tap water from the excess heat of water drained through the overflow. Additionally, timer, low temperature idle modes (lowering water temperature down to e.g. 50 °C in between cooking operations), and load controls could be considered to decrease time of operating at full power. Based on this and compared with the potential for fryers it is assumed that potential saving on 10 % for electric and 15 % for gas pasta cookers is realistic.

Yearly energy consumption for pasta cookers is for the current study calculated inspired from the method for Lot 22 task 3 for steam ovens[210]. This provides the assumptions that the appliances are used 6 days weekly, 52 weeks a year and 24 times daily. This is 4 times more than for steam cookers, but each time in shorter time 11 minutes vs. 40 minutes. Totally this means the operating time is assumed to be a little lower than for the steamer; The energy consumption for preparation and for standby mode is based on information products from the Swiss topten.ch product list for the electric model (Gastrofrit TW-350; 15 - 20 l capacity).

For the consumption calculation of gas heated pasta cooker a fictive similar gas model is modelled. It is assumed that the gas heated version consumes +25 % of final energy for cooking. This is similar for other appliances e.g. the combi steamer. The electric consumption of the gas pasta cooker is also based on the gas combi steamer, but assumed to be 1/10th of the gas steamers electric energy consumption for standby. This is in line with the ratio of the electric paste cooker/steamer.

Table 56. Energy consumption of pasta cookers. (Source: Own calculations and data from Topten.ch product list[211]).

	Energy consumption of heating from 24 to 99 °C (kWh) once daily.	Electricity consumption per on-mode cycle respectively per hour of standby (kWh, final energy)	Gas consumption per cycle resp. hour of standby (kWh, final energy)	No. of on-mode cycles and standby hours pr year	Yearly consumption (primary energy, MWh	Total yearly consumption (primary energy MWh/year)
Electric						
On-mode	1,32	0,66	0	7488	11243	11573
Standby mode		0,14	0	1123,2	330	
Gas						
On-mode	1,65	0,4	5,4	1872	11681	14639
Standby mode		0,6	1,9	936	2958	

Range hoods. As explained in chapter 4.4.8 several possible improvement methods for range hoods exist. One option is the use of make-up air (MUA) streams close to the cooking zone and range hood which is claimed to have the potential of reducing the necessary air flow for range hoods and kitchen ventilation by 20 - 40 %.

[210] European Commission (DG ENER), 2011, S. Mudgal, B. Tinnetti, E. Hoa Bio Intelligence Service & C. Robertson, P. Goodman, S. Pitman ERA Technology, Preparatory Study for Ecodesign Requirements of EuP's, Lot 22: Domestic and commercial ovens, Task 3 report

[211] https://www.topten.ch/business/products/pasta_cookers, Gastrofrit TW-350, Dec. 2020

Use of a Demand Control Kitchen Ventilation system (DCKV) has according to US EPA the potential to providing substantial energy of 60 %. Since this is to be applied on a system level these improvement potentials are not considered for the current study. However, it could be considered investigating if some kind of standardized "smart" control and connectivity requirements would be an option to harvest the greatest improvement potential. Promotion of application of communication interphase to the cooking appliances therefor could be relevant to consider as a potential policy option.

Use and optimal placing of sensors could be implemented on individual product model level of range hoods enabling the range hood to react on the actual need for ventilation e.g. by optimal use of thermometer(s), optical sensor to detect effluents, infrared sensor to detect temperature changes remotely.

For the improvement potential calculations a conservative estimate on 10 % improvement potential of the impact of sensors for needs-based automatically control.

Different sources provides data regarding energy consumption and air volumes for kitchen ventilations; extraction and supply. Daxbeck et al. e.g. found that the average energy consumption for air extraction and ventilation was about 17 % of the total energy consumption per meal[212]. The Swedish Arbetarskyddsstyrelsen (national agency for safety at work) and the Danish BAR initiative (organization working with health and safety at work) and several suppliers informs recommended levels of air volumes for the dimensioning of range hood for the extraction of fumes and heat. The air volume flow depends on the different appliances installed and the energy source for the appliance, for example as presented in Table 57.

Table 57. Recommended air extraction volumes from range hoods in litre per second per installed kW power for selected appliances (source BAR[213]).

Køkkenapparaturtype	Electric	Gas
	l/s per kW	l/s pr. kW
Convection oven	10	
Induction oven	20	
Micro wave oven	3	
Charbroiler	50	61
Fryer	28	
Range	32	35
Bain Marie	30	

Actual energy consumption of different categories of ranges hoods in professional kitchens is however complicated to estimate since it is extremely dependent on the actual configuration and installation, e.g. the dimensions in diameter and length of the ducts and components in the system. the control system, motor and drive etc.

212 Hans Daxbeck, Doris Ehrlinger, Diederik de Neef, Marianne Weineise, Ressourcen Management Agentur (RMA), Ressourcen Management Agentur (RMA), BIO AUSTRIA & Südböhmische Universität, ČR, EPOS (2011), Projekt SUKI – Energieverbrauch in Großküchen, Möglichkeiten von Großküchen zur Reduktion ihrer CO2-Emissionen, suki.rma.at/sites/suki.rma.at/files/Projekt%20SUKI%20-%20Endbericht%20Energie%20(Vers.%201.0).pdf

213 Arbejdstilsynet & Branchearbejdsmiljøudvalgets, Vejledning om indretning af ventilation i restaurationskøkkener (2004), ISBN nr.: 87-91106-23-0, www.bar-service.dk/Files/Billeder/BARservice/pdf/Hotel/104703_ventkok_d.pdf

Instead a simple estimation is produced based on the figures from chapter 4.1.1 regarding the share of energy consumption of professional kitchens and for different appliances. For the present study it is roughly assumed that kitchen ventilation is responsible of 15 % of the total energy consumption in professional kitchens, and that professional kitchens are responsible for 1.5 % of the total energy consumption in EU (a number which is only used for the present calculations regarding range hoods). According to [214] the EU-27 final energy consumption by 2018 was 989 MTOE.

The final energy consumption for air handling for professional kitchens thereby is estimated at roughly 26 TWh/year by 2018. By additionally assuming that requirement for range hoods would impact 50 % of the air moved in the professional kitchens leads to a total annual saving potential of 1.3 TWh/year by 2018.

Energy for cooling and heating of the replacement air is not included.

4.6.2 Energy savings

By focusing on products that are already covered by labelling or efficiency programmes from e.g. the US Energy Star and the topten programme efficient requirements based on proven test standards could be introduced quickly. The highest priority seems to be energy consumption for all the relevant products and for some products there might also be potential savings on water consumption or oil/fat consumption.

For calculating the savings potential, the product savings potentials as presented in Table 58 are estimated. The savings potentials are based on the explanations below and on BAT. Further improvement potentials from BNAT designs are not calculated.

Table 58. Improvement potentials and life time of professional cooking appliances.

Product	Fuel	Improvement potential [%]	Lifetime [years]	Typical annual saving per appliance	Unit	Saving converted to primary energy in kWh / (appliance*year)] [c)]
Static oven	Electricity	25	12	1650	kWh	3465
	Gas	25	18	15	MBtu	4396
Convection oven [a)]	Electricity	10	11	660	kWh	1386
	Gas	30	18	18	MBtu	5275
Steam and combi oven	Electricity	15	11		kWh	1946
	Gas	25	11		MBtu	4392
Griddle / fry top [a)]	Electricity	11	10	1300	kWh	2730
	Gas	10	11	12	MBtu	3517
Fryers [a)]	Electricity	10	10	2400	kWh	5040
	Gas	25	11	50	MBtu	14654
Steam cookers [a)]	Electricity	60	12	11500	kWh	24150
	Gas	60	12	130	MBtu	38099
Range hoods [b)]	Electricity	30	10	n.a.	kWh	n.a.

[a)] Lifetime is calculated based on data from Energy Star specification leaflets informing an annual savings potential and a lifetime saving.
[b)] Lifetime assumed at 10 years [c)] Conversion factors: From MBtu to kWh (primary energy): 0.29307. From final use electricity kWh to primary energy kWh, cc (elec) = 2.1.

[214] Eurostat, Energy data - 2020 edition, ISBN 978-92-76-20629-3, ec.europa.eu/eurostat/documents/3217494/11099022/KS-HB-20-001-EN-N.pdf/bf891880-1e3e-b4ba-0061-19810ebf2c64?t=1594715608000

The above energy improvement figures have been multiplied with estimated stock data to obtain total use phase energy efficiency improvements for 2020, 2025 and 2030 if the whole stock was substituted to the more efficient models (Table 59). These data were the results of the first iteration for the first draft version of the report. The following Table 60 contains the revised aggregated saving potential.

Table 59. Aggregate EU use phase saving potential of professional cooking appliances stock (primary energy GWh. Source: Own calculations)

Product category	Sub category	Heat source	2020	2025	2030
Ovens	Static oven	Electricity	0	0	0
		Gas	0	0	0
	Convection oven*	Electricity	382	394	427
		Gas	319	329	357
	Steam and combi oven	Electricity	9642	9958	10796
		Gas	2388	2467	2674
	Other; Air impingement, microwave and hybrid (rapid cooker)	Electricity	0	0	0
		Gas	0	0	0
Hobs and grills	Grills including char-grill	Electricity	869	897	973
		Gas	1119	1156	1253
	Fry-tops / griddles	Electricity	1739	1796	1947
		Gas	1118	1155	1252
	Hobs, gas	Electricity	0	0	0
		Gas	7102	7335	7952
	Hobs, induction	Electricity	628	648	703
		Gas	0	0	0
	Hobs, infrared	Electricity	748	772	837
		Gas	0	0	0
	Hobs, electric cast iron	Electricity	1330	1373	1489
		Gas	0	0	0
Steam cookers		Electricity	24621	25429	27567
		Gas	8526	8806	9547
Bain Marie		Electricity	739	763	827
		Gas	922	952	1032
Fryers		Electricity	12539	12950	14039
		Gas	18200	18798	20379
Bratt pans and kettles (incl. tilting)		Electricity	755	780	845
		Gas	486	502	544
Pasta cookers		Electricity	160	165	179
		Gas	74	76	83
Range hoods		Electricity	1294	1336	1449
		Gas	0	0	0
Total			**95697**	**98839**	**107151**

Table 60. Adjusted aggregate EU use phase saving potential of professional cooking appliances stock excluding range hoods (primary energy GWh. Source: Own calculations adjusted with data input from EFCEM and HKI)

Product category	Primary energy savings 2030	
	GWh/year	PJ/year
Convection ovens	1,610	5,796
Steam and combi ovens	7,027	25,297
Grills including chargrill Rise and fall grill	5,366	19,316
Fry-tops / Griddle plates	4,934	17,763
All hobs: gas, induction, infrared and electric resistance	3,796	13,664
Bain-marie (electric and gas)	1,859	6,692
Fryers	3,510	12,635
Bratt pans and kettles (incl. tilting)	4,254	15,314
Pasta cookers (electric and gas)	262	943
Total	**32,617**	**117,422**

The total primary energy saving potential excluding range hoods is estimated at about 33 TWh/year (117 PJ/year) by 2030.

The adjustments were made on the basis of inputs from stakeholders; primarily data from EFCEM (European Federation of Catering Equipment Manufacturers) and HKI (industrial association of House, Heating and Kitchen Technology). After the second stakeholder meeting, EFCEM and HKI provided more accurate estimations on the European stock of professional cooking appliances (extrapolated from the German market)[215] in addition to commenting on the assumptions made for the first version of the current task 3 study. The study team assessed the data and information and used the data for the above adjustments of the resulting energy saving potential where appropriate.

The main input used for the adjustments are the following:

Regarding stock data: Overall the estimated stock of appliances in the current study (15.5 mill.) is in line with the estimate from EFCEM/HKI (12.4 mill.). However, for individual product groups EFCEM/HKI suggests some major shifts which will impact the saving potentials significantly:

- For convection ovens, HKI expects the double (HKI 688,000 vs. 335,000 first estimated by the study team).
- For steam and combi ovens, HKI expects the half (HKI 1,580,000 vs. 3,020,000).
- For the group `Other´ the total number is about 5-6 times larger (HKI 1,760,000 micro ovens and 197,000 pizza ovens (air impingement) vs. 373,000 totally), however this category is still assumed to have neglegible savings potential.

[215] Adrian Brändle, Estimation of the stock of food service equipment in professional kitchens on the EU 27 market, Industrieverband Haus-, Heiz- Und Küchentechnik E.V HKI (2021)

- For grills HKI expects around 50 % more (HKI 1,530,000 rise and fall grills vs 636,000)
- For frytops / griddle plates HKI expects the stock is about two and a half times (HKI 1,470,000 vs 955,000)
- For hobs in general about a third stock is expected by HKI (HKI 1,169,000 vs 3,380,000)
- Steam cookers are not so common in the EU (HKI estimates 20,000 vs. 1,240,000) and is therefore considered negligable. This is one of the product groups for which a significant saving potential was assumed in the first draft version.
- For fryers, HKI finds the stock to be around the half (HKI 1,720,000 vs 3,730,000). Specifically for fryers HKI mentions that the extrapolation from the German market probably will underestimate the stock since other parts of EU have other food traditions. Together with the above mentioned correction for the expected lower energy consumption for European fryers, the total aggregated potential savings on fryers are cut by 75 % compared to the original estimates. Fryers is one of the product groups for which a significant saving potential was estimated.
- For tilting bratt pans and kettles, HKI expects the stock to be three times as large (HKI 1,270,000 vs 415,000)
- For pasta cookers the same as for tilting bratt pans and kettles

Additionally, EFCEM/HKI mentions multipurpose cooking appliances (367,000), pressure boiling kettles (66,000), pressure bratt pans (80,000), woks (214,000) and belt frying automats (3,000) as common cooking appliances. The sales/stock, energy consumption, and saving potentials of these would probably be too low to be relevant for this study.

Furthermore, it is assumed that Covid 19 will have more than a short term impact on the market development and stock. EFCEM[216] informs that the impact of Covid19 on their member companies' markets is more severe than expected in the current study. The market has shown a 25-30 % decrease in 2020, a drop that is expected to continue in 2021 and the reason is similar problems in the sector of professional kitchens. Furthermore, a large number of used appliances are expected on the market for the coming years, and there might be a long-term impact on the number of kitchens and nature of their business in the coming years (less business travel, more home office etc.). In a preparatory study this development and the degree of recovery of the market must be followed and the long-term impact on the stock from 2030 and beyond analysed further.

Regarding the energy saving potential, some main points are that:

- The energy consumption values to use for the energy saving calcuations are based on the US Energy Star label, which probably are overestimated due to larger and less efficient equipment in USA. This is particular the case for the fryers. For the revised estimate, the energy consumption is supposed to be closer to the measurements by Mudie et al (2013)[217]
- 3-layer glass is already now more common than suggested in the current study.

[216] European Federation of Catering Equipment Manufacturers EFCEM, Stakeholder comment 26th March 2021

[217] S. Mudie[1], E.A. Essah[1], A. Grandison[1] and R. Felgate[4] (2013), Electricity Use in the Commercial Kitchen, [1]University of Reading, Reading, Berkshire, UK, [2]Mitchells & Butlers plc., Birmingham, UK, Printed in International Journal of Low-Carbon Technologies, Oxford University Press

- Steam injector for steam ovens might not be a good solution because it will leave out a large share of the expected improvement potential.

4.7 Other stakeholder comments

Comments were received from the following stakeholders:

- EFCEM
- HKI
- Danish Energy Agency
- Swiss Federal Office of Energy (SFOE)
- SYNEG (French Union of the professional kitchen equipment manufacturers)

Due to the amounts of comments, the comments and the answers from the study team has been placed in Annex 2.

Annex 1 Calculation formulas and definitions - Griddles

Energy star[218] defines the formulas for normalizing the idle energy rates for gas and electric griddles are as follows:

$$q_{g-idle,n} = \frac{q_{gas}(Btu/h)}{A(ft^2)} \text{ , } q_{e-idle,n} = \frac{1000 \times q_{elec}(kW)}{A(ft^2)}$$

Where

qds-idle,n	= normalized gas griddle idle energy rate, Btu/h/ft²,,
qgas	= gas energy rate during idle , Btu/h,
qe-idle,n	= normalized electric griddle idle energy rate, W/ft²,
qelec	= electric energy rate during idle , kW,
A	= area of the bottom cooking surface (ft²) measured splashguard to splashguard and splashguard to grease trough

Double-sided griddles that include an electric top plate and gas bottom plate must meet the cooking energy efficiency and idle energy rate for gas griddles in Table 1, above. Manufacturers should use the formula provided below to determine normalized idle energy rate in Btu/h per ft².

$$q_{ds-idle,n} = \frac{q_{gas}(Btu/h) + 3413 \times q_{elec}(kW)}{A(ft^2)}$$

Where

qds-idle,n	= normalized gas griddle idle energy rate, Btu/h/ft²,
qgas	= gas energy rate during idle , Btu/h,
qe-idle,n	= normalized electric griddle idle energy rate, W/ft²,
qelec	= electric energy rate during idle , kW,
A	= area of the bottom cooking surface (ft²) measured splashguard to splashguard and splashguard to grease trough

[218] US EPA, 2011, Energy Star, Commercial Griddles Key Product Criteria, www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_products_criteria

Annex 2 Stakeholder comments

Organisation	Page	Topic	Comment	Reply from study team
Denmark		Scope	The scope include many different technologies and functionalities in the professional kitchen. Could these be bundled in functional areas, as done with domestic kitchen appliances (ovens, hobs and range hoods)? Please investigate how the current scope of this task report could be divided into regulations/implementing measures based on functional areas of the professional kitchen.	This would indeed be relevant to consider for a potential preparatory study
Denmark	10	Customised products	Product requirements should take into account that many of these product groups are customised.	Yes, the full savings potential might not be possible to harvest for this reason and this should be assessed in a preparatory study
Denmark			Elaborate which product groups are prone to be customised, and any barriers towards setting product requirements.	As above
Denmark	General	Missing CE-criteria	The report does not describe circular economy and environmental aspects.	Unfortunately, no valid information was available, This has been addressed now in section 1.1.3 Test standards and 1.6 Improvement potential. Environment aspect are considered in relation to energy consumption and e.g. data on use of different material including electronics. A further breakdown on components including e.g. rare earth elements would be relevant for a preparatory study.

Organisa-tion	Page	Topic	Comment	Reply from study team
Switzerland	40	Scope	"In-store bakery convection ovens. Convection ovens designed specifically for baking. Neither of the appliance energy efficiency programmes, topten or Energy Star, include professional or commercial static ovens. In-store bakery ovens will not be considered for the scope."	
			Comment: This oven type is rapidly increasing with more and more shops baking bread freshly on site (often pre-baked or raw frozen dough pieces). Topten Switzerland is finalising a study about in-store bakery convection ovens on behalf of SFOE. The study will be published this summer. Part of the mentioned study includes a survey with 15 oven suppliers to gather data on energy consumption. So far, this proves to be hard: there is very little data available. Some manufacturers report that energy consumption is increasingly topical for their customers and they would be supportive of a uniform declaration of energy consumption values. As of today, manufacturers measure mostly according to their own specifications. In one case, efficiency improvements of 20-30% are highlighted in the catalogue comparing to previous models. A product information requirement by means of eco-design regulation would greatly help to show efficiency potentials and motivate market players. published this summer. Preliminary results show that DIN 18873-4 and DIN 18873-7 are suitable for this oven type. These ovens are technically not different from convection ovens. The main difference is the visual design (because visible to customers), in particular featuring large glass doors (triple glazing = BAT). Within the framework of product regulation, it could be rather difficult to distinguish between in-store bakery convection ovens and other convection ovens. We therefore	The information about the standards potential applicability for in-store bakery convection ovens has been added to the standardizations section 1.1.3. The study team suggest to evaluate the in-store bakery convection ovens for the scope as well, also in the light of the risk of a potential loop hole in case standard convection ovens are selected for a ecodesign regulation.

Organisa-tion	Page	Topic	Comment	Reply from study team
			hope, that in-store bakery convection ovens can be in-cluded in the scope.	

Organisa-tion	Page	Topic	Comment	Reply from study team
SYNEG	15	1.1.3 Test standards	Please add the French standards for energy performance to the list: •NF D 40-020 : Professional catering equipement -Grid-dles- Energy performance •NF D 40-016 Equipement for mass catering Reheating and temperature maintaining appliances Energy perfor-mance •NF D 40-050 : Professional cooking and refrigerating equipement noise test code (precision class and control) •NF D 40-002 : Professionnal catering equipement - deep fryers -Energy performance •XP D 40-021 : Professional catering equipement -Boiling pans- Energy performance (experimental standard soon to be a national French standard)	The standards have been added to the standards section.
EFCEM	7	The energy consump-tion of professional kitchens represents a significant footprint - environmentally - where a the kitchen of restaurants, hotels or even office buildings could be the largest en-ergy consumers	"The energy consumption depends on the convenience level. Partly it is ready made by the industry, partly it is fully prepared at home and displacements are going on all the time. Ergo: The comparison is difficult. Second, the ra-tio must be the consumption per dish (in relation to the household?) and the sizes are an efficiency advantage in the professional sector! Due to a high food output per cooking unit a professional kitchen has a reduced environ-ment footprint in comparison with the private sector. For example, a pizza prepared in a household oven will require more energy than a pizza in a commercial oven that is pre-pared together with 9 other pizzas. It must also be taken into account that the household oven only needs to be pre-heated for one pizza and the professional oven only once per service. In foodservice the functionality and energy use of the industry specific equipment is directly affected by the time needed to cook high volumes of food quickly, and in line with the food safety requirements. When en-ergy use is linked to the meals served it can be less per meal than with domestic equipment. "	It cannot be an argument for not estab-lishing ecodesign requirements for this product group that it is more efficient compared to domestic cooking. The key point is if the product group is scope of the Ecodesign Directive and has suffi-cient saving potential etc. for imple-menting measures.

Organisation	Page	Topic	Comment	Reply from study team
EFCEM	7	and financially, where energy could be the second largest expenditure to catering business after labour (and before food ingredients	"This is a market-based incentive to reduce costs and driving improvements on energy demand and efficiency forward by planners or consultants of professional kitchens. Expenditures: Labour, Food ingredients and then energy. "	Yes, and this is also the reason for establishing Ecodesign or Energy Labelling regulations, if a feasible potential is available.
EFCEM	7	The impact assessment explains that commercial cooking appliances are excluded from the scope because of deficiencies in test standards and market data required to design effective and responsible measures.	Also, important points were the different usage and quantities, which are missing here. These appliances are often individually manufactured on customer request. Comparisons are problematic. Energy issues are taken into account by the customer / planner due to the cost factors. There is no reason to replace those incentives with a regulation.	A preparatory study would have to go into more details on customised products, etc.
EFCEM	7	The commercial and professional sector is potentially a high impact sector from the energy consumption point of view (initial exploratory calculations indicate it might be around half the energy consumption of the domestic market, with a significantly lower market share	"Proportion to the household is missing! The sector of professional cooking appliances is working on technical improvements to be a solution provider for the Green Deal. The energy transition and electrification make smart grids necessary. But peak power is a big problem because power stations cannot run up and down without great stress. The standard on "interface for power optimisation in commercial kitchens" (DIN 18875) is a remedy here. It is probably a Smart Readiness Indicator for kitchen systems - a contribution to the Revision of the Energy Performance of Buildings Directive. The advantages can be seen in the reduction of the demanded KW used with possible economies for the user in the contract with the energy supplier and in lowering the load on the electrical distribution the grids: - Lowing the total connected power of the overall kitchen system. This means that more appliances than usual can be connected. - Levelling out the amount of KW. Peak power is very expensive and also a problem for the power	A text regarding smart readiness has been added. However, demand flexibility and smart grids will typically not provide energy savings and it is therefore still needed to assess possible feasible energy savings.

Organisation	Page	Topic	Comment	Reply from study team
			stations (policy makers should see appreciate this point) - Peak power calculation switching appliances off and on just for seconds to control the peak power without negative impacts on cooking performances. Ergo: The kitchen system has not always kept on the top and this is better for the environment avoiding harmful peak power. However, the procedure leads to an extension of the cooking time. Another solution would be to implement an electrical storage. In the future, these will be built into every larger building anyway. This could be charged by a photovoltaics system, a block-type thermal power station, but also from the power grid. Power peaks would then be absorbed by the electrical storage system. "	
EFCEM	8	1.1.1 Background	Data are based on sources coming from investigation (Danish study) performed in different time period (technologies not comparable) and is not clear if the context were the same (a canteen management is different from a small restaurant or a hotel)	The purpose of this section is generally to provide some introductory background information about regarding the potential for efficiency improvements and energy savings in the professional food preparation sector. Data from many sources have been used.
EFCEM	8	Introduction of an energy label for the commercial appliances	"The development of labels in the household sector has now led to an oven having an eco-mode, the standard tests must be carried out in this eco-mode, but customers often operate the appliance in a different mode. This ensures a good label in terms of energy efficiency, but in reality, hardly saves energy or greenhouse gases. A comparable situation for large kitchen appliances is not desirable In the household sector the energy label makes sense. The consumer, that makes the investment decision, is a layman. Before the labelling the only Information on which he could make his decision were the company's reputation and the price. The label adds valuable information for an	A comment about the complexity of these products hindering the benefit from a label is added on page 8.

Organisation	Page	Topic	Comment	Reply from study team
			unqualified decider. But this has nothing to do with the situation in professional kitchens. They are not simply bought and installed. Professional kitchens include so many interdependences that they need to be planned by kitchen architects/planners. They have to meet a variety of requirements to design the individual kitchen for its individual purpose like number of meals, convenience level (cooking everything fresh or only reheating components), nationality of dishes (e.g. Italian or Chinese food), type of cooking (cook&serve, cook&hold, cook&chill, cook&freeze, reheat …) Type of catering facility (e.g. restaurant à la card or canteen with 5 fix dishes) and so on. A one-dimensional label is not able to provide any value for the planner. In contrary the very nature of such a label implies the comparison of apples and "oranges". Procedures are different and their consumption vary: "	
			A commercial kitchen is a system of complex appliances that work together as a system to deliver complex menu offering to consumers. Therefore, the kitchen should be regarded as a system to deliver a high volume of meals, quickly. Because of the large variety of products that are used to prepare store, cook and clean utensils, cookware, crockery and glasses; a system based approach is more practical, more appropriate and more relevant. We believe this is the correct approach for further studies. It will be impractical and cost prohibitive to develop an energy label for each appliance type that is used in a kitchen.	
EFCEM	8	Considering the reasoning above provided by relevant stakeholders, it was concluded that regulation for commercial/professional cook-	"The conclusion is not admissible in accordance with the arguments that were also put together above in cooperation with the JRC. Since the there is a very high differentiation in the units to adapt customer needs and at the same time small quantities are produced of each version. A likely result of a regulation would be, that the variance of the units would drop significantly. As a result would be	A potential preparatory study will have to go in details with the technical aspects and limitations.

Organisation	Page	Topic	Comment	Reply from study team
		ing appliances is necessary, since it is potentially a high impact energy consumption sector with possibilities for improvement. Regulation in the commercial/professional sector could boost innovation and be a driver for efficiency.	that the customer does not have the optimal unit and this result in higher energy usage. For example could it be possible that the variance in griddleplate sizes and surface quality would be reduced, so the customer might have to buy a larger plate than needed or buy two griddle plates one flat and one rippled instead of a mixed version and then the energy usage would be higher than before because 2 units are running instead of one or a larger one than a smaller one. Please refer to our general position and start where work is already done. "	
EFCEM	8	Studies on professional kitchens from 2018 in the Danish hospitality sector presented in Table 1 found that in restaurants, 70 % of the electricity consumption is related to the kitchens, and that in other institutions 25 – 35 % of the electricity consumption is related to the kitchens (Table 1).	"Amazingly, 100% of the energy in a power plant is used to generate electricity - minus the losses. Only the losses can be minimized?! The energy consumption for cooking remains! NOTE: In order to cook, brown or crisp a product, water must be evaporated. Water needs a lot of energy to evaporate. If you save here, the desired cooking result will not be achieved. It would make more sense to recover the invested heat. This ensures high cooking quality with low final energy requirements. With the combi steamer, the energy is released very concentrated at the ventilation pipe. This is not the case with other cooking appliances. Thus, the combi-steamer would be preferable for heat recovery, whereby this can be done e.g. via a heat recovery integrated in the ventilation system above the. This has the advantage that the recovered energy can usually be supplied in the form of hot water to other consumers (heating, flushing technology) "	A preparatory study could consider looking at how the system could benefit from the potential heat recovery from combi steamers. A subsection regarding potential for heat recovery is added in section 1.4.1 on ovens.
EFCEM	9	The fundamental functions of household, commercial and professional cooking appliances are the same and	"This is only true for cooking in the sense of “simmer”. But the technology of the appliances are not comparable, that is a misconception. Nobody has a combi steamer with a temperature of 300° Celsius with numerous extra functions at home. In the household area the appliances is used to cook one meal. In professional kitchen the appliances is	References and comparisons with household cooking are removed or edited.

Organisation	Page	Topic	Comment	Reply from study team
		similarly they share technologies.	doing for a longer period of time multiple are completely different batches. Additionally, there are cooking philosophies like cook and serve, cook and chill, warming and so on. Due to the professional and heavy-duty use, the surfaces have to be much stronger and thicker, thus resulting in more specific energy needed for heating up. That cannot be compared with household appliances. "	
EFCEM	10	"In Consequently, professional, and commercial appliances overall have higher power, and larger cooking areas and cavities and have much more cooking options. Additionally, in some cases the professional and commercial appliances are part of a cooking system supplied and installed in a total enterprise, but not more specialized than it is normally possible for the kitchen entrepreneur to add combine products from different brands or 'no-brands'."	"It is simply not the case that the same manufacturers serve both sectors. Only in the rarest of cases. The reason lies in the individual customer requirements: size, kind of energy, precision, mass of the production needed etc. And this is why a customized manufactured appliance, individual appliance, cannot be measured by means of a uniform method. No comparability can be established here as this is in the household sector with mass production the case. This is the difference. It is clear that the professional sector needs energy for its supply requirements and commercial purposes. Therefore, energy savings are only possible to a limited extent. They place a direct burden on commercial use, as there is no heating-up time to wait. Cooking takes place here on a completely different scale, the cooking temperatures must be available when required, otherwise the appliances will simply be left on (that would cost more energy). So, the usage behavior would be negatively influenced. Basically, the larger scale in the professional sector is an advantage in order to achieve higher all over energy efficiency in relation to food preparation in the domestic area. There is also more energy consumption, but compared to the consumption in many individual households, the commercial expediency of professional appliances also makes sense for energy savings. This point is always missed in the report. In addition, the higher functionality also serves the appropriate consumption. Members use of the appliances in a very responsible way. Food	The message of this text was that there is some level of modularisation in the professional sector as well, not that the manufacturers and other economical operators generally serve both the household and professional sector. Generally references and comparisons to household sector has been removed from the current study or rewritten in order to prevent misunderstandings and make the focus more clear.

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			preparation has a higher value and use here. Comparability and measurement of energy consumption: The values determined for energy consumption are made available to the public by the manufacturers on a voluntary basis: https://grosskuechen.cert.hki-online.de/de in German, English and Italian and are constantly updated. "	
EFCEM	10	"A similar distinction is made on commercial and professional refrigeration appliances. However, the standards on cooking do not seem to make the same distinction between commercial and professional cooking appliances and the literature did not consequently use that distinction. "	"What is intendent when it is mentioned “standards on cooking do not seem to make the same distinction …”? This causing confusions and therefore not helpful. "	The point was that opposite with the professional and commercial refrigeration business there does not seem to be a clear distinction between commercial and professional cooking appliances. Text is adapted to clarify.
EFCEM	12	1.1.2.1 EU policies	References to Machinery Directive is missing (and it is the main policy in the professional sector)	Is mentioned in the section 1.1.2 on the scope but indeed it would be relevant to mention here as well. It has been added.
EFCEM	12	However, it could be relevant to study the product group of commercial and professional warm storage appliances as bain-maries as its own category to evaluate if their performance and technical characteristics based on the estimates that their	"Let us not take the second step before the first. Please proceed step by step, there is a lot at stake. Note: An open bain-maries where the steam can escape requires a lot of energy. This should be prevented. Cook and hold means that you need energy to hold the food at a minimum food safety related temperature. Cook and serve is not always possible. The alternative would be cook and chill and reheating when needed, food quality is better but more energy is need because of additional cooling and reheating. This is the reason why commercial kitchen can not be compared to household, where cook and serve is the	Agree

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		energy consumption constitutes 5-10 % of the total energy consumption in the professional kitchen as presented in the introduction 1.1.1.	rule. In commercial kitchen this is the exception from the rule. "	
EFCEM	13	The Energy Star label from US Environmental Protection Agency (EPA) is applied for a number of products for restaurant and commercial use (food service)26.	"It is worth mentioning here that there is also a clear distinction between household and professional appliances. Moreover, the Energy star is only available for appliance types for which there is also a measurement standard for energy consumption. You need a certain amount of products available at the market (more than 5 at each category). "	Agree
EFCEM	15	1.1.3 Test Standards	We highlight the limit in the application of DIN standards 18873 series (e.g. for Ovens the standards practically is not applicable for all sizes). However, these standards are not connected with the cooking. performance and material efficiency. French standards for energy performance: NF D 40-020 : Professional catering equipement -Griddles- Energy performance	Comment on limitations + information on the NF standards series is added.
EFCEM	15		typo] The EN 2031-1 standard series does not deal with rational use of energy…	Corrected
EFCEM	23	1.2.2 Market for appliances	The Prodcom category 28211330 "Electric bakery and biscuit ovens" are not involved in professional/ commercial sector.	
EFCEM	23	1.2.2 Market for appliances	"The Prodcom category 28931580 "Non-domestic equipment for cooking or heating food": practically in this category could involve every type of cooking appliance and try to use these mixed data to forecasting trends and growth	

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			can mislead (annual volumes are different between different products categories (a grill cannot be considered as a combi oven) and are affected also by "where" they are installed (e.g. type of restaurant: a chain has different needs from an hotel or a canteen). "	
EFCEM	26/27	"A study performed by University of Reading (Mudie, Essah, Grandison and Felgate, 201360) on the electricity consumption in commercial kitchens energy consumption mapped typical appliances including cooking appliances and their energy consumption in 14 professional kitchens in an English chain of "gastro-pubs". Incombination with Table 13 "	"Assuming that this one English pub chain represents the average kitchen in Europe is a serious mistake given that the whole following calculation is based on this assumption. As "The European hotel and restaurant sector is dominated by small independent restaurants." (page 22) it is impossible that the average kitchen has 5 ovens (1. Steamer, 3 Combi Steamer, 1 Gas Oven à Table13) and 3 Fryers. A typical small commercial/Professional kitchen has 1 (max 2) Ovens und 1-2 Fryers. There is not such thing as an average kitchen. It depends on what you want to prepare. The sector's operator market comprises independent and group operators. Foodservice equipment is extensively used for out of home eating and drinking across the following key operator sectors: Primary sector operators – where foodservice is the primary function: • Hotels, Quick Service Restaurants, Restaurants, Pubs and Bars. Secondary sector operators – where foodservice is a secondary function:- • Healthcare, Education, Public and Community Services, Armed Forces, Leisure and Recreation, Workplace, Visitor Attractions, Venues, Travel, Stadia and Event Catering, Food Retail Sector As a result there is not an average kitchen and this approach is simplistic and inappropriate, EFCEM will be pleased to work collaboratively to help with further understanding. The assumptions of Table 13 lead to a serious overestimation of the appliances in all the following calculations. This is where the concern arises, if the stdy team is aware of our sector? There are different chains and structure of the market!	Agree. We try for this small pre-study to find and present several sources on "typical" kitchens and their appliances to extract a kind of an average representing the large span of professional kitchens. The study team appreciate the data and estimations supplied from EFCEM on the market size ad nature. For the current study the full benefit cannot be taken in although some adjustments are made. These input would also valuable as input for a starting point for a potential preparatory study.

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			Where is the focus? Please refer our general position and start where work is already done. "	
EFCEM	31	"1.2.2 Market for appliances Table 17. Stock estimates (in 1000s) based on a top-down and a simplified bottom-up approach. "	The collected data is very critical. Many assumptions where made and which multiply with each other, the real life error is to be larger than 100%	See comment above
EFCEM	32	"Forecast - Stock The average growth rate is assumed to be 0 % in the years 2020-2023 due to the setbacks from the Covid-19 epidemy. From 2024 to 2030 the average growth rate is assumed at 1.6 %/year, similar to the growth rate found for commercial kitchens (Table 4). "	"Reality: • Growth in 2020= - 25-30% !, the drop will continue in 2021. • Growth of kitchens is also to be clearly negative (wave of bankruptcies) • This leads to a flood of used appliances (already in 2020 for professional combi steamers an increase of 30% has been registered at platforms like ebay) • The Operators that have survived so far have no capital with which to invest • Plus a Change in customer behaviour (less business travel, more home office, less ToGo...) "	In a preparatory study this development and the degree of recovery of the market and impact on the stock must be followed and analysed further. A comment on this has been added in the final section.
EFCEM	34	"1.3 Usage Usage patterns and also operation modes differ for the different types of machines considered. Professional cooking appliances are used in professional kitchens in different sectors and establishments like restaurants, mobile food	"The potential savings that result here are considerable?! We should emphasize this in relation to the appliances -> remedy = autom. detections and smart technology. But the investor / operator problem - then the label or anything else doesn't bring anything?! Promotion and development are necessary here -> Funds?! The study also found that this energy wise "inappropriate" behavior was more the rule than the opposite. A conclusion could be that professional cooking appliances need to support efficient usage behavior per default. In principle it is true, but we	Agree that it will be important to consider the reason for the energy-wise "inappropriate" user behaviour before potential requirements. Some of the sources (UK gastro study e.g.) suggest that even in similar use situations the energy consumptions can vary significantly.

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		service, catering (parties, festivals, companies etc.), canteens for employees and schools in the public service sector like hospitals, child and elderly care, etc. "	shall consider the fact that during the normal use, it is expected to have an appliance "ready to be used" so for example the "use eventual timer control" that turn off or reduce the temperature set is not always applicable (it is not so easy find the right compromise especially considering the different location (and consequently the usage) where the appliances can be installed – configurable options can be considered but in any case they can be "affected" on the field by the "user behaviour"). If the "active usage" is to consider, it seems a not realistic estimation; can be useful distinguish the active usage connected to the different installation/location (e.g. restaurants vs supermarkets). "	It will probably not be possible to introduce requirements based on the installation or location since this is not part of the ecodesign directive frame.
EFCEM	35	Generally, the daily hours of active usage of cooking appliances are estimated at 3-4 hours, based on calculation in the lot 22 and 23 preparatory studies and on the investigations from Daxbeck et al. on some Austrian and Czech professional kitchens.	"That is totally dependent ... which user/ company?! In the fast food sector, the active usage is 24h. The estimation is very uncertain. We have customers which use the units in a range of 24/7 and others with 1 hour a week. Calculations with this data and with the uncertain units data and with uncertain energy usage data results in values which have nothing to do in real life. NOTE: It is possible that data from several thousand networked appliances can be evaluated here in order to analyze usage behavior more closely. "	Agree. We try for this small pre-study to find and present several sources on use hours and situations and extract a kind of an average representing the large span.
EFCEM	35	Guidance efficient usage	"Appreciation of introducing efficient usage As can be seen in the comment, correct use is crucial. The appliances are developed for the corresponding use. In addition, digitization could support this. Communication between the appliances (e.g. smart kitchen ventilation), communication of the devices with the staff, communication of the food with the appliances We are in the process of laying the foundations of this digitization. With this in mind, we welcome every effort to make energy consumption visible, e.g. with a digital display of the consumption, which can be the basis for trying out comparable cooking performance with	A subsection on digitisation as a means for energy efficient cooking performance is added in section 1.3 on usage.

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			lower energy. A sufficient cooking performance can only be evaluated through this transparency. Other types of energy saving come at the expense of performance. "	
EFCEM	37	BNAT of not yet used technologies in the professional sector	"Three glass layers in glass doors are already usual. Vacuum insulted panels and vacuum insulted windows according to the referred study is not viable for every kind of an professional oven door/ window stressed by temperature differences from 0° to 300° Celcius Such solutions have already been considered but are not available. More insulation hampers also the smartness of the appliance, will reduce the sensors and lead to the expense of the cooking performance – healthy food intentions. The wording is unclear regarding sensors. Only thicker insulation is limited with regard to the larger appliance dimensions. In particular, device heights are specified for ergonomic and safety reasons. The study is referring to the Preparatory study for ecodesign requirements of EuPs Lot 22. Please also note the conclusions accordingly: "Several BNAT design options have also been identified but it is not clear whether some of these will be viable for commercial catering ovens. This may be because energy savings are too less due to insoluble technology problems."	As presented in section 1.6 the improvement potentials are not based on the BNAT but on the previous work from the preparatory study, Energy Star etc. A preparatory study will study this more in details in the technology task. However if a solution like 3-layer glass is already usual this will decrease the improvement potential for ovens may be smaller than estimated (an amended calculation is on aggregated level presented in section 1.6.2).
EFCEM	37	BNAT Sleep Mode	"Probably this will cause more energy for heating-up again. However, it is unclear what the different modes are: Idle, sleep or stand-by. Second, an empty appliance is a misuse of a professional appliance. It made to use the full capacity. That's why it is customized or has several sizes. The usage of the appliance is planned. Therefore, idle mode and sleep mode makes no difference. These suggestions show misunderstandings about the professional sector/ foodservice equipment sector. It would be conceivable to provide the customer with the option to select Standby	A preparatory study will study this more in details in the technology task.

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			Mode. This gives the customer the opportunity to consciously save energy. This could make sense. However, the appliance should be kept ready for use. The proposed lowering to 100 ° C requires subsequent preheating and disrupts kitchen processes. Many customers would not take advantage of this. It is better to save a little less energy that the customer also uses instead of storing functions that would save a lot of energy but do not fit into the customer's process. A pause button would also be conceivable. The appliance does nothing in this case. If the customer presses play again. So the appliance goes into the last operating state. Conclusion: A clear definition in standards of what is an idle mode, sleep mode or stand-by mode is necessary in order to be able to offer appropriate operating procedures "	
EFCEM	38	Improved temperature control with lower oscillation; pilot light	"We measured with thermoelectric fryers and electronic controlled fryers at standby (180°C) a deviation of 2%. Our engineers don't understand exactly what the report is intending here. However, any better temperature control has just few effects on efficiency. A pilot light is outdated since a long time and already unusual. Pilot lights are still in use on gas hobs – this belongs to the product groups. It is simple, reliable and easy to use. That is a reason why simple gas hobs are used. There is very good energy transfer and use when cooking. But with modern equipment like convection steamers, pilot lights are not used anymore. Electronic very precise controls are a standard according to the standard. Temperature deviation of +/- 1-5 ° C over the entire temperature range depending on the standard. Please refer our general position and start where work is already done."	A preparatory study will study this more in details in the technology task.

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EFCEM	38	Electric ovens have a cooking efficiency of 65% and gas ovens only 30%.	"What is the reference of these numbers? Is the calculation based on a standard? As described, the values are below the certification for the Energystar. Is a standard appliance really that bad? Then everyone would be really good with Energystar. "	A preparatory study will study this more in details in the technology task. The improvement calculations however are also partly based on the actual measured (and estimated) consumptions as presented in subsequent sections.
EFCEM	38	Injector is more efficient than steam generator	To evaporate water, 2257 kJ / kg are required. This is independent of whether the steam is generated by an injector or a steam generator. The combi steamers with steam generator usually control a high level of steam saturation in the cooking space. This takes energy. Appliances with injection technology, on the other hand, usually control a much lower vapor saturation and take much longer to achieve this. This takes less energy. This means that products dry off and have a longer cooking time. If an injector were to control the high steam saturation, much more water would have to be injected and heated, a significant part of which would flow out of the cooking chamber. The heat losses increase as a result. The injector is therefore to be regarded as inefficient when the steam saturation is high. With a desired low steam saturation, the DG would also be more efficient than its reputation.	A preparatory study will study this more in details in the technology task. However this comment could indicate that the improvement potential for steam ovens may be smaller than estimated (an amended calculation is on aggregated level presented in section 1.6.2).
EFCEM	38	Table 24. Representation of energy fluxes	This information is very much dependent on the application and the load. Allegedly only 35% hot air flows into the food (load)? With the Energystar, approx. 80% are measured. Why is there no energy flow through the door when steaming? Why does 16% flow into liquids with hot air and only 1% when steaming? For this one would have to take a closer look at the study by Burton.	

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EFCEM	42	1.4.1 Ovens: Noise	"We consider that noise is irrelevant for professional cooking appliances. Manufacturer never had problems, complains about this. This doesn't make sense. Please notice that noise is covered by the machinery directive as it is considered to be a safety related matter. "	The pre-study suggests to investigate if noise is a relevant parameter but makes no conclusions. A comment regarding EFCEMs' information is added.
EFCEM	43	1.4.1 Ovens: Water consumption	There is no standard available for this.	Comment added.
EFCEM	44	An important use factor for griddles – especially for electric griddles – is the heat-up time, which need to be short, otherwise the users are tempted to leave it on heated during the entire working day.	"That leads to high performance and probably consumption in the heating phase. This should not be transferred to other appliances. This is not in line with environmental consciences. In terms of heating-up time our sector has experience to deal with trade-offs. Please refer our general position and start where work is already done. "	A preparatory study will study this more in details in the technology task.
EFCEM	44	"The US EPA also mentions other construction factors as important for energy efficiency and efficient use of griddles: • Improved thermostatic controls and strategically placed thermocouples; and only thermostatically controlled, not manually controlled griddles and fry-top ranges, are eligible for Energy Star • Unform temperature distribution across the griddle	"See above Fryer. Uniform distribution and correct temperature is a must for the chef! That has to be fulfilled anyway. Please refer our general position and start where work is already done. "	A preparatory study will study this more in details in the technology task.

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		plate • Highly conductive or reflective plate materials. "		
EFCEM	44	General factors for improved energy efficiency for hobs. Generally for the professional kitchen temperature sensors and thermostats as well as automatic controls and temperature display, timer etc. are factors that support energy efficient cooking. For glass-ceramic hobs in particular cooking sensors for automatic shut-down of cooking zones	Electronic controls only have a low impact on efficiency.	A preparatory study will study this more in details in the technology task.
EFCEM	45	"Table 27. Energy Star minimum requirements to commercial griddles101 Appliance Idle Energy rate Griddles Gas fuelled single- and double-sided 2,650 Btu/h/ft2 Gas/electric double-sided that include an electric top plate and gas bottom plate 2,650 Btu/h/ft2	"For all such requirements from the Energy Star, it should be pointed out that the requirement for rapid heating-up is/ can be in contradiction to an energy consideration. This must be carefully considered in test scenarios -> Differentiation between heating, holding, cooking?! It is controversial. Please refer our general position and start where work is already done. "	A preparatory study will study this more in details in the technology task.

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		Electric single- and double-sided 0.320 kW/ft2 "		
EFCEM	46	"Steam cookers could improve their energy efficiency by better insulation and more efficient steam delivery systems. According to the EPA added benefits are shorter cook times and higher production rates. Steam cookers with three "	"There is a misunderstanding. We are talking about combi ovens with a steam function. And this steam cooker is a completey other appliance. They are not common in the European market. Please refer our general position and start where work is already done. "	This section could have been placed next to the steam ovens section. A sentence explaining the relation is added for clarity. The information that it is not common in Europe is added. In the recalculated savings potential in last chapter, the potential from Steam cookers is written down to zero.
EFCEM	47	Examples of components with significant influence on the energy efficiency are door gaskets (heat loss), thermal insulation 5.1 Professional cooking apliances and placement, steam vent and exhaust tubing design, temperature control etc.106.	"The listing is correct, even if it is generally not right. Just the thickness of an insulation says nothing about better or worse compared to a thinner insulation with better insulation values. Due to a high ratio food to meters of door seal in comparison with a household unit the influence is much lower! Example: A 10 grid Combi steamer has a seal length of 2,2 to 2.5 m and can cook 50 kg of food. Where a household oven has a seal length of 1.2- 1.4 m and can cook 5 kg of food. So the mean ratio is 21 to 4. "	Agree, that the insulation value and not the thickness itself is important. "Thickness" is deleted.
EFCEM	48	"Fryers • Frypot insulation which reduces standby losses resulting in a lower idle energy rate. • Lid which re-	"Operator is responsible and must use the appliances in a very responsible way. Food preparation has a higher value and use here. That is our standard. But the user has to use the lid. Instruction for users clarifies energy saving options. Please refer to our general position and start where work is already done."	A preparatory study will study this more in details regarding technology and use.

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		duces energy consumption especially during the heating phase. "		
EFCEM	49	"The public procurement advices from the Danish Energy Agency regarding tilting pans and kettles are to invest in appliances with the following charcteristics: • Sufficient insulation • Quick and efficient heating (high power) "	"Tilting pans and kettles are only available in the commercial sector. The masses of the walls and floors to be heated and the resulting inertia of the system are of interest here. Depending on the measurement standard, this can be good or bad in terms of energy efficiency. Good if the energy stored in the mass is taken into account - bad if not (e.g. individual test). Please refer to our general position and start where work is already done. "	Interesting point, again this could be studied in more a preparatory study
EFCEM	51	"1.4.9 Range hoods In a professional kitchen the primary purposes of a range hood is to extract pollutants, steam and heat from the cooking zones. "	"In particular on range hoods in the professional sector: In general, they are just a box of metal; the ventilation unit (including the motor and the fan) is not part of the kitchen but of the ventilation system of the building in which the professional kitchen is located and it is already covered by Ecodesign (2014/1253/EU). As consequence, considering that professional range hoods are part of a system and not stand-alone products, it would be very difficult to define a common testing mode and to communicate to the user the efficiency behaviour that can only be determined on each very specific ventilation system once installed and put in operation. Please refer to our general position and start where work is already done."	The preparatory study tried to explain this complexity, but nevertheless also identify some potential technical characteristics related to the construction range hoods – the box – itself. If these measures at a closer look proves to be relevant measures for range hoods might be possible.
EFCEM	54	The demand depends on number of appliances being used in the kitchen generally and under a specific hood. Control systems are	"In general, it is not possible to simply regulate the air volume depending on the unit's output in operation, because the separators only separate at a defined air flow range. Further, commercial kitchen hoods are connected to the ventilation system of the building. This system (including fans and building control software) needs to be suitable,	Agree that this potential is related to the system and not the product – the box – itself. Section 1.6.2 on improvement potentials for range hoods also explains that for this reason the potential savings

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		available where the range hoods or even the make-up air kitchen ventilation system are operated by demand control instead, meaning that the range hoods are regulated up or down depending on when a heat load is detected and one or more of the cooking zones are in use.	respectively adaptable to that kind of air flow regulation. Therefore, real smart kitchen ventilation solutions needs to be considered right in the beginning of planning a project. "	from integrated systems is not counted in.
EFCEM	55	EPA mentions that optimal function of the systems also depends on how quickly the system responds. A slower respond to cooking activity may delay exhausting cooking effluent and heat, and as a consequence the minimum fan speed may be increased resulting in lower overall savings.	Therefore, real smart kitchen ventilation solutions needs to be considered right in the beginning of planning a project.	Agree – see above
EFCEM	61	Table 35: The energy requirements of various appliances in the professional kitchen are shown.	"It is unclear what number of dishes was prepared. Does it make sense to prepare a product in the oven instead on the grill? Which appliances is economical to prepare and should be used more? Who should decide this – policymakers? Key figure: Energy requirement / portion with comparable cooking quality and percentage of appliance utilization. "	The tables and estimates are based on our assumptions on the current use and does not foresee any changes in appliances selected for the cooking process.

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EFCEM	66	For the present study 10 % improvement potential on both gas and electric fry tops is assumed.	"The questions raised in the chapter must first be checked for relevance in industry as well. From our point of view this is nonsense. How do you want to improve the efficiency of electric fry tops? The heaters are insulated, the heat is uniform, the radiation emission values are very low (<0,1). The heating elements have a efficiency of nearly 100%. Making the top thinner to reduce thermal mass reduces heat up energy, but in commercial application the fry top is used for a longer time period, so heating up energy usage is not so relevant like in household where only one product is cooked. Due to the large area and use of stainless steel with large thermal expansion coefficient, the thickness of the top has to have a minimum to prevent warping. Fry tops also warp because chefs use cold water shocks for cleaning purposes. This does not play a role in household use. "	The suggestion in are based on EPA analysis on professional appliances, not household. To be further analysed in the technical task of a potential preparatory study.
EFCEM	71	Table 44. Aggregate EU use phase saving potential of professional cooking appliances stock (primary energy GWh. Source: Own calculations) Product category Sub category Heat source	"The source of the numbers must be clarified. Where are they from, how were they calculated, under what assumptions? ... From our point of view this is not correct. The numbers were guessed in 2012. "	The calculations are based on the assumptions and findings in the current pre-study. The current pre-study includes more product categories and revised analysis of the professional ad commercial kitchen sector compared to the 2012 numbers. And again, a deeper analysis on the market users, technology etc. would be made in case of a preparatory study.

5 SMALL-SCALE COOKING PRODUCTS

5.1 Scope, policy measures and test standards

Small-scale electric cooking appliances are defined in this study as: ‘Domestic cooking products connected to the mains electricity, which contain a heating element that conducts heat via air, water, steam, oil, or similar or a combination of these to the food to be processed’.

The latest statistical classification of economic activities in the European Union, i.e. NACE Rev. 2 from 2008, includes cookers and fry pans under manufacture of domestic electrothermic appliances. The PRODCOM includes one relevant category, 27.51.24.90: *Electrothermic appliances, for domestic use (excluding hairdressing appliances and hand dryers, space-heating and soil-heating apparatus, water heaters, immersion heaters, smoothing irons, microwave ovens, ovens, cookers, cooking plates, boiling rings, grillers, roasters, coffee makers, tea makers and toasters)*[219]

The Preparatory study for the Ecodesign Working Plan 2015-2017 included only two relevant categories: deep fryers and rice cookers. The study provides data on market and stock, resource consumption and improvement potential.

Based on the definition above and after an online market research[220], the following products have been selected for assessment because they have been estimated to have largest importance in terms of energy and resource consumption and saving potentials:

- Multi-cookers
- Pressure cookers
- Steamers
- Rice cookers
- Deep fryers
- Sous-vide cookers (water baths and sticks)
- Slow cooker
- Other products such as fondues and air fryers

Other products the study team considered for this product group were: egg boilers, baking machines, woks, fruit dryers, food preservation products, grills, raclettes and yogurt machines. However, these rather specialised products are seen as niche markets with low total energy consumption, and are thus not selected for further assessment.

[219] https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=DSP_NOM_DTL_VIEW&StrNom=PRD_2016&StrLanguageCode=EN&IntPcKey=&IntKey=40215068&IntCurrentPage=101&linear=yes

[220] Amazon UK, Amazon DE, eBay DE and a Danish website selling a broad range of house appliances (https://www.skiftselv.dk/husholdning/koekken/)

Based on the data and information available, the base cases are categorised according to market availability. There are no performance standards relevant to these appliances, except for safety (mostly for deep fryers[221]), and a report was found about a draft standard for rice cookers in Japan[222].

Regarding ecodesign and energy labelling requirements, these products are only covered by the Standby Regulation 1275/2008, where they fall under in Annex I, point 1 as: 'Other appliances for cooking and other processing of food, cleaning and maintenance of clothes'.

5.2 Market

Table 61 and Table 62 show estimated unit sales and stock data for small-scale electric cooking appliances based on data from Statista[223] and Calameo[224] and checked against data from the Preparatory study for the Ecodesign Working Plan 2015-2017. Some data were for the US market, other only for France and the Netherlands and all these data were converted to EU-27 based on the number of households. Due to differences in food and food preparation preferences between the markets the data originate from and EU-27, this may have induced some uncertainties.

Table 61: Sales of small-scale electric cooking appliances.

Year Category	Sales – Million units				
	2010	**2015**	**2020**	**2025**	**2030**
Steamers	10.9	9.4	8.7	9.5	10.4
Deep fryers	9.7	9.6	8.9	8.5	8.1
Slow cookers	15.9	20.6	17.9	19.5	21.1
Rice cookers	1.5	1.5	1.5	1.5	1.5
Multi-cookers	2.2	2.3	2.4	2.4	2.6
Pressure cookers	0.5	0.5	0.5	0.5	0.5
Sous vide	2.4	2.5	2.6	2.6	2.9
Other products	3.7	3.9	4.0	4.0	4.4
Total	**46.7**	**50.3**	**46.4**	**48.6**	**51.4**

Table 62: Stock of small-scale electric cooking appliances.

Year Category	Stock – Million units				
	2010	**2015**	**2020**	**2025**	**2030**

[221] https://www.en-standard.eu/ics-codes/97-domestic-and-commercial-equipment-entertainment-sports/97-040-kitchen-equipment/97-040-50-small-kitchen-appliances/

[222] https://www.eccj.or.jp/top_runner/pdf/tr_electric_rice_cooker.pdf

[w]www.statista.com

[224] https://fr.calameo.com/read/003495799de4c15298979

Steamers	54.6	46.8	43.5	47.7	51.9
Deep fryers	54.0	52.1	49.8	47.8	45.6
Slow cookers	90.9	103.1	107.3	103.3	112.1
Rice cookers	22.3	32.3	40.3	44.5	53.9
Multi-cookers	11.0	11.6	12.0	12.1	13.2
Pressure cookers	3.4	3.9	4.5	5.1	5.6
Sous vide	11.9	12.6	13.0	13.2	14.3
Other products	18.3	19.4	20.0	20.2	21.9
Total	**266.4**	**281.8**	**290.4**	**293.9**	**318.5**

The total number of households in EU-27 is about 195 million and the average number of small-scale electric cooking appliances per household in 2020 is 1.5.

5.3 Usage

The appliances in scope of the current assessments are most often additional basic domestic cooking appliances, namely hobs, pots and oven. They are purchased and used for dedicated processes for increasing the food quality, for preserving the nutrition properties of the food ingredients and/or for simpler and time-saving food processing.

When much of the European dishes and food processing differ from region to region and from family to family, use of dedicated cooking appliances also differ in a high degree.

Within the context of the assessment in this study, it was not possible to find relevant data on usage pattern. Instead, estimations have been used. In some cases, data on annual consumption per unit was reported by sources, in other cases, no data was to be found.

Table 63 presents the main usage parameters, estimated average power consumption in use, calculated annual energy consumption per unit and estimated purchase cost.

Table 63: Main usage parameters, estimated average power consumption in use, calculated annual energy consumption per unit and estimated purchase cost[225]. *Own estimates.

Category	Lifetime Years	Uses per week	Average runtime per use Hours	Average power in use Watt	Annual energy consumption KWh/unit	Purchase cost EUR/unit
Steamers*	5	3	0.3	550	26	40
Deep fryers[226]	5	3	0.5	600	50	70
Slow cookers*	5	1	6	180	56	40
Rice cookers[227]	5	3	3	120	62	50
Multi-cookers[228]	5	2	0.5	300	16	120
Pressure cookers*	5	2	0.25	1000	29	100
Sous vide*	5	1	5.4	190	53	100
Other products*	5	3	0.3	550	45	94

5.4 Technologies

Small-scale electric cooking appliances typically consist, at least, of a heating element built into the base, a thermostat to regulate the heat, a base and a pot container to store the food ingredients and where the heat transfer occurs. Some have also a pump or a fan.

See Table 83 for an overview of the technologies and Figure *9*, Figure *10*, Figure *11*, Figure *12* and Figure *13* for the typical appliances available at online shopping portals in different price ranges.

[225] Based on www.bol.com.
[226] Ecodesign Working Plan Study 2015-17
[227] Ecodesign Working Plan Study 2015-17
[228] Vorwerk and own estimates

Table 64: Technology description of the product types assessed.

Base case	Description
Steamers	Food is cooked through heat transfer by steam, typically in three separate compartments in the pot to provide different levels of steaming. A timer is typically included at the front of the base. Base is made of plastic, steel and/or aluminium and the food container made of plastic.
Deep fryers	Food is fried through heat transfer from oil, placed in a container and applying heat. A thermostat is typically included and in some cases there is a timer. Made of stainless steel, aluminium and/or plastic.
Slow cookers	A slow cooker is used to simmer at a lower temperature than other cooking methods. This facilitates unattended cooking for many hours of dishes that would otherwise be boiled.
Rice cookers	A rice cooker is an automated appliance designed to boil rice and keep it warm for longer periods. Some rice cookers use induction heating, with one or more induction heaters directly warming the pot. This can improve energy efficiency.
Multi-cookers	Programmable appliances that offer from 10 to 100+ programmes for steaming, slow cooking, fermentation, blending, sous-vide, etc. A digital display controls temperature, pressure and time, and depending on the product, it can offer intelligent cooking. Some offer a pre-cleaning function. Made of many different materials primarily stainless steel, aluminium, cast iron and hard plastics.
Pressure cookers	Food is cooked through heat transfer by steam and pressure from the base to pot containing the food. A controller offers the possibility to apply different degrees of heating according to food texture. Made of stainless steel, cast iron and/or aluminium.
Sous-vide	Appliances transferring heat from an immersed stick into a container with water, where vacuum-sealed food bags are deposited in. The container may be the user's own pot or may be a dedicated container delivered with the stick. The sous vide contains a very precise thermostat, PID controller (proportional–integral–derivative). This results in a very-tightly controlled temperature cooking, usually with better taste and reduction of food waste. Often the processing time is long, from 1 hour to 72 hours at temperatures between 55 ºC and 75 ºC. A digital display controls temperature and time, and the stick contains a circulator to circulate the water and aid the cooking process. May be made of stainless steel, cast iron, aluminium and plastics
Other products	Includes electric fondues and air fryers. These products do not share similar properties but have been merged due to limited data availability. Electric fondues can either be used at low temperature for cheese or chocolate or at high temperature for oil or broth (hot pot). They come with a build-in thermostat and are typically made of stainless steel. Air fryers are an alternative to deep fryer with no or little use of oil that instead use air to transfer heat for frying food. They typically come with a controller to adjust power and set a timer. Made of primarily plastic with a metal basket inside.

Figure 9: Electric pressure cookers in two price ranges (medium and high) available at online shopping portals[229]

Figure 10: Electric steamers in three price ranges (low, medium and high) available at online shopping portals[230]

[229] Amazon UK, Amazon DE and eBay DE

[230] Amazon UK, Amazon DE and eBay DE

Figure 11: Deep fryers in three price ranges (low, medium and high) available at online shopping portals[231]

Figure 12: Electric multi-cookers in three price ranges (low, medium and high) available at online shopping portals[232]

Figure 13: Sous-vide water baths in two price ranges (medium and high) available at online shopping portals[233]

[231] Amazon UK, Amazon DE and eBay DE
[232] Amazon UK, Amazon DE and eBay DE
[233] Amazon UK, Amazon DE and eBay DE

5.5 Energy, Emissions and Costs

Energy, emission and monetary costs are given in the tables below based on the data provided in the previous sections.

Table 65: Final energy consumption for the stock of small-scale electric cooking appliances.

Year Category	**Final energy consumption EU-27 TWh/year**				
	2010	**2015**	**2020**	**2025**	**2030**
Steamers	1.4	1.2	1.1	1.2	1.3
Deep fryers	2.7	2.6	2.5	2.4	2.3
Slow cookers	5.1	5.8	6.0	5.8	6.3
Rice cookers	1.4	2.0	2.5	2.8	3.4
Multi-cookers	1.6	1.7	1.8	1.8	1.9
Pressure cookers	0.1	0.1	0.1	0.1	0.2
Sous vide	0.6	0.7	0.7	0.7	0.8
Other products	0.8	0.9	0.9	0.9	1.0
Total	**13.8**	**15.0**	**15.6**	**15.7**	**17.1**

Table 66: Primary energy consumption for the stock of small-scale electric cooking appliances. Primary Energy Factor =2.1.

Year Category	**Primary energy consumption EU-27 PJ/year**				
	2010	**2015**	**2020**	**2025**	**2030**
Steamers	10.6	9.1	8.5	9.3	10.1
Deep fryers	20.4	19.7	18.8	18.1	17.3
Slow cookers	38.6	43.8	45.6	43.9	47.6
Rice cookers	10.5	15.2	19.0	21.0	25.4
Multi-cookers	12.1	12.9	13.3	13.4	14.6
Pressure cookers	0.7	0.8	1.0	1.1	1.2
Sous vide	4.8	5.1	5.2	5.3	5.7
Other products	6.3	6.6	6.8	6.9	7.5
Total	**104.0**	**113.2**	**118.1**	**118.9**	**129.3**

Table 67: GHG emissions for the stock of small-scale electric cooking appliances.

Year Category	GHG emissions EU-27 MT CO2eq/year				
	2010	**2015**	**2020**	**2025**	**2030**
Steamers	678.0	603.2	575.4	638.5	699.1
Deep fryers	1140.5	1166.8	1128.4	1095.2	1052.7
Slow cookers	1512.9	1924.4	1941.8	1994.4	2182.1
Rice cookers	312.2	456.6	584.3	655.0	787.2
Multi-cookers	539.5	602.6	644.7	663.1	724.5
Pressure cookers	62.5	67.1	72.2	76.2	80.0
Sous vide	346.4	379.2	400.1	409.2	445.7
Other products	310.4	344.8	367.5	377.4	412.1
Total	**4,902**	**5,545**	**5,714**	**5,909**	**6,384**

Table 68: End-user expenditure. Purchase costs of the year's sales plus energy costs for the stock of small-scale electric cooking appliances.

Year Category	End-user expenditure (purchase & energy costs) Million EUR				
	2010	**2015**	**2020**	**2025**	**2030**
Steamers	678.0	603.2	575.4	638.5	699.1
Deep fryers	1140.5	1166.8	1128.4	1095.2	1052.7
Slow cookers	1512.9	1924.4	1941.8	1994.4	2182.1
Rice cookers	312.2	456.6	584.3	655.0	787.2
Multi-cookers	539.5	602.6	644.7	663.1	724.5
Pressure cookers	62.5	67.1	72.2	76.2	80.0
Sous vide	346.4	379.2	400.1	409.2	445.7
Other products	310.4	344.8	367.5	377.4	412.1
Total	4,902	5,545	5,714	5,909	6,384

5.6 Saving potential

There are various options for improvement of energy efficiency for the assessed small-scale electric cooking appliances. However, when most of the energy service needed as heat and the conversion efficiency from electricity to heat is 100 %, the improvement options are concentrated on having as much as possible of the heat from the heating element being at the right temperatur and time and used to process the food, avoiding heat losses during the food processing and avoiding unncessary material to be heated.

Main improvement options are:

- Insulation reducing the heat losses, especially for appliances with typical long processing time such as sous vide and slow cookers. Insulation can be vacuum insulation like used in stainless steel thermos or building insulation like polyurethane rigid foam (PUR). However, this option increases the amount of material used and may decrease recyclability.
- Use of electromagnetic induction heating for reducing the amount of material to be heated. Some rice cookers on the market already use this principle. However, the material surrounding the food, may in any case be heated especially for long time

food preparation and there is also losses in the induction heating unit. Therefore the saving potential is considered as relatively low.

- Precise temperature and time control
- User guidance in good practices regarding time, temperatures, amount of heat transfer medium, etc.

In order to estimate a saving potential, the study team made a test with a sous vide stick used with a stainless steel pot. 4 litres of waters was heating to 60 ºC and maintained for 1 hour. The test was first made with a traditional setup with the pot on a table without lid. The test was repeated with the pot put into a box stuffed with bubble plastic, cloths etc. The heat losses in maintaining the required temperature at 60 ºC was reduced from 150 W to 41 W (73% savings).

For a typical food process of heating the water from 10 ºC to 60 ºC and maintain the temperature for 5 hours, the saving is 56%. The energy need for the actual heating of the water is unchanged. This test is naturally very simple and could be used only as a very rough indication of a saving potential by improvement of insulation for appliances using long time food preparation.

At least 60% of the total EU-27 energy consumption for the cooking appliances assessed are for product types with extended period of keeping a certain temperature level in the appliance, where insulation would be an opportunity with high potential. The other improvement options would also yield a saving potential. Based on this, the total savings are estimated at 30% as an average for all product types. Applying this factor on the total final energy consumption for the stock of appliances, the estimated savings in 2020 are totally about 5 TWh/year corresponding to 39 PJ/year in primary energy consumption. See the details in Table 69. It has to be noted that there are many uncertainties in this saving potential and that it covers many different products, where test methods are not available.

Table 69: Savings in final energy consumption for the stock of small-scale electric cooking appliances.

Year Category	**Savings in final energy consumption EU-27 TWh/year**				
	2010	**2015**	**2020**	**2025**	**2030**
Steamers	0.4	0.4	0.3	0.4	0.4
Deep fryers	0.8	0.8	0.7	0.7	0.7
Slow cookers	1.5	1.7	1.8	1.7	1.9
Rice cookers	0.4	0.6	0.8	0.8	1.0
Multi-cookers	0.5	0.5	0.5	0.5	0.6
Pressure cookers	0.0	0.0	0.0	0.0	0.0
Sous vide	0.2	0.2	0.2	0.2	0.2
Other products	0.2	0.3	0.3	0.3	0.3
Total	**4.1**	**4.5**	**4.7**	**4.7**	**5.1**

5.7 Stakeholder comments

APPLiA provided a number of comments summarised as:

- The performance standards actually available in CENELEC or IEC do not cover adequately all the mentioned product categories.

- Further insulation for multi-cookers increases the material used and may decrease recyclability. The energy efficiency gain is very limited, as these products are already very efficient.

- Electromagnetic induction heating to reduce the amount of material to be heated is not relevant for multi-cookers. Energy is "lost" by heating the pot, which in turn heats the food inside. Thus, energy loss is relatively low.

- The assumption that based on the one sous-vide stick, the energy savings potential is similar with all the other appliances in the small-scale cooking products group is highly unlikely.

- APPLiA questions whether the energy-savings potential of this heterogeneous product group justifies the extensive work that is required to properly design ecodesign and / or energy labelling regulations.

- Multi-cookers i.e. multi-functional cooking appliances are very complex to regulate, because they vary significantly in their functionality and output i.e. performance. It is therefore very difficult to design useful and robust tests that would allow to assess and compare appliances. One has to consider for example:
  a. What is a function?
  b. Appliances that can perform more than one function concurrently
  c. Products with a single function (e.g. mixer) should not be compared to multi-functional products
  d. How to assess and compare performance (i.e. output e.g. prepared food). Multifunctional appliances offer many different functions using little material (plastic, aluminium etc.)

UBA and BAM (Germany) commented that it should be assessed if the effort of regulation is proportionate with regard to the saving potential. Additionally, microwave ovens and mini ovens should be considered as they might not be regulated in the regulation of domestic cooking appliances.

The Netherlands Enterprise Agency commented that the estimated savings potential is questionable and only relevant for one product (slow cookers), therefore these products should not be included in the Working Plan.

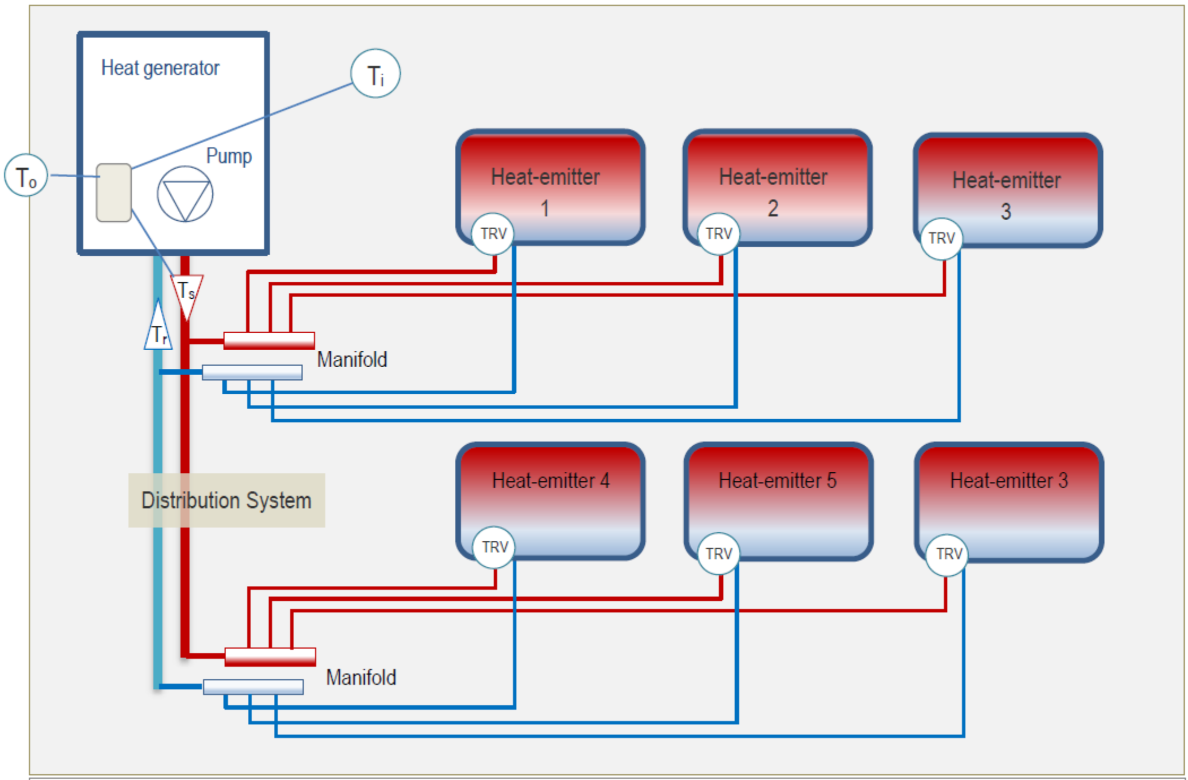
The comments received have been taking into account when preparing this final draft version.

6 Low temperature emitters

1.1 Scope, policy measures and test standards

1.1.1 Scope

In Europe, the most common household heating solution is the hydronic central heating (CH) system, i.e. a water-based CH system. The hydronic heating system consists of: a central heat generator (e.g. a condensing boiler or heat pump), a circulator pump that pumps the hot CH-water throughout the system and a series of heat emitters to heat the actual rooms (e.g. radiators, convectors, floor- or wall-heating) (**Figure 14**). The latter are the intended scope of this section, specifically those emitters used with low-temperature heating system operation.



Ti = Indoor temperature	Ts = Supply temperature
To = Outdoor temperature	Tr = Return temperature

Figure 14. *Space Heating Components (source: Review Study of Commission Ecodesign and Energy labelling Regulation on Space and Combination heaters – Task 4, p.28)*

Choosing the right heat emitter for your house is important, because once you have bought and installed the tubing and emitters for your CH system it is a costly, often technically and aesthetically challenging job to change. From the point of view of having a comfortably heated house in the hardest winter there are several routes: You can chose a normal emitter size, e.g. standard steel panel radiator, to be operated at higher water temperature during the lowest outdoor temperature, or you can choose a large emitter, i.e. floor heating with a high water volume, operating at lower temperatures of even 30 °C. They both do the job, but there is a difference in your energy bill (all other things being equal). Why? Because your heat generator, especially a heat pump but also --in another way-- the modern gas- or oil boilers, operate considerably more efficient with a lower water temperature.

For newly built houses, this efficiency is easily obtained by choosing to build it in a way that maximizes efficiency, namely: by insulating the house to minimize heat loss whilst allowing for ventilation and by installing floor-heating that allows to keep the house warm even at a CH-water temperature of only 30-35 degrees. However, new houses only make up 6% of the heat generator market and, unless the owner is prepared to make a sizeable investment, older buildings will have to make do with the existing tubing and emitters. To reduce heat loss in these older dwellings there are several options. The first option would be to replace the older heat generator and controls with newer models. Even though this option requires the lowest investment costs, the impact on increasing the building's efficiency will be minimal. The second option would be to reduce the heat demand of the building by ensuring the walls and windows are properly insulated. This allows existing radiators to operate at a lower CH temperature. Finally, the third option would be to leave the current piping system in place, but increase the radiator/convector's emitting capacity. Increasing the emitting capacity can either be achieved by installing bigger emitters (taking up more space in the room) or through Low Temperature (LT) Radiators, which use smart design to allow for an increased emitter capacity whilst retaining the habitual radiator size.

This third option would seem to be the most attractive solution, but is not sufficiently known and receives insufficient attention. This option ensures considerably higher seasonal generator efficiencies for heat pumps and condensing boilers with the least amount of structural/invasive change to the building itself. More remarkably, this solution has the capacity to deliver the same amount of heat as a regular radiator, whilst occupying the same amount of space, but at a lower CH water temperature. These two aspects allow for a lower energy bill and a lower greenhouse gas impact, which are particularly important when considering the EU's ambitious environmental goal of attaining near-zero energy buildings in the near future.

Consequently, the subject of LT emitters was proposed as a highly relevant subject for the Ecodesign Working Plan in the ongoing Ecodesign review study on Ecodesign and Labelling regulations for space heaters[234] following a stakeholder meeting. Especially considering that they are projected to have a monumental role in increasing heat generator efficiency overall and as of yet its potential remains generally unexplored in current EU legislation. It is not possible to include them in the review study.

1.1.2 Policy measures

So far, no dedicated policy measures are in place that promote this highly effective strategy for improving the seasonal heating system efficiency in the existing building stock by replacing the emitters. The Energy Performance of Buildings Directive 2010/31/EU (EPBD) does address the advantages of low temperature heating systems in new building projects and really extensive renovation projects, but LT system temperatures will primarily be pursued with a focus on floor heating. However, for minor renovation and replacement projects in the existing building stock, the options for achieving lower system temperatures

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[234] VHK, Ecodesign Review Study on Space Heaters, ongoing. 2020. https://www.ecoboiler-review.eu/

by replacing existing heat emitters are largely neglected. If any actions are undertaken here at all, they mainly depend on the installer employed for the renovation/replacement-project and their knowledge and motivation.

1.1.3 Test standards

The test standard to be used for CE marking of emitters are the following:
1.
EN 442:2014[235]. Radiators and Convectors, part 1 and part 2
Part 2 of EN 442 defines procedures for determining the standard thermal outputs and other characteristics of metallic radiators and convectors installed in a permanent manner in construction works, fed with water or steam at temperatures below 120 °C, supplied by a remote heat source. This European Standard specifies the laboratory arrangements and testing methods to be adopted, the admissible tolerances, the criteria for selecting the samples to be tested and for verifying the conformity of the current production with the samples tested at the initial test. There are two excess temperatures ΔT = 50K and ΔT = 30K. This European Standard also defines the additional common data that the manufacturer shall provide to the trade in order to ensure the correct application of the products.

Unlike the 2013 version of the Standard, EN 442:2014 does include fan assisted radiators, fan assisted convectors and trench convectors and only excludes independent heating appliances from its scope.

2.
EN 16430: 2015[236]. Fan assisted radiators, convectors and trench convectors. part 1 & 2
This European Standard applies to the thermal output testing of fan-assisted radiators, convectors and trench convectors which are factory assembled or kits, i.e.

- fan assisted radiators and convectors, provided the heater has a dedicated fan or fans
- trench convectors with and without fan(s), provided the heater and the fans are dedicated
- ventilation radiators and convectors

According to these standards measurements are to be done at three excess temperatures (ΔT = 60K, ΔT = 50K and ΔT = 30K) to determine the characteristic equation of the heat emitter. With this equation the heat output at other (lower) temperature levels can be calculated.

These three test point are rather high. An excess temperature of 50K means that the water temperature at the radiator inlet/outlet is 75°C/65°C, giving an average temperature of (75°C + 65°C)/2 = 70°C. Compared to the reference indoor temperature of 20°C this results in an excess temperature of 50K. And the average radiator temperature at ΔT = 30K still is 50°C, hardly a low temperature regime.

In short, the inlet water temperature used for radiator testing is not (yet) adapted for real low system temperatures of 35 °C – 45 °C (and lower) which are considered appropriate for Low Temperature emitters[237]. Illustrative for this LT-context is the EN 14825 which uses a testing method – rather than a calculation – for determining the seasonal efficiency

[235] EN 442-2:2014.
[236] EN 16430-2:2015.
[237] Standard Assessment Procedure (SAP 2012) for Energy Rating of Dwellings, *9.3. Temperature of heat emitters for condensing boilers and heat pumps,* p.27.

which includes a testing condition with a lower temperature of 35 °C[238]. Similarly, an actual test with an emitter test temperature of 35°C (ΔT = 15K), would be more appropriate in this context than a calculation that extrapolates the results from higher test-temperatures to any required low temperature regime.

1.2 Market

Market research companies indicate that the *hydronic radiator market* is expected to expand again in the EU with an annual growth rate of around 2.5% due to an increased activity in the building construction and renovation market[239]. In 2018 the market size was estimated at 1.2 billion euro.

In 2014 the total amount of radiator sales in the EU (UK excluded) was around 26.5 million units. The radiator market had been declining since 2004 and from 2014 to 2018 it even declined slightly further than before. This measured decline was principally due to the stagnant market in building construction and the growing application of floor heating at the cost of wall mounted emitters in the newbuilt market.
The largest share of the radiator sales relates to hydronic emitters (see **Figure 15**). The number includes various types of emitters, amongst which:

- steel panel radiator (share: 49%)
- aluminium radiator (share: 14%
- convectors (share 1.5%)
- electric emitters (share: 15%)
- other (share: 20.5%)

These 'other emitters' include oil filled emitters, cast iron emitters, towel warmers and decorative steel tubular emitters (see Figure 9).

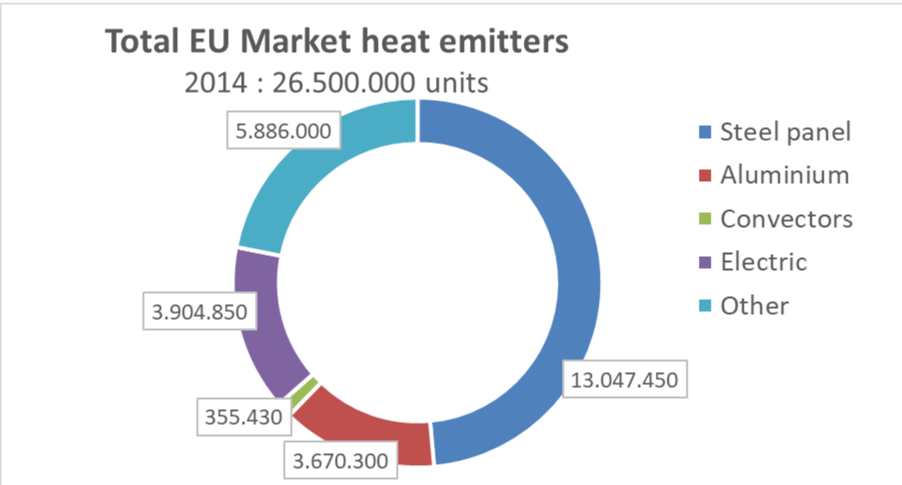

Figure 15. Market heat emitters and their types 2014 (various sources[240]).

[238] EN 14825:2018.
[239] Global Market Insights, *Europe Hydronic Radiators Market Forecasts – 2019-2025 Report* (May, 2019) https://www.gminsights.com/industry-analysis/europe-hydronic-radiators-market
[240] Annual reports, BRG Building Solutions, VHK modelling of hydronic space heating, pers. comm. manufacturers

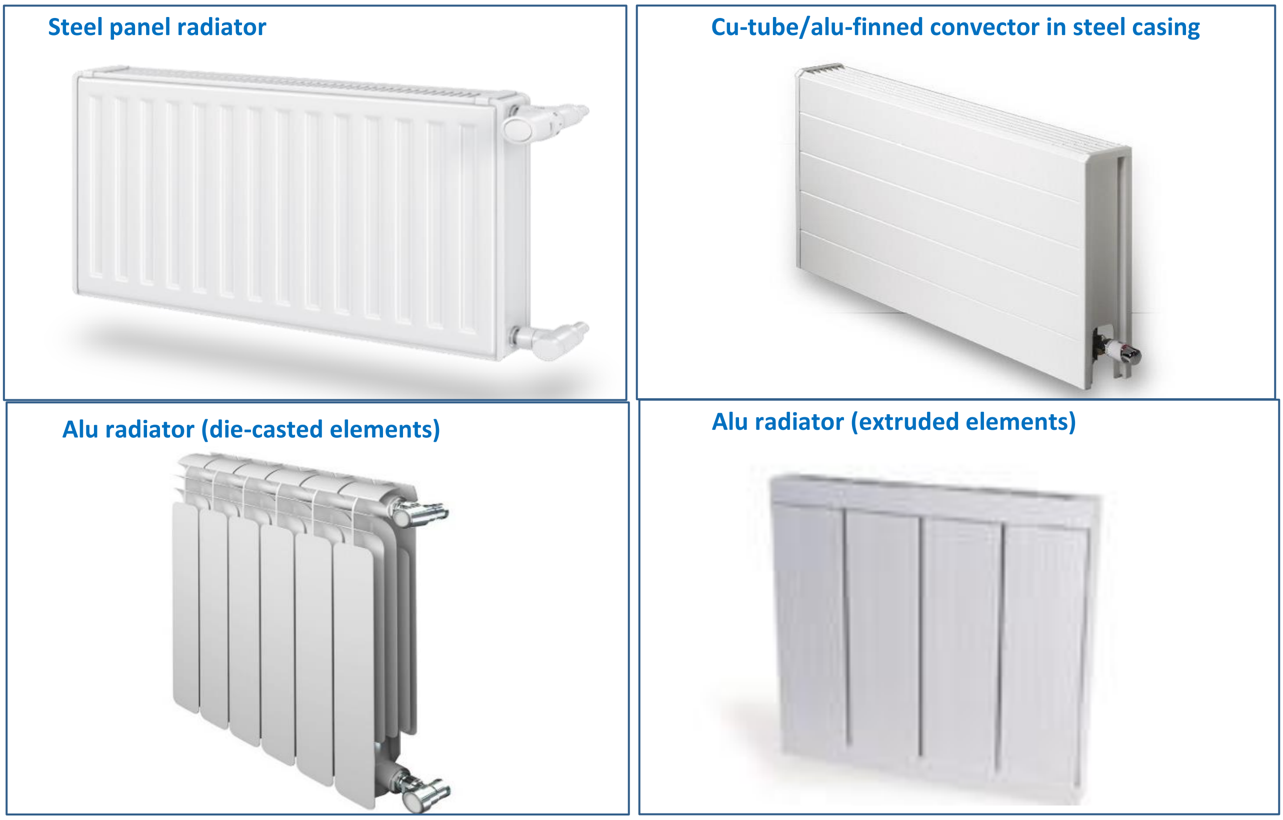

Figure 16. Four arche-types of hydronic heat emitters

1.3 Usage

Hydronic emitters are generally used in residential, commercial and industrial buildings, with residential being the predominant sector of application. In this sector (EU households) space heating and hot water alone account for 79% (192.5 Mtoe) of the total final energy use[241].

The energy use for space heating is principally determined by the seasonal efficiency of the heat generator used to feed the hydronic emitter system, which in its turn strongly depends on the occurring system temperatures. The system temperature, on the other hand, is determined by the capacity of the emitter in relation to the heat load of the building. In other words, heat output capacity of the emitter in relation to the heat load of the room (HC/EC-Ratio) largely determines the generator efficiency and the energy consumption for space heating. The higher the Emitter Capacity (EC), the lower the system temperature will be[242].

The Germany industry association BDH specifies that Low-temperature emitters are used for hydronic central heating systems in buildings. The heat transfer is increased e.g. by enlarging convective surface and/or by forced convection (use of fan). Radiators influence

[241] European Commission (EC), *Heating and Cooling: facts and figures,* Last updated: 23 April 2020 https://ec.europa.eu/energy/topics/energy-efficiency/heating-and-cooling_en

[242] European Commission, ***Review Study of Commission Ecodesign and Energy labelling Regulation on Space and Combination heaters – Task 4 (July, 2019), 3.3 Heating System Efficiency.*.**

the efficiency of an entire heating system: The heat transfer capacity and heat demand together determine the required flow temperature of the central heating system, which in turn influences the energy efficiency of the heating system.

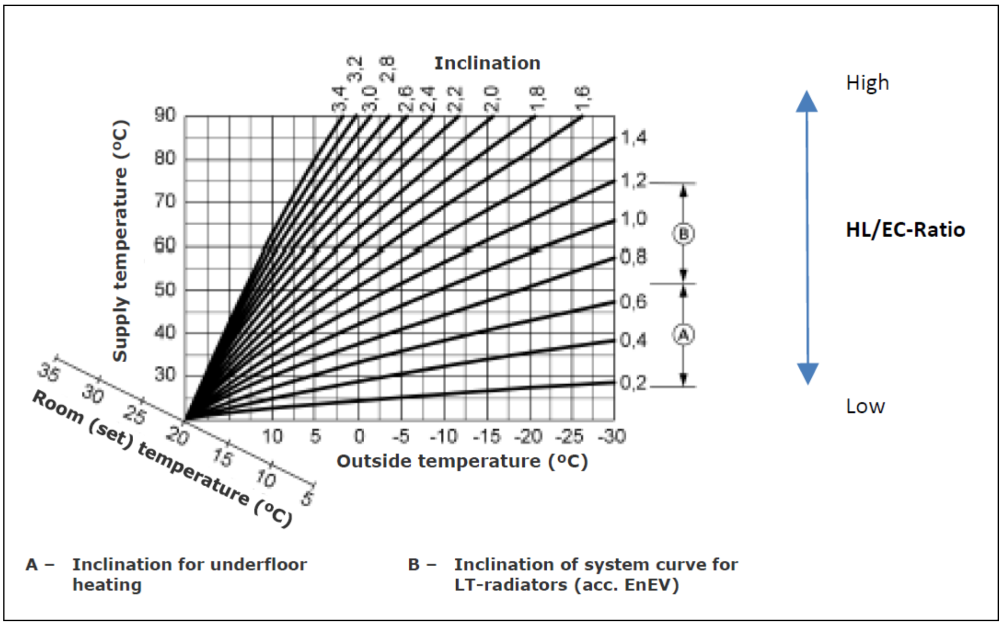

Figure 17. Heating curves for various HL/EC-Ratios (source: Viessmann)

Over the years, the reduction of buildings' heat load (through the process of increasing insulation levels, allowing for minimal transmission-, infiltration- and ventilation losses) has resulted in a drop in systems design temperatures from around 80 °C to around 50 °C (**Table 70**).

Presently, however, with buildings' heat load already being significantly reduced, it is time to tackle the other side of the coin, namely: improving emitter capacity. The EU's increased emphasis on attaining net-zero energy buildings (NZEB) by 2050 and improving the energy efficiency of the current market, marks the need to take the next step in maximizing hydronic CH-system's energy saving potential.

Table 70: Heat load, system temperatures and average emitter capacity over the years (source: Viessmann, Vaillant et al.)

Year of construction	Heat load dwelling [W/m2]	System design temperature	Avg. emitter capacity @ design temp. for avg. 100m^2 dwelling
Old (before 1960)	≥ 250	80°C	>25 kW
1960 – 1977	130 - 250	80°C	20 kW
1977 – 1982	70 – 130	70°C	13 kW
1982 – 1995	60 – 100	70°C	10 kW
1995 – 2002	40 – 60	65°C	6 kW
2002 – 2009	30 – 50	60°C	5 kW
2009 –	25 – 40	50°C	4 kW
Passive house	≤ 15	40°C	< 2 kW

1.4 Technologies

1.4.1 Introduction

Using existing standard steel panel radiator and commonly accepted radiator dimensions, system design temperatures in existing dwellings may at best drop to around 50 to 55 °C. However, if the emitter capacity is further increased these values can drop to even lower temperatures of around 40 °C. To achieve these lower system temperatures, there are several options.

Of course it is possible to replace the existing radiators by bigger steel panel radiators or install additional radiators, thereby allowing multiple emitters to share the burden of fulfilling the room's required heat load. But adding additional or installing bigger radiators is neither functionally nor aesthetically appealing. Standard steel panel radiators are not optimised for emitting heat at low temperatures. Firstly, they consist of water containing panels, which are intended to radiate heat. However, the heat transfer principle using radiation dramatically reduces at lower system temperatures. At these temperatures, it is rather the convectors used in the steel-panel radiators that remain as sole heat transfer principle. Nonetheless, also convectors appear to be less than ideal, considering the conductivity of steel together with the way the convectors are shaped, indicate that heat-transfer principle using convection is not optimised.

Another option for increasing emitter capacity is to install floor and/or wall heating systems as additions to the existing emitters. However, such emitter systems are both expensive and labour intensive (considering the building will need to be stripped and rebuilt to accommodate such a heating system).

The strategy proposed in this study is to replace the existing radiators/convectors by emitter types that are designed specifically for the purpose of meeting identical heating demands at lower temperatures – thereby maximizing the heating system's efficiency[243]. These heat emitters would possess the generally accepted radiator dimensions, whilst delivering the same heat-output at 45/35°C as the standard steel panel radiator would at 55/45°C.

1.4.2 Principles

Low temperature heating systems are defined as systems in which the hot water leaving the heat generator never exceeds 45 °C, even on the coldest day (e.g. T_{out} = -10°C) which is often used to calculate the maximum heat loss of a building[244]. Consequently, LT emitters can be defined as emitters that are at least capable of delivering the same amount of heat a traditional steel panel radiator would at medium temperature regimes (55/45/20°C), at system temperatures equal or lower than 45/35/20°C[245].

[243] European Commission, ***Review Study of Commission Ecodesign and Energy labelling Regulation on Space and Combination heaters – Task 4 (July, 2019), 3.3.1 System Temperature Heat Emitters.***

[244] Standard Assessment Procedure (SAP 2012) for Energy Rating of Dwellings, *9.3. Temperature of heat emitters for condensing boilers and heat pumps,* p.27.

[245] Standard Assessment Procedure (SAP 2012) for Energy Rating of Dwellings, *9.3. Temperature of heat emitters for condensing boilers and heat pumps,* p.27.

Proper designed LT emitters can achieve higher heat output (at lower temperatures) than conventional radiators at 55/45/20°C through a combination of measures. One of the most important measures is to optimise the heat transfer through free convection by applying materials with higher thermal conductivity. Other measures include: enhancing the flow-path and heat transfer coefficient of the fluid, enhancing convector shape, fin dimensions and fin pitch. Given that free convection is the key characteristic of the existing radiator market -- and a very comfortable and noiseless way to heat the house -- this quality must be preserved and remain the principle way to heat the house, if the LT emitter is to replace the existing standard panel radiators. Additionally, the heat output can be further increased by applying forced convection (silent fans that do not hinder free-convection) and which would preferably be needed on rare occasions only, e.g. when outdoor temperatures are too low or during heating-up of the house.

Figure 4 shows some examples of heat outputs of existing heat emitters at standard test-temperatures and extrapolated heat-output values for lower temperature regimes.

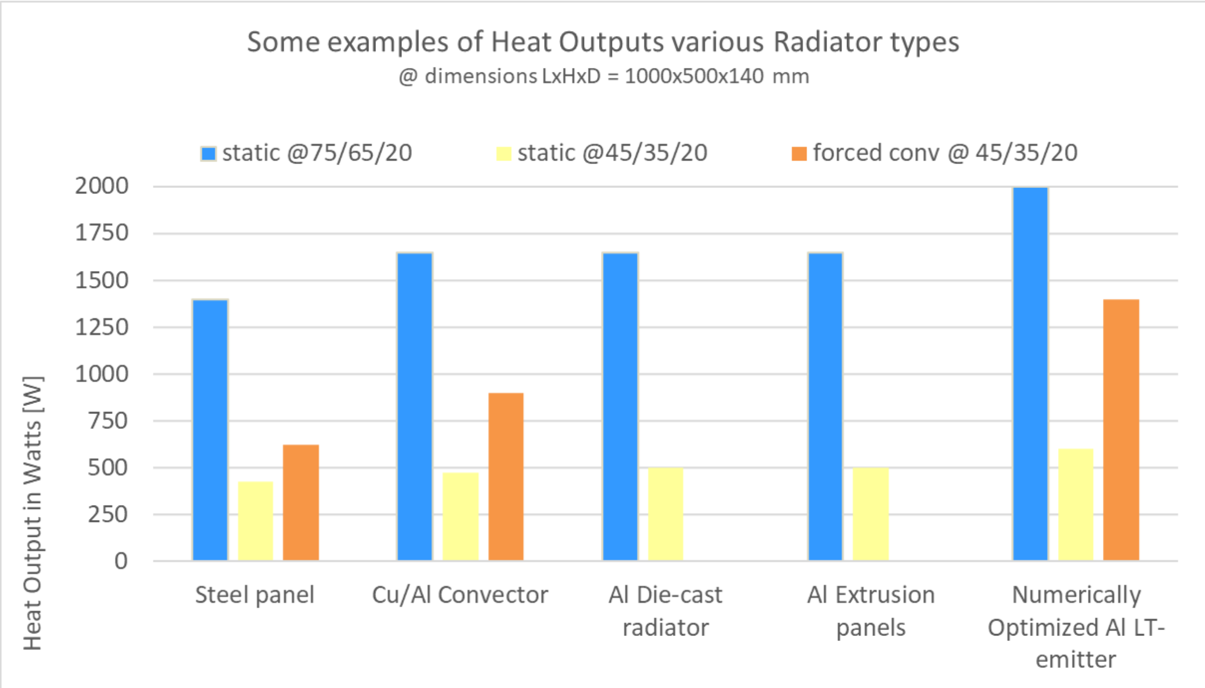

Figure 18. Examples of heat emitters and their heat output at standard and low temperature regimes (source VHK)

Apart from offering the better LT-emitters and doing the right tests it is important that more awareness is created in the sector and that the selection and application of LT-emitters is actively promoted, e.g. through Energy Label. This is relevant not only for consumers that eventually pay for the emitters, but also for system designers and installers that play a vital role in this technological transformation of our current heating system.

Note that there are some top-end examples of LT-emitters on the market. Policy measures could increase production volume and thus consumer price for these models. Also the LT-heat transfer can be further improved. Figure 22 gives an example.

Figure 19. Example of an LT-radiator (source: www.jaga.nl)

1.5 Energy, Emissions and Costs

1.5.1 Energy and emissions

As indicated, lowering system temperatures directly affects the overall seasonal efficiency of the heating system. A reduction of the temperature regime to 45/35/20 degrees may improve the overall seasonal efficiency with up to 10% for systems using condensing boilers and up to 50% or more for systems using heat pumps. The savings primarily depend on the extent to which the actual system temperatures are reduced.

The annual primary energy that is needed for space heating using central heating boilers with hydronic systems in the EU in 2020 is 1894 TWh, emitting around 403 $MtCO_2eq$/a. An increase of the overall seasonal efficiency with only 1% would already result in annual savings of around 19 TWh and 4 $MtCO_2eq$. To achieve this, e.g. around 10% of the existing buildings using traditional steel panel radiators and condensing gas boilers would need to shift to LT-emitters.

1.5.2 Costs

European (and non-EU) radiator manufacturers over the years have optimized their production systems in order to be able to survive in a declining market. As a result, the production- and labor costs for standard radiators are minimized, and manufacturing prices are quite low (around 70 euro per kW @ 45/35/20 -regime).

New LT-radiators will probably cost a little more than that, but with a simultaneous upgrade of the radiator design and the right marketing approach people can be persuaded to replace their 30 year old radiators.

1.6 Saving potential

In the context of the recent Review Study on hydronic Central Heating boilers LT-emitters were proposed as a separate Ecodesign product group, relevant for but outside the scope of the boiler measures. As such it found support from the vast majority of stakeholders. [246]

If all heat emitters in the EU are to be replaced by state-of-the-art LT-emitters, the saving potential compared to the reference BAU-scenario is around 190 TWh (primary energy) per annum. The related reduction of greenhous gas emmissions amounts to around 40 $MtCO_2eq/a$.

When considering the impact lower system temperature has on the overall seasonal efficiency of the heating system, LT emitters promise to deliver a meaningful difference in CH-systems annual energy savings. Especially in light of the 10% it is projected to improve on the seasonal efficiency of heating systems based on condensing boilers, and even a staggering 50% or more for those using heat pumps.

6.1 Stakeholder comments

Member State stakeholders generally recognize the merit of the LT-emitter subject.

The German heating industry association BDH challenges the added value of regulating space heating emitters to promote low temperature (LT) heating for existing housing, pointing out that the current radiators and radiator performance standards are adequate for energy-efficient and renewable LT heating solutions and also suggest a switch to floor heating as an alternative, disregarding the costs and feasibility issues that might be connected to such a choice for consumers in existing houses.

The Danish Energy Agency supports the LT-emitter subject but stresses the need for market surveillance in this competitive sector.

The Netherlands Enterprise Agency says in its comments that the preliminary analysis of product groups in Task 3 leaves no doubt that LT emitters, due to their energy savings potential, should be priority products in the Working Plan.

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[246] https://www.ecoboiler-review.eu/

7 WINDOW PRODUCTS

7.1 Scope, policy measures and test standards

Windows for buildings were the subject of an Ecodesign preparatory study by VHK and ift Rosenheim [247] which ran from July 2013 to May 2015 to provide the European Commission with a technical, environmental and economic analysis of windows as required under Article 15 of the Ecodesign Directive 2009/125/EC. The study was carried out for the European Commission, DG Energy under specific contract ENER.C3.2012-418-lot 1.

Windows are energy-related products in the sense that their own energy consumption is minimal (or zero generally speaking), but their characteristics have significant impact on related energy systems such as space heating systems, space cooling systems and ventilation systems of buildings.

The study concluded that, while it would not be useful to have an ecodesign measure as efficiency requirements are covered by Member States' implementation of the Energy Performance of Buildings Directive, an EU energy label could be considered in order to realise further energy savings and emission reductions.

On 30 September 2015, a Consultation Forum meeting took place with the aim to obtain the views of stakeholders on whether and how to regulate this product group, based on a proposal from the Commission to develop an energy label.

The Consultation Forum showed limited support for going forward with a traditional product-related energy label. An interest was expressed in labelling options (e.g. an 'installer label') that consider site-specific parameters (e.g. climate, orientation of the window, and many other parameters that go beyond the simple product boundaries) so that the performance indicated is of more relevance to the consumer. Due to a focus on other product groups, the Commission has not finalised an impact assessment for windows under the energy-labelling framework[248]. A draft Impact Assessment was used as input to the Consultation Forum meeting.

Scope, policy measures and test standards

Windows are building products, for which harmonized product standards EN 14351-1:2006+A2:2016 "Windows and doors - Product standard, performance characteristics - Part 1: Windows and external pedestrian doorsets" was drafted by working group WG1 of CEN Technical Committee TC33 (last amendment published in Oct 2016). This standard was developed following requests for standardisation M101 (windows) and M122 (roof windows).

[247] Martijn van Elburg (VHK), Norbert Sack (ift Rosenheim), Sarah Bogaerts e.a. (VITO); LOT 32 / Ecodesign of Window Products. TASK 7 – Policy Options & Scenarios, Final report, consolidated version of 22 June 2015; 22 June 2015; Specific contract No ENER/C3/2012-418-Lot1/03

[248] https://www.europarl.europa.eu/doceo/document/E-9-2019-002916-ASW_EN.html [EC reply of 8 Nov 2019 in response to question from EP of 23 Sep 2019: https://www.europarl.europa.eu/doceo/document/E-9-2019-002916_EN.html]

Due to the implementation of the Construction Products Regulation (EU) No 305/2011 (CPR)[249] EN 14351-1 is mandatory for all member states since 1st July 2013. The standard serves as a "manual" for the evaluation of the relevant characteristics of windows and provides the rules for the CE marking of the product.

The harmonized European product standard for windows defines the relevant parameters of windows and supersedes test standards in individual member states. The main (energy) performance parameters of windows are assessed using various other European standards for measurement and calculation. These standards are given in the harmonized product standard for windows EN 14351-1.

Base cases

The preparatory study identified various window technologies (mainly a combination of glazing and frame characteristics) that were used as a basis for identifying the base cases used in the assessment. As these base cases are based on typical technologies involved these are also generic design options (specifying options for better energy balances and emissions reductions). These base cases / options are presented in the table below.

Table 71. Window base cases

Base case #	Uw in W/m²K	g	Description
Facade window			
1	5.8	0.85	Single glazing; Frame: even, no or bad thermal break
2	2.8	0.78	Double IGU; Standard frame (wood, PVC, Metal)
3	1.7	0.65	Double IGU with Low-e coating and argon filling; Standard frame (wood, PVC, Metal)
4	1.3	0.60	Double IGU with Low-e coating and argon filling; Standard frame (wood, PVC, Metal)
5	1.0	0.55	Triple IGU with Low-e coating and argon filling; Standard frame (wood, PVC, Metal)
6	0.8	0.60	Triple IGU with optimized Low-e coating and argon filling, thermally improved spacer; Improved frame (wood, PVC, Metal)
7	1.0	0.58	Single and Double IGU with Low-e coating and argon filling, thermally improved spacer; Coupled window(wood, PVC, Metal)
8	0.6	0.47	2 Double IGU with Low-e coating and argon filling, thermally improved spacer; Double window (wood, PVC, Metal)
9	2.8	0.35	Double IGU low g-value solar control; Standard frame (wood, PVC, Metal)
10	1.3	0.35	Double IGU low g-value solar control with Low-e coating and argon filling; Standard frame (wood, PVC, Metal)
11	0.8	0.35	Triple IGU low g-value solar control with Low-e coating and argon filling, thermally improved spacer; Improved frame (wood, PVC, Metal)
Roof windows			
roof_3	1.7	0.60	Double IGU with Low-e coating and argon filling; Frame metal-PVC/PU or metal-wood
roof_4	1.1	0.50	Triple IGU with Low-e coating and argon filling; thermally improved spacer; Frame metal-PVC/PU or metal-wood
roof_5	0.9	0.50	Triple IGU with optimized Low-e coating and argon filling, thermally improved spacer; Frame metal-PVC/PU or metal-wood
roof_6	1.7	0.35	Double IGU with Low-e coating and argon filling and solar control glazing; Standard frame metal-PVC/PU or metal-wood

Test standards

The test standard to be used for CE marking of windows is EN 14351-1 "Windows and doors - Product standard, performance characteristics - Part 1: Windows and external pedestrian doorsets".

Further activities

A revised standard prEN 14351-1 (WI=00033572) is being developed and the forecasted voting date is 12 Jun 2020.

[249] REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC

7.2 Market

The preparatory study calculations were based on data provided by stakeholders and not on values derived from PRODCOM and CN (COMEXT) databases as these latter databases include many more products than windows only (doors, thresholds, etc.) and or exclude certain window frame materials (no trade data for windows made from wood).
The table below shows the stock and market volume for the year 2013, based on data from VFF (Verband Fenster + Fassade[250]), expressed as 'window units', a standardised window size.

Table 72. EU27 Window sales and stock according VFF 2013 (million window units)

	Stock (million window units)	% of total EU 27 stock	Activity index (% points)	Market volume (million window units)					
	2011	**2011**	**2011**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
EU27 (mln.units 1.3*1.3 m = 1.69m²)	3422			93,7	89,9	80,1	76,2	74,6	73,2
EU27 (mln. m²)	**5783**			**158**	**152**	**135**	**129**	**126**	**124**
EU27 (mln.units re-calculated to 1.23*1.48 m = 1.82m²)	**3177**			**86.8**	**83.5**	**74.2**	**70.9**	**69.2**	**68.1**
Belgium	75	2%	3.3	2.5	2.5	5.45	2.45	2.47	2.43
Bulgaria	50	1%	0.93	0.6	0.7	0.57	0.51	0.46	0.44
Denmark	38	1%	3.18	1.4	1.4	1.27	1.22	1.22	1.22
Germany	560	16%	2.3	11.6	11.7	12.04	12.46	12.86	13.3
Estonia	9.2	0%	1.78	0.4	0.4	0.18	0.16	0.156	0.17
Finland	37	1%	2.54	1.1	1.1	0.95	0.92	0.94	0.95
France	434	13%	2.63	12	12.2	11.6	11.4	11.4	11.2
Greece	77	2%	1.47	2	2.1	1.93	1.29	1.14	0.98
Ireland	31	1%	2.52	1.5	1.1	0.94	0.84	0.79	0.78
Italy	415	12%	1.59	7.6	7.5	6.98	6.73	6.6	6.43
Latvia	14	0%	3.28	0.8	0.9	0.5	0.45	0.46	0.47
Lithuania	22	1%	2	0.9	1	0.45	0.41	0.41	0.42
Luxembourg	3.6	0%	2.84	0.1	0.1	0.1	0.1	0.1	0.1
Malta	2.9	0%	5.93	0.2	0.2	0.19	0.18	0.17	0.16
Netherlands	115	3%	2.9	3.7	3.7	3.53	3.29	3.32	2.92
Austria	58	2%	5.22	2.7	2.8	2.88	2.96	3.02	3.06
Poland	264	8%	2.35	5.1	6.2	6.23	6.14	6.2	6.38
Portugal	72	2%	1.31	1.4	1.3	1.17	1.06	0.95	0.83
Romania	146	4%	0.72	1.9	1.9	1.27	1.08	1.05	1.02
Sweden	65	2%	2.55	1.9	1.9	1.71	1.62	1.66	1.62
Slovakia	37	1%	2	0.9	0.9	0.83	0.77	0.74	0.72
Slovenia	14	0%	2.7	0.5	0.5	0.45	0.4	0.38	0.37
Spain	316	9%	1.49	14.7	12	7.92	6.14	4.73	4.16
Czech Republic	72	2%	2.54	2.1	2.2	2.01	1.89	1.83	1.84
Hungary	68	2%	2.1	2.1	2.1	1.81	1.64	1.43	1.34
UK	*426*	*12%*	*2.37*	*14*	*11.5*	*10.12*	*10.07*	*10.12*	*9.92*

[250] https://www.window.de/verband-fenster-fassade/

The data may contain an unknown amount of 'curtain walls' as this differentiation was not possible when collecting the date.
The values shows that approximately 70 million units of windows were placed on the market in 2012. The total market value (end consumer prices) as assessed by VHK was estimated at 36 billion euros in 2020, of which some 70% are for replacement.

Based on data from Eurowindoor the window frame market is made up of 47% plastic, 35% aluminium , 20% wood and the remainder a wood-metal combination.

7.3 Usage

Windows are installed in buildings for various reasons (admittance of light and air, keeping cold or heat out or in, being able to look outside and/or inside, aesthetics, etc.).

In the preparatory study it was estimated that some 63% of sales are used in residential applications, and some 37% in non-residential applications with 'office' as the single largest contributor.

Table 73. Windows by applications

Application	Share of group
single family	38%
multi family	25%
all residential applications	63%
offices	7%
educational	4%
health	3%
gastro	3%
trade	7%
sports	1%
other	12%
all non-residential applications	37%
all façade windows (residential + non-residential)	100%
roofwindow residential applications	53%
roofwindow non-residential applications	47%
all roof windows	100%

In the preparatory study usage scenarios were defined and in particular the use of (integrated) solar blinds as these have profound impacts on the need for cooling.

7.4 Technologies

The different window technologies apply to the design of the glazing, or integrated glazing unit (IGU – if the glazing is made up of different sheets of glass or other materials, a spacer and a frame), the window frame, air leakage and the various designs for opening the window and the armatures used for that.

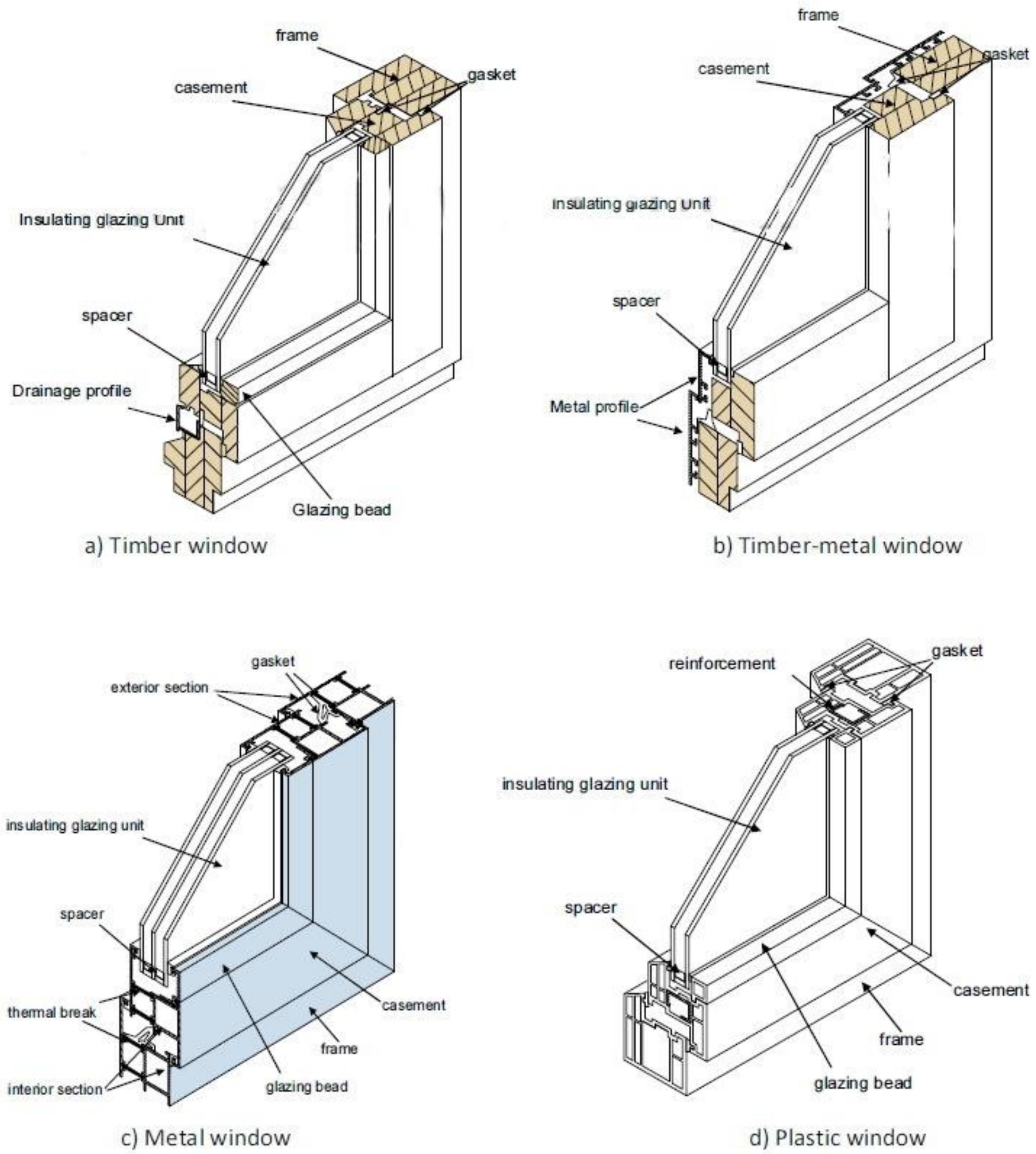

Figure 20. Typical cross sections of windows by frame material

The technologies aim to improve one or more aspects relevant to the overall performance of the window.

Table 74. Window characteristics relevant for CE marking

Parameter		Symbol	Units	Window	Roof Window
Environmental characteristics	Thermal transmittance	U_w	W/m^{2}K	Y (when required)	Y (when required)
	Total solar energy transmittance	g	-	Y (when required)	Y (when required)
	Light transmittance	□$_v$	-	Y (when required)	Y (when required)
	Air permeability		Technical class	Y (when required)	Y (when required)
	Dangerous substances			Y (indoor impact only)	N
Water tightness			Technical class	Y	Y
Acoustic performance		R_w (C,C_{tr})	dB	Y (when required)	Y
Resistance to wind load				Y	Y
Resistance to snow and permanent load				N	Y
Impact resistance				N	Y
Load-bearing capacity of safety devices				Y	Y
Reaction to fire				N	Y
External fire performance				N	Y

The preparatory study was one of multiple attempts to introduce the concept of an energy balance calculation to express/calculate the energy performance of windows. The study showed that simply aiming at the lowest U-value of the window is not always the best approach for many applications as this often is achieved at the expense of a lower g-value, reducing solar gains.

The study presented the outcomes of calculations in which the solar gains and thermal losses are calculated per hour. These values partially depend on boundary conditions such as the thermal mass (that determines how fast a room heats up, cools down), the room size (a small room with large window, facing south, with average g-values will more easily overheat), ventilation regime (how fast is heated air removed and replaced by incoming air), thermal transmittance of other building components, and of course the orientation and inclination of the window, the presence and use of solar shading devices and the presence of other components/items that influence the amount of solar energy transmitted through the window (such as overhangings, or trees that put the window in its shade , etc.).

Based on an elaborate hourly calculation, Rosenheim developed an approach that allowed the calculation of energy balances of windows with only the U-value and g-value as inputs. These energy balances are based on the average of equal sized windows facing North, East, South and West, and take into account the climate conditions specified for "Cold" (Helsinki), "Average" (Strasbourg) and "Warm" (Athens). Boundary conditions such as window-to-floor area, ventilation regime, solar shading use were fixed.

7.5 Energy, Emissions and Costs

An elaborate stock model, taking into account the estimated share of sales of various window types in Member States (to arrive at known shares of types in installed base), building volumes, including demolition rates and product life was developed during the preparatory study to calculate energy, emissions and costs.

The results for sales, stock, energy, emissions, resource use and costs of the 'business-as-usual' scenario for residential windows is shown below.

Table 75. Business-as-usual scenario /residential windows

REFERENCE (FIXED VALUES): residential/all res	unit	1990	2000	2010	2020	2030	2040	2050
Sales to new buildings	M m²/yr	68	44	48	47	45	44	43
Demolished[251]	M m²/yr	-12	-15	-19	-24	-34	-36	-41
Sales replacements[252]	M m²/yr	87	94	102	107	110	112	113
Total stock	bn m²/yr	3.5	3.8	4.1	4.3	4.4	4.5	4.5
Heating energy	TWh_fuel	1308	985	642	335	153	83.8	58.9
Cooling energy	TWh_fuel	3	8	21	23	28	29.1	30.1
Final energy windows	TWh_fuel/yr	1311	993	663	358	181	113	89
	PJ_prim	4719	3576	2387	1287	651	407	320
GHG Emissions	Mt CO2 eq./yr	261	191	122	65	32	20	15
Mat. in	kton	3190	2988	3480	3678	3790	3883	3937
Mat. out	kton	-1948	-2295	-2660	-3064	-3459	-3607	-3761
Ind. energy balance	TWh_fuel	24	26	30	27	21	16	13
New+replace purchase costs	bn EUR (10^9)	48	38	37	29	23	19	15
Glazing replace./ maintenance costs	bn EUR (10^9)	32	28	27	24	21	19	18
Energy costs	bn EUR (10^9)	86	66	46	26	15	11	9
Overall costs	bn EUR (10^9)	166	132	110	79	60	49	42
Employees	'000			434	393	364	345	335
Avg. heating perf. new	kWh/m²*yr	114	77	30	18	15	11	8
Avg. cooling perf. new	kWh/m²*yr	67	63	57	53	52	50	48
Stock cool. perf.	TWh_cool	246	256	261	255	247	239	232
Share window heat loss of heat demand	%	37%	31%	24%	15%	10%	7%	6%

[251] Windows in existing buildings
[252] Sales of windows replacing those in existing buildings

7.6 Saving potential

The table below shows the results of a scenario whereby all windows are replaced by the best available technology ('BAT'). The actual technology differs per member state as climate conditions differ.

Table 76. BAT scenario /residential windows

OUTPUT: residential/all res	unit	1990	2000	2010	2020	2030	2040	2050
Sales new build	M m²/yr	68	44	48	47	45	44	43
Demolished	M m²/yr	-12	-15	-19	-24	-34	-36	-41
Sales replacements	M m²/yr	87	94	102	107	110	112	113
Total stock	bn m²/yr	3.5	3.8	4.1	4.3	4.4	4.5	4.5
Heating energy	TWh_fuel	1308	985	642	272	76	-4.7	-39.6
Cooling energy	TWh_fuel	3	8	21	23	26	26.5	26.0
Final energy windows	TWh_fuel/yr	1311	993	663	294	103	22	-14
	PJ_prim	4719	3576	2387	1060	370	78	-49
GHG Emissions	Mt CO2 eq./yr	261	191	122.1	53.5	18.9	5.1	-0.3
Mat. in	kton	3190	2988	3480	4475	4567	4636	4659
Mat. out	kton	-1948	-2295	-2660	-3303	-3890	-4189	-4496
Ind. energy balance (production)	TWh_fuel	24	26	30.0	33.2	25.7	19.3	15.3
New+replace purchase costs	bn EUR(10^9)	48	38	37.3	35.6	28.7	23.2	18.8
Glazing replace./ maintenance costs	bn EUR(10^9)	32	28	26.8	23.9	21.3	19.3	18.0
Energy costs	bn EUR(10^9)	86	66	45.7	21.9	10.0	4.9	2.8
Overall costs	bn EUR(10^9)	166	132	109.8	81.4	60.0	47.4	39.6
Employees	'000			434	448	411	385	373
Avg. heating perf. new	kWh/m²*yr	114	77	30	-13	-16	-18	-20
Avg. cooling perf. new	kWh/m²*yr	67	63	57	47	47	46	46
Stock cool.perf.	TWh_cool	246	256	261	246	232	222	212
Share window heat loss of heat demand	%	37%	31%	24%	12%	5%	0%	-4%

The saving potential compared to the reference BAU is shown below (relative values, negative values are a saving).

Table 77. BAT scenario savings /residential windows

RELATIVE CHANGE: residential/all res	unit	1990	2000	2010	2020	2030	2040	2050
Sales new build	M m²/yr	0%	0%	0%	0%	0%	0%	0%
Demolished	M m²/yr	0%	0%	0%	0%	0%	0%	0%
Sales replacements	M m²/yr	0%	0%	0%	0%	0%	0%	0%
Total stock	bn m²/yr	0%	0%	0%	0%	0%	0%	0%
Heating energy	TWh_fuel	0%	0%	0%	-19%	-50%	-106%	-167%
Cooling energy	TWh_fuel	0%	0%	0%	0%	-5%	-9%	-14%
Final energy windows	TWh_fuel/yr	0%	0%	0%	-18%	-43%	-81%	-115%
	PJ_prim							
GHG Emissions	Mt CO2 eq./yr	0%	0%	0%	-17%	-41%	-74%	-102%
Mat. in	kton	0%	0%	0%	22%	21%	19%	18%
Mat. out	kton	0%	0%	0%	8%	12%	16%	20%
Ind. energy balance	TWh_fuel	0%	0%	0%	23%	24%	22%	16%
New+replace purchase costs	bn EUR(10^9)	0%	0%	0%	23%	24%	25%	26%
Glazing replace./maintenance costs	bn EUR(10^9)	0%	0%	0%	0%	0%	0%	2%
Energy costs	bn EUR(10^9)	0%	0%	0%	-16%	-34%	-54%	-70%
Overall costs	bn EUR(10^9)	0%	0%	0%	3%	1%	-2%	-5%
Employees	'000			0%	14%	13%	11%	11%
Avg. heating perf. new	kWh/m²*yr	0%	0%	0%	-173%	-206%	-258%	-358%
Avg. cooling perf. new	kWh/m²*yr	0%	0%	0%	-12%	-10%	-8%	-5%
Stock cool.perf.	TWh_cool	0%	0%	0%	-4%	-6%	-7%	-8%
Share window heat loss of heat demand	%	0%	0%	0%	-19%	-50%	-106%	-167%

In summary, in the year 2030 there is a potential to:

- save 50% on heating energy lost through windows (from 153 TWh/a to 76 TWh/a);
- which equals a saving of 41% on GHG emissions;
- and a 34% saving on energy costs;
- and a 1 % saving on overall costs, meaning that this saving could be achieved at almost zero extra costs;
- and the windows become a net surplus contributor to heating energy instead of a heating energy loss factor.

However, the main bottleneck hindering the market uptake of high-performance window products is the low renovation rate in Europe, currently only about 1% per year.

The calculation of window (indirect) energy consumption and savings from window improvement shown above is from the Lot 32 study and based upon the EN ISO 13790 standard for building heating/cooling needs and ISO 18292 for window performance. In the study an hourly calculation was applied to arrive at a simpler parametric calculation of the energy balance of the window. Such methods are used in many national window labelling schemes and/or schemes for building improvement[253].

[253] In the UK (https://www.bfrc.org), in Sweden (https://www.energifonster.nu) or the basis for building requirements (https://www.byggeriogenergi.dk/media/2202/danishbuildingregulations_2018_energy-requirements.pdf) and subsidies in Denmark (http://www.vinduesvidensystem.dk/energimarkningsdata.html)

The proposed EU Energy Label for windows was criticised in the Consultation Forum because it did not allow calculation of window performance (or better: energy balance) using local, site-specific characteristics. But the Ecodesign Directive provides an opportunity to do this if the information requirement for manufacturers placing products on the market allows the use of an interactive tool in which these local, site-specific characteristics can be inserted (probably by the person who puts the product into service). The interactive tool would provide a step-by-step guide for window assessment guiding the user to more optimal windows. Such tools (have) exist(ed) elsewhere to great appraise[254]

The Ecodesign information tool is a perfect complement to the information required by the CPR as it takes the information form the standards to a real-world application. Studies have shown that more information on window performance helps consumers buying more efficient windows than required by law. Better information on window performance should be considered indispensable for achieving the Union's goals for energy saving, use of renewable energy and emissions reduction.

Material use of windows is also relevant but it must be said that the preparatory study showed that the use-phase impacts due to the indirect energy consumption far outweigh the material impacts related to resource extraction (considering that rather paradoxically the relevance of window materials increase with higher window efficiency, because the energy loss is reduced). This is not to say that recycling should be ignored. Without going into details the present recovery rate of window glass is fairly low and could/should be improved. The recovery of metal frames is considerably higher because of available recovery options and scrap value. Advanced glazing materials that enter the market at present will reach their end-of-life phase until some 30 years in the future. By that time they will have recovered their (energetic) value many times when compared to other types of glasses used in windows.

[254] http://blog.lichtnstein.org/2005/05/window-window-in-wall.html

8 WATER DECALCIFIERS AND SOFTENERS

8.1 Scope, policy measures and test standards

Every year, millions of washing machines, dishwashers, water heaters, coffeemakers, kettles, taps, shower heads, pumps, etc. break down – often fatally – because of hard water. Water hardness is determined by the amount of dissolved minerals (largely calcium and magnesium) and iron in the water. Hard water causes solid deposits (scale) in pipes and water using equipment. E.g. heat transfer in (space and water) heating elements and heat exchangers suffers from scaling, resulting in energy loss. Also, the effective passage in piping decreases due to scaling, causing extra energy consumption for pumping. Water hardness also affects the corrosivity and taste of water.

There are two common types of systems available in order to treat hard water: water softeners, subvided in ion exchange and reverse osmosis,and descaling systems. Water softeners change the chemical composition of water; descaling systems do not alter the chemical composition but neutralise the minerals to prevent the formation of scale. Water softeners are more commonly used, therefore the scope is restricted to water softeners.

Every year, households consume up to a million tonne of dishwasher salt and decalcifying compounds in all sorts of laundry and cleaning detergents to combat the impact of hard water. Sales of residential water softening installations is rising at a steady pace, with currently over 5 million units installed. With a (regeneration) salt consumption of about 100 kg/unit/year, this means almost half a million tonne salt per year that ultimately – in one form or another – ends up in waste water systems and may hamper water re-use/re-cycling. On the positive side: The energy use of water softening installations will probably not be a large issue; most types can work 1 or 2 years on a battery for the controls, indicating power use <1W.

Drinking hard water does not cause serious health issues; since it contains high concentrations of magnesium and calcium, drinking hard water may help to reach the recommended daily intake of these minerals. Washing with hard water may cause dry skin and hair, and alter the pH-value of the skin – weakening it as a barrier against harmful bacteria and infections[255]. On the other hand, it is reported that long-term consumption of demineralized water or water very low in essential elements such as calcium and magnesium may compromise human health. A certain amount of these minerals is reportedly also vital in order to ensure the water is neither aggressive nor corrosive and to improve taste of water.[256]

Policy measures

The Drinking Water Directive (98/83/EC) on the quality of water intended for human consumption does not set boundaries to the hardness or softness of drinking water[257], but

[255] https://www.healthline.com/health/hard-water-and-soft-water#hard-water-benefits

[256] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CONSIL:ST_6060_2020_REV_1&from=EN (consideration 13)

[257] Its predecessor, Council Directive 80/778/EEC, did regulate water hardness.

Member States regulate it via law or technical guidance[258]. The Directive is currently under review and the current status is 2020 Political Agreement (under review)[256].

Test standards

Possible applicable standards concerning water softeners are listed in Table 78.

Table 78. Reference numbers and titles for European standards for drinking water treatment units[259].

European standard	Title
EN 13443-1:2002 +A1:2007	Water conditioning equipment inside buildings — Mechanical filters — Part 1: Particle rating 80 µm to 150 µm
EN 13443-2:2005 +A1:2007	Water conditioning equipment inside buildings — Mechanical filters — Part 2: Particle rating 1 µm to less than 80 µm
EN 14095:2003	Water conditioning equipment inside buildings — Electrolytic treatment systems with aluminum anodes
EN 14652:2005 +A1:2007	Water conditioning equipment inside buildings — Membrane separation devices
EN 14743:2005 +A1:2007	Water conditioning equipment inside buildings — Softeners
EN 14812:2005 +A1:2007	Water conditioning equipment inside buildings — Chemical dosing systems — pre-set dosing systems
EN 14897:2006 +A1:2007	Water conditioning equipment inside buildings — Devices using mercury low-pressure ultraviolet radiators
EN 14898:2006 +A1:2007	Water conditioning equipment inside buildings — Active media filters
EN 15161:2006	Water conditioning equipment inside buildings — Installation, operation, maintenance and repair
EN 15219:2006 +A1:2007	Water equipment inside buildings — Nitrate removal devices
EN 13443-2:2005 +A1:2007	Both POU and POE[260], plumbed-in only, mechanical filters, 1 µm to less than 80 µm
EN 14652:2005 +A1:2007	Microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), both POE and POU; If pre- and post- filters are included, they must conform to the relevant standard
EN 14743:2005 +A1:2007	Automatic, salt regenerating cation exchange water softeners
EN 14897:2006 +A1:2007	POU and POE, low pressure mercury lamps with 85% of total radiation intensity at 254 nm
EN 14898:2006 +A1:2007	Both POU and POE, plumbed-in only, "active" media filters only
EN 15219:2006 +A1:2007	Plumbed-in, automatic, salt regenerated anion exchange nitrate removal devices

Note that there are also standards and measures in other parts of the world. Notably, in the US there is NSF 44 and the EPA also investigated water-softeners in the framework of their WaterSense programme in 2011.

[258] Kozisek, F. (2020), Regulations for calcium, magnesium or hardness in drinking water in the European Union member states. *Regulatory Toxicology and Pharmacology*, vol. 112. Available at https://www.sciencedirect.com/science/article/abs/pii/S0273230020300155

[259] This is an indicative and non-exhaustive list which needs to be updated with stakeholder input. Adapted from https://www.nsf.org/newsroom_pdf/European_Stds_Guide_LT_EN_LDW10050309.pdf.

[260] POE = Point Of Entry, POU = Point Of Use.

8.2 Market

According to the Europe water softeners market outlook of 2020[261], the water softeners market was valued at approximately 423 million euros in 2019, growing towards 775 million euros (with a compound annual growth rate of 6.2%)[262]. Drivers for growth of the market are an increasing urbanization, increasing demand of end-user industries and increasingly innovative wastewater treatment (e.g. ion-exchange resin method, lime softening, reverse osmosis, and washing soda). Especially in France, Spain and the Netherlands the market for water softeners is expected to grow due to strict government guidelines to control contamination in drinking water, and rising awareness toward public health.

The market can be divided by type into salt-based water softeners and salt-free water softeners. By process, the technology with the largest market share is ion exchange, conditioning, followed at a large distance by reverse osmosis[263] . Finally, the market can be divided by end use into residential, industrial, and commercial application, see Figure 21.

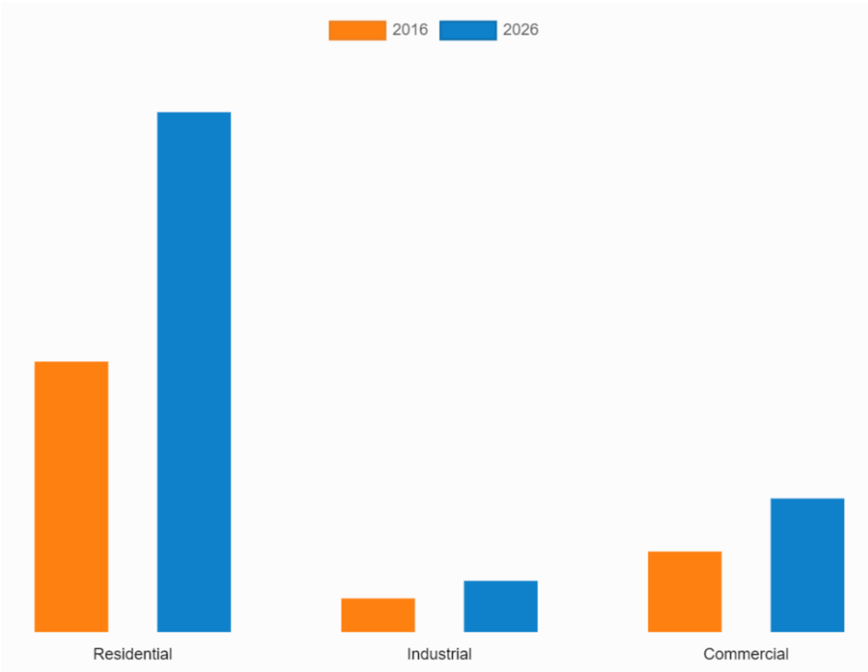

Figure 21. European water softeners market by end-use (source: https://www.alliedmarketresearch.com/europe-water-softeners-market-A06069)

Following Figure 21 it is estimated that the residential market has a market share of approximately 70 per cent, followed by 20 per cent for the commercial market and 10 per cent of the industrial market. Estimating the average consumer price of a water softener of 1.000 euros[264], the amount of annual sales of residential water softener units in the EU is roughly estimated at almost 300 000 units. With a lifespan of approximately 15 – 20 years, the estimated stock of the residential market is 4.5 – 6 million units. This stock

[261] https://www.alliedmarketresearch.com/europe-water-softeners-market-A06069

[262] The market outlook includes several technologies, such as ion exchange, reverse osmosis and conditioning. Water conditioning is a descaling technology, not a water softener – they are however included in the market value size; their share of the market size is estimated at 10-15%.

[263] Conditioners are omitted here.

[264] https://waterontharderkiezen.nl/modellen-waterontharders/prijzen

estimate does not include the commercial and industrial market. For comparison, the EPA estimated that in 2011 there were 6-10 million water softeners installed in the US (with a smaller population). [265]

8.3 Usage

Water softeners are used to remove the minerals, mainly calcium (Ca^{2+}) and magnesium (Mg^{2+}), that cause the water to be hard. These appliances are widely used not only in households, and restaurants but also in industrial appliances like preparation of drinking water or soda.

The water quality and hardness differ throughout Europe but also within a region the hardness can differ. Hardness can be classified in different units and can differ slightly per Member State. See Table 79 for commonly used classification categories and units. *Figure 22* provides an overview of hardness in several EU-countries and the UK; light blue means soft water, dark blue means hard water. Grey areas means that no data were found.
Note that water utilities also use water softeners.[266]

Table 79. Commonly used classification categories and units

Classification	mg/l or ppm[267]	French degrees °f[268]	German degrees °dH[269]
Soft	<70	0 – 7	0 – 4
Slightly hard	70 – 150	7 – 15	4 – 8
Moderately hard	150 – 300	15 – 30	8 – 12
Hard	300 – 450	30 – 45	12 – 18
Very hard	>450	>45	>18

During the use phase the softeners use most energy and consumables. The consumption is depended on a couple of factors like the hardness of the water, how soft does the water need to be and how much water is used.

Salt

As a rule of thumb, 3 kg of regeneration salt per person per month (based on an average water consumption per person of 120 l/day[270]) is needed[271]. With an average household size of 2.3 persons[272] this results in an average of 82.8 kg salt consumption per household per year.

[265] https://www.epa.gov/sites/production/files/2017-01/documents/ws-products-presentation-water-softeners.pdf
[266] Copenhagen has started reducing from 20 °dH to 10-12 °dH. Other cities may also do.
https://www.hofor.dk/baeredygtige-byer/udviklingsprojekter/bloedere-vand/
[267] 1ppm= 0.056 * °dH, 0,07* °e, 0.1*°f, 0.01*mmol/l
[268] https://www.dewatergroep.be/nl-be/drinkwater/waterkwaliteit-en-hardheid/waterhardheid
[269] https://www.lenntech.nl/waterhardheid.htm
[270] Average consumption of tap water per person in EU is 120l/day or 43.800 l/year.
[271] https://waterontharderkiezen.be/faq
[272] https://ec.europa.eu/eurostat/statistics-explained/index.php/People_in_the_EU_-_statistics_on_household_and_family_structures

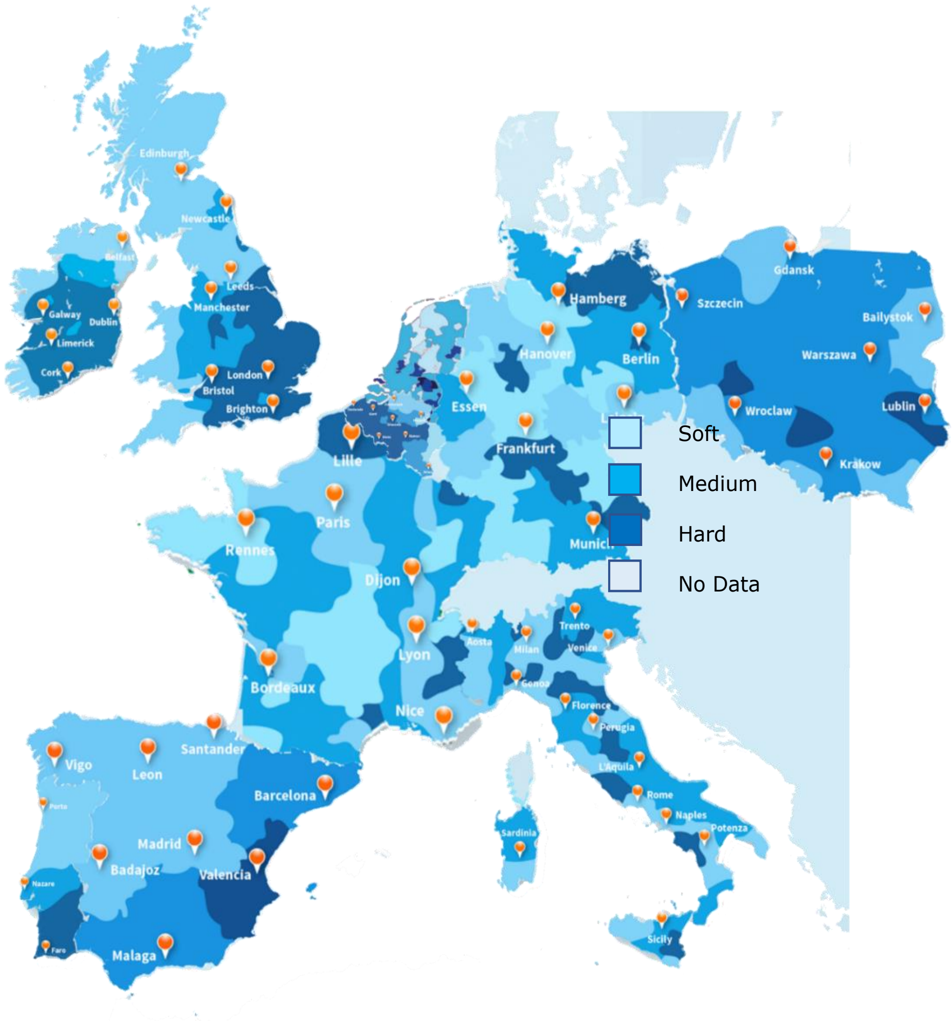

Figure 22. Water hardness in several EU-countries.
(Source: VHK 2020 adapted from http://www.ionicsystems.com/be/waterhardheid-kaarten/)[273]

Water

Depending on the softness of the water the amount of water used during a regeneration process is 2-4% of the yearly water consumption. When the water is softened by 20 °f this would be around 2% of the yearly water consumption that is used for the regeneration process. When softening by 30 °f this will be around 3%[274]. An average household uses 100 m^3 water per year[275] this results in a water consumption of 3 m^3 for regeneration.

Electricity

Mains operated water softeners consume electricity directly from the net. With an average energy consumption of 3 W[276] an electric mains operated softener consumes yearly 26.3[277] kWh.

[273] In Scandinavia water is soft. On average < 1 mmol/L, except for Denmark (average 2.4 mmol/L). Source: https://www.europeandrinkingwater.eu/fileadmin/edw/documents_links/MaiD_Report_1_final_11.9.2017.pdf

[274] https://www.waterverzachteraquagroup.be/waterverzachter/water-en-zoutverbruik

[275] 120 l/day * 365 days * 2.3 person/household = 100.7 m^3

[276] https://waterontharderkiezen.be/faq

[277] 3W * 24h * 365 days = 26.280 Wh.

Maintenance

Regular maintenance[278] includes the following steps[279]:

- check the hardness of the water;
- check and cleaning of the mechanical parts (e.g. valves) and filters;
- disinfection of the water softener;
- cleaning of the brine tank;
- adjustment of the settings, if needed.

The maintenance costs are estimated at a minimum of 60 euro per year[280], depending on the amount of work and whether spare parts are needed or not.

Larger maintenance includes replacement of the resin. This has to be done approximately every 10 years, depending on the hardness, chlorine and iron content of the water; i.e. the lifespan of the resin depends on the quality of the water it is treating.

Total costs of maintenance (service and repair) are therefore estimated somewhat higher at €125 (12.5% of average purchase price of €1 000, see Table 80).

Table 80. Usage parameters

Category	Cost items	Units	Value
Purchase	Purchase price	euros/unit	500 – 3 500
Purchase	Delivery and installation	% of product price	4
Use	Electricity rate (70% residential, 30% other)[281]	euros/kWh	0.20
Use	D-type batteries (1.5V)	euros/unit	3.75
Use	Water rates[282]	euros/m^3	4.49
Use	Salt	euros/kg	0.5-2
Use	Discount rate (=interest minus inflation)	%	4
Maintenance	Servicing and repair	% of product price	3–25
Disposal	Removal and disposal / recycling	euros/product	0

8.4 Technologies

A water softener changes the chemical composition of the water. Water softening is a technique that removes the ions that cause the water to be hard, in most cases calcium and magnesium ions. Iron ions are also removed during the softening process. The most common technologies that are used to soften water are ion-exchange and reverse osmosis.

[278] Depending on type, household size and water quality this regular maintenance is done every 1 to 3 years. Manufacturers often offer a maintenance and servicing plan (of for example 10 years) when purchasing a water softener installation.

[279] https://www.waterverzachteraquagroup.be/waterverzachter/heeft-een-waterverzachter-onderhoud-nodig and https://radio2.be/de-inspecteur/moet-je-waterontharder-elk-jaar-een-onderhoud-krijgen

[280] https://www.waterontharder-expert.be/onderhoud

[281] https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

[282] Water tariff residential 2020, according to VHK Ecodesign Impact Accounting (2018). For comparison: tariff in Belgium (Vivaqua, also includes sewage etc.) in 2019: €3.63/m^3. Total cost (water, sewage, purification tax) for an average family (100 m^3/year): €5.37/m^3.

Ion-exchange

This is the most widely used, most affordable and most effective descaling method for private individuals. A water softener based on this technique exchanges the hard calcium and magnesium particles via millions of spheres of synthetic resin for soft sodium ions.

When all the sodium ions have been replaced by calcium and magnesium ions the system needs to be regenerated. This is most commonly done by regeneration salt supplied to the softener from a brine tank. The salt is manually added to the brine tank in the form of pellets or blocks. During the regeneration process, the resin in the water is flooded with brine water, thereby cleaning the hardness minerals off the resin. The minerals and salt are then drained into the waste water system. Figure 23, Figure 24, Figure 25 show the working principle of a ion-exchange resin water softener.

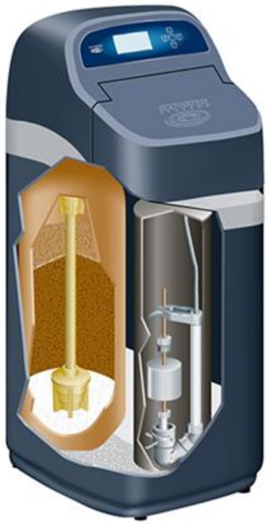

Figure 23. Cut-out of a water softening installation
(source https://www.ecowater.be/nl/waterontkalkers-evolution)

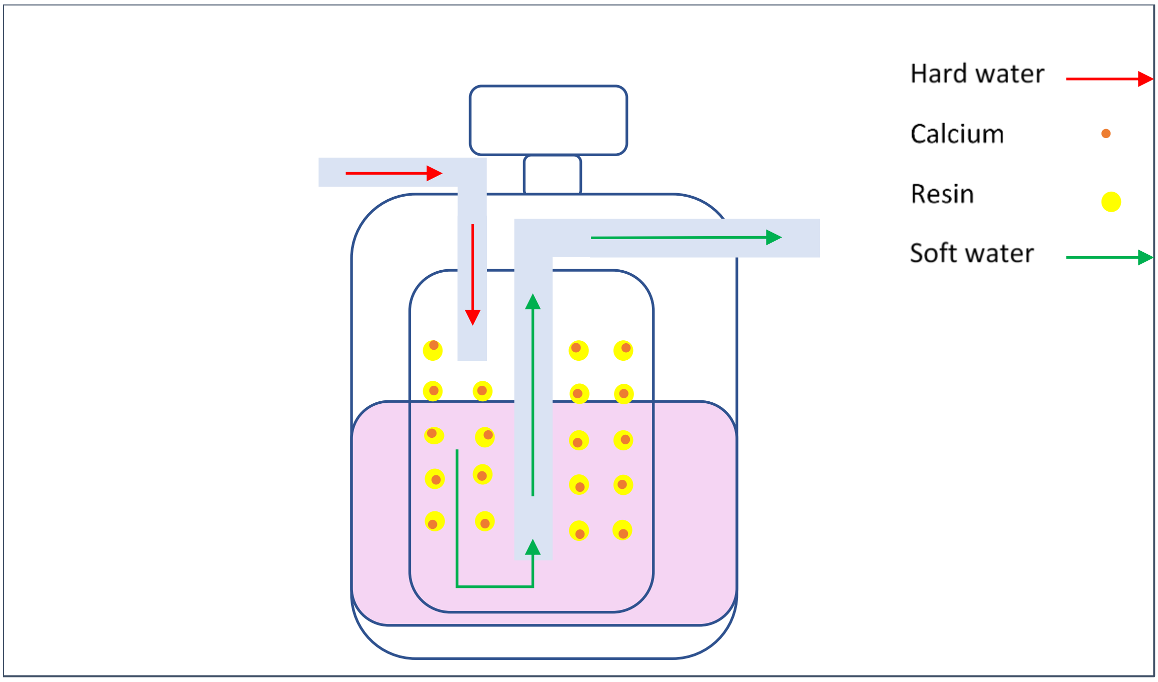

Figure 24. The water softening process.

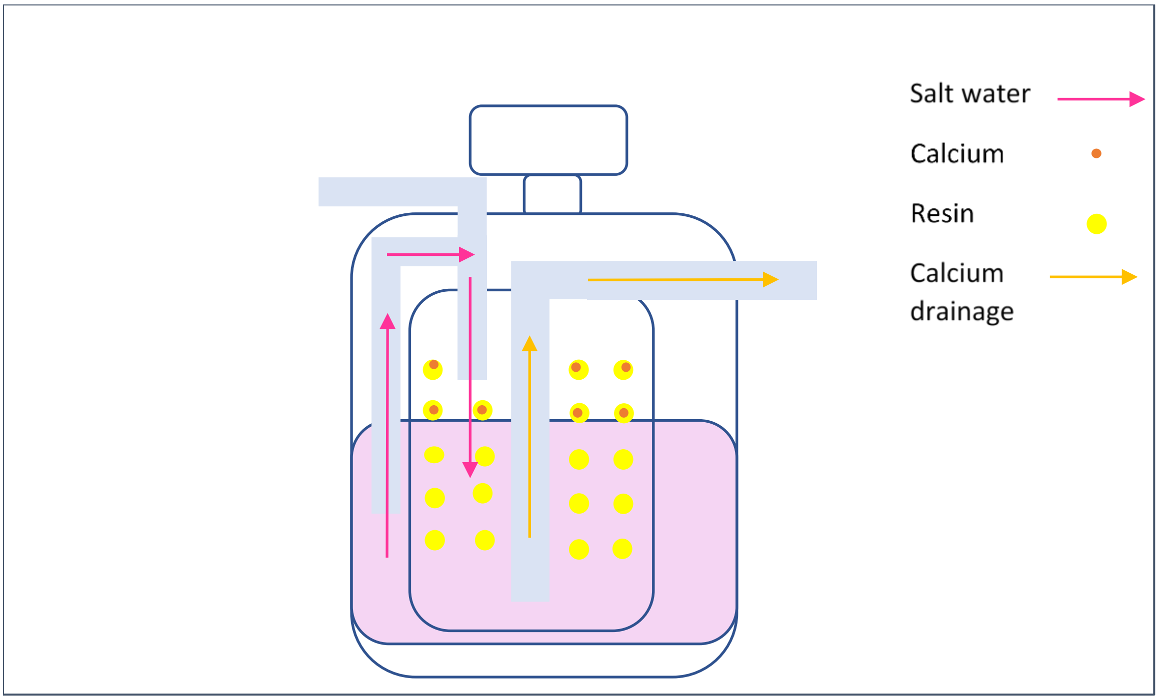

Figure 25. The regeneration process.

There are three main types of ion-exchange water softeners: hydraulic, battery and mains operated. Hydraulic water softeners function via the hydraulic pressure of the incoming water, and therefore do not need another power supply. Battery and mains operated water softeners are electrically powered.

Reverse osmosis
This technology uses a semi-permeable membrane to remove hardness ions. The membrane has pores large enough to let water molecules through, but hardness ions such as calcium and magnesium will not fit through the pores. The resulting soft water is free of hardness ions without any other ions being added.

Other water softening technologies used are sand filtration (this is a regular softening technique at water supply companies), lime softening, washing soda (causing a chemical reaction which causes the magnesium and calcium to precipitate) and distillation.

The Europe water softeners market outlook of 2020 projects the salt-free water softeners a faster growing technology segment than salt-based water softeners[283].

In 2011, the EPA investigated water softeners as a possible topic and found wide disparity in water efficiency for regeneration, in particular comparing manual, auto-initiated, and demand-initiated (DIR) regeneration residential cation exchange water softeners.[284]

8.5 Energy, Emissions and Costs

Several manufacturers of ion-exchange water softeners states that the energy required to run a water softener over the course of one year is the same as what an alarm clock uses[285]. A Dutch medium-sized ion-exchange water softener is known to consume the equivalent of two D-type batteries (1.5V, 13Ah per piece) in ~1.5 year[286].

Table 81 shows an estimation of the energy, salt and water consumption of residential water softeners in the EU. It is hereby assumed that hydraulic, battery and electric mains operated water softeners each have a third of the market share, and that the energy consumption of the latter two is similar at 26.3 kWh per year[287]. An estimation of the involved costs are included in Table 82.

Table 81. Estimated consumption of residential water softeners in the EU (2020)[288].

	Per unit			Sales (~0.3M units/yr)			Stock (5 mln units)		
Type	**Energy [kWh /a]**	**Salt [kg]**	**Water [m^3]**	**Energy [GWh /a]**	**Salt [kton]**	**Water [m^3]**	**Energy [GWh /a]**	**Salt [kton]**	**Water [mln m^3]**
Hydraulic	0	82.8	3	0	8.28	300 000	0	138	5
Battery	26.3	82.8	3	2.6	8.28	300 000	43.8	138	5
Electric	26.3	82.8	3	2.6	8.28	300 000	43.8	138	5
Total	**52.6**	**248.4**	**9**	**5.2**	**24.8**	**900 000**	**87.6**	**414**	**15**
CO_2 [tonne][289]	**0.02**			**1 976**			**33 288**		

[283] For example magnetic descalers (such as https://www.eddy.uk.com/) which reportedly continuously avoids scaling of tubes and fixtures so that the small quantities involved are flushed out. Reports on the effectiveness of this technology vary.
[284] https://www.epa.gov/sites/production/files/2017-01/documents/ws-products-noi-water-softners.pdf
[285] https://www.ecowater-softeners.co.uk/frequently-asked-questions-about-water-softeners
[286] https://www.boshuis.nl/
[287] https://waterontharderkiezen.be/faq
[288] Based on annual sales of 300 000 residential units per year and a stock of 5 million units.
[289] Based on an emission of 0.38 kg CO_2/kWh.

Table 82. Total costs per year of residential water softeners (total stock).

Type	Running costs				Acquisition [mln euros]	Total [mln euros]
	Electricity [mln euros]	Salt [mln euros]	Water [mln euros]	Maintenance [mln euros]		
Hydraulic	0	138	22.5	208.3	100.0	468.8
Battery	8.3	138	22.5	208.3	100.0	468.8
Electric	8.8	138	22.5	208.3	100.0	468.8
Total	**17.1**	**414**	**67.4**	**625.0**	**300.0**	**1 415.1**

The values in Table 82 assume an electricity price of 0.1 euro/kWh, an average purchase price of a unit of €1 000, salt price of 1 euro/kg, water price of 2.64 euro/m^3 and total maintenance costs of €125 per unit/year.

8.6 Saving potential

There are – at least – two categories of policy measures and savings in the field of water softeners.

The first category of policy measures could be an Energy Label and – possibly at a later stage when there is more information – Ecodesign measures to guide the consumers on the most energy- and material-efficient water softener products/solutions, i.e. regarding:

savings on direct costs:
- salt consumption;
- electricity consumption;
- water consumption in cleaning/regeneration cycle.

Indirect savings on material and energy efficiency:
- extended lifespan of water-using appliances;
- electricity consumption of water-using appliances.
- soap/detergent consumption (softer water requires less of these products);
- clothing wear.

Table 83 shows the potential indirect savings in euros per unit. With an estimated stock of 5 million units this results in an indirect savings potential of 3.3 billion euros EU-wide.

Table 83. Saving potential of water softeners[290]

Type of saving	Value [euros]
50% reduction of use of detergents and soap products	210
15% savings on energy costs hot water appliances	63
Less maintenance and wear of hot water appliances	200
Reduced wear on clothes	177
Total	**650**

[290] Source: Aqua Belgica, the Belgian Federation for water treatment. Calculation based on figures from the National Statistical Institute. https://www.ecowater.be/nl/nieuws/bespaar-tot-650-euro-jaar-met-een-wateron-tharder

On average, a family consumes €420 a year in soap products (€186 euros in detergent and cleaning products and €234 euros in body care products), since softer water requires less detergent, considerable savings of even 50% can be achieved. Hot water appliances work more efficiently without scaling, leading to approximately 15% savings on energy costs, and in addition these appliances require less maintenance. Lastly, calcium and other minerals deposit in clothing, leading to clothes wearing out faster.

In Denmark there has been a study with 30 households investigating the impacts of water softening[291].

A second category of policy measures that might result from a preparatory Ecodesign study in the Working Plan could go beyond the 'classic' Ecodesign and Energy Label policy measures and pose the question whether the problem of hard water should be solved at the level of individual households or whether it should be solved at the water supply (out of Ecodesign scope) and/or an intermediate level (larger water softeners for apartment building, city-zone, etc.). Note that water softeners are also used in non-residential environments (hospitals[292], swimming pools)

8.7 Stakeholder comments

The Netherlands Enterprise Agency mentions that the scope is restricted to softeners, but applying a measure only to these products would run the risk of diverting to non-regulated products. The main comment is that it is unclear which role ecodesign and energy labelling could have for this product group since the savings come from applying a water decalcifier or softener as such and not from applying a certain, more efficient product. Given the above, this product group should have a lower priority than ICT products.

The European Ventilation Industry Association EVIA thinks that the scope of a potential ErP implementing measure for water decalcifiers and softeners should be limited to household/domestic equipment. Process and industrial products and components shall be excluded.

Appliance manufacturer association APPLiA points out that It should be ensured that components which are part of products that are already regulated under the ErP framework are excluded from the scope of the working plan. Especially for components which are also offered as spare parts, but exclusively intended for the repair of the concerned containing product. This in order to avoid double regulation. E.g. integrated water softeners in household appliances (e.g. dishwashers).

[291] https://orbit.dtu.dk/en/publications/f%C3%B8r-og-efterm%C3%A5linger-af-effekter-af-bl%C3%B8dg%C3%B8ring-i-br%C3%B8ndby-et-samar

... there is an effect on the efficiency of central heating water, which confirms previous estimates,...

[292] https://www.ecowater.be/nl/waterbehandeling-voor-de-zorgsector-chu-brugmann

9 SWIMMING POOL HEATERS

9.1 Scope, policy measures and test standards

Swimming pool heaters were evaluated in the previous working plan study[293]. The main conclusions from this study were that there are some improvement potentials on swimming pool heating and that no existing measures were addressing that potential. The product group was suggested for evaluation for inclusion for the review of the Regulation (EU) No 814/2013 on ecodesign for water heaters and hot water storage tanks[294].

The savings potential of swimming pool heaters was estimated roughly at 4.7 TWh (electric) primary energy consumption in 2030, although the estimations regarding the EU stock of pool heaters were relatively uncertain.

The swimming pool heaters were however not considered in the review study of regulation 814/2013 except by mentioning that some suppliers are uncertain if they are in the scope of the regulation or not. The reason being that the water in swimming pools is not drinking water as the regulation 814/2013 considers so for the review it was decided to keep the focus of the regulation on water heaters for domestic hot water of drinking quality. It was therefore decided to include the swimming pool heaters in this study.

9.1.1 Scope

The US Code of Federal Regulations (CFR) defines 'Pool heater´ as an appliance designed for heating non-potable water contained at atmospheric pressure, including heating water in swimming pools, spas, hot tubs and similar applications.[295] The main swimming pool heater technologies are:

- gas heaters
- oil heater
- electric resistance heating
- electric heat pumps
- solar heating alone and in combination with other heat sources
- heating via a heat exchanger and other heat source like the buildings central heating system, district heating or e.g. a free standing gas boiler

The previous working plan study[293] concluded that the product category oil heaters was a declining product group. For the present study oil heaters are not seen to have any significant position on the market and this technology will only be treated briefly by mentioning in the technology section.

For a new preparatory study the following other scope issues could be considered:

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[293] Fischer, C e.a. (Öko-Institut e.V. Institute for Applied Ecology, Germany), Mudgal, Shailendra e.a. (BIO by Deloitte, France), Goodman, P (ERA Technology), Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC Task 3 Final Report, 2015

[294] Commission Regulation (EU) No 814/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water heaters and hot water storage tanks, OJ L 239, 6.9.2013

[295] EREE Appliance and equipment standards, https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=44&action=viewcurrent

- Size and capacity of products: Are the markets fundamentally different for heaters above a certain capacity?
- Public vs. residential sector: Are there technological differences on the heaters for these markets?
- Spa heaters: Spa heaters are not in the scope, but could they be distinguished from pool heaters? And should there be a distinction?

The aim of the current study is:

- to improve and update the previous data and assessments of market, stock and technology distribution with European market data in order to see if there have been relevant changes especially with respect to market trends, technology development and savings potentials that would merit an inclusion of the product group into the Working Plan 2020-2024;
- To address gaps or potential inclusion in other regulations, since these heaters are not regulated as heaters in regulation 813/2013 nor as water heaters in regulation 814/2020[296]

9.1.2 Policy measures

In the EU no policy measures exist for pool heaters. However, since 2010, in the USA the Department of Energy has had mandatory energy conservation standards for gas-fired pool heaters (10 CFR 430.32 (k)). Pool heaters should comply with the amended standards since April, 2013[297].

The tier 2 in the US requirements for pool heaters require that gas-fired pool heaters manufactured on or after April 16, 2013, shall have a thermal efficiency not less than 82%[298].

9.1.3 Test standards

Under the aegis of CEN and CENELEC no harmonized standards directly related to pool heaters are available; no standardization activities are taking place in this respect, and no standardisation mandates have currently been issued for CEN or CENELEC regarding swimming pool heaters. US and French standards exist for swimming pool heaters.

In the USA thermal efficiency for gas pool heaters are tested as in American National Standard for Gas Fired Pool Heaters, Z21.56–1986[299]. For pool heaters, the test is incorporated by reference to Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Standard 1160-2009, "Performance Rating of Heat Pump Pool Heaters," and ANSI/American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard

[296] COMMISSION REGULATION (EU) No 813/2013of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters, OJ L 239, 6.9.2013

[297] Energy Efficiency and Renewable Energy Office (EERE), 2015-10-26 Energy Conservation Standards for Pool Heaters; Notice of data availability (NODA), https://www.regulations.gov/document?D=EERE-2015-BT-STD-0003-0012

[298] Electronic Code of Federal Regulations, September, 2020, Title 10: Energy PART 430—ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS Subpart C—Energy and Water Conservation Standards, https://www.ecfr.gov/cgi-bin/text-idx?SID=762f10cb94fc6de0f518360b9b303233&mc=true&node=se10.3.430_132&rgn=div8

[299] 2015-01-06 Energy Conservation Program for Consumer Products: Test Procedures for Direct Heating Equipment and Pool Heaters; Final rule, https://www.regulations.gov/document?D=EERE-2013-BT-TP-0004-0012

146-2011, "Method of Testing and Rating Pool Heaters,". The test procedures also clarify the test procedure's applicability to oil-fired pool heaters.

The standard testing conditions for heat pump pool heaters are described in AHRI 1160 as "high air temperature – high humidity", "high air temperature- mid humidity", and "low air temperature- mid humidity" conditions, the specific temperatures and humidity conditions are presented in Table 84.[300]

Table 84. Typical heat pump rating conditions

Type of appliance	Relative Humidity (%)	Air Temperature (°F / °C)	Air Temperature (°F / °C)
Heat pump			
"High Air Temperature- High Humidity	80	80 / 26.7	80 / 26.7
High Air Temperature- Mid Humidity	63	80 / 26.7	80 / 26.7
Low Air Temperature- Mid Humidity	63	50 /10	80/ 26.7

The national French test standard for pool heat pumps, NF 414, uses the same test principles as the European standard EN 14511:2018 for heat pumps, but with temperature setting adapted for swimming pool water. NF414 serves as basis for a French certification scheme, NF Mark, for swimming pool heat pumps and for this mark the following values are tested[301]:

- The Coefficient of Performance (COP)
- The heating capacity
- The power input
- The sound power level.

The test conditions in NF 414 are presented in **Table 85**.

Table 85. Examples of heat pump rating conditions according to NF 414 (RH 70 %) and minimum COP for receiving a NF mark.

	Relative Humidity (%)	Air temperature (°C)	Water temperature (in/out °C)	Min. COP
For seasonal use	80	15	26/28 or 26/31	4.2
	63	7	26/28 or 26/31	3.4
For all year use: An extra temperature set is added to the seasonal use conditions	63	2	26/28 or 26/31	2.7

NF414 applies maximum limits on the sound power levels of swimming pool heat pumps. Outside the building, they must comply with the thresholds in Table 86.

300 Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory for U.S. Department of Energy (2015), Technical support document: Energy efficiency program for consumer products and commercial and industrial equipment: Pool heaters

301 Eurovent Certita, AFNOR Certification identification no.: NF 414 Revision 15–20/12/2018, CERTIFICATION-REFERENCE STANDARDFOR THE MARK, NF Pompe à chaleur, https://www.eurovent-certification.com/sites/default/files/2020-01/NF414_Technical_standard_Rev15_appendix_1_2_3_4_5_6.pdf

Table 86. NF414 sound power threshold values[302]

Heating capacity [in kW]	Sound power [in dB(A)]
00 ≤ 10	≤ 70
10 ≤ 20	≤ 73
20 ≤ 50	≤ 78
50 ≤ 100	No threshold defined

9.1.4 Lateral legislation

For the similar technologies of water heaters space and combination heaters the regulations 813/2012 and 814/2012 consider appliances with different water qualities (inactive water in closed heating systems respectively drinking water) compared to the corrosive and chlorine containing water of swimming pools. The physical properties regarding heating efficacy of the appliances are similar anyway. Particular the standards for space heating e.g. for underfloor heating are close the tests relevant for swimming pool heaters (circulation systems and relatively low ΔTs), and it could be considered to review and adapt those standards for appliances for pool heating.

For the regulations (EU) 813/2012 and (EU) 814/2012 harmonized test standards are not available. However, a set of well proven test standards for the heater products exists, in particular EN14511:2018. The European Commission has issued the standardization mandates M534 and M535 for CEN and CENELEC as well as two sets of transitional methods of measuring and testing referring to the relevant test standards. [303, 304, 305, 306]

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[302] Eurovent Certita, AFNOR Certification identification no.: NF 414 Revision 15–20/12/2018, CERTIFICATION-REFERENCE STANDARDFOR THE MARK, NF Pompe à chaleur, https://www.eurovent-certification.com/sites/default/files/2020-01/NF414_Technical_standard_Rev15_appendix_1_2_3_4_5_6.pdf

[303] M/535 COMMISSION IMPLEMENTING DECISION of 27.4.2015 on a standardisation request to the European standardisation organisations pursuant to Article 10(1) of Regulation (EU) No 1025/2012 of the European Parliament and of the Council in support of implementation of Commission Regulation (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters and Commission Delegated Regulation (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heaters, temperature control and solar device and packages of combination heater, temperature control and solar device

[304] M/534 COMMISSION IMPLEMENTING DECISION of 27.4.2015 on a standardisation request to the European standardisation organisations pursuant to Article 10(1) of Regulation (EU) No 1025/2012 of the European Parliament and of the Council in support of implementation of Commission Regulation (EU) No 814/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water heaters and hot water storage tanks and Commission Delegated Regulation (EU) No 812/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device

[305] Commission communication in the framework of the implementation of Commission Regulation (EU) No 813/2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters and of Commission Delegated Regulation (EU) No 811/2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device, OJ C 207, 3.7.2014

[306] Commission communication in the framework of the implementation of Commission Regulation (EU) No 814/2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to

9.2 Market

Neither PRODCOM or other statistics or studies provides data on the distribution and ratio of different swimming pool heating technologies in the European Union. The previous working plan study[293] based its analyses on US market data on heaters and the share of heater swimming pools in US[307]. This was correlated to EU numbers of swimming pools provided by EUSA. The US data on the heating technologies were relatively old (2007). Since the first preparatory study an updated technical support document (TSD) has produced for the U.S. Department of Energy (DoE) to support updated US requirements for pool heaters[308].

The market data and estimated shares of swimming pool heater technologies in this updated TSD however are based on the same data from 2007 as used in the working plan study Task 3 report.

The swimming pool market in EU is divided into the categories

- residential pools
- and public pools.

This distinction refers to the users of the pools and not to physical characteristics like the size or volume. Standards and legislation (mainly safety related regarding pool equipment) related to swimming pools refer this distinction. Additionally, it could be considered to distinguish between heaters for pools and for spas due to capacity and technical difference of pools[309].

In the USA the stock of spas is approximately 70 % of the stock of pools, meaning that should the same relation be representative in the EU there would be around 8 million residential spas in the EU. Spa heaters are out of scope of the present study.

9.2.1 Residential swimming pools

The residential swimming pool market and stock has been in growth the last decades – with a set-back in 2007/2008 in most countries due to the financial crisis. In 2020, the sales and installation of pools so far (September 2020) seem to have increased due to the impact of the COVID-19 pandemic on travel restrictions[310].

In 2011, the stock of residential swimming pools in eight of the countries with the largest number of swimming pools (plus Switzerland) was estimated at 4.8 million pools. Hereof were 1.6 million pools installed in France. Propiscines, the French swimming pool professionals association, - Fédération des professionnels de la piscine, informed that in 2019

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[307] Consortium for Energy Efficiency (2012), CEE High Efficiency Residential Swimming Pool Initiative, http://library.cee1.org/sites/default/files/library/9986/cee_res_swimmingpoolinitiative_07dec2012_pdf_10557.pdf

[308] Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory for U.S. Department of Energy (2015), Technical support document: Energy efficiency program for consumer products and commercial and industrial equipment: Pool heaters

[309] Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory for U.S. Department of Energy (2015), Technical support document: Energy efficiency program for consumer products and commercial and industrial equipment: Pool heaters

[310] Ref. Personal contact EUSA secretariat, September 2020.

the number of pools in France rose to 2.5 million residential pools[311]. For the present study it is assumed that this growth represents the development of the total stock in EU.

The table below shows estimated unit sales and stock of residential swimming pools based on the data from the previous working plan study and the 2019 data from Propiscines. Based on these market data based on population ratio the stock has been extrapolated to entire EU.

The Review study on water pumps[312] analyzed the sales and stock of pool pumps. The development in the stock of pool pumps generally would correlate with the number of pools and therefore the number of pool heaters. For the pool pumps, an annual growth rate of 3 % was used for the sales from 2001-2020[313]. Growth rates after 2020 are assumed to go linearly to zero in 2030; this decrease in growth is similar to what has been assumed in the 2015 Impact Assessment for water pumps and electric motors (Figure 26).

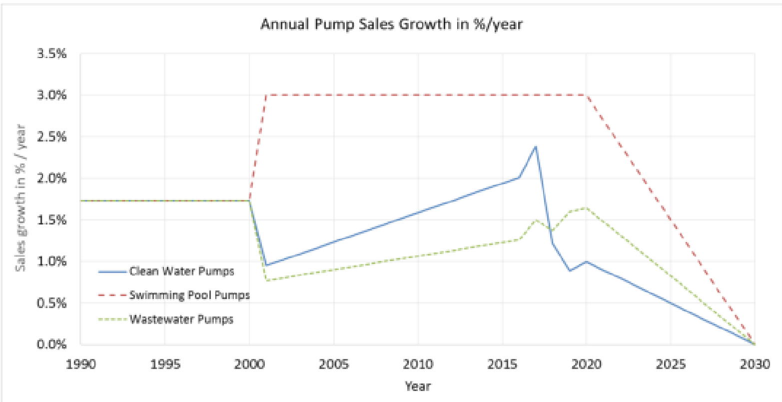

Figure 26. Annual growth rates for pump sales in % per year

Table 87. Stock of swimming pool pumps with rated power ≤ 2.2 kW from the review study on water pumps. For the present study other stock data were developed.

Water pump category, stock		2014(1)	2020	2025	2030
Swimming pool pumps For filtration and circulation	**Stock**	4,463,343	5,329,465	6,138,516	6,805,872
	Index	0.837	1.000	1.152	1,277

1) The 2014 stock is calculated from sales figures and stock that were provided by Europump and EUSA Working Group based on their estimates for 2014. The following years based on the estimated development in swimming pool pumps sale and pump lifetime (10 years).

Table 88 shows the sales of swimming pools in the EU.

311 Fédération des professionnels de la piscine et du spa (Nov. 2019), Dossier des Presse, Chauffages : de nombreuses solutions écologiques, propiscines.fr, https://www.propiscines.fr/sites/default/files/espace_presse/dp_fpp_conf051119.pdf

312 Viegand Maagøe and Van Holsteijn en Kemna B.V. for European Commission, DG Energy (Dec. 2018) Ecodesign Pump Review Study of Commission Regulation (EU) No. 547/2012 (Ecodesign requirements for water pumps) Extended report (final version)

313 Lot 29, Preparatory study on clean water pumps

Table 88. Sales of residential swimming pools (in 1000 units) (1)

Country	Private Pool Sales (1000 units)				
	2007	2008	2009	2010	2011
France	96	61	59	63	57
Germany	21	21	20	20	20
UK	6	5	2.5	2.5	2.3
Italy	21	24	22	20.7	19
Spain	38	35	15	16	14
Sweden	2	2	2	2	2
Portugal	5	5	4	4	3
Hungary	3	3.5	3	3	2.5
Switzerland	2	2	2	2	1.9
Total EUSA [1]	**194**	**158**	**129**	**133**	**121**
[1] Total value is representative of EUSA members. Members include national associations of Greece, Portugal, Italy, UK, Germany, Spain, France, Hungary, Austria, Sweden, and Switzerland.					
1[1] EUSA estimated data (2012), Market Data 2011.					

Table 89 below shows the calculated stock of residential swimming pools in the EU. The stock in 2020 is projected to be more than 11 million swimming pools and in 2030 almost 13 million swimming pools. These numbers include on ground standing as well as subterrain pools.

Table 89. Stock of residential swimming pools (in 1000 units)

	Installed residential swimming pools(1) [1000 units]				Projected stock(5)		
Country \ Year	**2006**	**2008,5**	**2011**	**2019(4)**	**2020**	**2025**	**2030**
France	1270	1448	1606,2	2500	2689		
Germany	998	1050	1100	1813	1813		
Italy	200	259	306,7	447	447		
Spain	1112	1172	1230	2024	2024		
Sweden	40	45	50	78	78		
Portugal	75	86	96	149	149		
Hungary	59	67	74	116	116		
Greece(2)	64	70	75	120	120		
Total EUSA3 excl. CH & UK	3818	4197	4538	7248	7436		
Extrapolated to EU 27(3)	**5718**	**6,286**	**6,796**	**10,854**	**11,137**	**12,448**	**12,922**

(1) 2008-mid (=2008,5) is extrapolated by mean square method from 2006 and 2011
(2) Greece 2006 was not available from EUSA and is extrapolated from the 2011-stock minus 15 %
(3) EU Population 2019: 446 million[314]
(4) The estimated 2019 stock is based on the assumption that all EU has shown the same development as France
(5) From 2019 to 2020 the same growth rate as from mid-2008 to 2019 (= 7,6 % / year) is assumed. From 2020 to 2030 the assumed growth is based on the index number for swimming pool pumps.

[314] https://www.eu.dk/da/fakta-og-tal/medlemslande/medlemslande

Another ongoing trend is that more pool owners want to extend the use season by adding pool heating so the ratio of pools with heater is growing[315]. Propiscines informs that in 2019 almost a third of the swimming pools hade some kind of pool heating[316]. In the following, this has been interpreted as to 30 % of the private swimming pool have pool heaters. Since no other data has been found for the EU this number will be used as basis for the calculations of stock and sales of private swimming pool heater for the EU.

The preparatory study assumed a stable share of pool heaters on 21 % but according to the updated data the share has been growing and this is assumed to continue. The growth rate is assumed to be 1 percentage point per year until it stabilizes on 40 % of all residential pools in 2029. Also, it is assumed that there has been a stable growth from the 21 % in 2006 to 30 % in 2019.

The Table 90 shows estimated unit sales and stock of residential swimming pool heaters based on the data from the working plan study and the 2019 data from Propiscines.

Table 90. Stock of residential swimming pool heaters (in 1000 units)

Country \ Year	2006	2011	2019	2020	2025	2030
Share of residential pools with pool heaters	0.21	0.24	0.30	0.31	0.36	0.40
Stock of residential swimming pools	5718	6796	7248	11137	8565	9496
Stock of residential swimming pool heaters	**1,201**	**1,538**	**2,039**	**3,365**	**4,009**	**3,426**

A third trend is that preferences are changing towards smaller pools, e.g. due to urbanization with smaller gardens, and the desire for a pool combined with a wish to minimize water consumption according to Propiscines. Propiscines reports that the average size of a swimming pools decreases as presented in the Table 91.

Table 91. Evolution of swimming pools in France (Propiscines 2019317)

	Average swimming pool size		
	1980	**2015**	**2025 Predicted**
Pool dimensions	12 x 6 m	8 x 4 m	7 x 3 m
Water depth	1.8 m	1.4 m	1,3 m
Volume	130 m^3	45 m^3	27 m^3

A trend towards smaller swimming pools is expected to result in lesser requirements to the heating capacity of the pool heaters.

Indoor vs outdoor. Residential pools are mainly considered to be placed outside, but does that mean, the share of indoor pools is negligible? It was not possible to retrieve data

[315] Ref. Personal contact EUSA secretariat, September 2020.

[316] Fédération des professionnels de la piscine et du spa (Nov. 2019), Dossier des Presse, Chauffages : de nombreuses solutions écologiques, propiscines.fr, https://www.propiscines.fr/sites/default/files/espace_presse/dp_fpp_conf051119.pdf

[317] https://www.propiscines.fr/piscine-actualite/piscines-basse-consommation-les-professionnels-engages-dans-une-revolution-durable-1

from Eurostat, Statista or other market research, trade organization or literature etc. regarding the share of indoor residential pools. Instead, property sales portals was studied. A search on Danish properties (all property categories) on Boliga.dk (property sales portal) with swimming pool or with indoor swimming pool showed that around 17 % of the pools were indoor pools. A search on the German Immobilienscout24 (houses terraced houses and apartments for sale) in Nordrhein-Westphalen showed a higher share on around 30 % - although it was a more difficult to extract the data. Probably indoor pools will be marketed more intensively than outdoor pools, since it is a more costly installation so the real share could be lower. In warmer climates the indoor share probably is lower. Based on this the share of indoor residential swimming pools is assumed at 20 % and a projected stock is found as in Table 92.

Table 92. Indoor and outdoor projected stock of residential pool heaters

Location \ Year	2020	2025	2030
Outdoor	2692	3207	2741
Indoor	673	802	685

9.2.2 Public swimming pools

The term `Public swimming pools´ includes pools used by the public for water-related activities, as defined in EN 15288–2, as Type 1, 2 or 3[318,319]. These include:

- communal pools
- leisure pools
- water parks
- hotel pools
- camping pools
- club pools
- paddling pools that are part of a larger pool
- or complex therapeutic pools in places of education
- diving pools
- military training pools
- rescue training pools
- counter-current training pools
- scuba-diving pools.

The term also applies in other non-conventional settings, such as to holiday lets in residential complexes:

- pools for hotels and other short-term accommodation
- shared pools in residential multi dwellings, smaller wellness centres etc.
- private aquaparks, fun and leisure centers
- municipal pools in pool halls and by sports facilities etc. inside as well in as open air.

As could be seen this means that public pool could be commercial or non-commercial and with access for the public generally or a more limited number (like hotel guests or user of in a pool house).

[318] HSE Health and Safety Executive, HSG179 (4. ed.) UK, 2018, Managing health and safety in swimming pools, https://www.hse.gov.uk/pUbns/priced/hsg179.pdf

[319] EN 15288-1:2018 and 15288-2:2018 Swimming pools for public use

For the present study the public pool categories are summarized as in Table 93 with the following characteristics and assumptions:

- Pools for hotels, elderly healthcare centres etc. are often smaller pools, especially when placed inside, although larger outdoor pool are common in larger holiday hotels and centers.
- Pools in leisure centers and municipal pools are typically larger pools placed outdoor or inside. The general assumption is that basically all of these swimming pools that are placed inside, are heated.
- Outside pools for leisure centers will also often be equipped with pool heating. It is assumed that all are heated.
- A large share of the municipal swimming pools are outdoor. Municipal outdoor swimming pools are mostly unheated and for the present study it is assumed that they are not heated. However, heated municipal pools should remain in scope of a possible regulation to avoid loopholes.

Table 93. Category and share of public swimming pools that are heated

Category of public pool	Heated share
Public pools at hotels, etc. – indoor	1
Public pools at hotels, etc. - outdoor	0.5
Shared pools in residential multi dwellings, smaller wellness centers etc. – indoor	1
Shared pools in residential multi dwellings, smaller wellness centers etc. – outdoor	0.5
Larger pools - municipal – indoor	1
Larger pools – municipal – outdoor	0
Larger pools – commercial - fun and leisure centers – indoor	1
Larger pools – commercia - leisure centers – outdoor	1

Total stock of public pools. Based on data from EUSA, the working plan study estimated that approximately 102,000 public swimming pools were installed in some of the main EU countries (EUSA3) and that this number would have grown to 140,000 by 2020.

Like for the residential swimming pools this stock is extrapolated to EU27 in order to estimate the total stock of public pools in EU27. Based on this, the stock is estimated at 191,000 public pools by 2020 as presented in Table 94. The table shows the 2009 country specific stock from EUSA, the total stock of public pools extrapolated to EU27 and the projected development to 2020.

Table 94. Stock of public swimming pools in EU countries

Country	Stock of public pools in 2009(1)	2011	2014	2020
France	25630			
Germany	25800			
Italy	14930			
Spain	16900			
Sweden	4030			
Portugal	2700			
Hungary	2055			
Greece	200			
UK	7100			
Switzerland	2560			
Total EUSA3	101905			
Total EUSA3 (excl. UK and CH)	92245	92366	102811	127374
Extrapolated to EU 27(2)	**138,151**	**138,332**	**153,974**	**190,762**

(1) Working plan study and EUSA (2) Without UK and CH. EU27 population 446 million[320]

In the following the total stock will be broken down on the subcategories summarized in Table 93. The purpose is to be able to estimate the stock of pool heaters and later to more detailed evaluate the expected development and user behavior. The estimation method will – based on the available sources – be a combination of a top-down approach using the total EU stock as reference, and bottom-up using other data sources. The consistency between these data also could provide some indication on the strength and quality of the data and estimates.

Large public swimming pools. Germany has (2020) almost 5500 public swimming pools in swim halls and outdoor according to baederportal.com[321]. The members of BäderPortal, Deutsche Geselschaft für Bäderwesen e.V. are mainly related to large public swimming pool and it is assumed that close to all large public swimming pools (public and commercial) are counted in the reported stock of 5500.

In 2016 a bit more than half of the big public pools were outdoor swimming pools in Germany[322]. For the present study this ratio is assumed to be constant from 2009 to 2020 and it is assumed that 50 % of all municipal swimming pools in EU are outdoor. Likewise it is assumed that the ratio of all public pools vs large swim halls /leisure centers swimming pools in the EU in average is similar to the German ratio. Based on this, a total stock on 29,000 large public swimming pools in 2020 is estimated (Table 95).

320 EU Population 2019: 446 mio [https://www.eu.dk/da/fakta-og-tal/medlemslande/medlemslande]

321 https://www.baederportal.com/weiterfuehrende-seiten/haeufig-gestellte-fragen-faq/#c1162

322 AB Archiv des Badewesens 12/2016, Dipl.-Sportwiss. Michael Weilandt, Deutsche Gesellschaft für das Badewesen e.V., Essen, und Oliver Wulf, Bergische Universität Wuppertal, Arbeitsbereich Sportsoziologie, Sanierungsbedarf und Schließungspläne in der deutschen Bäderlandschaft https://www.baederportal.com/fileadmin/user_upload/FAQs/Sanierungsbedarf_2016_Weilandt_Wulf.pdf

Table 95. Stock of large public pools (municipal and commercial)

Country	2009	2014	2020
Total public pools EUSA3(1)	92245	102811	127374
Total number of public pool Extrapolated to EU 27	138151	153,974	190,762
Large public swimming pools in swim halls, leisure centres etc.(1)	**21328**	**23771**	**29451**

(1) Major EU pool countries excl. UK and CH
(2) Calculated from the ratio of German pools and the projected totals

Small public swimming pools. No statistical sources were found on small public pools e.g. in hotels. In order to estimate the size of the stock, the number of hotels and the share of hotels with pools has been estimated by extracting data from the hotel and accommodation booking portal booking.com. On this portal is possible to count the total number of accommodations and to use search criteria, e.g. `swimming pool´. Almost 290,000 accommodations were found in the EU. 41,000 of these (= 14,4 %) had a swimming pool. The portal covers the major part of the market.

Data from OTREC indicate that in some countries e.g. large tourist destinations like Greece and Croatia, booking portals are not represented as broadly as in other countries[323].

Therefore, to check that the data extracted from the booking portal is representative Eurostat data was also consulted. The booking portal found in most countries more hotels and accommodation than counted in the Eurostat category ´Hotels and similar accommodation´ and less than in the category `Hotels; Holiday and other short stay accommodation, camping grounds, vehicle parks, trailer parks´. This seems reasonable since the portal also have smaller B&B places etc. which are overlapping the two Eurostat groups (Table 96) and also confirms a broad coverage of the EU hotel and accommodation market.

[323] University of Applied Sciences and Arts, Western Switzerland, July 2020, European Hotel Distribution Study. Statista.

Table 96. Total number hotels and accommodation from different sources and hotels with pools found at a booking portal.

Country	Totally number of hotels(1)	Hotels with swimming pools(1)	Hotels and similar accommodation(3)	Hotels; Holiday and other short stay accommodation, camping grounds, vehicle parks, trailer parks
Austria	7239	1025	11823	21951
Belgium	4045	360	1505	9651
Bulgaria	5421	1642	2166	3664
Croatia	14621	1444	1089	113761
Cyprus	1232	515	814	816
Czechia	6867	813	6236	9383
Denmark	1580	122	585	1197
Estonia	1428	89	450	1424
Finland	4001	136	794	1.374
France	39625	8232	17960	29683
Germany	28555	1842	32182	50498
Greece(2)	16124	3330	9910	38180
Hungary	5317	536	2324	4444
Ireland(2)	2175	171	2348	3145
Italy	66848	7002	32730	218327
Latvia	1659	108	348	1220
Lithuania	1997	145	494	3756
Luxembourg	360	40	227	422
Malta	409	84	224	244
Netherlands	4978	392	3806	8844
Polen	16651	1263	4229	11.251
Portugal	9748	2774	2401	7.196
Rumania	9903	790	2857	8.202
Slovakia	2870	284	1731	3.420
Slovenia(2)	2175	157	698	3699
Spain	28242	7785	19663	52894
Sweden	3009	224	2143	4.358
Sum	**287079**	**41305**	**161737**	**613004**

(1) Available hotels from Booking.com checked Sept. 2020

(2), Ireland, Grece and Slovenia: No Eurostat data for 2019. Latest available data are used.

(3) Eurostat, Number of establishments, 2019[324]

The Eurostat dataset `Hotels; Holiday and other short stay accommodation, camping grounds etc.´ contains more than 613,000 accommodation places (Table 96). For the present study it is assumed that the ratio on 14,4 % also represent the Eurostat group of accommodation sites. The Eurostat data is considered to represent the total number of hotels etc. Hence, it is estimated that there are 88,000 public swimming pools in 2019 related to hotels, holiday accommodation, camping sites etc.

[324] Eurostat, NACE_R2 Hotels; holiday and other short-stay accommodation; camping grounds, recreational vehicle parks and trailer parks

Likewise, no data are available for the category of other smaller public shared pools in residential multi dwellings, smaller wellness centers, elder case health centers etc. For the present study, it is assumed to be the residual of the total public swimming pools stock estimate from EUSA subtracted the estimated stock data from the other subgroups (large, municipal, commercial). Hereby the estimated stock of other smaller swimming pools is in the same magnitude (17 % smaller) as the smaller hotels etc. It seems like a reasonable number, hence it serves as a cross check on the total stock from the EUSA.

Stock of swimming pool heaters. Comparing the estimated share of heated swimming pools (Table 93) with the estimated numbers of different categories of swimming pools the number of heated pools is found as in Table 97.

Table 97. Stock of public swimming pools and stock of swimming pool heaters (by 2020)

	Stock of public swimming pools	Heated	Stock of swimming pool heaters
GENERAL TOTAL	***190,762***	-	***143,071***
Smaller public pools at hotels, etc. - indoor	44099	1	44099
Smaller public pools at hotels, etc. - outdoor	44099	0,5	22050
Shared pools in residential multi dwellings, smaller wellness centres etc. – indoor	36556	1	36556
Shared pools in residential multi dwellings, smaller wellness centres etc. - outdoor	36556	0,5	18278
Larger pools – municipal – indoor	7363	1	7363
Larger pools - municipal – oudoor	7363	0	0
Larger pools – fun and leisure centers – indoor	7363	1	7363
Larger pools - leisure centers – outdoor	7363	1	7363

Projected stock of public swimming pool heaters. To project the stock of smaller public swimming pools and pool heaters at hotels etc. we are looking at the dataset from Eurostat but now at the yearly development of the number of hotels, holiday accommodation sites etc. In 2008 to 2019 an average growth at 4,2 % per year is seen (Figure 27).

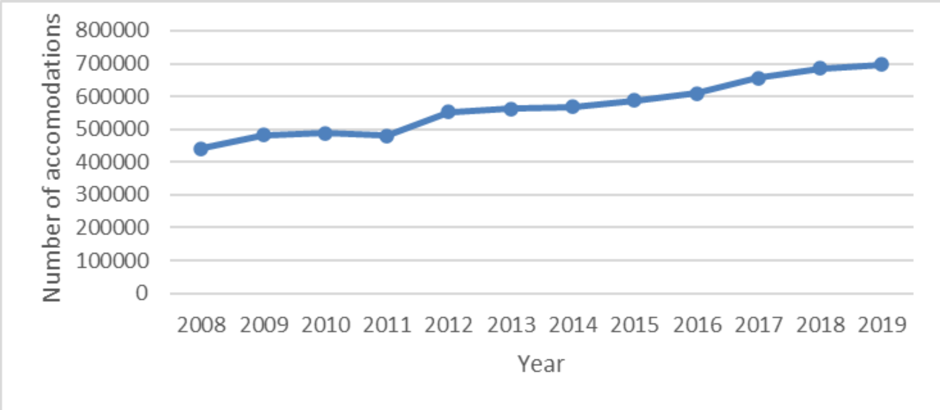

Figure 27. Development in hotels; holiday and other short-stay accommodation; camping grounds, recreational vehicle parks and trailer parks[325]

This growth is assumed to be on halt in the coming years due to the impact of COVID19, giving an average yearly growth on 0 % in 2020 to 2025. From 2025, the growth is expected to return to 4.2 %. The share of hotels etc. with swimming pools is expected to remain stable which means the stock of public swimming pools at hotels etc. will follow the number of hotels and other accommodation.

The stocks of smaller shared public residential swimming pools and of larger commercial public swimming pools are assumed to follow the residential pool market. The stock of larger municipal swimming pools is assumed to remain stable due to restricted public budgets.

The share of heated swimming pools is considered to reflect a saturated market and therefore expected to remain stable at the current level for all the public pools, in contrary to the expectations for private swimming pools and the stocks for subcategories and in total are estimated as in Table 98.

[325] Eurostat, NACE_R2 Hotels; holiday and other short-stay accommodation; camping grounds, recreational vehicle parks and trailer parks

Table 98. Projected stocks of public swimming pools and pool heaters

	Stock of public swimming pools			Share with pool heater	Stock of public swimming pool heaters		
Year	**2020**	**2025**	**2030**	**Constant**	**2020**	**2025**	**2030**
GENERAL TOTAL	***190,762***	***207,655***	***252,231***	**-**	***143,071***	***155,741***	***190,024***
Smaller public pools at hotels, etc. – indoor	44099	44099	54289	1	44099	44099	54289
Smaller public pools at hotels, etc. – outdoor	44099	44099	54289	0,5	22050	22050	27144
Shared pools in residential multi dwellings, smaller wellness centres etc., indoor	36556	45003	55401	1	36556	45003	55401
Shared pools in residential multi dwellings, smaller wellness centers etc., outdoor	36556	45003	55401	0,5	18278	22501	27700
Larger pools – municipal – indoor	7363	7363	7363	1	7363	7363	7363
Larger pools – municipal – oudoor	7363	7363	7363	0	0	0	0
Larger pools – fun and leisure centers – indoor	7363	7363	9064	1	7363	7363	9064
Larger pools - leisure centers – outdoor	7363	7363	9064	1	7363	7363	9064

9.3 Usage

For usage patterns for the heaters as for the different user groups differ. For private swimming pools there is a trend towards higher share that are heated but at on the opposite concerns regarding the energy (and water) consumption. The latter resulting in smaller swimming pools, more efficient heating and e.g. increased use of pool covers[326].

9.3.1 Heating season

For residential pools that are equipped with heating the purpose of the heating normally is to expand the pool season, not to have all-year round pool season in cold climates. The duration of the outdoor swimming pool season varies from about 4 months in colder climates to year-round in warmer climates. The same assumption is applied for public outdoor swimming pools. Based on this an average operating time of 6 months per years is estimated for outdoor swimming pools in the EU.

[326] https://www.piscine-global-europe.com/fr/blog/2018/12/attentes-clients-secteur-piscine

Municipal public pools indoor in swim halls are typically used and heated all year round as are indoor public pools in leisure centers etc. Outdoor municipal pools would rarely be heated, while on the other hand a share of the public pools for leisure centers etc. is assumed to be heated, some of them only during peak season. For the present study an average heating season of 6 months is assumed for the outdoor pools for leisure centers that are heated.

Hotel and similar public pools that are placed indoor are assumed to be heated all year round. Of the pools that are placed outdoor some will be heated all year round, some only in the peak season and some never. For the present study an average heating season on 6 months is assumed for the outdoor pools that are heated.

An overview is presented in Table 99.

Table 99. The assumed average heating season of swimming pools

Category of swimming pool	Heating season
Residential	
Indoor	Full year
Outdoor	6 months
Public	
Pools at hotels, etc. – indoor	Full year
Pools at hotels, etc. - outdoor	6 months
Shared pools in residential multi dwellings, smaller wellness centers etc. – indoor	Full year
Shared pools in residential multi dwellings, smaller wellness centers etc. – outdoor	6 months
Larger pools - municipal – indoor	Full year
Larger pools – fun and leisure centers – indoor	Full year
Larger pools - leisure centers – outdoor	6 months
Larger pools – municipal – outdoor	None

9.3.2 Size of swimming pools - heated volume

Residential pools. According to the French association of pool professionals, Propiscines, an increased awareness on environment and a tendency towards smaller pools which also results in lower energy consumption. The tendency to smaller pools is also driven by increased urbanization leading to smaller gardens (Table 100)[327].

Table 100. The average residential swimming pool dimensions and volume (Propiscines[34])

	1980	2015	2025 Predicted
Pool dimensions	12 x 6 m	8 x 4 m	7 x 3 m
Surface area	72 m^2	32 m^2	21 m^2
Water depth	1,8 m	1,4 m	1,3 m
Volume	130 m^3	45 m^3	27 m^3

[327] Propiscines.fr, www.propiscines.fr/sites/default/files/espace_presse/dp_fpp_conf051119.pdf

For the energy consumption calculations on aggregated levels the 2015 size on 32 m^2 is assumed to be the average size of the 2030 stock.

Smaller public pools. For the category `Smaller public pools at hotels, etc. – indoor´ a typical pool size would be 12.5 m x 5 m with a water depth on 1,35 m[328] leading to a water volume on 84 m^3, which is assumed to be the standard measures for the calculation on energy consumption. Since it has not been possible to retrieve information about the dimensions of other categories of smaller public pools it is assumed that the categories `Shared pools in residential multi dwellings, smaller wellness centers etc.′ and outdoor pools of the same categories in average have comparable dimensions.

Larger public pools. Similar information about dimensions of larger public pools was not possible to retrieve. However, a pool length of 25 meters, in some cases 50 meters, is common for municipal swimming pools. Therefore, the assumptions from the working plan study that the standard pool size is 500 m^2 still seems reasonable. With an average water depth on 1.8 m the basin volume is 900 m^3. Again, the same overall pool dimensions are assumed for indoor and outdoor swimming pools.

9.3.3 Heat and water losses

The purpose of heating swimming pools is to compensate for heat losses. In addition, the pools are losing water due to evaporation, filter washing and other losses. The lost water is replaced with fresh cold water, which will be heated.

Heat loss. BSW estimates that outdoor swimming pools that are not covered lose 1 - 3 °C per day[329], Ausgrid estimate the loss to 3 °C depending om position of the pool, wind, solar and excess temperature[330]. Both sources inform that pool covers will reduce the heat losses with 50 %. Pool covers are the most commonly applied equipment for pools and 86 % of all private pools (in FR) are covered according to Propiscines[331]. For indoor hotel pools a typical temperature loss is estimated at 1.5 °C [332], and this is assumed to be the case for all other categories of indoor swimming pools in average. For other categories of outdoor swimming pools than residential pools, pool covers are not assumed being used, due to the higher number of users and longer usage time than for residential swimming pools.
Based on these assumptions the average daily heat loss for heated outdoor residential swimming pools is 2 °C, the average daily heat loss is 3 °C for all other outdoor swimming pools, and for all indoor pools it is 1.5 °C / day.

Water losses. Swimming pools loses water to evaporation, general losses during use – overflow etc. and in some cases for backwashing of filters. For these study it is assumed that backwashing is done by means of tap water and not reflux from the pool. The fill water for replacing the evaporated water and other losses is typically 10 °C which means it will automatically be heated to the required water temperature on 26 – 30 °C in heated swimming pools a temperature raise om 16 to 20 °C.

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[328] Hotel & Spa 2019, Pool Spa Technik Für Hotels - Sonderheft von SCHWIMMBAD+SAUNA und Spa & Home, Fachschriften Verlag, Fellbach, Germany, https://www.schwimmbad.de/sonderhefte/

[329] Bundesverband Swimmbad & Wellness e.V (2009), Heat and water losses, BSW Energieguide

[330] Ausgrid (2015), Pool/Spa 2015/16 Guideline, Swimming pool efficiency

[331] https://www.piscine-global-europe.com/fr/blog/2018/12/attentes-clients-secteur-piscine

[332] Hotel & Spa 2019, Pool Spa Technik Für Hotels - Sonderheft von SCHWIMMBAD+SAUNA und Spa & Home, Fachschriften Verlag, Fellbach, Germany, https://www.schwimmbad.de/sonderhefte/

For an average **residential pool** (45 m^3) Propiscines estimate water losses on 15 m^3 per year[333] or 82 liter per day. Indoor pools are in more shallow areas with no wind and higher air humidity but on the other hand with warmer ambient air. For this study equal water losses are assumed for indoor and outdoor residential heated pools.

For **larger swimming pools** Kershaw & Fitzsimmons[334] calculate that a typical indoor swimming pool, i.e. water temperature on 28 °C in a swim hall with an air temperature on 29 °C, loses between 0,31 and 0,17 kg water per m^2 per hour due to evaporation depending on the relative humidity in the air; which in this case is in the range 50 to 70 %. This is assumed to be the case for all public indoor pools.

The calculated heat losses, sizes and water losses for the different categories based on the above findings and assumptions are presented in Table 101.

Table 101. Estimated heat and daily water losses for different swimming pools

Category of swimming pool	Heat loss [°C / day]	Average volume [m^3]	Average surface [m^2]	Water loss [l / day]
Residential				
Indoor	1.5	45	32	82
Outdoor	2	45	32	82
Public				
Pools at hotels, etc. – indoor	1.5	84	62.5	300
Pools at hotels, etc. - outdoor	3	84	62.5	300
Shared pools in residential multi dwellings, smaller wellness centers etc. – indoor	1.5	84	62.5	300
Shared pools in residential multi dwellings, smaller wellness centers etc. – outdoor	3	84	62.5	300
Larger pools - municipal – indoor	1.5	900	500	2400
Larger pools – fun and leisure centers – indoor	3	900	500	2400
Larger pools - leisure centers – outdoor	1.5	900	500	2400
Larger pools – municipal – outdoor	3	900	500	2400

9.4 Technologies

For pools that are heated a part of the year, there are potential energy savings from converting to more efficient heating equipment. The most common technologies with the highest improvement potential for heating efficiency compared to the electric resistance heaters are:

- high-efficiency natural gas heaters
- heat pumps
- solar absorbers

[333] Propiscines.fr, www.propiscines.fr/sites/default/files/espace_presse/dp_fpp_conf051119.pdf

[334] T. Kershaw & J. Fitzsimmons, Swim4Exeter (2013), Modelling Low Energy Swimming Pools Adapted to Climate Change. https://issuu.com/gale-snowden/docs/pool_modelling_paper_v2

- heat exchangers linked to a heating source or heating system.

Which of the technologies that is the best depends on the system and use patterns. Solar thermal systems and heat pumps are good at keeping a pool within a set temperature range for a long period of time, but especially the solar heaters are very sensitive to climate variability. Natural gas heaters are often preferred for pools that require occasional rapid heating[335]. Historically also oil heaters have been used, however they seem to have disappeared from the market.

All pool heaters depend on the following functions from the pools' water handling system[336]:

- Skimmer and filter which removes dirt before the pool water is pumped through the heater
- A pump which circulates the pool water through the filter and heater
- A flow–control valve that diverts pool water through the heater.

While pool pumps are often integrated in and marketed with a pool pumping package solution with water treatment like a water filter and a chlorination unit and controls, similar package solutions are not found for the heaters. Swimming pool heaters are marketed solely as pool heaters that are added to the existing water treatment system with no additional functionalities except timer and controls.

Material properties. One significant technical characteristic for pool heaters is their ability to resist the highly corrosive chlorinated water in swimming pool. Therefore, pool pumps are configured with corrosion resistance materials, particular for the heat exchanger transferring heat from the heater to the pool water. This could be by using a semi-resistant material. which is coated with a protective surface or by using highly resistant materials. For this purpose titanium heat tubes or coiled titanium tubes in a UV and chlorine resitance plastic lining are solutions which is gaining market.

The choice of materials and technology for the heat exchanging is esential for the heaters heat transfer properties and efficiency. Again, the properties of titanium exchangers are rather ideal in-spite of the higher material costs. Solutions with protective coatings all results in lower heat tranfer efficiency and the same goes all other traditional materials. The lower efficiency could to some extend be compensated by larger surfaces for the heat transfer, but that impacts the volume and materials consumption – and thereby also the price[337].

9.4.1 Gas heaters

Gas heating is one of the quickest heating methods for pools and spas and particular relevant for pools that are only heated occasionally. When used for more permanent heating

[335] Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory for U.S. Department of Energy (2015), Technical support document: Energy efficiency program for consumer products and commercial and industrial equipment: Pool heaters

[336] Ausgrid, Pool/Spa 2015/16, Swimming pool efficiency, https://www.ausgrid.com.au/-/media/Documents/energy-use/Swimming-pool-efficiency

[337] Eileen Eaton, January 2013, CEESM High Efficiency Residential Swimming Pool Initiative

of a pool they are relative expensive – although still less costly than electric resistance heaters. At least in the US it is also the most popular pool heater technology[338].
Gas heaters uses natural gas or propane gas (from bottle).

The market research performed for the present task found that condensing boilers are available but only limited and most gas heaters for swimming pools are non-condensing. The operating conditions – low temperature and high liquid volumes – however indicates that swimming pool heating should be ideal for condensing technology (more about that below).

The thermal efficiency of gas swimming pool heater is in the range from 60 % to 95 % for the most efficient condensing heaters. However, the high-efficient heaters are not widely available, perhaps because of lack of awareness of the benefits.

70 % thermal efficiency is assumed as the average. Since the gas pool heater technology is an old product type and the thermal efficiency of the group does seem to develop significantly without policy measures the thermal efficiency is not assumed to develop in a BAU scenario.

Regulation (EU) No 813/2012 on space heaters requires that the seasonal space heating energy efficiency does not fall below 75 % for B1 (= non-condensing) boilers. For condensing boilers, the required useful efficiency at 100 % of the rated heat output is that it shall not fall below 86 %, and at 30 % of the rated heat output it shall not fall below 94 %[339]. Since the operating conditions are more favorable for swimming pool heaters than for space heaters (as explained below), these threshold values should be equally or more possible to reach for swimming pool pumps.

The review study on space heaters studied the impact of lo return temperatures on condensing boilers efficiency[340]. One conclusion is that condensation will take place from return temperatures below 56 °C and that max efficiency thereby is raised from 87 % and up to 97 % when the return temperature approaches room temperature. This could be the case for swimming pool heaters which are characterized by a large heat sink at low temperatures (with maximum temperatures typically being 30 °C).

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[338] Energy Saver, U.S. Department of Energy, Gas Swimming Pool Heaters, https://www.energy.gov/energysaver/gas-swimming-pool-heaters

[339] COMMISSION REGULATION (EU) No 813/2013 of 2 August 2013implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters

[340] Rob van Holsteijn, René Kemna & Martijn van Elburg (all VHK), Review Study existing ecodesign & energy labelling Space Heaters & Combination Heaters, Task 4, Final, July2019, https://www.ecoboiler-review.eu/Boilers2017-2019/downloads/Boilers%20Task%204%20final%20report%20July%202019.pdf

Figure 28. Example of a condensing boiler for pool heating with a declared thermal efficiency of 94 %[341].

Gas pool heaters are available with capacities ranging typically from 20 to more than 100 kW.

9.4.2 Heat pump heaters

Electric heat pumps are except for solar heating the most energy efficient techology for pools, especially for swimming pools where a more constant temperature is desired and when they are more constantly heated.

The energy efficiency of heat pumps is declared as a COP at a specific set of air and water temperatures and eventually corresponding relative humidity. As explained in 9.1 in the standards section heat pumps are typically measured at 27 °C water temperature and 15 °C (cold) respectively 27 °C (warm) ambient air temperature.

The COP typically is in the ranges from 4.0 to 6.0 (= 400 - 600 % efficiency), although for the smallest heat pumps COPs down to 3.5 are relatively common.

Heat pump heaters are found with on-off compressor technology or inverter technology adapting the compressor to the use and avoiding inefficient start/stop operation. Inverter heat pumps typically has higher efficiency and an increasing share of heat pumps, including for swimming pool heating, has inverter control. Another development is the ability to perform at lower temperatures below zero even with decent COPs and additionally smaller heat pumps with good performance are developed (Figure 29).

[341] https://www.ukpoolstore.co.uk/acatalog/Genie_Condensing_Gas_Boiler.html

Figure 29. Example of a plug'n play compact pool heat pump with a capacity on 2,3 - 2,9 kW (at T_{air} 15 - 26°C and T_{water} 26°C) for small swimming pools up to 20 m^3or spas. It's corresponding COP is 3,9 – 5 and it measures 385 x 400 x 280 mm [342].

The most common swimming pool heat pump type is the air to water heat pump but especially for larger swimming pools in colder climates (ground) ground source to water heat pumps are availble, although in limited numbers since the installation is expensive and since air to water heat pumps are constantly developing to be more efficient also at low air temperatures. Ground source heat pumps are mainly relevant for medium sized and larger public swimming pools.

Other heat pump technologies like gas or electric heated absorption heat pumps excist. No examples of these other heat pump technologies were found on the marked for pool heaters.

Supplier and dealer product catalogues from DE, DK, FR and NL has been reviewed (2020) for an initial screening of the market for swimming pool heaters; heat pumps as well as resistance heaters. Heat pump swimming pool heaters are widely available from 2.5-3 kW and up to 15-20 kW. The higher the capacity, the more likely is the product with inverter technology. Figure 30 plots a number of randomly selected product models. The inverter heat pumps (variable heating capacity) are plotted with their average performance (e.g. heating capacity 8 – 12 kW and COP 4 – 8 will be plotted as 10 kW / COP 6), so in reality more of the heat pumps that are plotted in the capacity range 8 to 17 kW are capable of providing heating outputs that are both lower and higher.

[342] https://www.poolex.fr/en/produit/swimming-pool-heat-pump-poolex-nano-turbo-3kw

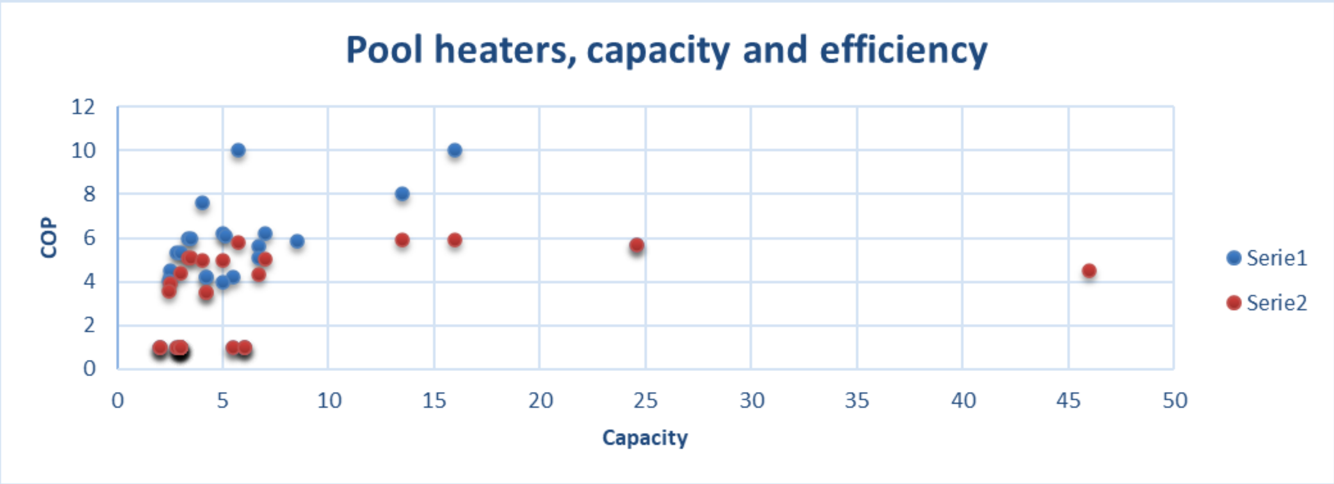

Figure 30. Examples of pool heaters (heat pump and electric resistance - with COP1); capacity and COP at low air temperature (15 °C, Serie1) and high (26-28 °C, Serie2).

As presented in Table 85 the NF Mark requires a minimum COP on 4,2 at 15 °C air temperature. As seen in the plot most of the medium sized and all the larger heat pumps for this review comply.

Heat pumps for swimming pool heating benefit from the low temperature difference between ambient and the heat sink (i.e. swimming pool).

A COP on 4.0 is estimated as the average efficiency of heat pump pool heaters in 2020 and the development without policy measures is assumed to go towards lower prices and higher market share of the heat pumps, but same average energy efficiency in average since more small heat pumps (with lower efficiency) are also expected.

Particularly for heat pumps noise should be considered as well. The NF Mark also applies maximum limits on the sound power levels of swimming pool heat pumps (Table 86). From 10 kW and below the limit is 70 DB(A) and in the range from 10 to 20 kW (incl.) the requirements is ≤ 73 dB(A). The suppliers of the reviewed heat pumps declared the sound power levels for about half of the products. In these cases the products sound power were ranging from 40 to 65 dB(A) - far below the NF threshold values.

9.4.3 Electric resistance heaters

Electric resistance pool heaters are the cheapest heaters to install and the most costly and inefficent heaters to use. Possible improvement potentials are related to the controls – timers, bypass when not being used etc. While the heating technology itself has no improvement potential. A thermal efficiency on 100 % is estimated now and in the future for this product group – before conversion and grid losses.

Electric heaters are avaiable in basically all capacities up to higher two digits. For residential applications however they are typically marketed for for spas (primarily) and small pools and in capacities ranging from 2 to 3 kW although up to 6 kW are also seen (Figure 30). Higher capacities thans that seems to be more rare and to be purchased from specialty manufacturers directly.

A related product is a electric immersion heater, which is more commomnly used for process tank or bucket heating than for pool heating, and this product woould not be considered safe for use in a pool were users could be risking to come in direct contact with the heater.

9.4.4 Solar heaters

Solar collectors for pool heating are the most cost-effective use of solar energy in many climates and they are cost competitive with both gas and heat pump pool heaters with relatively low installation costs as well as very low annual operating costs and the energy consumption is considered to be insignificant compared to other heating technologies for the calculations of total energy consumption of the stock. Solar heaters could be combined with other heaters as a hybrid system.

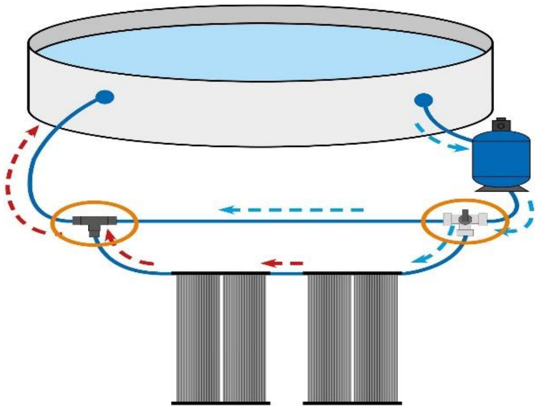

Figure 31. Example of a small solar heater and configuration diagram (Steinbach Technik[343]).

The energy consumption is very low, since the absorber normally would supplied from the filter pump flow[344] and the pressure loss in the absorber is low. A specific component particularly important for solar heaters is the application of a manual or an automatic bypass when there is no solar radiation. This is to avoid:

- thermal radiation losses from the solar collector, otherwise it will function as pool cooler. This could by the way also be a desired effect in hot climates.
- the pressure loss from the water flow through the pool heater.

Figure 31 shows an example of such a configuration.

Some systems include sensors and an automatic or manual valve to control the water flow through the collector(s) depending on the collector temperature.

Solar absorbers heat the pool water directly as the flow goes through the absorber. For usages at temperatures above freezing, an unglazed collector system would normally be suitable for residential applications. The constructions and materials vary from basic to high-end. The most inexpensive are foldable UV protected black rubber mats with tubing

[343] Steinbach Technik https://www.amazon.de/Speed-Solar-Pools-Wasserinhalt-Schlauchanschluss/dp/B003AQTJSA?ref_=ast_sto_dp
[344] [344] Bundesverband Swimmbad & Wellness e.V (2009), Heat and water losses, BSW Energieguide

as collectors for laying on a lawn or a carport roof and black metal tube and plate collectors are the step better.
Glazed collectors with frost resistance and as the top solar heating product collectors in vacuum tubes are also used for heating pool water, but these products use their own liquid circuit being connected to the pool water flow via a heat exchanger. The last two are also used in larger scale for public swimming pools and.

9.4.5 Controls

The controls influence the energy consumption and costs of heating.

Accurate temperature control is important to control the heat losses since excess temperatures above the desired temperature will increase the energy consumption.

Day and week timers also could improve the energy costs and consumption. For a preparatory study it would be relevant to look at the energy consumption for heating depending on the use patterns. One question also could be to evaluate the temperature fluctuation from the cooling due to heat losses and heating cycles to obtain comfort temperatures.

Specifically for electric heating including electric heat pumps it should be possible to react on peak price. This requires timer controls or smart controls which adapts to grid peaks and price signals e.g. from a smart meter as specified in the Australian smart appliance standard `AS/NZS 4755.3'[345].

For the hydraulic system use of an automatic bypass so that the water flow is not led through pool heaters when they are not heating could also reduce the pumping energy.

9.4.6 Spa heaters

For spas electric resistance heaters are the primary heating technology. Spa heaters are often integrated in the spa with resulting space constraints and the spa is supplied with the heater by the manufacturer of the spa. Although the space is limited, it could be considered to evaluate if the smaller heat pumps (e.g. Figure 29) could be feasible for such applications.

Navigant and Berkeley conclude in the TSD for DOE that electric heaters up to 11 kW are used for spas[346]. A brief market research in European supplier catalogues indicated that in EU more typical values is up to 3 kW for the larger residential spas with around 1.5 m^3 water volume.

Spa heaters are sold as spare parts for has integrated heating, but there also seems to be is some overlap with plug'n play swimming pool heaters for an external water heating circuit.

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[345] Standards New Zealand 2016, AS/NZS 4755.3 Australian/New Zealand Standard Demand response capabilities and supporting technologies for electrical products, Part 2 – Swimming pool pumps, shop.standards.govt.nz/catalog/4755.3.5:2016(AS%7CNZS)/scope

[346] Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory for U.S. Department of Energy (2015), Technical support document: Energy efficiency program for consumer products and commercial and industrial equipment: Pool heaters

In a preparatory study it is recommended to address the risk of loopholes by not including spa heaters.

9.4.7 Weight and material composition

The average weight and material compositions (Bill of Materials – BoM) of the different products were estimated in the preparatory study. These data are presented in the following tables.

Swimming pool gas heaters weight 36 to 115 kg (average 75 kg). Assumed BoM is found in Table 102.

Table 102: Assumed BoM of swimming pool gas heater

Material	Share [%]	Weight [kg]
Plastics	8.0%	6.0
Steel – galvanized	62.1%	46.6
Cast iron	2.6%	2.0
Ins. Ceramic	1.8%	1.4
Stainless steel	5.9%	4.4
Aluminium die cast	4.3%	3.2
Copper	9.4%	7.1
Brass	3.6%	2.7
Electronics	1.5%	1.1
Others	0.8%	0.6
Total	100.0%	75.0

The lifetime of swimming pool heaters has been analysed in the TSD from US Department of Energy (DoE) [347]. It concluded that the expected lifetime for swimming pool gas heaters is typical 5 years or more which corresponds nicely with the 7.5 years assumed in the working plan study.

Swimming pool heat pumps weight 55 to 145 kg (average 100 kg). A simplified assumed BoM is found in Table 103. Since the preparatory study and the VHK preparatory study[348] was performed, titanium heat coils have been standard for swimming pool heat pumps. The materials table below is updated with 2 kg titanium which is assumed corresponding to the cupper tubes it replaces.

Table 103: Assumed BoM of swimming pool heat pumps

Material	Share [%]	Weight [kg]
Steel	85%	83
Titanium	2%	2
Plastics	14%	14
R410a refrigerant	1%	1
Total	100%	100

[347] Energy Saver, U.S. Department of Energy, Gas Swimming Pool Heaters, https://www.energy.gov/energysaver/gas-swimming-pool-heaters

[348] VHK (2007), Ecodesign Preparatory Study on water heaters - Task 5 final report.

The lifetime was analysed in the DoE's TSD and it concluded that the expected lifetime for swimming pool heat pumps is around 10 years[349].

Swimming pool electric heaters weight 4 to 12 kg (average 8 kg). Assumed BoM is found in Table 104.

Table 104: Assumed BoM of swimming pool electric heater

Material	Share [%]	Weight [kg]
Plastics	24.2%	1.9
PA6	24.8%	2.0
Steel - galvanised	3.8%	0.3
Stainless steel	3.6%	0.3
Copper	14.0%	1.1
Brass	10.5%	0.8
Electronics	9.1%	0.7
Others	10.0%	0.8
Total	100%	8.0

Swimming pool electric heaters have an average life time 3 to 6 years (average 4.5)

The BoM of a typical solar water heating system[350] was been assumed applicable for swimming pool solar heaters too (Table 105).

Table 105: Assumed BoM of swimming pool solar heater.

Material	Weight [kg]
Heated glass	12
Copper	5
Aluminium	11
Steel	40
Polyurethane	7
Fibre glass	5
EPDM	2
Total	82

Swimming pool solar heaters have an average lifetime of 10 to 15 years (average 12,5).

9.4.8 Market share

No stock or market data indicating the share of the different swimming pool heater types was retrieved. The 2015-17 WP prep study [REF] assumed based on a US study from 1997[351] and market interpretation and projections for EU that solar heaters are thought to have a on 30% (increasing from 20 % in 1997 to 30 % in 2020).

[349] Energy Saver, U.S. Department of Energy, Gas Swimming Pool Heaters, https://www.energy.gov/energysaver/gas-swimming-pool-heaters

[350] C Koroneos, E Nanaki (2012), Life cycle environmental impact assessment of a solar water heater.

[351] Bill Quam (1997), A Marketing Analysis of SolarAttic Inc

The remaining 70 % were divided equally between heat pumps, gas and electrical resistance heaters. Based on the market research for the current study the 30 % solar heaters seems reasonable, they share might continue to increase but potentially in hybrid units with other heaters, heat pumps or electric heaters potentially giving a kind of a rebound effect with more heated pool, so for the calculations below their share is considered to be constant 30 %.
The gas heaters used to be the most common heater type and a few dealers still refer to them as so. However the majority of the dealers and suppliers in the pool business focus on heat pumps, and to some extend small electric heaters. Since the electric heaters are small, their relative share of the heating capacity will be even lower. According to Propiscines and several pool and pool equipment suppliers heat pumps are by far the most common swimming pool heater technology. One (French) professional pool installer mentions that 90 % of all heaters (he installs, probably) are heat pumps[352]. However, France is a country with high degree for electrification for heating, and other EU countries have higher shares of gas heaters for other heating purposes. In spite of that the conclusion is that heat pumps are the most dominating pool heating technology and that it seems to be increasing. Based on these observation, the assumed market share of the heating capacity is 30 % for solar heaters, 20 % for electric heaters, 20 % for gas heaters and 30 % for heat pump heaters in 2020. It is also assumed that the share of heat pumps will continue to grow, with on percentage point yearly to 40 % in 2030, if no policy measures are taken.

Table 106: Assumed market share of the different swimming pools heating technologies

Material	2020 [%]	2030 [%]
Electric resistance	20	15
Gas	20	15
Electric heat pump	30	40
Solar absorber	30	30
Total	100%	100

The above assumptions are considered to be valid for all categories of swimming pools including the large.

A dark horse in this is the share of swimming pools heated via heat exchanger e.g. supplied via the central heating system, district heating or CHP. For a potential preparatory study, it is recommended to consider the heat sources for large public pools are of different nature, are they e.g. connected via heat exchangers to central heating systems of buildings or to ground source heat pumps or gas heaters? These heaters may already be covered by the existing regulation 813/2012 on space and combination heaters. If not, there could be a risk of loop hole should swimming pool heaters be subject to ecodesign requirements.

9.5 Energy and Emissions

The daily and yearly energy losses for the different categories of swimming pools based on the estimated daily temperature compensation and evaporative losses (Table 101) are presented in Table 107.

[352] Propiscines.fr, www.propiscines.fr/sites/default/files/espace_presse/dp_fpp_conf051119.pdf

Table 107. Estimated energy losses per average swimming pool in each category

Category of swimming pool	Energy loss from cooling [MJ/day]	Energy loss from heating fill water[1)] [MJ/day]	Heating season [months]	Total energy need per pool MWh/year
Residential				
Indoor	282	5.8	12	29
Outdoor	376	5.8	6	19
Smaller public				
Pools at hotels, etc. – indoor	527	21.3	12	55
Pools at hotels, etc. - outdoor	1054	21.3	6	54
Shared pools in residential multi dwellings, smaller wellness centers etc. – indoor	527	21.3	12	55
Shared pools in residential multi dwellings, smaller wellness centers etc. – outdoor	1054	21.3	6	54
Larger public				
Larger pools - municipal – indoor	5646	170.6	12	581
Larger pools – fun and leisure centers – indoor	11291	170.6	12	1146
Larger pools - leisure centers – outdoor	5646	170.6	6	291
Larger pools – municipal – outdoor	11291	170.6	0	0

1) Tap water heated from 10 to 27 °C

Heat capacity water (20 C): 4,182 kJ/(kg*K) ~ 4,18 kJ/(l*K). Conversion kWh/MJ: 1 MJ = 0,2778 kWh

The calculations of energy consumption and emissions from different heat sources and are based om Table 107.

Table 108. Energy consumption (final energy) of the stock for retaining temperature and compensating for the heating of evaporated water.

Category of swimming pool	Total energy need per pool [MWh/year]	Stock of heated pools [1000 units]		Total energy consumption of stock, final energy [TWh/year]	
		2020	2030	2020	2030
Grand total		**3430**	**3620**	**92**	**98**
Residential		**3365**	**3426**	**71**	**72**
Indoor	29	673	685	19	20
Outdoor	19	2692	2741	51	52
Smaller public		**121**	**165**	**7**	**9,0**
Pools at hotels, etc. – indoor	55	44	54	2.4	3.0
Pools at hotels, etc. - outdoor	54	22	27	1.2	1.5
Shared pools in residential multi dwellings, smaller wellness centers etc. – indoor	55	37	55	2.0	3.0
Shared pools in residential multi dwellings, smaller wellness centers etc. – outdoor	54	18	28	1.0	1.5
Larger public		**22**	**26**	**15**	**17**
Larger pools - municipal – indoor	581	7.4	7.4	4.3	4.3
Larger pools – municipal – outdoor	0	0	0.0	0	0.0
Larger pools – fun and leisure centers – indoor	1146	7.4	9.1	8.4	10.4
Larger pools - leisure centers – outdoor	291	7.4	9.1	2.1	2.6

Table 109 summarizes the typical pool heaters energy efficiency in 2020 and 2030 as found in section 9.4 on technologies. Two alternative scenarios are suggested:

- S1: Stricter requirements to
  - Gas heaters corresponding to a best practice for non-condensing boiler
  - Heat pumps corresponding to the NF Mark for 15 °C
  - No requirements to electric heaters and solar heaters
- S2: Stricter requirements to:
  - Gas heaters corresponding average (at 100 % and 30 % of rated) for condensing boiler in regulation (EU) No 813/2012
  - Heat pumps corresponding to the NF Mark for 15 °C
  - Electric heaters which in practice will not allow this product
  - No requirements to solar heaters

The efficiencies related to final energy are converted to efficiency values for primary energy using the conversion factor 2.1 for electricity and a conversion factor on 1 for natural gas.

Table 109. Average efficiency of swimming pools heaters; 2020, 2030 BAU, S1 and S2. Conversion coefficient to primary energy for electricity: 2.1

Heater type	2020 [%]	2030 (BAU) [%]	2030 (S1) [%]	2030 (S2) [%]	Converted to primary energy			
					2020 [%]	2030 (BAU) [%]	2030 (S1) [%]	2030 (S2) [%]
Electric resistance	100	100	100	-	48	48	48	48
Gas	70	70	80	90	70	70	80	90
Electric heat pump	400	400	420	420	190	190	200	200
Solar absorber	-	-	-	-	-	-	-	-

Table 110 shows projected market share by different scenarios compared to BAU, assuming that in Scenario 2 (S2), all electric heaters will be converted to heat pumps and the resulting CO_2 emissions per kWh final energy. Hereby a weighted CO_2 emission factor is found for the later calculations.

Table 110. Weighted efficiency of electric, gas and heat pump swimming pools heaters based on the assumed average efficiency and market share (BAU 2030, S1 and S2) and corresponding CO2 emissions per consumed kWh (final energy)

Heater type	Market share				CO2 emission based on efficiency and market share [kg CO_2/kWh]			
	2020 [%]	2030 (BAU) [%]	2030 (S1) [%]	2030 (S2) [%]	2020 [%]	2030 (BAU) [%]	2030 (S1) [%]	2030 (S2) [%]
Electric resistance[1)]	20	15	15	0	0.076	0.057	0.057	0.000
Gas[2)]	20	15	15	15	0.058	0.043	0.038	0.034
Electric heat pump[1)]	30	40	40	55	0.029	0.038	0.036	0.050
Solar absorber	30	30	30	30	0.000	0.000	0.000	0.000
Total					0.162	0.138	0.131	0.083

[1)] CO_2 emission factor EU electricity [kg CO_2/kWh] 2020: 0.380; 2030: 0.340[353]

[2)] CO_2 emission factor natural gas: 56,1 ton CO_2/TJ on a Net Calorific Basis ~ 0,202 kg CO_2/kWh heat from natural gas[354]

Table 111 gives the estimated energy consumption and savings potentials on the total stock in primary energy (TWh) based on a 100 % conversion of the stock according to the scenarios and compared to BAU.

Note that some swimming pools, especially the indoor and the large public pools are heated via heat exchangers. As explained in section 9.4.8 that means that it is not possible to estimate the improvement potential without specific analysis of these installations.

Table 111. CO2 emissions and improvement potential for the scenarios S1 and S2

Category of swimming pool	CO_2 emissions [kt CO_2/year]	Improvement potential, CO_2 emissions [kt/year] vs BAU	Improvement potential, Primary energy consumption [%] vs BAU

[353] Source EIA

[354] IPPCC, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, vol. 2, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

	2020	2030 (BAU)	2030 (S1)	2030 (S2)	2030 (S1)	2030 (S2)	2030 (PS1)	2030 (PS2)
Grand total	**11484**	**9968**	**9448**	**6014**	**520**	**3954**	**5**	**40**
Residential	**11484**	**9968**	**9448**	**6014**	**520**	**3954**	**5.2**	**40**
Indoor	3143	2729	2586	1646	142	1082	5.2	40
Outdoor	8340	7239	6862	4368	378	2872	5.2	40
Smaller public	**1068**	**1239**	**1174**	**747**	**65**	**491**	**5.2**	**40**
Pools at hotels, etc. – indoor	392	411	390	248	21	163	5.2	40
Pools at hotels, etc. - outdoor	192	202	191	122	11	80	5.2	40
Shared pools in residential multi dwellings, smaller wellness centers etc. – indoor	325	420	398	253	22	167	5.2	40
Shared pools in residential multi dwellings, smaller wellness centers etc. – outdoor	159	206	195	124	11	82	5.2	40
Larger public	**2410**	**2392**	**2267**	**1443**	**125**	**949**	**5.2**	**40**
Larger pools - municipal – indoor	694	592	561	357	31	235	5.2	40
Larger pools – municipal – outdoor	0	0	0	0	0	0	0.0	0
Larger pools – fun and leisure centers – indoor	1368	1436	1361	866	75	570	5.2	40
Larger pools - leisure centers – outdoor	347	364	345	220	19	145	5.2	40

Heat capacity water (20 C) 4,18 kJ/(l*K). Conversion: kWh/MJ 0,277778

CO_2 emissions kg/kWh for the heating of swimming pools based on the overall mix of heating technologies and corrected for the projected CO_2 emission factors for 2020 and 2030 (see Table 110) is presented in Table 111.

9.6 Saving potential

In total, scenario 1 provides an improvement potential on 3.9 TWh/year and scenario 2 on 17.6 TWh/year, hereof the 12.9 TWh/year alone from the residential swimming pool heaters, see Table 112.

Table 112. Total energy consumption and saving potential for scenario 1 and 2.

Category of swimming pool	Total energy consumption (stock) TWh/year	Improvement potential. Primary energy consumption [TWh/year] vs BAU		Improvement potential. Primary energy consumption [PJ/year] vs BAU	
		2030 (S1)	2030 (S2)	2030 (S1)	2030 (S2)
Residential	**72.1**	**2.9**	**12.9**	**10.4**	**46.5**
Indoor	19.7	0.8	3.5	2.8	12.7
Outdoor	52.4	2.1	9.4	7.5	33.8
Smaller public	**9.0**	**0.4**	**1.6**	**1.3**	**5.8**
Pools at hotels, etc. – indoor	3.0	0.1	0.5	0.4	1.9
Pools at hotels, etc. - outdoor	1.5	0.1	0.3	0.2	0.9
Shared pools in residential multi dwellings, smaller wellness centers etc. – indoor	3.0	0.1	0.5	0.4	2.0
Shared pools in residential multi dwellings, smaller wellness centers etc. – outdoor	1.5	0.1	0.3	0.2	1.0
Larger public	**17.3**	**0.7**	**3.1**	**2.5**	**11.2**
Larger pools - municipal – indoor	4.3	0.2	0.8	0.6	2.8
Larger pools – municipal – outdoor	0.0	0.0	0.0	0.0	0.0
Larger pools – fun and leisure centers – indoor	10.4	0.4	1.9	1.5	6.7
Larger pools - leisure centers – outdoor	2.6	0.1	0.5	0.4	1.7
Total	**98.3**	**3.9**	**17.6**	**14.1**	**63.4**

The options which could bring these savings are

- Higher efficiency for gas heaters than those from the ecodesign requirements for space heaters but still possible to reach for non-condensing boilers, considering that

operating temperatures are more optimal for swimming pool heaters that for space heaters.
- Or higher efficiency for gas heaters using condensing boilers
- Higher efficiency for electric heat pumps corresponding to the French NF mark
- Or higher efficiency for all electric heaters corresponding to the to the French NF mark for pool heat pumps. This will displace electric resistance heaters. For other heating appliances this has not been desired in order to keep simple and cheap (in purchase price) products in the market. But having in mind that swimming pools them-self are luxury products this argument is less relevant.

Other parameters and additional measures which are not considered in the current study but could be relevant to consider are;

- energy labelling e.g. on products with heating capacity up to 50 kW, since the major part of the products and their energy consumption is related to residential use. This option could also promote solar absorbers and potentially hybrid heaters e.g. solar absorber in combination with heat pump via a package label.
- best available technology scenarios for heat pumps as well. The approach of the current study is relatively conservative regarding heat pumps, focusing on replacing the most consuming heater technologies.
- measures related to heat exchanger pool heaters and their heat sources and potential double regulation or loop holes.
- Other environmental parameters like NO_x emissions from gas boilers and noise from heat pumps.
- Pool and spas could be required to be able to respond to smart meters and peak or price signals

9.7 Stakeholder comments

Comments were received from the following stakeholders:

- ANEC and BEUC
- BAM and UBA
- Danish Energy Agency
- EPEE – European Partnership for Energy and the Environment

The following comments were provided; the study team's answers are provided where relevant:

ANEC and BEUC welcome the recommendation of the study team to consider energy labelling with heating capacity up to 50 kW, as we consider these are the most common heaters used in the private/residential sector.

BAM and UBA ask to include outdoor municipal swimming pools for the case that they are heated. (It is ok to omit them from the preliminary analysis.): The study team agrees and has adjusted the text accordingly.

Danish Energy Agency asks if bio-fueled heat sources considered in this report: They have not been considered and the study team is not aware of commercial dedicated swimming pool heaters using bio-fuels. This may be assessed if a preparatory study will be launched.

EPEE – European Partnership for Energy and the Environment agrees with the study team and supports including swimming pool heaters, provided heaters do not eventually risk double-regulation, when products are already covered by existing Ecodesign requirements: The study team did not identify any risk of double-regulation during the assessments.

Additionally, a few factual comments were provided resulting in minor adjustments in the text.

10 AIR CURTAINS

10.1 Scope, policy measures and test standards

Air curtains are products, which creates a uniform stream of directed air, heated or unheated, across an opening to create a barrier inhibiting the transfer of heat and particulate matter from one zone to the other.

An appropriately designed system will create this barrier across the entire height and width of the opening to create the effects air curtains discharge a controlled flow of (warm/cold) air across an opening to create an air seal that separates different climatic environments, e.g. store entrances. While allowing unhindered and unobstructed passage through the opening, air curtains help preserve the indoor temperature by forming a barrier to resist the ingress of outdoor air. Although air curtains do contribute to the heating of space, their primary function is a thermal replacement for a door.

Air curtains are typically used in commercial and industrial buildings to create an air seal between different climatic environments, e.g. shop entrances. Typically, lower power capacities (3 – 24 kW) of air curtains are for public and commercial buildings, whilst bigger openings found in factories and warehouses require higher power capacities (12 -50 kW).

According to ISO 27327-1 'Laboratory methods of testing for aerodynamic performance rating', an air curtain unit is: "Air-moving device which produces an air curtain airstream" Where an air curtain airstream is: "Directionally-controlled airstream, moving across the entire height and width of an opening, which can reduce the infiltration or transfer of air from one side of the opening to the other and/or inhibit the passage of insects, dust and debris".

Overall, there are five types of air curtains, which are presented in Table 113.

Table 113: Types of air curtains and a short description

Product category	Description
Ambient only	The unit has no heating or cooling function but still reduces the infiltration or transfer of air from one side of the opening to the other by an air stream
Electrical heated units	The unit has an integrated electrical heating element
Hydronic coil units	To supply the coil with hot/cold water or steam, there must be an external power source such as, for example, a local boiler, district heating/cooling or a chiller.
Direct expansion heat pump coil units	Heat pump based air curtains: A direct expansion heat pump is a heat pump connected to the refrigerant circuit. The heat exchanger in the air curtain will work as a condenser and/or evaporator, depending if heated or chilled air is required.

Direct electrical heated air curtains were assessed as a base case in the 2012 preparatory study of local space heating products, but not included in the regulation due to low sales. Air curtains were once considered again during the review study (2019) but it was concluded that:

”From a technical point of view, the focus on its primary purpose to establish an “air wall” or “air door” would require potential policy measures more related to effectively establishing air streams and to the prevention of transmission and ventilation losses, rather than to the heating function itself”

Of relevant regulations, standard and other initiatives, the following are considered relevant for the products in scope:

a) Regulations

Air curtains are not currently covered by any regulation. However, the external heat or cooling source is covered by one of the following regulations:

1. Commission Regulation (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters. The Ecodesign Regulation covers products with a rated output up to 400 kW, the Energy Labelling Regulation covers products with a rated output up to 70 kW. In both cases, heaters designed for using gaseous or liquid fuels from biomass are excluded. Heaters using solid fuels are also excluded; these are covered by the Ecodesign and Energy Labelling Regulations with regard to solid fuel boilers.
2. Commission Regulation (EU) 2015/1189 of 28 April 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for solid fuel boilers. The Regulation establishes ecodesign requirements for placing on the market and putting into service solid fuel boilers with a rated heat output of 500 kilowatt (‘kW’) or less, including those integrated in packages of a solid fuel boiler, supplementary heaters, temperature controls and solar devices.
3. Commission Regulation (EU) 2016/2281 of 30 November 2016 implementing Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for energy-related products, with regard to ecodesign requirements for air heating products, cooling products, high temperature process chillers and fan coil units. The Ecodesign Regulation covers air-heating products with a rated heating capacity not exceeding 1 MW, cooling products and high temperature process chillers with a rated cooling capacity not exceeding 2 MW and fan coil units.

b) Standards

1. ISO 27327-1: Fans - Air curtain units - Part 1: Laboratory methods of testing for aerodynamic performance rating[355] establishes uniform methods for laboratory testing of air curtain units to determine aerodynamic performance in terms of airflow rate, outlet air velocity uniformity, power consumption and air velocity projection, for rating or guarantee purposes.
2. ISO 27327-2: Fans - Air curtain units - Part 2: Laboratory methods of testing for sound power[356] deals with the determination of the acoustic performance of air curtain units. In addition, it can be used to determine the acoustic performance of air curtain units combined with an ancillary device.

[355] https://www.iso.org/standard/44100.html
[356] https://www.iso.org/standard/56780.html

c) **Other initiatives**

None of the listed standards can be used to measure the efficiency of the air curtains, which is relevant in the perspective of the review study. However, the European Industry Association, Eurovent, has developed a recommendation for testing of air curtains

1. Air curtain unit - Classification, test conditions and energy performance calculations developed by Eurovent includes methods to calculate air curtain climate separation efficiency and heat losses from buildings as well as the heating capacity as a function of the airflow and temperature.

10.2 Market

The market data is based on data from a stakeholder who has provided sales values of the different types of air curtains and presented in Table 114.

Table 114: Sales data on air curtains based on stakeholder input

Year Product types	Sales			
	2016	**2017**	**2018**	**2019**
Ambient only	15,291	18,863	20,357	21,876
Electrical heated units	37,555	46,925	46,731	42,997
Hydronic coil units	35,297	27,680	26,414	25,841
Direct expansion heat pump coil units	4,268	2,058	2,308	2,162
Total	**92,411**	**95,526**	**95,810**	**92,876**

The sales are assumed to be stable between 2010 and 2030. A stock is calculated based on an assumed average life of 15 years and presented in Table 115.

Table 115: The calculated stock based on sales and an average lifetime of 15 years

Year Product types	Stock		
	2020	**2025**	**2030**
Ambient only	295,267	295,997	295,997
Electrical heated units	673,386	675,049	675,049
Hydronic coil units	445,420	446,519	446,519
Direct expansion heat pump coil units	41,731	41,834	41,834
Total	**1,455,804**	**1,459,399**	**1,459,399**

Due to the assumptions regarding stable sales, the stock reaches a stable plateau with approximately 1.5 million air curtains. However, based on recent sales numbers, it seems that the sales of air curtains with an external heater/cooling source is decreasing.

The average prices of the different types of air curtains are based on input from a stakeholder. The assumed average prices are presented in Table 116.

Table 116: Average cost of the different types of air curtains

Year Product type	Purchase price EUR	Installation EUR	Repair cost EUR	Annual maintenance EUR	Total EUR
Ambient only	2,500	1,000	650	300	**4,450**
Electrical heated units	2,500	1,000	650	300	**4,450**
Hydronic coil units	2,700	1,200	800	300	**5,000**
Direct expansion heat pump coil units	4,000	1,200	800	300	**6,300**

10.3 Usage

Air curtains are installed in a combination with a door or a gate. They are in use during the opening hours of a shop/supermarket or during the working hours in the factory, where people are entering and exiting the opening frequently. Operation hours of air curtains highly depend on the use of the building. The most common field of applications are:

1 Commercial/comfort air curtain units used to reduce physical barriers to entry for customers (shops, public buildings, etc.) Their main purpose is to create a climate division between two areas. The barrier created by the air curtain unit allows a significant reduction of the heat losses through the opening and increases building energy savings.

2 Industrial air curtain units used in the large opening of an industrial building for production and/or transportation processes. Their main purpose is to protect the internal (working environment) preventing dirt, particles and insects from entering and keeping a certain level of comfort. The barrier created by the air curtain unit allows a significant reduction of the heat losses through the opening and significantly increases building energy savings.

3 Cold storage air curtains used for chilled or cold storage applications are placed on the warm side of the doorway to create a barrier of air to reduce warm air entering the refrigerated space and cold air leaving the space. Their main purpose is to create a non-obstructive barrier to limit refrigeration energy losses, ice forming on the cold room cooling system which increases maintenance, and ice forming on the floor of the doorway which is a slip hazard.

In Table 117, the assumed hours of use are presented, and in Table 118, the average energy consumption in each mode is presented.

Table 117: Use pattern of air curtains

Product type	On mode Hours	Standby Hours	Off/idle mode Hours
Ambient only	4	4	16
Electrical heated units	2	6	16
Hydronic coil units	2	6	16
Direct expansion heat pump coil units	2	6	16

Table 118: Energy consumption of air curtains in the different modes

Product type	On mode Watt	Standby Watt	Off/idle mode Watt
Ambient only	212.5	125	0
Electrical heated units	4500	125	0
Hydronic coil units	212.5	125	0
Direct expansion heat pump coil units	212.5	125	0

10.4 Technologies

In order to function properly, an air curtain must be designed in relation to the specific width and height of the opening. The air curtain must blow air along the entire width of the opening and must have an airstream strong enough to reach the floor. Typically, a third-party company with expertise about air curtains provides the design, installation and regulation of the system to make sure the setup is optimal.

Commercial air curtains have an integrated heater or coil to provide heated or chilled air. However, their primary purpose is to act as an air wall or air door to prevent heat transfer across an opening.

Technical parameters of the typical air curtain are:

- Width 1.5 meters
- Manual setting of the heater in stages at 0 %, 50 % or 100% and a thermostat to control the heat after the stage is set
- 2 to 3 fan speeds selected manually
- Crossflow fan wheels with AC motors or forward curved radial fans with AC/EC[357] motors

The BAT includes AC/EC motors and advanced control solutions, taking into account week times and cold/warm seasons. Door contacts may prevent the air curtain running when the

[357] EC motors are DC brushless motors that are controlled by external electronic circuit board. This provides greater control and higher efficiency.

doors are closed. The BNAT may include even more efficient motors and more advanced controls, including dynamic algorithms handling the fluctuating pressure difference over the door opening caused by wind loads and integration of intelligent control via the BMS-system. The jet beam can also be optimised further.

The assumed average material composition is presented in Table 119 and is based on the review study[358].

Table 119: Material composition of air curtains

Description of component	g	Material group	Material
Plastic covers etc.	300	1-BlkPlastics	11 -ABS
Other types of plastic	0	2-TecPlastics	12 -PA 6
Iron parts	76,000	3-Ferro	24 -Cast iron
Copper e.g. wires	7,000	4-Non-ferro	30 -Cu wire
Aluminum parts	7,000	4-Non-ferro	27 -Al sheet/extrusion
Paint/coating	300	5-Coating	40 -powder coating
Electronics	300	6-Electronics	98 -controller board
Glass	0	7-Misc.	55 -Glass for lamps
Total	**90,900**		

10.5 Energy, Emissions and Costs

Energy, emission and simple LCC (Life Cycle Costs) calculations are presented in Table 120, Table 121 and Table 122. The stock presented in Section 10.2, the energy consumption in Section 10.3 and material composition in task 10.4 are used to calculate the annual primary energy consumption of the stock and the primary energy from the materials Table 119 and Table 121 and Table 120). Note that EcoReport Tool has been used to calculate the primary energy consumption of the materials in the current stock.

Table 120: Annual energy consumption of the stock and the combined embedded energy in the materials in the stock

Annual input EU-27 2020	**ENERGY INPUT**		**Material INPUT**
Product type	**Annual electricity**	**Annual primary energy**[359]	**Primary Energy (stock)**
	TWh	**PJ**	**PJ**
Ambient only	0.15	1.1	1.02
Electrical heated units	2.40	18.1	2.34
Hydronic coil units	0.19	1.4	1.55
Direct expansion heat pump coil units	0.02	0.1	0.14
TOTAL	**2.75**	**20.8**	**5.05**

Table 121 gives greenhouse gas emissions (in CO2 equivalent GWP-100).

[358] https://www.eco-localspaceheaters.eu/documents

[359] A CC factor of 2.1 is used

Table 121: GHG emissions from air curtains in the stock

EU-27 2020 Product type	GHG	
	From the electricity consumption [kt]	From the materials [kt]
Ambient only	55	1.02
Electrical heated units	911	2.34
Hydronic coil units	73	1.55
Direct expansion heat pump coil units	7	0.14
Total	**1,046**	**5.05**

From Table 120 and Table 121, it can be seen that air curtains in the stock consume 21 PJ of primary energy each year, resulting in CO_2 emissions of 1000 kt. Also, the combined stock includes materials with embedded primary energy of 5 PJ, resulting in CO2 emissions of 5 kt (for the entire stock in one year). However, if the lifetime of CO2-emission from the materials is distributed over the lifetime of the equipment, the annual emission is 0.33 kt.

The end-user expenditure in Table 122 is calculated based on the stock, purchase price and the energy consumption presented in previous section.

Table 122: End-user expenditure

End-user expenditure, EU-27 2020 (stock)	Running costs mill. EUR	Acquisition (stock) mill. EUR	Total mill. EUR
Ambient only	116	1,033	1,149
Electrical heated units	465	2,357	2,822
Hydronic coil units	176	1,737	1,913
Direct expansion heat pump coil units	16	217	233
Total	**774**	**5,344**	**6,118**

The total stock of air curtains had an approximate purchase cost of 6 billion EUR. Each year the end-users spend 774 million EUR in running cost.

10.6 Saving potential

In Table 123, the assumed obtainable energy savings are presented. Note that the savings are based on stakeholder input. The assessed energy saving potential is based on the current and future more advanced control strategy as well as to the improvement in the airflow uniformity.

Table 123: Obtainable energy improvements[360]

Product type	2030	2040	2050
Ambient only	5%	9.5%	14%
Electrical heated units	7.5%	14%	20%
Hydronic coil units	5%	9.5%	14%
Direct expansion heat pump coil units	5%	9.5%	14%

The savings obtained by better controls are based on the available number of control options[361]. At least an air curtain should be able to regulate airspeed and if possible, it should also be capable of conditioning the air jet and the level of heating/cooling available. By regulating these parameters, energy can be saved, and the overall energy efficiency of the unit is increased. Air curtain systems may also accept zone control and linked system commands as well as receiving remote instructions from a central building management system (BMS). Localised control can be implemented to modulate an air curtain's activity by placing various sensors in the vicinity of the opening that the air curtain screens (door contactors, proximity sensors, etc.).

Based on these savings the potential savings at EU level are presented in Table 124 and Table 125.

Table 124: Potential energy savings – EU-27 level based on a complete replacement of the stock.

Potential annual savings EU-27 2030	ENERGY INPUT		GHG
Product type	Annual electricity	Annual primary energy[362]	From electricity consumption
	TWh	PJ	Kt
Ambient only	0.007	0.06	5.2
Electrical heated units	0.180	1.36	128.7
Hydronic coil units	0.010	0.07	6.8
Direct expansion heat pump coil units	0.001	0.01	0.6
TOTAL	**0.198**	**1.50**	**141.4**

[360] Note that these numbers might be updated at a later stage. The values are the current best estimate from stakeholders.
[361] Based on input from stakeholders
[362] A CC factor of 2.1 is used

Table 125: Potential monetary savings – EU level with a complete replacement of the stock

Potential savings EU-27 2030 (stock)	Running costs mill. EUR
Ambient only	1
Electrical heated units	18
Hydronic coil units	1
Direct expansion heat pump coil units	0
Total	**20**

It is expected that the annual energy electricity savings can amount to approximately 0.2 TWh, 141 kt of CO_2-emission and 20 million euros in running costs. This estimation may be a bit conservative if the market is moving towards more electrical heated units, which in turn would impose higher saving potential.

If the energy consumption of the building is included in the saving potential, the saving potential could prove to be significantly higher. If an air curtain has a poor climate separation efficiency energy is lost (heated or cooled air), which means that the heating/cooling supply needs to consume extra energy to ensure the proper temperature level.

One stakeholder, Eurovent, has provided an estimate on this additional saving potential based on the following assumptions:

By assuming that:

- Energy consumption for heating the buildings' entrance area (as an average for the current building stock of EU non-residential buildings): 100 W/m2
- Average entrance area of the current stock of non-residential buildings: 35 m2
- The Climate Separation Efficiency (CSE) of an average air curtain today: 50%
- The Climate Separation Efficiency (CSE) of an efficient (BNAT) air curtain, estimated: 55%
- The operating days/year of an air curtain, estimated: 260
- The operating hours per day: 8

With these assumptions, the calculated saving potential per average air curtain is 364 kWh/year.

Furthermore the stakeholder includes the following assumptions on the overall potential: By assuming that 1/3 of the current EU-28 building stock of non-residential buildings (= 15,432,000 buildings) could be equipped with efficient air curtains by 2030, the final saving potential at the building level can be calculated as: 364 * 15,432,000 = 5.61 TWh.

However, in the stock model (see Section 10.2) the expected number of installed air curtains is around 1.5 million units in 2030. If these stock values are used in combination with the saving potential of 364 kWh/year it will result in energy savings of approximately 0.5 TWh/year. This value cannot directly be added to the potential electricity saving presented in Table 124 as the energy consumption of the building consist of a mix of different heating sources with different efficiencies.

10.7 Stakeholder comments

EPEE – European Partnership for Energy agrees with the study team and supports excluding air curtains from the scope of the Working Plan. EPEE would recommend against regulating them as a separate product group under Ecodesign as they do not meet eligibility criteria as regards their negligible volume of sales.

Eurovent welcomes the inclusion of air curtains and the acknowledgement that the design parameters of an air curtain have a significant impact on heat losses of the building. Ecodesign requirements at the product level for air curtains would result in much higher energy savings at the building level. Eurovent requests that an attempt is made to quantify these savings potentials. In this respect, the study team has had a dialogue with Eurovent on this quantification and included it in the assessments.

Netherlands Enterprise Agency commented that when looking at the energy savings potential, 0.2 TWh/year, this product should not be included in the Working Plan.

11 NON-TERTIARY COFFEE MACHINES

11.1 Scope, policy measures and test standards

11.1.1 Scope

Non-tertiary coffee machines were the subject of an Ecodesign preparatory study published in 2011[363]. The preparatory study defined coffee machines as machines that heat water with built-in electric heating devices, and pass it through grinded coffee beans so as to produce a coffee for consumption. This coffee drink can be dispensed in various containers, such as cups, pots or in the machine itself.

The scope for the preparatory study was restricted to non-tertiary coffee machines, i.e. not involving commercial use coffee machines, but those used in households and coffee machines intended for domestic use that are used in offices. Coffee machines within the scope have a built-in electricity based heating element and are not dependent on energy supplied to another appliance (i.e. stove top percolator).

The following types of coffee machines were in the scope of the preparatory study, see Figure 32:

- Drip filter coffee machines
    - Traditional filter coffee machines, using ground coffee (with non-insulated or insulated container)
    - Combo filter coffee machines that can use either ground coffee or pad filter
- Pad filter coffee machines
- Espresso coffee machines
    - Steam/non-pump espresso machines
    - Automatic espresso machines (semi-automatic, automatic, or fully-automatic)
    - Hard cap espresso machines
- Combined coffee machines (espresso machine and traditional filter coffee machine)

Figure 32: From left to right: Drip filter coffee machine, Pad filter coffee machine, Hard cap espresso coffee machine, Semi-automatic espresso coffee machine, Fully automatic espresso coffee machine; source: Ecodesign preparatory study on non-tertiary coffee machines 2011, Task 4

[363] Mudgal et al. (BIO Intelligence Service, France): Preparatory Studies for Eco-design Requirements of Energy-using Products - Lot 25: Non-tertiary Coffee Machines, 2011

The Ecodesign preparatory study analysed the following five base cases:

- Drip filter coffee machine
- Pad filter coffee machine
- Hard cap espresso machine
- Semi-automatic espresso machine
- Fully automatic espresso machine

Excluded from the scope of the 2011 Ecodesign preparatory study were:

- Manual coffee machines, without any independent heat source (e.g. presses, manual pump espresso machines with piston lever)
- Traditional coffee machines not having an independent source of energy but using e.g. the hob, as well as their electric versions which include an independent heating stove or internal resistance e.g. integrated into the base of the pot (traditional manual coffee machines; traditional Percolator; traditional mocha pot; vacuum coffee machine; the Neapolitan flip coffee pot)
- Tertiary coffee machines (coffee urns; commercial filter coffee machines; commercial espresso machines; vending machines)

The preparatory study to establish the Ecodesign Working Plan 2015-2017[364] analysed the product group "Tertiary hot beverage equipment", which includes three categories in the market: freestanding hot beverage machines, table-top "full automatic" machines, and café/restaurant espresso machines (porta filter espresso machines). A free-standing hot beverage vending machine is designated for high capacity areas and majority of this equipment offers a broad range of hot beverages such as tea, coffee, hot chocolate, cappuccino, etc. which do have a vending function. In the end, tertiary hot beverage equipment was not taken forward as a whole group because projected savings were slightly below the threshold. Only free-standing hot vending machines were recommended for inclusion into the Ecodesign Working Plan 2015-2017 because a window of opportunity was seen to regulate them together with cold vending machines. However, finally, they were not taken up by the Commission having lower priority due to relatively low savings potential.

When revisiting coffee machines for the Ecodesign and Energy labelling Working Plan 2020-2024, it has been carefully decided how to set the scope by splitting into non-tertiary coffee machines on the one side and tertiary hot beverage equipment incl. hot beverage vending machines on the other side. Other alternatives were not selected such as splitting into coffee machines without a vending function (non-tertiary, but also tertiary coffee machines like coffee urns or large-capacity filter coffee machines; filter coffee machines with one or several integrated warmer(s); commercial espresso machines) on the one side, and hot-beverage vending machines on the other side.

[364] Bio by Deloitte, Oeko-Institut and ERA Technology (2015): Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC, final reports Task 3 and Task 4; http://ec.europa.eu/DocsRoom/documents/20374/attachments/4/translations/en/renditions/pdf; http://ec.europa.eu/DocsRoom/documents/20374/attachments/5/translations/en/renditions/pdf

11.1.2 Policy measures

On the basis of the Ecodesign preparatory study back in 2011, the Ecodesign Consultation Forum meetings of December 2011 and April 2012 supported the view that a product-specific implementing measure should not be adopted, but that the standby requirements of Regulation (EC) No 1275/2008 should be made more explicit for coffee machines. Hence, the Ecodesign regulation 801/2013 on networked standby introduced specifications for the application of the power management requirements to household coffee machines (i.e. non-commercial appliance for brewing coffee) with regard to the default delay time after which the equipment is automatically switched into standby/off mode.

From 1 January 2015, the delay time after which different coffee machine technologies should go into standby and off modes are:

- For domestic drip filter coffee machines storing the coffee in an insulated jug, a maximum time of five minutes after completion of the last brewing cycle or 30 minutes after completion of a descaling or self-cleaning process;
- For domestic drip filter coffee machines storing the coffee in a non-insulated jug, a maximum time of 40 minutes after completion of the last brewing cycle or 30 minutes after completion of a descaling or self-cleaning process;
- For domestic coffee machines other than drip filter coffee machines, a maximum time of 30 minutes after completion of the last brewing cycle, or a maximum of 30 minutes after activation of the heating element, or a maximum of 60 minutes after activation of the cup preheating function, or a maximum of 30 minutes after completion of a descaling or self-cleaning process, unless an alarm has been triggered requiring users' intervention to prevent possible damage or accident.

More generic European legislation relevant to non-tertiary coffee machines includes the Low Voltage Directive (LVD) 2014/35/EU, the Electromagnetic Compatibility Directive (EMC) 2014/30/EC, the General Product Safety Directive (GPSD) 2001/95/EC, Directive 2012/19/EU on waste electrical and electronic equipment (WEEE), Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), Regulation (EC) 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), Regulation (EC) 1935/2004 on materials and articles intended to come into contact with food (FCM).

Voluntary or mandatory measures for non-tertiary coffee machines at national level include among others:

- German Blue Angel label for Coffee Machines for Household Use (DE-UZ 136, edition July 2014)[365]. They include requirements on the power consumption, plastics (used in the housing, housing parts, water container, and collection container), metal parts in contact with water and milk, durability, fitness for use, recyclable design and consumer information.
- Swiss energy label for coffee machines[366], mandatory for coffee machines in Switzerland since 2015, assigning the machines to energy efficiency classes from A+++ (high energy efficiency) to D (low energy efficiency). Not only the absolute power

[365] https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20136-201407-en%20Criteria.pdf

[366] https://www.bfe.admin.ch/bfe/en/home/efficiency/energy-labels-and-efficiency-requirements/household-appliances/coffee-machines.html

consumption is taken into account, but also various properties of the machines, e.g. the energy consumption of coffee or steam in a precisely defined rhythm, i.e. the cooling and reheating of the water and the standby properties are also taken into account. Furthermore, the annual consumption of the coffee machine is indicated on the energy label in kilowatt hours per year. The label applies to mains operated household coffee machines, namely espresso machines with or without pump, capsule and portion espresso machines and fully automatic espresso machines. Domestic coffee machines which can also be operated with other energy sources and pressure-less filter coffee machines are excluded.

- City of Vienna[367]: Ecological criteria for the procurement of fully automatic coffee machines and pad machines regarding energy consumption (total power consumption, automatic switch into standby, power input in standby mode, and power switch), cleaning, anti-microbial coatings and reparability (tenderers shall prove that the producers guarantee repair and supply of spare parts and accessories for a minimum of 5 years). Although consumers are presumably professional users in the context of public procurement, the criteria might be also be related to non-tertiary fully automatic coffee machines.

Regarding circular economy, it is relevant to mention that coffee machines were one integral part of a Product Environmental Footprint (PEF) pilot study to develop Category Rules (PEFCR) for coffee. However, the PEFCR pilot study was discontinued[368].

11.1.3 Test standards

Standards applicable for non-tertiary coffee machines were listed and described in the Ecodesign preparatory study 2011.

The most relevant update is the publication of the European standard EN 60661:2014 *Methods for measuring the performance of electric household coffee makers*. The standard applies to electric coffee makers for household and similar use. It does not apply to appliances designed exclusively for commercial or industrial use. The object of this standard is to state and to define the main performance characteristics, which are of interest to the user and to describe the standard methods for measuring these characteristics. This standard is also the basis also for determining the energy classes of the Swiss energy label[369].

For coffee machines, also the standards to support Ecodesign requirements on material efficiency aspects for energy-related products could be applied, covering the following aspects: extending product lifetime, ability to reuse components or recycle materials from products at end-of-life, use of reused components and/or recycled materials in products.[370]

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[367] https://www.wien.gv.at/english/environment/protection/oekokauf/pdf/04023-fully-automatic-coffee-machines.pdf

[368] https://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm

[369] The annual energy consumption indicated on the Swiss energy label is calculated by multiplying the energy consumption determined according to the standard EN 60661:2014 by 365 days per year.

[370] EN 45552:2020 (General method for the assessment of the durability of energy-related products), EN 45553:2020 (General method for the assessment of the ability to remanufacture energy-related products); EN 45554:2020 (General methods for the assessment of the ability to repair, reuse and upgrade energy-related products); EN 45555:2019 (General methods for assessing the recyclability and recoverability of energy-related products); EN 45556:2019 (General method for assessing the proportion of reused components in energy-related products); EN 45557:2020 (General method for assessing the proportion of recycled material content in

11.2 Market

The Ecodesign preparatory study on non-tertiary coffee machines published in 2011 concluded that more than 18 million coffee machines are sold in the European Union every year, of which 10 million are drip filter coffee machines and 8 million are pad filter and espresso coffee machines, however, based on 2007 sales data.

Table 126: Domestic coffee machine sales in Europe by product type (units); source: Ecodesign preparatory study on non-tertiary coffee machines, Task 2 report (2011)

	Unit sales, 2007
Drip filter coffee machine	10 088 075
Pad filter coffee machine	3 438 419
Hard cap espresso coffee machine	2 141 383
Semi-automatic espresso coffee machine	1 242 076
Fully automatic coffee machine	815 048
Combis, others*	800 436
Total	**18 525 437**

*Not taken into account in subsequent calculations.

The stock of non-tertiary coffee machines on the EU-27 market in 2010 has been estimated as follows in the Ecodesign preparatory study on non-tertiary coffee machines.

Table 127: Estimated stock of non-tertiary coffee machines, 2010; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 2 report (2011)

	Stock (units)
Drip filter coffee machine	58 820 091
Pad filter coffee machine	22 698 517
Hard cap espresso coffee machine	12 547 263
Semi-automatic espresso coffee machine	9 012 548
Fully automatic coffee machine	7 621 483
Total	**110 699 902**

Drip filter coffee machines accounted for the largest number of appliances sold back at that time but the espresso portioned category (hard cap espresso machines) was growing by far the fastest, at around 40% per year. The market share of hard cap espresso machines was increasing extremely rapidly, while those of all other categories were relatively stable or in slight decline. Sales of drip filter coffee machines were expected to decrease over the coming years, while sales of hard cap espresso coffee machines were expected to continue their rise.

energy-related products); EN 45558:2019 (General method to declare the use of critical raw materials in energy-related products); and EN 45559:2019 (Methods for providing information relating to material efficiency aspects of energy-related products)

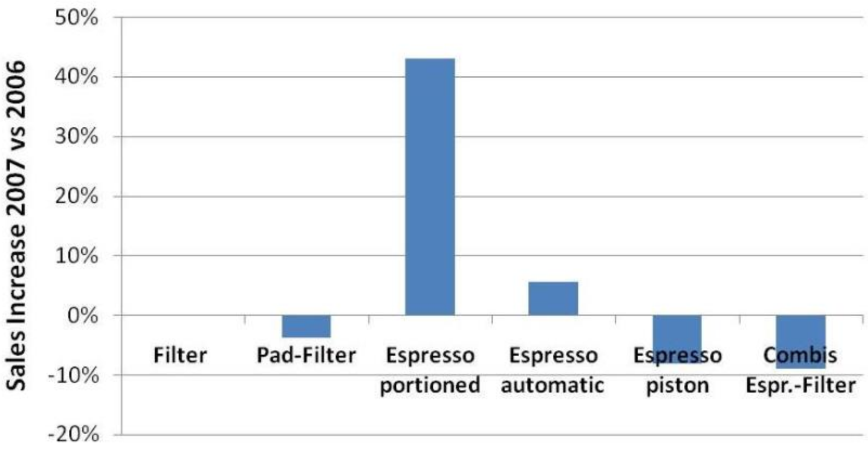


Figure 33: Total percentage sales value increase in 18 European countries by product category, 2006-2007; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 2 report (2011)

The following table summarizes the sales and stock estimates for non-tertiary coffee machine products (millions) for key years according to the Ecodesign preparatory study published in 2011.

Table 128: Sales and stock estimates for key years for Lot 25 products (millions); source: Ecodesign preparatory study on non-tertiary coffee machines, Task 2 report (2011)

	Sales					Stock				
	2010	2012	2015	2020	2025	2010	2012	2015	2020	2025
Drip filter coffee machine	9.24	9.26	8.63	6.48	3.14	58.82	57.12	54.50	45.71	29.42
Pad filter coffee machine	3.53	3.75	4.09	4.75	5.50	22.70	24.72	26.37	30.45	35.30
Hard cap espresso machine	3.01	3.77	5.11	7.51	11.04	12.55	18.60	26.91	42.24	62.06
Semi-automatic espresso machine	1.16	1.04	0.90	0.90	0.90	9.01	8.29	7.32	6.31	6.27
Fully automatic espresso machine	0.82	0.90	1.04	1.14	1.26	7.62	8.01	8.78	10.21	11.57

The sales data predicted for 2020 are very close to current market data:
According to Statista, in 2018 the number of household coffee machines traded in Europe accounted to 20 million units[371]. Therefore, also the stock data predicted for 2020 with near 135 million units as well as the 145 million units expected in 2025 is assumed to be still fitting, the latter due to the market of non-tertiary coffee machines expected to be further growing. In a similar range, the *Study on the Review of the Regulation (EC) No 1275/2008*, published in 2017, estimates the stock on household coffee makers at about 149 million units in 2025 and 171 million units in 2030.[372]

[371] Number of units of small home appliances traded in Europe in 2018, by product type (in millions), cf. https://www.statista.com/statistics/912347/small-home-appliances-traded-by-type-europe/, published on June 25, 2020

[372] Viegand et al. (2017): Study on the Review of the Regulation (EC) No 1275/2008. Final Report, 2017. Online available at https://www.ecostandbyreview.eu/downloads/Review%20study%20standby%20regulation%20-%20final%20report%20april%202017.pdf, last accessed on 1 Aug 2020

According to the Coffee Business Intelligence consultancy[373] it is expected that there is / will be some effect on sales due to the COVID-19 crisis. The closing of bars, restaurants and other commercial operators has caused the consumption of coffee away-from-home to collapse. Drinking coffee in the bar or office has been partially replaced by coffee consumption at home, with some data indicating strong growth in online purchases of coffee machines and capsules in the short term. In the medium- and long-term, however, the greatest risk is reported an impact on the general demand for coffee due to a global recession triggered directly and indirectly by the pandemic. No market data could be found regarding the current share of the different technologies. Coffee consumption patterns have changed in the recent decades, especially regarding the proliferation of single-use hard capsule machines which might influence the number and different types of devices in stock. Therefore, more in-depth analysis would be necessary to analyse the current stock and market shares of different technologies.

11.3 Usage

11.3.1 Coffee consumption

According to Statista (2016)[374], the coffee consumption in Europe is differing between the countries: in Finland, on average 1,310 cups of coffee were consumed per year in 2015, whereas in Portugal and France, 482 cups/year were drunk. Other countries listed are Sweden (1,070 cups/year), Netherlands (1,004 cups/year), Denmark (863 cups/year), Germany (675 cups/year), Italy (658 cups/year), Estonia (635 cups/year) and Austria (623 cups/year). No specification is available if this consumption relies to non-tertiary coffee machines, i.e. private consumption only or if these data also include coffee consumption in the professional context, i.e. in hotels, restaurants and cafés.

CBI (2019)[375] reports that Europe has one of the highest average annual per capita consumption in the world at just above 5 kg of coffee per person a year. The leading country in per capita consumption in the world is Finland, where the average annual coffee consumption is 12 kg per capita. Scandinavian countries also have high coffee consumption rates: Norway 9.9 kg, Denmark 8.7 kg and Sweden 8.2 kg. Other relatively large per capita coffee consuming countries in Europe are the Netherlands (8.4 kg), Switzerland (7.9 kg) and Belgium (6.8 kg). In Western Europe, there is a strong growth in out-of-home consumption of coffee as coffee shops and small and medium-sized coffee roasters lead the way for the introduction of high-quality coffees. Between 2010 and 2017, sales of out-of-home consumption in Western Europe increased by 50%.

Further, CBI (2019)[376] reports that the European demand for single-serve coffee, such as coffee pods and capsules, has been growing strongly for the past 10 years. European countries with the highest share of coffee pods and capsules consumption in 2018 include

[373] https://coffeebi.com/2020/02/13/professional-coffee-machines-in-europe-part-2/

[374] https://de.statista.com/infografik/6066/europas-top-10-kaffeenationen/

[375] https://www.cbi.eu/market-information/coffee/trade-statistics#:~:text=%20Which%20European%20markets%20offer%20most%20opportunities%20for,coffee%20in%20Europe.%20Belgium%20is%20Europe%E2%80%99s...%20More%20

[376] https://www.cbi.eu/market-information/coffee/trends#convenience-drives-growth-of-european-single-serve-and-ready-to-drink-coffee-market

France (32% of all coffee consumption), the Netherlands (31%) and Belgium (27%). Especially in Northern and Western Europe, retailers keep expanding their assortments of single-serve methods. The European market of pods and capsules is dominated by Nespresso and Jacobs Douwe Egberts. However, according to CBI, the single-serve market has a major downside as well, which is the negative environmental impact of coffee capsules. In response, the industry has introduced recyclable and compostable solutions and alternatives, and biodegradable capsules.

11.3.2 Usage, consumption and consumer expenditure data of non-tertiary coffee machines

The following tables summarize the data on consumables, user behaviour, and electricity consumption as well as the consumer expenditure data used in the preparatory study of 2011 for the calculation of the base cases.

For the use phase, the preparatory study defined a so called "**coffee period**" as functional unit. During one "coffee period", in total four coffee cups are prepared: three cups of 40 ml and one cup of 120 ml. Further, the preparatory study presented two different descriptions on duration of the coffee periods: Figure 34 shows a coffee period for cup-by-cup machines, i.e. pressure coffee machines[377]; Figure 35 shows a coffee period for drip filter machines.

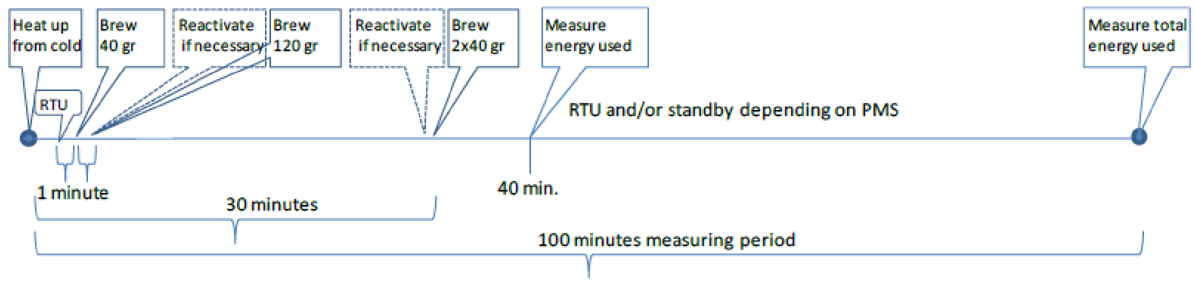
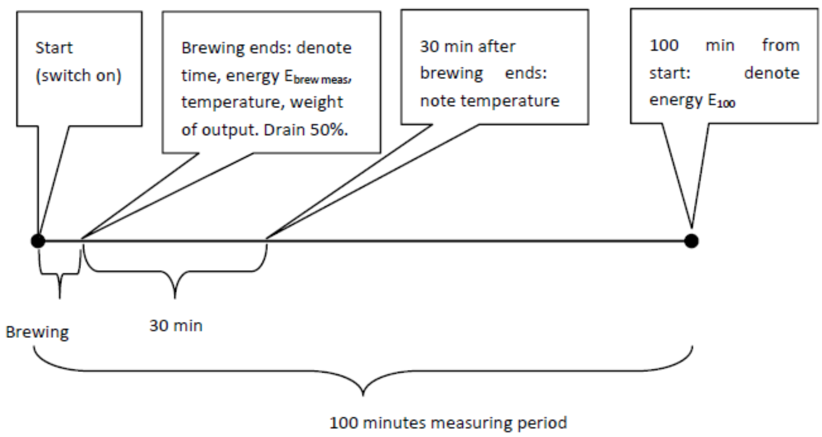


Figure 34: Description of a coffee period for a cup-by-cup coffee machine; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 3 report (2011)



[377] RTU is the time in Ready-to-Use mode; PMS is the power management system

Figure 35: Description of a coffee period for a drip filter coffee machine; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 3 report (2011)

Table 129 shows the consumables used by each the different machine types per coffee period, i.e. when brewing in total the three cups of 40 ml and one cup of 120 ml.

Table 129: Consumables used per coffee period; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 3 report (2011)

	Water (ml coffee)	Coffee (g)
Drip filter coffee machine	850	50
Pad filter coffee machine	240[2]	4 pad filters
Hard cap espresso machine	240[2]	4 hard caps
Semi-automatic espresso machine	240[2]	28=4*7
Fully automatic espresso machine	240[2]	28=4*7

2: Four coffee cups are prepared during a coffee period: three cups of 40 ml and one cup of 120 ml

Table 130: Summary of user behaviour data; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 3 report (2011)

Type of machine	Number of coffee periods per day	Quantity of coffee produced per coffee period (ml)	Duration of a coffee period (minutes)	Time in Ready-to-Use per day (hours)[18]	Time in off mode per day (hours)
Drip filter	2	850[19]	100	12.7	8
All others	3	240	100	11	

[18] For the calculations in the preparatory study, it was assumed that there was no auto-power down, and so time in standby was considered as time in Ready-to-use mode.
[19] The filter machines coffee period was based on brewing 900 ml of water (testing is done without coffee). In practice this results in around 800-850 ml of coffee.

Table 131: Electricity consumption of the different product types; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 3 report (2011)

	Electricity consumption during coffee period (Wh)	Yearly electricity consumption due to coffee periods (kWh)	Ready-to-use mode (W)	Yearly electricity consumption due to Ready mode (kWh)	Total yearly consumption (kWh)	Lifetime (years)	Lifetime electricity consumption (kWh)
Drip filter coffee machine	232	169	0.5	2.4	172	6	1 030
Pad filter coffee machine	93	102	15	60	162	7	1 134
Hard cap espresso machine	73	80	10	40	120	7	843
Semi-automatic espresso machine	83	91	26	104	195	7	1 367
Fully automatic espresso machine	62	68	11	45	113	10	1 133

For the electricity consumption of the base cases, the time in "ready to use mode" per day is probably reduced for current coffee machines to around 1-2 hours per day (using the machine for 2-3 coffee periods per day) due to the requirements of Ecodesign regulation 801/2013 specifying the delay time after which the different coffee machine technologies have to go into standby and off modes.

Table 132: User expenditure base data; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 2 report (2011)

Category	Cost items	Units	Reference value for Lot 25
Purchase	Purchase price	€/machine	35-595
Use	Electricity rate	€/kWh	0.166
Use	Water rates	€/m^3	2.64
Use	Coffee beans	€/kg	14.25
Use	Ground coffee	€/kg	12
Use	Coffee filter	€/filter	0.03
Use	Coffee pad filter	€/pad	0.15
Use	Coffee hard caps	€/cap	0.30
Use	Interest-inflation rate	%	4.0

Only for fully automatic espresso machine, the preparatory study considered repair costs of 20% of the product price due to its complexity compared to other product types. For drip filter coffee machines with an average product price of about 35 Euros, it was assumed that consumers rather prefer purchasing new appliance than changing default components.

11.3.3 Lifetime of non-tertiary coffee machines

The "design lifetime" of different coffee machines calculated in the Ecodesign preparatory study on non-tertiary coffee machines is about 6 years for the drip filter coffee machines, 7 years for pad filter, hard cap and semi-automatic espresso coffee machines and 10 years for fully automatic espresso coffee machines.

Table 133: Estimated average lifetime of products; source: Ecodesign preparatory study on non-tertiary coffee machines, Task 3 report (2011)[378]

	Lifetime
Drip filter coffee machine	6
Pad filter coffee machine	7
Hard cap espresso coffee machine	7
Semi-automatic espresso coffee machine	7
Fully automatic espresso coffee machine	10

Lifetime, durability and reparability are main approaches of the Circular Economy concept being one of the main foci of the Ecodesign and Energy Labelling Working Plan 2020-2024. These aspects were not analysed and addressed in detail in the Ecodesign preparatory study of 2011, therefore, more information as far as available is compiled here.

[378] One industry stakeholder suggests an average lifetime of 7 years for fully automatic espresso coffee machines.

No current lifetime data detailed for the different coffee machine technologies is publicly available. However, some literature might indicate a possibly lower lifetimes of coffee machines: For example, an empirical investigation among Austrian households by Wieser and Tröger (2015)[379] revealed that the average service life of coffee machines is 4.9 years, whereas on average 8.7 years is the service life for coffee machines expected by consumers in that study.

Also, the German consumer testing magazine Stiftung Warentest (2018)[380] indicates that fully automatic coffee machines break down on average after only five years. In the network of independent repair shops, they account for around a third of all repair requests - no other type of household appliance goes there more often.

This is confirmed by an international Repair Monitor (2019)[381] with more than 60 repair cafés participating from Netherlands, France, UK, Australia, Canada, Germany, Belgium, and the United States. Coffee makers have the highest share with about 22% of the registered repairs (1,053 of 4,779 repairs) among the different product categories. At the same time, the repair success rate of coffee machines is with 55% (579 appliances) the second worst of the ten product categories registered in 2019. 30% of the registered coffee machine products (312 products) could be half-repaired and 15% (162 products) could not be repaired at all. The average estimated age of the coffee makers was 8 years.

Failures and defects of coffee machines might be for example:[382]

- Brew head gasket replacement
- Steam wand begins to drip
- If not steaming correctly, boiler performance may degrade over time due to heating element damage
- Grinder and brew unit, portafilter and baskets can clog from coffee bean oils
- Water reservoir sensor can fail, resulting in machine not sensing it has water and then not heating
- Screen will need to be replaced over use
- Seals (brew head, vacuum valve seal, overpressure seal, expansion valve seal) and hoses will commonly wear down over time and need to be replaced

Also, some machines seem to be designed for special repair tools.

Stiftung Warentest (2018) also calculated the environmental impacts and costs of using a coffee machine over a time of 10 years for two different scenarios (usage calculated for the environmental impact and costs of consumption of electricity, water, coffee, descaler and cleaner), with :

- User repairs three times: calculated for 10 years; first repair after 5 years. Costs calculated for an average purchase price of 810 euros and three repairs at an average of 118 euros each; first repair after 5 years.

[379] https://www.beuc.eu/documents/files/FC/durablegoods/articles/0515_AK_Austria.pdf; https://www.arbeiterkammer.at/infopool/wien/Bericht_Produktnutzungsdauer.pdf

[380] https://www.test.de/Defekte-Haushaltsgeraete-Wann-sich-eine-Reparatur-lohnt-5157064-5157074/

[381] https://repaircafe.org/de/wp-content/uploads/sites/4/2020/05/RepairMonitor_analysis_2019_05052020_FIGURES_ENGLISH.pdf

[382] https://www.seattlecoffeegear.com/learn/coffee-101/articles/lifetime-maintenance-espresso

- User never repairs: charged for a new purchase approximately every 5 years. Costs calculated for about 2 devices in 10 years (new purchase after 5 years).

Both environmental impacts and costs are lower for the reparability scenario: The main environmental impacts are related to the production phase of a fully automatic coffee machine, due to its approximately 600 grams of electronics made from valuable raw materials. Calculating that, on average, an automatic coffee machine fails three times in ten years with typical defects, having it repaired each time costs less overall than buying a new one for the first time.

In their *Study on socioeconomic impacts of increased reparability*, Deloitte (2016)[383] calculated with an average technical lifetime of coffee machines of 8 years without repairs, one lifetime extension of 4 years due to repair activities during the mid-life (32% of the current machine sales) and another lifetime extension of 4 years due to refurbishment at the end-of-life (2% of the current machine sales), estimating a purchase price of 595 Euro for coffee machines and 83 Euro repair costs (including both labour costs and the purchase of spare parts).

The European Economic and Social Committee (EESC) published in 2016 a study on the influence of life span labelling on consumers.[384] The main aim of the study was to analyse whether lifespan labelling on products might influence consumers' purchasing decisions. Several different ways of displaying this information were tested. Differentiated analyses were performed on nine categories of product, four label formats, ranges of purchase prices, and participants' country of residence. An experiment was designed to test the potential influence of lifespan labelling. The experiment was based on simulated online shopping and involved designing a dummy retail website. The effects of this labelling on nine product categories were tested, inter alia filter coffee makers; participants could choose between 10 different models for each product category (e.g. 10 different coffee makers). For coffee makers, a significant influence (+14.4%) on purchasing decisions was noted, i.e. in general, sales for filter coffee makers with long lifespans improve when that lifespan is displayed.

A viable second hand market for coffee machines is rather observed for the professional than for the market segment.

11.3.4 Consumables: Single-use coffee capsules

The Ecodesign preparatory study on non-tertiary coffee machines of 2011 already pointed out on the environmental impacts of the production and disposal of single-use coffee capsules which are made of either aluminium, plastics, or a combination of plastics and aluminium. With the market share of capsule coffee machines in the household application segment still rising due to their convenient usage, wide range of blends and time-pressed consumers[385], the total environmental impacts of the consumables are also increasing.

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[383] https://op.europa.eu/en/publication-detail/-/publication/c6865b39-2628-11e6-86d0-01aa75ed71a1/language-en

[384] https://op.europa.eu/en/publication-detail/-/publication/13cac894-fc83-11e5-b713-01aa75ed71a1/language-en/format-PDF

[385385] See for example https://www.grandviewresearch.com/industry-analysis/capsule-coffee-machine-market

In its 2019 status and 2020 outlook report[386], Nestlé with its Nespresso aluminium capsules reports about their efforts which are targeted to offer convenient recycling solutions to their consumers (91.0% collection capacity achieved in 2019), continue to increase the capsule recycling rate (+15.3% vs. 2009 achieved in 2019), unlock the circular use of aluminium (2.0% line made out of recycled capsules), and to source "ASI certified" aluminium (with recycled aluminium suppliers identified for ASI certification achieved in 2019).

Other technical developments were oriented towards the development of 100% biodegradable capsules from plant-based fibres that are compostable.[387] Also reusable capsules are available[388] or capsules made of recyclable polypropylene plastic which are very small, compact and with less material[389].

Although Nespresso as well as some other capsule manufacturers have launched recycling services, the effect is depending on the consumers making use of it (drop-off / collection points; free ship back through the postal system). This means that the actual recycling rates is remarkably lower compared to the potential capacity to recycle aluminium.[390,391] Further, according to Deutsche Umwelthilfe (2018)[392], the recycling of aluminium capsules causes problems: The capsules are often not sorted correctly but thrown into the residual waste and end up in incineration. In the process, the aluminium oxidises and is lost. Due to many impurities - including coffee grounds, varnish, residual contents, incorrect sorting, composite materials - the aluminium fraction is usually pre-treated with pyrolysis. The material losses due to the pyrolysis and melting process steps can be quite considerable and can quickly amount to 20 per cent or more. Another particular problem with aluminium coffee capsules is that they are currently made from new aluminium and old capsules are only to a very small proportion turned into new ones.

11.4 Technologies

The Ecodesign preparatory study on non-tertiary coffee machines of 2011, Task 4 report[393] analysed the technologies for five different types of coffee machines:

- Drip filter coffee machine
- Pad filter coffee machine
- Hard cap espresso coffee machine
- Semi-automatic espresso coffee machine
- Fully automatic espresso coffee machine.

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[386] https://www.nestle-nespresso.com/asset-library/Documents/CSV%20REPORT%202019.pdf

[387] See for example https://www.packaginginsights.com/news/Biodegradable-wood-based-coffee-capsules-launched-by-uk-start-up-Lost-Sheep-Coffee.html

[388] See e.g. https://www.quarks.de/umwelt/muell/darum-sind-kaffeekapseln-nicht-umweltfreundlich/

[389] https://www.br.de/radio/bayern1/inhalt/experten-tipps/umweltkommissar/kaffee-kapseln-pads-umwelt-100.html

[390] https://www.evergreen-capsules.com/blogs/news/the-recycling-of-disposable-coffee-capsules-myth-or-reality; http://bbia.org.uk/wp-content/uploads/2017/04/CAF26_52_SustainablePods-1.pdf

[391] https://www.wz.de/politik/inland/kaffeekapseln-so-schlecht-ist-die-umweltbilanz-wirklich_aid-25977725

[392] https://www.presseportal.de/pm/22521/4053101

[393] https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/lot25-non-tertiary-coffee-machines/final-report-task4.pdf

Table 134 summarizes the main functional components and operational principles of the analysed coffee machine types

Table 134: Main functional components and operational principles of the analysed coffee machine types; source: Ecodesign preparatory study on non-tertiary coffee machines 2011, Task 4

Machine type	Main functional components	Operational principle
Drip filter coffee machine	Housing, plate unit, electric network, water network	A flow-type heating system heats water from a storage tank. The boiling water is driven by steam power and flows through a tube to reach a paper filter filled with ground coffee set on top of a jug. Drops of hot water fall on the ground coffee and slowly percolate down to the jug.
Pad filter coffee machine	Housing, percolation system, electric network and resistance, pump system	Water is pumped at low pressure (<8 bars, often as low as 2.5 bars) through the heating unit (traditional boiler, thermoblock or flow-through heater). At a temperature of around 90°C, a set amount of water is forced through a pad, from where the brewing process sends coffee to a cup placed below the spout.
Hard cap espresso coffee machine	Housing, percolator capsule system, electric network and resistance system, pump system	Water is pumped, usually at high pressure (>8bars) though for some types at low pressure, through a heating unit (traditional boiler, thermoblock or flow-through[394] heater). At a temperature of around 90°C, a set amount of water is injected into the capsule, from where the brewing process sends coffee to a cup placed below the spout
Semi-automatic espresso coffee machine	Housing, percolation system, pump system, control system, resistance system, steam system, filter holder system	A piston lever (portafilter) containing coffee grounds in a metal filter is manually placed in a support. A set amount of water is pumped at high pressure (>8 bars, usually 15 bars) through the heating unit (traditional boiler or thermoblock or flow-through heater). At a temperature of about 90°C, water is pressed through the piston, from where the brewing process sends coffee to a cup placed below the spout.
Fully automatic coffee machine	Housing, brewing module including grinder, control system, pump system, steam system	Similar to a semi-automatic machine but containing an electrically-driven brewing unit and a grinder. A set amount of coffee is ground from beans. The ground coffee is placed in the brewing unit and after brewing ejected. Water is pumped at high pressure (usually 15 bars) through the heating unit (traditional boiler, thermoblock or flow-through heater) and through the brewing unit at around 90°C to a cup

The general operational principles and also Bill of Materials (BoM) described in the preparatory study for these types used back in 2011 seem still applicable for today's coffee machines.

The following technological developments and design options with improvement potential since that time were observed; however, it is not clear if these are applied also to non-tertiary coffee machines or mainly in the professional segment:

[394] One industry stakeholder commented that the flow-through technology was addressed in 2011, but since there is no massive uptake of this technology there must be a reason that flow-through is not used widely.

- Smart coffee machines
- Repair-friendly coffee machines
- Post-consumer recycled plastics content

Smart coffee machines, equipped with sensors and an internet connection, allow for example the user live tracking and observing the brewing process, or aim at receiving push notifications about the status of the coffee machine via app; e.g. if there is no water or beans in the machine anymore, a warning signal sounds. Besides consumers' comfort, the smart technology can also be used to control the energy usage and temperature, and to facilitate maintenance and repair operations for extension of product life.
Smart coffee machines are capable of recording performance parameters including the duration of the grinder, the pressure used, as well as the amount of coffee consumed during set periods. The different amounts of water, coffee, and milk used can also be measured, and service partners can use the gathered information to efficiently service, clean, maintain and repair coffee machines via online performance tracking in a timely manner. Customers can also receive cleaning reminders and statistics from the machine to help them plan better for maintenance and stock management, ultimately reducing downtime and increasing efficiency. Technicians have remote access to these data and information.[395] However, there is no information found if smart coffee machines apply digital usage meters which are recording the individual usage patterns, number and type of coffee preparations or failures and maintenance cycles to be read out e.g. for statistical purposes.

There might be some shortcomings related to increasingly connected products. Networked devices are often characterised by a shorter life or useful life than equivalent, non-networked devices that fulfil the same core use. As a result, significantly more devices are purchased and produced. However, this observed trend has not yet been systematically studied or even quantified, yet it may contribute to increasing resource consumption. Reasons for a possibly shorter lifespan or useful life are:

- Higher risk of failure for additional integrated components with a high level of complexity, especially if rather cheap components are used,
- Rapid degradation of communication interfaces,
- Software-related hardware obsolescence due to expiring support, lack of security updates, or shutdown of cloud services required to use the devices,

Psychological obsolescence due to a high innovation dynamic.
An example for a **repair-friendly designed coffee machine** was found at CIRCit Norden, a website collecting Nordic cases of circular economy.[396] The respective coffee machine is designed with features to ease maintenance and repair, including non-destructive disassembly, one-tool access for daily maintenance and operation, minimised use of screws, easy access to functional modules, modules that are easy to replace, and pictogram-signage on the modules for disassembly. These features are estimated to save around 30 km service transportation per machine each year, as well as enabling remanufacturing.

Also the German Blue Angel ecolabelling scheme includes requirements for reparability and facilitating recyclability of coffee machines[397]: For fully automatic and portafilter coffee machines the provision of spare parts for the repair of the machines is guaranteed during

[395] https://news.microsoft.com/europe/features/caffeine-in-the-cloud-how-connected-coffee-machines-are-brewing-coffee-with-data/
[396] http://circitnord.com/inspiration-cases/cecase-7/
[397] https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20136-201407-en%20Criteria.pdf

ongoing production and for at least 10 years following the termination of production. For all other coffee machines, the following requirements have to be fulfilled: the provision of spare parts for the repair of the machines is guaranteed during ongoing production and for at least 5 years following the termination of production. The equipment shall be designed and constructed in such a way that it is possible to easily and quickly dismantle it for the purposes of separating recyclable components and materials. This means: having suitable connections that can be removed using standard tools and these connecting joints shall be easily accessible; plastics should consist of only one polymer or plastic parts whose mass is greater than 25 grams shall be labelled in accordance with the ISO 11469 standard to enable the separation of different plastic materials; and instructions for dismantling the appliance shall be available for those handling old appliances – with the aim of recycling as many resources as possible.

Another circular economy approach is the **use of post-consumer recycled plastics** (PCR) in coffee machines. For example, Philips[398] saw the best suitability for recycled plastics in the baseplate of one of their pad filter coffee machine models, as this is a black part and does not come into contact with food. Further challenges besides optical design aspects to overcome were the need that the recycled plastics shall not generate any negative smell experience for consumers and that the recycled plastics needs to withstand challenging heat resistance requirements. The baseplate of the pad filter coffee machine finally contains 95% post-consumer recycled PP. According to the "Eco passport"[399], the machine model contains a total of 132 grams recycled plastics. A general analysis and assessment of recycled content can be found in a separate study in this report.

11.5 Energy, Emissions and Costs

According to the Ecodesign preparatory study on non-tertiary coffee machines of 2011, Task 5, the following total environmental impacts (cf. Table 135) as well as total annual consumer expenditure (cf. Table 136) of all non-tertiary coffee machine products in operation in EU-27 in 2010 were reported. In addition, the total electricity consumption of the stock of coffee machines corresponded to about 17 TWh for the year 2010. For the consumer expenditure, about 89% of the total costs were due to the price of coffee, with this percentage only being lower for fully-automatic espresso machines (71%) due to the higher price of that product category.

Note that the tables were calculated in the 2013-2014 preliminary VHK impact analysis with the primary energy factors at the time (PEF 2.5 for electricity). If this product group is selected, the preparatory/impact studies should update not only for increase in base data but also for reduction of the primary energy factor for electricity, which was recently changed from 2.5 to 2.1, and the fact that Croatia entered and the UK has left the EU28 (13% less EU-population).

Table 135: Environmental impacts of the EU-27 stock in 2010 for all Base-cases (source: Ecodesign preparatory study on non-tertiary coffee machines 2011, Task 5)

[398] https://www.philips.com/a-w/about/sustainability/sustainable-planet/circular-economy/senseo.html

[399] https://www.download.p4c.philips.com/files/h/hd6554_90/hd6554_90_eco_.pdf

Environmental Impact	Base-Case 1	Base-Case 2	Base-Case 3	Base-Case 4	Base-Case 5	Total
Total Energy (GER) (in PJ)	108.76	35.77	15.76	19.31	7.51	187.11
of which electricity (in PJ)	105.67	34.76	14.73	18.66	6.77	180.58
Water process (in million m^3)	44.31	7.75	4.18	3.73	2.03	62.00
Waste,non-hazardous/landfill (in kt)	143.28	52.79	28.73	29.35	15.26	269.42
Waste, hazardous/ incinerated *(in kt)*	16.78	5.07	4.59	3.45	4.67	34.55
Emissions to air						
Greenhouse Gases in GWP100 (in Mt CO_2 eq.)	4.81	1.58	0.71	0.85	0.33	8.29
Acidification, emissions (in kt SO_2 eq.)	28.35	9.32	4.20	5.05	2.01	48.94
Volatile Organic Compounds (VOC) (in kt)	0.05	0.02	0.01	0.01	0.01	0.09
Persistent Organic Pollutants (POP) (in g i-Teq.)	0.81	0.25	0.24	0.21	0.07	1.58
Heavy Metals emissions to the air (in ton Ni eq.)	2.86	0.81	0.54	0.46	0.24	4.91
PAHs (in ton Ni eq.)	0.39	0.28	0.16	0.07	0.06	0.96
Particulate Matter (PM, dust) (in kt)	3.13	1.00	0.76	0.51	0.63	6.02
Emissions to water						
Heavy Metals emissions to water (in ton Hg/20)	1.32	0.40	0.28	0.21	0.12	2.33
Eutrophication (in kt PO_4)	0.03	0.01	0.01	0.01	0.01	0.06

Table 136: Total annual consumer expenditure in EU-27, 2010 (source: Ecodesign preparatory study on non-tertiary coffee machines 2011, Task 5)

	Base-case 1	Base-case 2	Base-case 3	Base-case 4	Base-case 5	Total
EU-27 sales (mln units)	9,24	3,53	3,01	1,16	0,81	**17,75**
Share of the EU-27 sales	*52.1%*	*19.9%*	*17.0%*	*6.5%*	*4.6%*	
Product Price (mln €)	323	286	470	119	482	**1 680**
Energy costs (mln €)	1 654	547	229	292	104	**2 826**
Coffee costs (mln €)	21 899	13 350	15 045	3 315	2 042	**55 651**
Other costs (water, filter, ...) (mln €)	1 384	14	8	6	4	**1 416**
Repair and maintenance costs (mln €)	0	244	137	108	133	**622**
Total (mln €)	25 260	14 441	15 889	3 840	2 765	**62 195**
Share of Total Annual Consumer Expenditure	*40.6%*	*23.2%*	*25.5%*	*6.2%*	*4.4%*	

More recent data is given in the Ecodesign Impact Accounting (EIA) study by VHK, 2019. For this report, not the BAU (business as usual), but the 'ECO scenario' is chosen as underlying basis which already includes the impacts of known implementing measures under Ecodesign and Energy Labelling regulations. This is due to the fact that coffee machines are covered by EU Ecodesign regulation 801/2013 on networked standby, thus estimating that the saving potential calculated in the Ecodesign preparatory study of 2011 has already been realized due to the adopted implementing measures.

In this respect, the following **total electricity use** is expected for non-tertiary coffee machines for the years 2020, 2030, and 2050 according to the Environmental Impact Accounting (EIA) study (VHK 2019)[400].

[400] Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, ELECECO

Table 137. Total electricity use 2020, 2030 and 2050 of currently regulated non-tertiary coffee machines for ECO scenario (source: Ecodesign Impact Accounting study by VHK, 2019)

Total final electricity consumption (ECO scenario) for non-tertiary coffee machines	2020	2030	2050
Drip filter (glass)	3.2	2.9	2.9
Drip filter (thermos)	1.1	1.1	1.2
Drip filter (full automatic)	0.6	0.8	1.1
Pad filter	0.6	0.8	1.0
Hard cap espresso	0.4	0.5	0.5
Semi-auto espresso	0.1	0.1	0.0
Fully-auto espresso	0.1	0.1	0.2
Drip filter (glass), standby/keep warm	1.2	1.0	1.0
Drip filter (thermos), standby/keep warm	0.0	0.0	0.0
Drip filter (full automatic), standby/keep warm	0.0	0.0	0.0
Pad filter, standby/keep warm	0.4	0.4	0.5
Hard cap espresso, standby/keep warm	0.2	0.3	0.3
Semi-auto espresso, standby/keep warm	0.0	0.0	0.0
Fully-auto espresso, standby/keep warm	0.0	0.1	0.1
Total (TWh)	**7.9**	**8.1**	**8.8**
Total (PJ)	**28.44**	**29.16**	**31.68**

The following **total primary energy use**, i.e. primary electricity and fuel for the full lifecycle, is expected for the years 2020, 2030, and 2050 for non-tertiary coffee machines according to the Environmental Impact Accounting (EIA) study (VHK 2019)[401].

Table 138. Total primary energy use 2020, 2030 and 2050 of currently regulated non-tertiary coffee machines for ECO scenario. PEF: 2.5 (source: Ecodesign Impact Accounting study by VHK, 2019)

Total primary energy use (ECO scenario) for non-tertiary coffee machines	2020	2030	2050
Drip filter (glass)	8	7	7
Drip filter (thermos)	3	3	3
Drip filter (full automatic)	2	2	3
Pad filter	2	2	2
Hard cap espresso	1	1	1
Semi-auto espresso	0	0	0
Fully-auto espresso	0	0	0
Drip filter (glass), standby/keep warm	3	2	2
Drip filter (thermos), standby/keep warm	0	0	0
Drip filter (full automatic), standby/keep warm	0	0	0
Pad filter, standby/keep warm	1	1	1
Hard cap espresso, standby/keep warm	1	1	1
Semi-auto espresso, standby/keep warm	0	0	0
Fully-auto espresso, standby/keep warm	0	0	0
Total (TWh)	**20**	**20**	**22**
Total (PJ)	**72**	**72**	**79**

[401] Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, NRGECO; Primary Energy Factor (PEF) of 2.5 according to Energy Efficiency Directive (2012/27/EU) as basis

The following **total greenhouse gas emissions** are expected for non-tertiary coffee machines for the years 2020, 2030, and 2050 according to the Environmental Impact Accounting (EIA) study (VHK 2019)[402].

Table 139. Total emissions of greenhouse gases (GHG) 2020, 2030 and 2050 of currently regulated non-tertiary coffee machines for ECO scenario (source: Ecodesign Impact Accounting study by VHK, 2019)

GHG emissions (ECO scenario) for non-tertiary coffee machines	2020	2030	2050
Drip filter (glass)	1.2	1.0	0.7
Drip filter (thermos)	0.4	0.4	0.3
Drip filter (full automatic)	0.2	0.3	0.3
Pad filter	0.2	0.3	0.3
Hard cap espresso	0.2	0.2	0.1
Semi-auto espresso	0.0	0.0	0.0
Fully-auto espresso	0.0	0.0	0.0
Drip filter (glass), standby/keep warm	0.4	0.3	0.3
Drip filter (thermos), standby/keep warm	0.0	0.0	0.0
Drip filter (full automatic), standby/keep warm	0.0	0.0	0.0
Pad filter, standby/keep warm	0.1	0.1	0.1
Hard cap espresso, standby/keep warm	0.1	0.1	0.1
Semi-auto espresso, standby/keep warm	0.0	0.0	0.0
Fully-auto espresso, standby/keep warm	0.0	0.0	0.0
Total (Mt CO_{2eq})	**3**	**3**	**2**

Other environmental impacts relate to the consumption of coffee as consumable and their packaging, mainly those portioned in capsules made of aluminium and plastics.

According to the Environmental Impact Accounting (EIA) study (VHK 2019)[403], the total acquisition cost of currently regulated ErP for the ECO scenario for non-tertiary coffee machines is around €2.5 bn/a in end-consumer prices in 2020, see table below, expected to rise to €3.3 bn/a in 2050.

Table 140. Total acquisition costs 2020, 2030 and 2050 of currently regulated non-tertiary coffee machines for ECO scenario (source: Ecodesign Impact Accounting study by VHK, 2019)

Total acquisition costs (ECO scenario) for non-tertiary coffee machines	2020	2030	2050
Drip filter (glass)	0.22	0.19	0.19
Drip filter (thermos)	0.12	0.13	0.13
Drip filter (full automatic)	0.25	0.30	0.41
Pad filter	0.55	0.63	0.80
Hard cap espresso	0.77	0.81	0.81
Semi-auto espresso	0.06	0.06	0.04
Fully-auto espresso	0.56	0.69	0.96
Total (bn €/a incl. VAT & installation)	**2.5**	**2.8**	**3.3**

The results of the energy, emissions and costs would have to be updated as soon as more recent sales and stock data would be available.

[402] Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, EMISSECO
[403] Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, ACQECO

11.6 Saving potential

The Ecodesign preparatory study on non-tertiary coffee machines in 2011, Task 6, has investigated the options for improvement of energy efficiency and concluded that a cost-effective savings potential exists. The technical design options that could bring about such savings were identified in the preparatory studies as follows:

- Reduction of the time in ready-to-use mode (auto-power down and short delay time)[404]
- Reduction of the electricity consumption in ready-to-use mode
- Reduction of the the electricity consumption in standby mode ("zero standby")
- Additional or better insulation of hot parts (thermo-block, boiler, water heater)
- Flow-through water heater or continuous flow heaters (instant heating devices), i.e. activating just before coffee production begins and switching automatically off once it is finished so that auto-power down is much less relevant.

Most of these savings potentials identified in the initial preparatory study of 2011 were already achieved through the inclusion of non-tertiary coffee machines in the EU Ecodesign regulation 801/2013 on networked standby (cf. section 11.1.2).

Still, according to the Ecodesign review study on standby (2017)[405], there is further saving potential beyond the current standby regulation as several coffee machines consume rather below the threshold of 0.5W in standby mode; 54% of the models retrieved in that study presented standby mode consumption ≤0.2W, 69% ≤0.3W and 73% ≤0.4W, therefore presenting an average consumption of 0.25W. Also, it seems as there are still some coffee machines on the market that can be manually reprogrammed by the user to have a delayed switch-off time of several hours instead of the mandatory maximum minutes. These aspects and improvement potential, however, will presumably be covered by the ongoing revision of EU Ecodesign regulation 801/2013.

Until now, the energy consumption of the on-mode phase of non-tertiary coffee machines is not covered by any regulatory measure as not being part of Ecodesign regulation 801/2013 on networked standby and due to a lack of a measurement standard back at that time. With standard EN 60661:2014 in place, an EU Energy label could be introduced for non-tertiary coffee machines, similar to the Swiss energy label for coffee machines[406], taking into account the various properties of the different machine types, including the energy consumption of coffee or steam making, cooling and reheating of the water.

As the overall power-saving potential seems to be rather lowe, further relevant saving potential for non-tertiary coffee machines is expected mainly in design approaches and requirements with regard to better facilitating reparability including spare parts availability (mainly of semi-automatic and automatic espresso machines), extending durability (e.g.

[404] One stakeholder commented that it should be noted that a manual extension of the ready to use time e.g. in the machine settings is required to account for use in office or office-like environments where frequent shut-down and boot-up cycles with rinsing would consume much more energy than the machine remaining in a longer ready-to-use state.

[405] https://www.ecostandbyreview.eu/downloads/Review%20study%20standby%20regulation%20-%20final%20report%20april%202017.pdf

[406] https://www.bfe.admin.ch/bfe/en/home/efficiency/energy-labels-and-efficiency-requirements/household-appliances/coffee-machines.html

for drip filter, pad filter and hard-cap espresso machines where repairs might not be as cost effective due to the lower prices of the machines), and increasing the content of recycled plastic.

Savings potential of these material efficiency measures for non-tertiary coffee machines is estimated to be in a similar, slightly lower range as calculated in the recent Ecodesign review study for the product category vacuum cleaners[407], thus estimating 15-20% saving potential for non-tertiary coffee machines.

In summary, with both introducing an Energy label and material efficiency requirements, the total savings in the year 2030 are estimated to be around 20%:

- 14.4 PJ (4 TWh) primary energy saving, including 5.8 PJ (1.6 TWh) electricity saving;
- 0.6 $MtCO_{2eq}$ carbon saving;

Acquisition costs may be slightly increasing, but overall lower annual expenditure for consumers.

Other than mentioned for tertiary machines, the Ecodesign review study for non-tertiary machines did not assess the potential savings due to the quantity of coffee the machines use to deliver a cup of coffee of a given quality. In a further review, it could be analysed if at least for automatic and/or smart coffee machines monitoring the quantity of coffee used it might be possible to apply an environmental footprint for the coffee consumption of the appliance. Further, a review study should assess what it would mean in terms of material savings if aluminium/plastic capsules were reduced by a certain percentage (through e.g. mandatory implementation of reusable capsules, etc.) over the lifetime of the espresso coffee machines. Also, a review study should analyse if the energy effiency of different types of machines would be in such a range that an energy label would be a suitable option for non-tertiary coffee machines to enable sound and cost-efficient purchasing decisions for consumers.

[407] For vacuum cleaners, the recent ecodesign review study (Rames et al. 2019) calculated a policy scenario which includes both measures to facilitate increased lifetime and information requirements on the content of recycled plastic in the product. Lifetime requirements cover motor life, hose oscillation, and battery lifetime (of cordless and robots), as well as spare parts availability, easy changeable repair-prone parts and information requirements on repairs. The impact of this policy scenario compared to the business-as-usual (BAU) scenario. According to (Rames et al. 2019), the savings are caused by an assumed increase in the lifetime of vacuum cleaners of 25%, and an increased use of recycled plastic. Although it means that more material (spare parts) are used per vacuum cleaner and that the vacuum cleaners will miss out a potential energy improvement according to the longer lifetime, the average energy saving potential is 29%. https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/vacuum-cleaners/vacuum_cleaner_review_final_report_.pdf

12 TERTIARY HOT BEVERAGE EQUIPMENT

12.1 Scope, policy measures and test standards

12.1.1 Background

In the "Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC" (BIO by Deloitte et al. (2015), Task 3), tertiary hot beverage equipment was evaluated for its suitability for Ecodesign and Energy Labelling measures.

The following types were in scope:

- free standing hot beverage vending machines;
- table-top "full automatic" machines;
- café / restaurant espresso machines.

The study did not include commercial large capacity brewers such as satellite coffee machines or coffee urns.

In Task 3, it was concluded that the product group exhibits some savings potential which is however not too high (1.1 TWh (electric) in 2020, and 1.2 TWh (electric) in 2030, which translates into 10 resp. 11 PJ primary energy due to the conversion factor of 2.5). It was decided to carry only free-standing hot beverage vending machines over to Task 4 because there was a policy window for regulating them together with cold vending machines. In the end, they were not included in the Working Plan due to relatively low priority.

A study conducted by Bush Energie for the Swiss Federal Office of Energy (SFOE) in 2017 concludes that the savings potentials are underestimated, mainly through an underestimation of energy consumption (usage hours too low) and lack of a solid database for individual product power consumption and savings potential. Based on HKI and Topten databases, it assumes final energy savings to be more in the range of 4 TWh electric (assuming an immediate exchange of stock) (Rothwell und Bush 2017).

The aim of the current study is

- to discuss and potentially update the scope of the previous study;
- to update the previous data and assessments in order to see if there have been relevant changes especially with respect to market trends, technology development and savings potentials that would merit an inclusion of the product group into the Working Plan 2020-2024;
- to check if the novel policy focus on circular economy merits an inclusion.

The chapter is partly based on prior own work (by part of the study team), that is, Task 3 report, chapter 28, and Task 4 report, chapter 10 of the WP 3 study. It therefore includes sentences and paragraphs with identical or very similar wording. For ease of reading, these sections have not been specifically highlighted as citations.

12.1.2 Scope

Tertiary hot beverage equipment comprises machinery used for preparing hot drinks and intended for commercial purpose. This includes machines for self-service, found for example in workplaces, waiting rooms, retail stores, train stations and airports, educational institutions, hotels etc.; espresso and coffee machines operated by staff and found in restaurants, cafés, and bars; or machines used by caterers and in canteens.

When designing a preparatory study for coffee, (or, more general, hot beverage) machines, care must be taken with respect to defining the scope and suitable sub-groups. There are different criteria which can be – and are – used; such as functionality, brewing technology, usage scenario, degree of automation, existence or not of a payment system, structural form, and others. These criteria partly overlap, and in addition, the definitions of some of them vary, especially for "full automatic" vs. "semi-automatic".[408]

In this study, we use a distinction that is based basically on brewing technology and structural form as these impact energy and material consumption. Furthermore, it shall as far as possible fit to classifications used in existing sources e.g. for sales data. For this reason, we do not use the existence of a payment system as a distinction criterion (as it affects energy use very little), nor do we use the distinction between fully and semi-automatic machines to categorize machines (as these terms are used differently).

We work with the following types, illustrated by the figures below:

- free-standing hot beverage vending machines
- table-top machines;
- manually operated café/restaurant espresso machines (porta filter);
- "bulk and batch brewers": these include commercial (large capacity) filter or percolator brewers, including as satellite brewers or coffee urns

Figure 36: Table-top machines[409]

[408] For example, the European Vending & Coffee Service Association defines "full automatic" as being able to dispense cups or provide sugar or toppings automatically while "semi-automatic" machines require that the user places a receptacle. Other sources such as Coffee Business Intelligence use "full automatic" generally for all table-top and free-standing vending machines and distinguish them from "semi-automatic" machines, by which many manufacturers understand porta filter systems (e.g. https://www.melitta-professional.de/en/Cafina-Semi-Automatic-Machines-781.html; https://33coffeemakers.com/semi-automatic-coffee-machines/ ; http://www.promacitalia.com/en/)

[409] Source: European Vending Association.

Figure 37: Free-standing hot beverage vending machine. Source: EVA

Figure 38: Café/restaurant espresso machine (porta filter)

Figure 39: Commercial satellite filter coffee machine. Source: https://www.webstaurantstore.com/curtis-alp3gt63a000-12-cup-coffee-brewer-with-1-lower-and-2-upper-warmers-120-220v/945ALP3GT63.html

Figure 40: Coffee urn. Source: https://www.mtbeventrentals.com/product/55-cup-coffee-urn/

Free-standing hot beverage vending machines are designed for self-service and for high capacity areas. The majority of this equipment offers a broad range of hot beverages such as tea, coffee, hot chocolate, cappuccino, soup etc. They are generally fully automatic although machines exist where the automatic dispensing of a cup can be stopped by the user. They generally have a payment system.

Table-top machines are smaller machines positioned on a work surface or bespoke cabinet. They might be designated for self-service for example in the Hotel, Restaurant, and Catering business (HoReCa) or in offices (OCS). Sometimes they are also operated by vending staff in places such as bakeries or service stations. Some incorporate a payment system, but it has limited impact on the design of the machine. They may be full automatic or semi-automatic according to the EVA definition (see footnote 408); while in other sources they are referred to as "table-top (full automatic) machines".

Café / restaurant espresso machines (porta filter) are operated by café / restaurant staff to brew coffee drinks for clients. They include a filter which is filled with coffee powder by staff or the user. There is an overlap of small café / restaurant coffee machines with more advanced domestic espresso machines. These dual use machines are called “prosumer” machines.[410]

Batch and bulk brewers are used for catering or in canteens. They produce and store large amounts of liquid coffee that can then be distributed to clients. They may use the percolator (coffee urns) or the drip filter principle (commercial satellite filter coffee machines).

For more detail, see section 12.4.1, “Types”.

In the present chapter, the scope includes the four types described above, being aware of the overlap with domestic machines. Where relevant, cross-reference to the chapter on ‘non-tertiary coffee machines’ is made.

12.1.3 Policy measures

12.1.3.1 EU policies

Currently, tertiary hot beverage equipment is regulated under Directive 2012/19/EU on waste electrical and electronic equipment (WEEE; category 4), the Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), and Regulation (EC) 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

Regarding health and hygiene issues, tertiary hot beverage equipment should comply with Regulation 1935/2004 on materials and articles intended to come into contact with food (FCM).

More generic European legislation relevant tertiary hot beverage equipment includes the Low Voltage Directive (LVD) 2014/35/EU (for Filter coffee machines and coffee urns), the Electromagnetic Compatibility Directive (EMC) 2014/30/EU, and the Machine Directive (MD) 2006/42/EC.

No European policies on energy efficiency of tertiary hot beverage equipment exist.

12.1.3.2 Selected national policies

The Nordic Ecolabel has requirements for “Coffee Services”, which also includes energy requirements for the coffee machine used for the service, and environmental and health requirements on the coffee machine’s components[411]. Coffee machines as a sole product cannot be Nordic Swan ecolabelled. Coffee machines included in the Nordic Swan ecolabelled coffee service are fully and semi-automatic machines for professional or public use. Capsule machines sold to professional and public environments, as well as coffee percolators, filter coffee machines and coffee machines for domestic use are not covered by the Nordic Swan Ecolabelled coffee service. The criteria document uses the "European Vending & Coffee Service Association (EVA) Energy Measurement Protocol (EMP) 3.1b" or the DIN 18873-2 (see section 4.1.3).

[410] e.g. https://www.wholelattelove.com/collections/prosumer-espresso-machines

[411] http://www.nordic-ecolabel.org/product-groups/group/?productGroupCode=100

For commercial coffee machines, the US Environmental Protection Agency (EPA) finalized an ENERGY STAR specification, Version 1.1 being in effect since May 2018[412]. In that document, commercial coffee brewers are characterized into three main types: single-cup brewers, batch brewers, and urn/satellite brewers. The ENERGY STAR specification focuses on coffee brewers intended for commercial use and excludes coffee makers used in households. The scope currently only includes batch commercial coffee brewers (Type II) designed to use loose, ground coffee and a re-usable or single-use coffee filter and has a standard brew volume of >24 to 384 fluid ounces (0.7 – 11.36 l) per brew event. Energy efficiency requirements are related to the "Normalized Ready-to-Brew Idle Energy Rate" and the "Normalized Heavy-Use Brew Energy Rate".

12.1.4 Test standards

Different test standards exist; however all of them cover only selected types of machines and / or selected modes of operation.

For commercial coffee machines, the German standard DIN 18873-2:2016-02 *Methods for measuring the energy consumption of commercial kitchen appliances - Part 2: Commercial coffee machines* is available. It applies to table-top machines and café/restaurant espresso machine (porta filter). This engineering standard is part of a standard series for measuring the energy use of equipment for commercial kitchens. Part 2 contains equipment-specific provisions for determining the energy loss and output power of commercial coffee machines.[413] The "energy loss" includes all necessary processes that take place without producing a beverage (heating, cleaning, rinsing, shutdown, standby). The values determined are made available to the public by the manufacturers on a voluntary basis at https://grosskuechen.cert.hki-online.de/de. Topten Switzerland is using the energy loss as their criteria for energy efficient commercial coffee machines.

The Italian standard UNI 11668:2017 also applies to table-top machines and café/restaurant espresso machine (porta filter). It measures all electrical energy used by the machine to performe any activity including the energy to deliver beverages.

Currently, a European standard (pr=61373) "Methods for measuring of the energy consumption for professional and commercial appliances for preparation of coffee and hot beverages" is currently being developed that is intended to supersede both DIN 18873-2:2016-02 and UNI 11668:2017. [414] It will apply to table-top machines and café/restaurant espresso machine (porta filter). The process is chaired by the CLC/TC 59X/WG21 "Professional and commercial coffee machines". According to a statement by EFCEM, "[it] was intended to draw up independent standards with device-specific requirements for traditional coffee machines and full automatic machines. All operating cycles (e.g. heating up, product purchase, stand-by phase) should be included. Within the product reference phase, the intention is to include coffee, espresso, hot water, hot milk and instant products as test

[412] https://www.energystar.gov/products/commercial_food_service_equipment/commercial_coffee_brewers; https://www.energystar.gov/sites/default/files/Commercial%20Coffee%20Brewers%20Version%201.1%20Specification_2.pdf

[413] https://www.beuth.de/en/standard/din-18873-2/231927739

[414] https://www.cenelec.eu/dyn/www/f?p=104:22:1419160475680801::::FSP_ORG_ID,FSP_LANG_ID:1257245,25#

media, provided the machine can dispense the product." Currently, the process has been delayed due to the COVID 19 crisis.

Further, for hot drinks vending machines, the European Vending & Coffee Service Association (EVA) provides the EVA Energy Measurement Protocol (EVA-EMP) 3.1b.[415] The EVA-EMP is a self-declaration standard.
Within the EVA-EMP standard, the energy consumption is measured in stand-by situation and vending situation. In details, there are seven test phases:

- Machine Heat Up phase;
- Machine Idle phase;
- Machine Vending phase;
- Energy Saving Mode phase;
- Heat Up phase from Energy Saving Mode to Idle;
- Machine Idle phase – Cold drinks only (if applicable); and
- Machine Vending phase – Cold drinks only (if applicable).

The results from the energy measuring protocol can be used to produce an energy rating level, which is expressed as an energy level of the machine in the scale between A++ and G, similar to the EU Energy labelling. The EMP forbids the rating scale to be used in function of a label on the machine.
For US ENERGY STAR specifications for commercial coffee brewers, ASTM F2990-12(2018) *Standard Test Method for Commercial Coffee Brewers*[416] is the basis. This test method covers the evaluation of the energy consumption, brewing, and holding performance of commercial coffee brewing machines (here after referred to as coffee brewers) used in commercial and institutional facilities. The operator can use this evaluation to select a coffee brewer and characterize its energy use and performance. This test method applies to single cup (Type I) and batch (Type II) coffee brewers. It does not cover residential coffee brewers, "urn" coffee brewers (Type III), or espresso machines. The coffee brewer will be tested for the following (where applicable): Maximum energy input rate, heavy use brewing energy consumption, production capacity, "Ready-to-Brew" (Standby/Idle) energy rate, and "Energy Save Mode" (Low power) energy rate.

Finally, the Swiss Association ENAK "has […] a measurement standard for table-top machines). Four energy consumption measurements are defined which are tested in a row:
– Energy consumption for heating up (until ready-to-operate) [kWh]
– Energy consumption for staying one hour in standby mode [kWh]
– Energy consumption for preparing 60 coffees [kWh]
– Energy consumption for cleaning [kWh]." (Rothwell und Bush 2017).[417]
ENAK also hosts a database with energy consumption data.

[415] https://www.vending-europe.eu/activities/technical-and-standards/
[416] https://www.astm.org/Standards/F2990.htm
[417] Available for members at https://enak.ch/

To address durability issues, the standards to support Ecodesign requirements on material efficiency aspects for energy-related products could be applied, covering the following aspects: extending product lifetime, ability to reuse components or recycle materials from products at end-of-life, use of reused components and/or recycled materials in products.[418]

12.2 Market

12.2.1 Present situation

Eurostat data is available for "Non-domestic percolators and other appliances for making coffee and other hot drinks" (Prodcom code 28.93.15.60), up until 2019. Apparently, data has been updated since 2015 as it differs from the data retrieved in 2014 for the preparatory study for the working plan 2016-2019 (Table 141).

Table 141: EU production of tertiary hot beverage equipment (units)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-28	420,466	525,149	466,781	565,934	533,097	515,168	546,649	589,385	773,571	745,761
EU-27 2020 (w/o UK)	394,808	499,652	426,781	485,934	469,666	447,611	484,028	559,385	745,751	718,911
EU 27 2007 (w/o Croatia)	420,466	525,149	478,653	n/a	n/a	n/a	n/a	n/a	n/a	n/a
WP 3 data for EU 27 2007	420,466	525,449	525,621	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Source: Prodcom

The EU-27 (2020) data indicate potentially significant rises in production in 2011, and then again in 2017 and 2018, after a period of relative stability (if it is not a reporting artefact). We will come back to the issue when dealing with the individual types of machines further below.

The single most important producer is Italy, with 514,000 units in 2019, ten times the production of Spain, the second. Smaller volumes are produced by the UK, Denmark, and, until 2015, Portugal. Their figures do not completely add up to the EU total, but production volumes for other countries are not provided. The consultant "Coffee business intelligence" reports that other relevant producers are Germany, France, the Netherlands, and Sweden, as well as (outside the EU) Switzerland.[419]

PRODCOM only provides the production volume of these products, no export and import. Therefore, apparent consumption cannot be calculated. However, given the information that Europe is world leading both in tertiary coffee machine production and market size,[420]

[418] EN 45552:2020 (General method for the assessment of the durability of energy-related products), EN 45553:2020 (General method for the assessment of the ability to remanufacture energy-related products); EN 45554:2020 (General methods for the assessment of the ability to repair, reuse and upgrade energy-related products); EN 45555:2019 (General methods for assessing the recyclability and recoverability of energy-related products); EN 45556:2019 (General method for assessing the proportion of reused components in energy-related products); EN 45557:2020 (General method for assessing the proportion of recycled material content in energy-related products); EN 45558:2019 (General method to declare the use of critical raw materials in energy-related products); and EN 45559:2019 (Methods for providing information relating to material efficiency aspects of energy-related products)

[419] https://coffeebi.com/2020/02/12/professional-coffee-machines-in-europe-part-1/

[420] https://coffeebi.com/2020/02/12/professional-coffee-machines-in-europe-part-1/

we assume that production and consumption are approximately equal, although a certain share of machines may be imported from Switzerland.

PRODCOM does not provide a breakdown for different types of equipment. We will attempt to estimate this in the following sections.

Free-standing vending machines and table-top machines
These types are grouped together here as a distinction is not possible for all years, based on the available sources.

Sales
Sales are calculated based on PRODCOM data on overall production, combined with information provided by EVA (2020, personal communication).
For the years 2010-2017, we use PRODCOM data and apply shares of different types as provided by consultant "Coffee Business Intelligence" [421] This source gives separate figures for café and restaurant espresso machines (20% of sales) and for filter coffee machines (33% according to the same source). It is assumed that all others are either free-standing vending machines or table top machines. In this case, the category would be identical to the category "super-automatic espresso and automatic office coffee system (OCS) machines" of that same source.
EVA adds sales data of vending machines for 2018 and 2019 (for EU 27 and UK). Some data from Statista is used for comparison. This renders the following sales (Table 142):

Table 142: EU-27 sales estimates for free-standing vending machines and tabletop machines

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Q1/ 2020
EU-27 sales free-standing vending and tabletop[422]	185,560	234,836	200,587	228,389	220,743	210,377	227,493	262,911	350,503	337,888	
thereof: vending machines[423]									73,540 [424]	66,430 [425]	14,513
thereof: full automatic machines sold to HORECA sector and offices[426]									261,000		

For 2018, the sum of the EVA and Statista information is some 16,000 lower than the figure calculated from Prodcom, even though EVA data include the UK. Taken together with

[421] https://coffeebi.com/2020/02/12/professional-coffee-machines-in-europe-part-1/
[422] Source: Own calculations based on Prodcom and Coffee Business Intelligence;
[423] Source: EVA, personal communication
[424] Including UK
[425] Including UK
[426] https://www.statista.com/statistics/1072950/number-of-coffee-machines-sales-in-europe-by-type/

the sudden and inexplicable increase in 2017/2018 in Prodcom, this indicates that Prodcom-based figures for 2018 and 2019 are probably overestimated.

Stock

For stock, we base our preliminary assessment on the EVA market report from 2015 (European Vending and Coffee Service Association 2015).[427], EVA personal communication on stock in 2018

According to EVA (personal communication), stock has been broadly stable over the last five years despite declining sales, which they attribute to increased lifetimes. For 2015, EVA reports 1.17 million table-top and 1.19 million free standing hot beverage vending machines, that is, with a payment system.. Based on EVA input to the WP 3 study, it is assumed that a further 1.17 million table-top units are non-vending, that is, without a payment system.

For 2018, EVA has communicated a stock of 1,257,000 free-standing vending machines, and for 2019, 4.16 million machines in total (free-standing and tabletop)

Stock for the other years is calculated using the 2015 stock as a starting point, adding 1/3 of the sales figures for each of the three categories and estimating a lifetime of 15 years, meaning that every year 6.7% of the stock go out of service.

Table 143: EU-27 stock estimates for vending machines and non-vending tabletop machines

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
free-standing vending	1,259,984	1,249,045	1,228,180	1,217,356	1,204,874	1,190,000	1,180,792	1,177,904	1,257,000	1,290,034
tabletop vending	1,231,745	1,222,689	1,203,581	1,194,397	1,183,446	1,170,000	1,162,126	1,160,482	1,170,753	1,209,537
tabletop non vending	1,231,745	1,222,689	1,203,581	1,194,397	1,183,446	1,170,000	1,162,126	1,160,482	1,170,753	1,209,537
total	3,723,473	3,694,422	3,635,342	3,606,149	3,571,766	3,530,000	3,505,044	3,498,867	3,528,521	3,643,789

Source: Own calculations; for 2018 free standing vending machines: EVA personal communication

It must be noted that the result for 2019 is somewhat lower than the communicated 4.16 million communicated in an EVA press release on their 2019 market report.[428] Changing assumed machine lifetime did not significantly change this discrepancy. This means that the modelling is rather conservative and somwhat underestimates actual stock development.

[427] The following 21 countries are covered: Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Hungary, Republic of Ireland, Italy, Netherlands, Poland, Portugal, Russia, Slovakia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and Ukraine. Considering that some EU Member States are not included in the EVA statistics but that non-EU countries are, we assume that EVA figures are representative of EU-27.

[428] https://www.vending-europe.eu/eva-report-vending-market-growth-to-be-offset-by-covid-19-impact/

Café and restaurant espresso machines. According to the Eurostat Annual Detailed Enterprise Statistics for Services[429], the combined number of "Hotels and similar accommodation", "Restaurants and mobile food service activities" and "beverage serving activities"[430] was 1,545,138 in the EU-27 (without UK) in 2015. To calculate the share in which coffee from a coffee machine is served, we use information from the Global Coffee report[431], according to which the five countries Germany, Italy, Spain, France, and United Kingdom had a total of about 880,000 of hotels, restaurants and coffee shops in 2015. These same five countries had 981,825 enterprises in the food or beverage serving sectors according to Eurostat. Therefore, the share of hotels, restaurants and coffee shops can be calculated as 81%. If this share is applied to EU totals of establishments, and it is assumed that each of them owns a bar / restaurant espresso machine[432], this exercise delivers the following stock estimates (figures for 2010 and after 2017 not available).

Table 144: EU-27 stock estimates for café and restaurant espresso machines

	2011	2012	2013	2014	2015	2016	2017
Stock estimate	1,222,833	1,221,567	1,213,570	1,249,437	1,251,562	1,286,884	1,278,460

Source: Own calculations based on Eurostat and Global Coffee Report

With regard to sales, we have the following three sources for 2015:

- The Global Coffee Report (2015)[433] stated that the European espresso machine market is the largest in the world, with about 185,000 units sold every year (70% of the which is represented by the five countries Germany, Italy, Spain, France, and United Kingdom). The major share of espresso machines goes to the HoReCa segment (Hotel, restaurant, and cafés, but also including bars, catering services, canteens, service stations, bakeries etc.). This would render annual sales of more than 92,500 in 2015.
- If the stock estimate from
- Table 144 is taken and an average lifetime of 15 years is assumed, annual sales in 2015 would be around 83,400.
- Finally, Coffee Business Intelligence reports that "traditional espresso machines" make up for 20% of the professional coffee machine market.[434] If it is assumed that

[429] https://ec.europa.eu/eurostat/web/products-datasets/-/SBS_NA_1A_SE_R2

[430] "Hotels and similar accommodation" (NACE code 55.1) include "hotels, resort hotels, suite/apartment hotels, motels". "Restaurants and mobile food serving activities" (NACE code 56.10) include "the provision of food services to customers, whether they are served while seated or serve themselves from a display of items, whether they eat the prepared meals on the premises, take them out or have them delivered. This includes the preparation and serving of meals for immediate consumption from motorised vehicles or non-motorised carts. " "Beverage serving activities" (NACE code 56.30) include "preparation and serving of beverages for immediate consumption on the premises", including "bars, taverns, cocktail lounges, discotheques, beer parlours, coffee shops, fruit juice bars, mobile beverage vendors"

[431] http://gcrmag.com/marketing/view/a-look-at-the-professional-coffee-machine-market-in-europe; last accessed at 2 August 2020

[432] This approximation is not fully reliable. On the one hand, there may be more machines, as one enterprise can own several places, and there may be establishments not covered because beverage savings is not their main business (e.g. in service stations or retail stores). On the other hand, not all restaurants and bars have a professional espresso coffee machine; so we take the number as an approximation.

[433] http://gcrmag.com/marketing/view/a-look-at-the-professional-coffee-machine-market-in-europe; last accessed at 2 August 2020

[434] https://coffeebi.com/2020/02/12/professional-coffee-machines-in-europe-part-1/

all (and only) European production is sold in Europe, this would, combined with the Prodcom data of 2015, deliver sales of 89,500 in 2015.

All three figures are reasonably close, although somewhat lower than the WP 3 study estimate of 100,000 in 2012.

For 2018, a Statista source reports sales of 113,500 "traditional espresso machines" in Europe.[435]

A comparison of these sources is shown in Table 145.

Table 145: EU-27 Comparison of sales estimates for café and restaurant espresso machines

Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Global Coffee Report						92,500				
Calculated stock (Table 144) + lifetime 15 y.						83,400				
Prodcom + CBI	78,962	99,930	85,356	97,187	93,933	89,522	96,806	111,877	149,150	143,782
Statista									113,500	

Sources: Various, see table.

The figures calculated from Prodcom have the advantage that timelines are available, and for 2015, they fit pretty well with the other sources and represent the middle value of all sources. However, the sudden increase in 2017/2018 seems somewhat implausible and does not fit with the Statista data for 2018 either. This data will therefore not be used for the forecast (see for details Section 12.2.2).

Batch and bulk brewers. Although sometimes seen in an event catering context or in canteens, percolator urns do not seem to play a large role in Europe, as they are neglected in most statistics. Commercial filter coffee machines, in contrast, are currently 33% of the professional market, according to consultancy Coffee Business Intelligence.[436] This figure is applied to the PRODCOM production volume of in the EU-27 to estimate annual sales.

Table 146: EU -27 sales estimate for batch and bulk brewers

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ann. production Filter coffee machines (EU-27)	130,287	164,885	140,838	160,358	154,990	147,712	159,729	184,597	246,098	237,241

Source: Own calculations based on Prodcom and Coffee Business Intelligence

For comparison, Statista[437] reports for 2018 sales of 181,510 "filter and instant machines" to the European HORECA sector and offices. This again indicates that Prodcom data for 2018 and 2019 are probably too high.

[435] https://www.statista.com/statistics/1072950/number-of-coffee-machines-sales-in-europe-by-type/
[436]https://coffeebi.com/2020/02/12/professional-coffee-machines-in-europe-part-1/
[437] https://www.statista.com/statistics/1072950/number-of-coffee-machines-sales-in-europe-by-type/

Stock is more difficult to estimate. One option is to multiply sales by an estimated average lifetime for this type of machines. Another one is to use Eurostat data on "event catering and other food service activities".[438] These include catering for specific events as well as the operation of canteens, food services in sports facilities etc.[439] One could assume that each firms owns a certain number of such devices. The two approaches only render comparable results when lifetime is set relatively short (for example 4 years)[440] and the number of devices per firm relatively high (for example 8 units). Table 145 shows this attempt to minimise the differences between the two approaches (figures for No. of enterprises are not available for 2010 and after 2017). For lack of better estimates, we will use the average of both approaches as presented in Table 145.

Table 147: EU-27 stock estimates for batch and bulk brewers (EU 27)

	2011	2012	2013	2014	2015	2016	2017
No. Enterprises	65,807	66,801	70,725	78,191	79,734	85,169	86,310
Production of machines	164,885	140,838	160,358	154,990	147,712	159,729	184,597
Stock estimate (derived from lifetime 4 years)	659,541	563,351	641,433	619,959	590,847	638,917	738,388
Stock estimate (derived from 8 machines per enterprise)	526,456	534,408	565,800	625,528	637,872	681,352	690,480
Difference of estimates	133,085	28,943	75,633	- 5,569	- 47,025	- 42,435	47,908
Average stock	**592,998**	**548,879**	**603,616**	**622,744**	**614,359**	**660,134**	**714,434**

Source: Own calculations

All sales and stock estimates are presented together in Table 148. For the years 2010-2012, figures from BIO by Deloitte et al. (2015) are provided for comparison. The only strong difference is observed in the sales and stock of vending and tabletop machines in 2012, which are estimated to be much lower in the present study. However, an error may have occurred with respect to these products in the WP 3 study when estimating the numbers of machines without payment system for which no data was available.
Furthermore, figures for 2018 and 2019 have to be taken with caution given the inconsistencies cited above, and are probably lower in reality.

[438] https://ec.europa.eu/eurostat/web/products-datasets/-/SBS_NA_1A_SE_R2

[439] "Event catering" includes "the provision of food services based on contractual arrangements with the customer, at the location specified by the customer, for a specific event." "Other food service activities" includes "industrial catering, i.e. the provision of food services based on contractual arrangements with the customer, for a specific period of time. […] This class includes

- activities of food service contractors (e.g. for transportation companies)
- operation of food concessions at sports and similar facilities
- operation of canteens or cafeterias (e.g. for factories, offices, hospitals or schools) on a concession basis." Eurostat 2008.

[440] A 2011 US source estimates lifetime at 6 years. https://www.statista.com/statistics/220433/life-expectancy-of-coffee-machines/

Table 148: Summary of EU-27 sales and stock estimates

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-27 sales estimates										
Vending and tabletop	185,560	234,836	200,587	228,389	220,743	210,377	227,493	262,911	350,503	337,888
WP 3 study	n/a	n/a	317,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Café espresso	78,962	99,930	85,356	97,187	93,933	89,522	96,806	111,877	149,150	143,782
WP 3 study	97,000	98,000	100,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Batch and bulk	130,287	164,885	140,838	160,358	154,990	147,712	159,729	184,597	246,098	237,241
WP 3 study	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total	**394.808**	**499.652**	**426.781**	**485.934**	**469.666**	**447.611**	**484.028**	**559.385**	**745.751**	**718.911**
WP 3 study	**n/a**	**n/a**	**417,000**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EU-27 stock estimates										
Vending and tabletop	3,723,473	3,694,422	3,635,342	3,606,149	3,571,766	3,530,000	3,505,044	3,498,867	3,528,521	3,643,789
WP 3 study	n/a	n/a	3,250,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Café espresso	n/a	1,222,833	1,221,567	1,213,570	1,249,437	1,251,562	1,286,884	1,278,460	n/a	n/a
WP 3 study	n/a	1,460,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Batch and bulk		592,998	548,879	603,616	622,744	614,359	660,134	714,434		
Total		**4,397,386**	**4,274,374**	**4,276,272**	**4,284,026**	**4,225,921**	**4,281,396**	**4,321,327**		

Source: Own calculations

12.2.2 Forecast

According to the Coffee Business Intelligence consultancy[441], for the European market of professional coffee machines for hotels, restaurants and cafés (HORECA) and offices an average growth rate of 3.5% has been recorded in recent years. The increase is mainly due to the opening of new coffee shops and coffee points in shops and convenience stores, all of which have required the purchase of new coffee machines. Also, a large contribution to growth is due to the use of table-top machines in offices as, in particular, the number of refreshment corners has increased. This observation fits with the Eurostat data on number of enterprises in the hotel, food serving, and drink serving sectors which have also seen some increase over the years, see Table 149.

[441] https://coffeebi.com/2020/02/12/professional-coffee-machines-in-europe-part-1/; https://coffeebi.com/2020/02/13/professional-coffee-machines-in-europe-part-2/

Table 149: Number of enterprises in the hotel, food serving, and beverage serving sectors in the EU-27 (without UK)

	2010	2011	2012	2013	2014	2015	2016	2017
Number of hotel, food and beverage serving enterprises, EU-27		1,509,670	1,508,108	1,498,235	1,542,515	1,545,138	1,588,746	1,578,346
Annual change			-0.1%	-0.7%	+3.0%	0.2%	+2.8%	-0.7%

Source: Eurostat[442], own calculations.

Also, the press release for the 2017 EVA market report (based on 2016 data) seems to support a growth trend: "Overall, the report […] reinforces the trend revealed last year that several mature markets who have seen a number of years of decline have either started to grow or at least remained stable. Indeed, as a whole the European vending market is growing with total annual revenue rising to €15.05 billion. […] The overall fieldbase (number of machines) is now 4 million (1.2% increase since 2015)].[443] Although this report refers to all vending machines, hot beverage machines are dominating this market with 62% in 2015 (European Vending and Coffee Service Association 2015).

The PRODCOM production data is somewhat erratic especially for 2010, 2018 and 2019, but also indicates growth. The total growth from 2010 to 2019 has been 82%; the growth rate from 2011 to 2017 12%, which seems much more realistic.

Table 150: EU production of commercial coffee machines and annual growth rates

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU27 w/o UK	394.808	499.652	426.781	485.934	469.666	447.611	484.028	559.385	745.751	718.911
Annual change rate		+26.6%	-14.6%	+13.9%	-3.3%	-4.7%	+8.1%	+15.6%	+33.3%	-3.6%

Source: PRODCOM, own calculations

It is expected that there is a decline of sales due to the COVID-19 crisis which will continue for some time to come. With public places, workplaces and restaurants / hotels closed over a time and less frequented after that, in the light of closing HoReCa and catering enterprises as well as general economic hardship, we expect that replacement or new acquisition of hot beverage equipment will be postponed.

In a stakeholder communication on an earlier version of this report, EVA reports the following declines in sales "a -66% drop in sales for freestanding automatic hot drinks machines, 73% reduction in table top automatic hot drinks machine sales and -60% reduction in table top semi auto machine sales (Q2). According to draft end of year sales figures, vending machine sales (all categories) ended the year with a -38% reduction." It is not fully clear whether "vending machines" in this communication also includes machines without a payment function.

In a similar vein, EFCEM states a decline of 33.7% for "fully automatic units" and -34.7% for porta filter machines in Q1/2020. It is unclear whether "fully automatic units" refers to all tabletop machines, or a subsection of those, or even includes free standing machines.

[443] https://www.comunicaffe.com/eva-releases-its-latest-report-on-vending-and-ocs-industry-in-europe/

Potential longterm effects are not yet clear. Once vaccinations and treatments are available, the frequentation of public places is likely to recover. We assume that this will be the case by the end of 2021 at the latest. The large differences between the figures reported by EVA for Q1/2020 and for the whole year 2020 indicate a potential for a relatively quick recovery.

On the other hand, there might be permanent changes e.g. due to increased home office but also due to general economic hardship. By affecting the volumes sold, , this might have an indirect effect on businesses' decisions to purchase coffee machines..

We base our forecast on 2017 figures and 2018 and 2019 figures based on Prodcom data do not seem reliable, as has been shown above. We assume a 3.5% growth in sales for 2018 and 2019.

For 2020, given the uncertainties in definitions in EVA and EFCEM communications, while on the other hand the actual values communicated are about in the same range, we assume a medium 35% decline in sales for all types for 2020.

For the following years, we assume a gradual recovery from 2021 to 2023 until sales have reached 2019 levels again. To reflect potential long-term effects, we are assuming that sales do not grow further but rather remain constant until 2026, and resume a 2% growth rate after that. As all of this is currently highly speculative, a dedicated preparatory study will have to investigate the actual effects on sales in more detail if the product group is chosen for the Working Plan.

The following sales and stock forecast results for the different categories.

Table 151: EU-27 sales and stock forecast for commercial coffee machines

	2020	2025	2030
EU-27 sales forecast			
Vending and tabletop	183,064 ,	281,637 ,	304,853 ,
Café espresso	77,900 ,	119,845 ,	129,725 ,
Batch and bulk	128,534 ,	197,745 ,	214,046 ,
Total	**389,498 ,**	**599,227 ,**	**648,623 ,**
EU-27 stock forecast			
Vending and tabletop	3,207,623 ,,	2,980,331 ,,	2,965,240 ,,
Café espresso	1,330,059 ,,	1,433,902 ,,	1,562,928 ,,
Batch and bulk	685,715 ,	741,668 ,	810,818 ,
Total	**5,223,397 ,,**	**5,155,901 ,,**	**5,338,987 ,,**

Source: Own calculations

12.3 Usage

Usage patterns and also operation modes differ for the different types of machines considered.

Free-standing vending machines are designed for 24/7 use. They are used, for example, in hotel / hostel lobbies, airports and train stations, or educational institutions. They can be purchased or rented from an operator who may offer full-service for maintenance and repair.

Table-top machines can be found in both HORECA (HOtel, REstaurant, Catering / Café) and OCS (Office Coffee Service[444]) sectors. They may or may not have a payment system; however this does not affect their core functionality. Usage patterns depend on the establishment where they are used – for example, in an office, during office hours, and in a hotel, restaurant or canteen, during and after meals. They, too, may be purchased or rented from an operator.

According to the "Global coffee report" (2015)[445], in Germany, Italy, Spain, France, and the United Kingdom "only 10 per cent of new coffee machines are distributed directly from manufacturers, while 59 per cent pass through coffee roasters and 31 per cent through other distributors." It becomes however not clear whether these figures refer only to purchases or also include rentals.

Professional batch and bulk brewers are used by event catering enterprises or canteens – and to some extent in hospitals, old peoples' homes workplaces and organisations such as associations or churches – to produce larger quantities of coffee for later distribution. Usage patterns depend on the pattern of activity of the operator. No information is available with respect to the operating model, but it is assumed that they are generally purchased by the catering enterprise or organisation as they are not as difficult to maintain as an automatic machine.

12.4 Technologies

12.4.1 Types

Free-standing vending machines and table top machines are very variable and can integrate a variety of different functions. "Full automatic machines" according to the definition by European Vending and Coffee Service Association (2019) dispense cups, sugar or toppings, which semi-automatic machines do not. ().

The machines are available for either instant beverage making from various powders, or for fresh brew made from either ground coffee, caps / pods or beans (the latter being called "bean-to-cup" machines). Machines for instant beverage making need receptacles for the powders and a functionality to heat water and mix the ingredients. Machines for fresh brew press the water through the coffee powder using a pump. Bean-to-cup machines also have an integrated coffee grinder.

Some machines may have an integrated milk module for cooling, storing, heating and foaming fresh milk. If they do not include a milk module, they may be operated with a separate external milk module or with powdered milk. They may either include a water tank or be connected to a water supply.

Equipment capacity is varied in the category of table-top machines, with average throughput of equipment ranging from 5 to 50 Litres/day.

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[444] OCS is a specific part of vending and involves a hot drink table-top operation in the office environment, maintained and supplied with ingredients by the operator.

[445] http://gcrmag.com/marketing/view/a-look-at-the-professional-coffee-machine-market-in-europe

Café / restaurant espresso machines (porta filter machines) must be operated by staff. The principle is that one portion of water is heated and pressed through a sieve filled with ground coffee with the help of a pump.

Professional batch and bulk brewersare commercial large capacity machines with the ability to brew and store 30-50 or more cups of coffee. "Satellite" types have detachable, insulated vessels that can be distributed e.g. to tables while a coffee urn is a single, integrated device for brewing and storing. Some of them include more than one brewing and / or heating place. Both satellite machines and coffee urns may use the drip filter principle where hot water is poured over ground coffee in a filter. Coffee urns may also use the percolator principle, where hot steam is rising from below, passing through a receptacle with ground coffee, and condensing in the upper part to create the liquid coffee. All types mainly need devices for heating the water and one or several heating plates to keep the drink warm. The heating plate or element generally adjusts to the temperature of the coffee, in order to avoid overheating and burning of the drink. The Energy star differentiates between "batch" machines with a capacity of 0.7 – 11.5 litres and "bulk" machines with a capacity of more than 11.5 litres.

12.4.2 Weight and material composition

As it is the only available complete bill of materials to date, the BOM from the WP 3 study is used, and cited here. Only information for batch and bulk brewers has been added, and an apparent error in the Bill of Materials for professional café / restaurant coffee machines has been corrected.

According to stakeholder input, this information might be outdated.[446] However, no new complete bill of material has been available to date that could have been entered into the EcoReport Tool. Therefore, the information is used here as it is. It is a potential topic for a dedicated preparatory study – if any – to provide more accurate information on material composition.

Resources used to manufacture tertiary hot beverage equipment mainly include metals and plastics. Other resources consumed have also been identified through Internet research of manufacturers' product factsheets, and comparison of bill of materials (BoM) for similar products.

Free-standing hot beverage equipment. The BoM for free-standing hot beverage equipment is based on a comparison between two BoM for hot/cold vending machines, presented by studies performed by S. Sampattagul et al.[447] (2002) and EPTA[448] (2007). Similar materials and corresponding compositions (%) have been assumed, although the weight has been corrected to the average weight of free-standing hot beverage equipment, assumed to be 160 kg.

[446] For example with reference to Table 14, EFCEM reports: Plastics should be between 5% and 10%, brass (used for delivery groups, Valves, Fittings) between 20% and 30%, and copper: between 5% and 10%

[447] Sampattagul S., Y. Kimura et al. (2002), An integrated life cycle eco-improvement and Nets-green productivity index of vending machines.

[448] EPTA (2007), Study for preparing the first Working Plan of the EcoDesign Directive.

Table 152: Assumed BoM for free-standing vending machine

Material	Share [%]	Weight [kg]
Plastics (ABS)	12%	19.2
Steel	20%	32
Iron	60%	96
Aluminium	2%	3.2
Copper	4%	6.4
Electronics	2%	3.2
Total	100%	160

Source: BIO by Deloitte et al. (2015)

Table-top machines. For table-top machines, it was assumed that the shares of materials were the same as presented in Table 152, although the average weight was 50 kg.[449]

Table 153: Assumed BOM for table-top automatic machine

Material	Share [%]	Weight [kg]
Plastics (ABS)	12%	6,0
Steel	20%	10,0
Iron	60%	30,0
Aluminium	2%	1,0
Copper	4%	2,0
Electronics	2%	1,0
Total	100%	50,00

Source: BIO by Deloitte et al. (2015)

Café / restaurant espresso machines. Regarding café/restaurant espresso machines, no BoM has been collected but brief indicative information on material consumption has been gathered through Internet research. Generally, the boiler and internal parts are made from metals. The exterior can be of a hard plastic or metal (stainless steel) finish. Similarly, the drip trays can be made from either metals or plastic. Average weight of these machines is about 50 kg.

Table 154: Assumed BoM for Café/Restaurant coffee machine

Material	**Share [%]**	**Weight [kg]**
Plastics – ABS	35%	17,5
Plastics – PP	15%	7,5
Steel	30%	15
Iron	10%	5
Aluminium	5%	2,5
Copper	5%	2,5

Source: BIO by Deloitte et al. (2015), corrected

[449] The assumption is derived from a cursory research of the technical specifications of different machines offered online. Weight is between around 33 and 67 kg.

Professional batch and bulk brewers. The weight of these machines is between 2.5 and 20 kg, depending on size. We assume an average weight of 5 kg as most machines are small to medium size. They are made mainly from steel, while the coffee jug can also be made from glass. The water tank and filter as well as cladding may be made from plastics. For lack of further information, we use the BOM prepared by the Preparatory Study on non-tertiary coffee machines and modify it slightly in the assumption that professional machines use more steel and iron and less plastic for durability.

Table 155: Assumed BoM for professional filter coffee machine

Material	Share (%)	Weight (kg)
PP	41.8	2.09
PC	0.42	0.02
PPS	1.63	0.08
PVC	1.23	0.06
Glass fiber	11.43	0.57
Non-iron metal	0.36	0.02
Iron	9.27	0.46
Stainless steel	23	1.15
Copper	1.23	0.06
Aluminium	5.69	0.28
Rubber	0.81	0.04
Electronics	2.98	0.15
Other	0.14	0.01
Total	100	5

Source: Adapted from Bio Intelligence Service (Bio IS) und ARTS (2011)

12.4.3 Innovation

Recent technological developments for tertiary coffee machines include:

- Smart coffee machines
- Repair-friendly coffee machines

"Smart" coffee machines are programmable via Wi-Fi, can monitor the brewing process, performance parameters, coffee flow, and may also be utilized to monitor energy usage. Repair-friendly machines include non-destructive disassembly, one-tool access for daily maintenance and operation, minimised use of screws, easy access to functional modules, modules that are easy to replace, and pictogram-signage on the modules for disassembly. According to EVA input, modular, repair-friendly construction is already common for vending machines.

In the domestic sector, also the use of post-consumer recycled plastics is intrroduced. The baseplate of a Philips[450] pad filter coffee machine contains 95% post-consumer recycled PP. Such an approach could also be imagined for tertiary machines.

More details and sources are given in the chapter on non-tertiary coffee machines.

[450] https://www.philips.com/a-w/about/sustainability/sustainable-planet/circular-economy/senseo.html

12.5 Energy, Emissions and Costs

12.5.1 Energy consumption

12.5.1.1 Product level

Free-standing vending machines. For calculating the use-phase energy of freestanding vending machines, the same approach as in the WP 3 study is chosen. They are estimated on the basis of the EVA Energy Measurement Protocol (EVA-EMP), version 3.1b. As the energy consumed for the payment system is minimal, as indicated by EVA, this standard can also be used for table-top machines without a payment system. Based on information provided by EVA, the average energy consumption is 190 Wh/Litres/day. To compute the annual consumption, we assume that free-standing vending machines have a throughput of 30 Litres/day and are never completely switched off.[451] As idle mode is already integrated in the standard, no specific assumptions for idle time are considered. This gives **2,809 kWh/year.** Gross energy requirement (GER) has been taken from the WP 3 study as no relevant change in bill of materials has taken place.

Table-top machines. Two different approaches have been chosen and compared for calculating use-phase energy. It is assumed that table-top machines have a throughput of 15 Litres/day[452]. Furthermore, it is assumed that table top machines in offices are switched completely off for 50 hours per week (for office machines, this might be the weekend, and for machines in hotels, some hours at night). In the first approach, the remaining days have been multiplied by 15 litres and 190 Wh/l. This renders an annual consumption of 744 kWh.

In the second approach, actual technical data from the ENAK database as reported by Rothwell und Bush (2017) have been used. Based on an evaluation of 14 machines, an average standby power of 125.3 W and an average energy consumption of 0.91 kWh for preparing 60 coffees has been used. It has been assumed that one coffee is 0.125 l as in the HKI database, which means a consumption of 121.3 Wh/l. Using the same running times as above, and additionally assuming that the machine is in standby mode for 20 of the 24 hours a day, an annual energy consumption of 1127.3 kWh results. The difference might be due to the fact that actual standby energy consumption might be underestimated by the EVA standard. We work with an average annual energy consumption of **935 kWh / year** (between the two values). Gross energy requirement (GER) has been taken from the WP 3 study as no relevant change in bill of materials has taken place.

Café / restaurant espresso machines. Here, we use recent analysis conducted by Topten Switzerland to calculate use-phase energy.[453] They provide an energy consumption of 7.01 kWh per day for one specific machine that was never completely switched off. This provides an annual energy consumption of **2,560 kWh/year.** However, the machine is not representative for all machines and consumption on average for various portafilter

[451] Where instant powders are used, the machine needs to remain on to avoid hygienic issues with the ingredients such as caking. If the machine brews freshly, it could be switched off, but from anecdotical evidence with operators this is rather rarely the case.

[452] Note that the energy consumed for the vending module is negligible as indicated by EVA. That is why we consider that the energy consumptions of vending and non-vending table-top "full automatic" machines are similar.

[453] Personal communication

machines could be higher. Gross energy requirement (GER) has been taken from the WP 3 study as no relevant change in bill of materials has taken place.

Professional batch and bulk brewers. To calculate energy use for these, we use the metrics and background dataset from Energy Star 1.1. Energy Star requirements are based on the "Normalized Ready-to-Brew Idle Energy Rate" in watts/gal (where the gallons represent tank capacity) and the "Normalized Heavy-Use Brew Energy Rate" in W/gal/hr (or Wh/gal) (with the gallons/hr representing brewing capacity). The dataset[454] shows the two parameters for 16 products. Idle energy rate ranges from about 12 W/gal (2.9 W/l) to about 290 W/gal (76.5 W/l) with the majority being between 12 W/gal and about 65 W/gal (17 W/l) (this is also the Energy Star cutoff).

Heavy-brew energy rate ranges from about 160 Wh/gal (42.2 Wh/l) to 420 Wh/gal (111 Wh/l) with the majority being under 350 Wh/gal (92 Wh/l) (Energy Star cutoff).

Based on this information, we model a device that might be used in a canteen with the following specifications, see Table 156.

Table 156: Specifications of a sample professional filter coffee machine

Tank capacity	1.5 gal (5,7 l)
Brewing capacity	17.5 gal/hr (66 l / hr)
Ready-to-brew idle rate	65 W/gal (17 W/l)
Heavy use brew energy rate	350 Wh/gal (92 Wh/l)
Brewing hours per year	260 days * 1,5 hrs = 520 hrs / year
Idle hours per year	260 days * 8,5 hours = 1560 hrs / year
"Off" hours per year	105 days * 25 hrs + 260 days * 14 hrs = 6160 hrs

Source: Authors' Own

The result is an idle mode consumption of 214 kWh and a brewing consumption of 2,368 kWh, which adds up to total annual electricity consumption of **2,582 kWh**. Gross energy requirement (GER) has been calculated with the EcoReportTool using the assumed BOM in Table 155.

Table 157 shows the electricity consumption (final energy and primary energy, using a conversion factor of 2.1) as well as the Gross Energy Requirement (GER) of the different cases. For comparison, the WP 3 values are given for final energy consumption. For table-top and free-standing machines, less idle mode energy has been calculated in WP 3. The WP 3 value for café / restaurant machines is higher because the estimate was based on an outdated measurement from the year 2000. For the present study, new data was available.

454 https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Draft%20Version%201.1%20Dataset.pdf

Table 157: Product-level annual energy consumption

Device	Annual electricity consumption (kWh / GJ)	Annual use phase primary energy consumption (GJ)	Gross Energy Requirement (GER) over life cycle (GJ)	For comparison: Annual electricity consumption in WP 3 study (kWh)
Free-standing vending machine	2,809 / 10.1	21.2	197.0	2,080
Table-top machine	935 / 3.4	7.1	67.0	715
Café / restaurant espresso machine	2,560 / 9.2	19.4	511.0	3,750
Batch and bulk brewer	2,582 / 9.3	19.5	93.8	n/a

Source: Own calculations, BIO by Deloitte et al. (2015)

12.5.1.2 Aggregate level

Annual use phase energy consumption values have been multiplied with estimated stock data to obtain total annual energy consumption for 2020, 2025 and 2030. GER data has been multiplied by the stock and divided by the lifetime to render aggregate annual values. It shows that the majority of the energy consumption is from the use phase, and that use phase energy consumption is rather constant, if not somewhat decreasing. The reason is the slightly declining stock in the group of vending and tabletop machines where sales are not high enough to replace all machines that go out of service. Table 158 shows the annual use phase energy consumption and GHG emissions as well as annualized GER. GHG emissions are only provided for use phase energy consumption, as the energy mix for production is unknown.

Table 158: Aggregate EU use phase energy consumption, GHG emissions, and annual GER of tertiary hot beverage equipment stock (TWh for final energy and PJ for primary energy)

	2020			2025			2030		
	Electricity (TWh)	Primary energy (PJ)	GHG (1,000 t)	Electricity (TWh)	Primary energy (PJ)	GHG (1,000 t)	Electricity (TWh)	Primary energy (PJ)	GHG (1,000 t)
Annual use phase consumption									
Vending and tabletop	9.0	68.1	3,424	8.4	63.3	3,017	8.3	63.0	2,834
Café espresso	1.3	10.1	509	1.5	11.2	535	1.6	12.3	555
Batch and bulk brewer	2.1	16.1	809	2.2	16.8	798	2.4	17.8	801
Total	12.5	94.3	4,741	12.1	91.3	4,350	12.3	93.1	4,185
Gross Energy Requirement									
Vending and tabletop		25.2			22.2			21.7	
Café espresso		45.3			48.8			53.2	
Batch and bulk brewer		2.1			3.2			3.4	
Total		72.5			74.2			78.4	

Source: Own calculations

12.5.2 Other resource consumption

Other resource consumption on product level has been described in section 15.4.2. presents the aggregate values for selected materials, based on annual sales.

Table 159: Total annual EU-27 material consumption (1000 t)

	2020	2025	2030
Plastics	4.2	6.5	7.0
Steel	4.5	6.9	7.5
Iron	10.0	15.3	16.6
Aluminium	0.5	0.8	0.9
Copper	0.8	1.3	1.4
Electronics	0.3	0.5	0.6
Total	20.4	31.4	34.0

Source: Own calculations

12.5.3 Main other environmental aspects

Relevant other environmental aspects are:

- use of consumables, mainly plastic cups in vending machines. Plastic consumption can be reduced if a machine allows for the use of users' resuable cups.
- potential use of post-consumer recycled content.

These aspects cannot be analysed in detail in the scope of this report. They are the subject of Task 4 in case the product group is relevant enough in terms of energy and resource savings to be followed up upon. For a horizontal discussion of recycled content, see the corresponding chapter in this report.

12.5.4 Cost

No valid information on purchase price ranges for the different types or on maintenance cost could be found. Stakeholder input on purchase price and maintenance cost is wel-comed.

12.6 Savings potential

12.6.1 Use phase energy consumption

In order to focus on priority issues, it would be advisable to tackle energy losses and standby power, as has been successfully done for household coffee machines (Rothwell und Bush 2017). For example, the ENAK database shows that for table-top machines, standby power can vary between 30 and 190 W (ibid., p.28). The HKI database for tabletop machines has energy losses (calculated on the basis of DIN 18873-2:2016-02) varying between 0.17 and 3.11 kWh/day (without milk cooling unit) and 1.1 to 4.19 kWh/day (including milk cooling unit). For filter coffee machines, the Energy Star data have shown a range between 2.9 and 17 W/l. Topten data for a restaurant espresso machine have shown that only 9% of the overall energy consumption were for actual brewing.[455]

In the use phase, energy savings could for example be achieved by better insulation, modulation of the heating plate, or – in the case of espresso machines – more efficient pumps. Also the cooling energy for integrated milk coolers, if any, should be looked at, although it is not fully clear inhowfar this is integrated into current measurements.

It was also considered to assess the efficiency of the brewing process, i.e. the quantity of coffee used per cup because the final quality of the coffee cup is partly dependent of the efficiency of coffee machine used. The challenge for doing this is that it should be related to the quality of the coffee produced by the coffee machine and the study team is not aware of any test standards available for measuring this. In any case, a possible preparatory study could look further into this topic.

Potentials for lighting (LED lighting) have largely already been implemented by manufacturers.

For calculating the savings potential, we assume the following per product savings:

- For table-top and free-standing vending machines we assume that the savings potential is between the average A machine (190 Wh/l) and the A+ machine (140 Wh/l). This would mean annual savings of 196 kWh for tabletop machines and 548 kWh for free-standing machines. (Standby and energy losses alone (according to DIN 18873-2:2016-02) could be reduced from 1,63 kWh/day (average of 131 values from the – already efficient - HKI database) to 1,04 kWh/day (average of 31 Topten products). This would mean savings of 0,6 kWh/day or annual savings of 150 kWh for table-top machines that we assume to be switched off two days a week and 216 kWh for free-standing machines that run throughout.)
- For espresso machines, we assume that the standby and other energy losses, estimated by Topten with 6.38 kWh/day, can be reduced more. Most of these machines have to be shut off manually. According to a small non-representative survey among cafés and restaurants done by Topten Switzerland, this is often not done. Therefore the machines could profit from an auto power off scheme. We assune that they could reduce energy losses by 50% or 3.2 kWh/day. If they run 6 days a week, this would save about 1000 kWh/year.
- Finally, for batch and bulk brewers, idle energy rate would be reduced from 97 Wh/gal (average of 16 Energy Star data points) to 65 Wh/gal. This would deliver savings of 32 Wh/gal or 8.4 Wh/litre, and for the example product: 106 kWh/year.[456]

If the whole stock was exchanged, this would render the following savings in 2025 and 2030 (given a primary energy factor of 2.1). For comparison, assessments of the WP 3 study and the SFOE study are also given.

[455] Personal communication.

[456] For heavy brew energy rate, current average of the 16 Energy Star data points is already below the threshold.

Table 160: Use phase savings for EU-27, given an exchange of stock

	2025			2030			For comparison: WP 3 (2030)		For compa-rison: SFOE (2030)
	Electricity (TWh/a)	Primary energy (PJ/a)	GHG (1,000 t)	Electricity (TWh/a)	Primary energy (PJ/a)	GHG (1,000 t)	Electricity (TWh/a)	Primary energy (PJ/a)	Electricity (TWh/a)
Free standing	0.6	4.2	197.6	0.5	4.1	182	0.2	2	0.7
Tabletop	0.4	3.0	140.3	0.4	2.9	131	0.3	3	0.7
Cafè es-presso	1.4	10.8	513.6	1.6	11.8	529	0.6	6	2.6
Batch and bulk	0.0	0.2	8	0.0	0.2	8	n/a	n/a	n/a
Total	**2.4**	**18.1**	**862.2**	**2.5**	**19.019.0**	**853.5854**	**1.2**	**11**	**4.0**

Source: Own calculations

Savings are about twice than what was calculated in the WP 3 study. We believe that the present assessment is more accurate than the WP 3 assessment, where overall percentual improvement potentials were assumed for lack of more detailed data (15% for free-standing and tabletop machines, 10% for café / restaurant espresso machines). The current assessment, in contrast, is based on more detailed technical information.
On the other hand, savings are lower than in the SFOE study (Rothwell und Bush 2017). They generally base their estimates on a comparison of the average products with the best available one. In the present study, the assumption that products are exchanged for the best available ones has been considered too ambitious.

The savings are comparable with those provided by the current regulation for household coffee machines (2 TWh electric in 2030) (Wierda und Kemna 2018 (rev. 2019)).

12.6.2 Resource savings by increased durability

In addition, if the lifetime were extended by 15%, the following annual savings would result for materials consumption:

Table 161: Aggregate EU-27 annual material savings, if lifetime is extended by 15% (1000t)

	2025	2030
Plastics	0.8	0.9
Steel	0.9	1
Iron	2	2.2
Aluminium	0.1	0.1
Copper	0.2	0.2
Electronics	0.1	0.1
Other	0	0
Total	**4.1**	**4.5**

By using the Ecoreport Tool, the saved embedded energy for these material savings has been calculated. It amounts to 0.5 PJ in 2025 and 2030 each.

12.6.3 End user cost savings

At a commercial electricity price of 0.1173 EUR / kWh (static price, 2019)[457], the mentioned electricity savings translate into the following energy cost savings for the end user:

Table 162: Annual end user energy cost savings, EU-27

	2025		2030	
	TWh/a	1000 EUR / a	TWh/a	1,000 EUR / a
Free standing	0,6	64,624	0,6	63,202
Tabletop	0,4	46,211	0,4	45,194
Cafè espresso	1,5	167,939	1,6	183,051
Batch and bulk	0,0	2,467	0,0	2,670
Total	**2,4**	**281,241**	**2,6**	**294,117**

As no valid information on purchase and maintenance cost and its potential increase was available, no result on life cycle costs can be given.

12.7 Summary

Table 163 presents a summary of the product group "Tertiary hot beverage equipment".

Table 163: Summary – Tertiary hot beverage equipment (TWh for final energy and PJ for primary energy)

	Year	Free-standing vending machines and table top machines	Café/Restaurant "porta filter" espresso machines	Batch and bulk brewers	Total
Market data (EU-27)					
Sales (1,000)	2020	183.1	77.9	128.5	389.5
	2025	281.6	119.8	197.7	599.2
	2030	304.9	129.7	214.0	648.6
Stock (1,000)	2020	3,207.6	1,330.1	685.7	5,223.4
	2025	2,980.3	1,433.9	741.7	5,155.9
	2030	2,956.2	1,562.9	810.8	5,339.0
EU-27 Energy consumption					
GER per year	2020	25.2	45.3	2.1	72.5
	2025	22.2	48.8	3.2	74.2
	2030	21.7	53.2	3.4	78.4
Use-phase energy per year (final in TWh / primary in PJ)	2020	9.0 / 68.1	1.3 / 10.1	2.1 / 16.1	12.5 / 94.3
	2025	8.4 / 63.3	1,5 / 11.2	2.2 / 16.8	12.3 / 12.1 / 91.3
	2030	8.3 / 63.0	1.6 / 12.3	2.4 / 17.8	12.3 / 93.1
Use-phase GHG per year (1,000 t)	2020	3,424	509	809	4,741
	2025	3,017	535	790	4,350
	2030	2,834	555	801	4,185

[457] https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

EU-27 Material consumption (1000 t)					
	2020				20.4
	2025				31.4
	2030				34.0
EU-27 Use phase savings					
Energy per year (final: TWh / PE: PJ)	2025	1.0 / 7.2	1.4 / 10.8	0.0 / 0.2	2.4 / 18.1
	2030	0.9 / 7.0	1.6 / 11.8	0.0 / 0.2	2.5 / 19.0
GHG per year (1,000 t)	2025	338	514	8	862
	2030	313	529	8	854
EU-27 resource savings by lifetime extension (per year) (1000 t)					
Materials (per year) (1000 t)	2025				4.1
	2030				4.5

Source: Own calculations.

12.8 Stakeholder comments

Manufacturers pointed to detrimental effects of the Covid crisis on sales. This consideration has been added, using stakeholder data for 2020 and projecting a considerably more conservative development of sales for the future. However, it changed results only marginally, as stock has a much higher impact on energy use, and is more inert, than sales. Also for resource use, impacts are only seen in the few years where sales decrease. Data will have to be verified by a dedicated preparatory study, if any.

Manufacturers also pointed out that Bill of Material figures are probably outdated. A discussion of this issue has been included. Details will have to be analyzed by a dedicated preparatory study, if any.

EVA criticized the unclear definition of "full-automatic" vs. "semi-automatic" and proposed a definition based on the ability to disperse a receptacle (full-automatic) or require the user to place a receptacle (semi-automatic). However, these terms are used differently across various source (for example, they might also distinguish tabletop machines from porta filter ones). As it is not always clear whether definitions are identical, the distinction has been dropped altogether as a criterion for grouping appliances.

Stakeholders from NGOs and Member States asked for a discussion of the use of consumables such as plastic cups, and of the potential use of post-consumer recycled plastics. The issues have been listed under "Main other environmental aspects". However, a detailed discussion was not possible in the scope of this analysis and should be reserved to Task 4 in case the energy and resource savings of the product group are relevant enough to follow up on it. For a horizontal discussion of recycled content, see the corresponding chapter in this report.

13 HAIR DRYERS

13.1 Scope, policy measures and test standards

13.1.1 Background

In the Preparatory Study for the 3rd Ecodesign Working Plan, hair dryers have been identified as the most relevant and reasonably homogeneous subgroup within a broad and heterogeneous group of "personal care appliances" , and have consequently been studied in more detail (BIO by Deloitte et al. 2015; hereafter: WP 3 study).

Projected annual use phase energy savings in 2030 were 1.4 – 2.5 TWh of electricity and 13-23 PJ primary energy. The product group was suggested for regulation but not taken up for the actual Working Plan. One problem was that sources differed widely with respect to actual energy usage of the individual product, resulting in a broad range of EU-wide energy consumption and savings potentials.

As the energy savings potential is not unimportant, and Circular Economy requirements seem also promising, it was decided to re-examine the product group in the present study. Special attention should be given to recent, reliable energy usage figures and potential Circular Economy requirements.

The main source used for this purpose is an unpublished 2018 background study conducted by Oeko-Institut for the German Federal Environmental Agency that underpins the revision of the Blue Angel criteria for hair dryers (Stratmann 2018). Where appropriate, it has been complemented by other sources.

The Section is partly based on prior own work (by part of the study team), that is, Task 3 report, Section 13, and Task 4 report, Section 13 of the WP 3 study, as well as Stratmann (2018). It therefore includes sentences and paragraphs with identical or very similar wording. For ease of reading, these sections have not been specifically highlighted as citations.

13.1.2 Scope

A hair dryer is an electric blower that can blow warm air onto the hair; it is usually handheld but it can also be some fixed device (like a drying hood). Different types of hair dryers may be distinguished, however the core technology does not vary from one item to the other.

Both professional and household hand-held hair dryers are in scope. Professional hair dryers are generally more powerful than household hair dryers (1,600-2,400 watts, while household hairdryers are available starting at about 1000 W (Stratmann 2018). Also, they often run with AC motors, whereas household hair dryers are usually equipped with DC motors. Additional differences between professional and household hair dryers are different air flow rates, as well as air temperature options (professional hair dryers often include at least two hot air stages and one cold air stage).

Figure 41: Typical hand-held hair dryer

13.1.3 Policy measures

This section is dedicated to the regulatory coverage of hair dryers, be it through legislation, within the EU or in third countries, through voluntary agreements and environmental labels or standards. The goal is to identify where Ecodesign or Energy Labelling regulations could have added value beyond the existing legislation, and, in the case of third country legislation, whether there is successful legislation that could serve as a model for Ecodesign or Energy Labelling legislation.

Within the EU, hair dryers are currently regulated under WEEE, RoHS and REACH. In Germany, there is a Blue Angel label for hair dryers, which has been revised in January 2019 (RAL gGmbH 2019). However, there are currently no certified products. Three products that had been certified before are not on the market any more for different reasons.

Table 164 shows an extract of the most relevant Blue Angel requirements for hair dryers.

Table 164: Core Blue Angel requirements for hair dryers. Source: RAL gGmbH 2019

Category	Metrics	Requirement
Energy consumption	Electricity consumption per drying rate	5.2 Wh / (g/min)
Noise emissions	Sound power level	76 dB
Recyclability		Plastic housings may only consist of two separate polymers or polymer blends. Plastic components weighing more than 25 grams must be marked in accordance with ISO standard 11469.
Material of housings and housing parts		They must not contain, as constitutional constituents: a) Sustances classified as SVHC under REACH and included in the "candidate list" b) Substances classified as carcinogene, mutagene or toxic to reproduction under CLP c) various other substances, e.g.halogenated polymeres and perfluorinated carboxylic acids
Safety		Compliance with requirements for GS[458] Existence of a switch that prevents overheating
Durability		Two of three units must pass a 400-hour endurance test, thereof 200 hours pure running time
Warranty	years	3

[458] GS (Geprüfte Sicherheit, "Tested Safety") is a voluntary German certification mark for technical equipment.

Further voluntary Ecolabels exist in Taiwan. An endorsement label for energy efficiency of hand-held hair dryers is issued by the Energy Labelling Programme, Bureau of Energy, Ministry of Economic Affairs[459]. The energy efficiency requirement UER is calculated for one minute running time and expressed in % (while the physical unit would be g/Wh):

UER = (Drying rate DR in g/min × 0.7136 / Electricity consumption EC in Wh/min) × 100%

The constant is set so that the expression becomes 100% when DR/EC = 1.4 or EC/DR = 0.7136

The threshold for the label is:

UER ≥ 19.5% (equivalent to DR/EC 0.27, or EC/DR = 3.66)

In addition, the "Green Mark" Ecolabel, last revised in February, 2019, has requirements related to

- energy efficiency (cross-reference to the Energy Labelling Programme);
- noise emissions (compliance with existing regulations);
- electromagnetic interference (compliance with existing regulations);
- disassemblability;
- maximum content of some hazardous substances for plastic components over 25g: cadmium, lead, chromium, mercury, PBB, PBDE, i.e. the six substances of the RoHS Directive, with chloroparaffins and chlorinated plastics in addition (Greenmark Labelling Program 2019); and
- plastic marking.

In Thailand, a voluntary Ecolabel "Green Label" TGL-84-13 exists since 2018. However, the criteria document is not available in English.[460] Furthermore, a 2017 study explored the possibility of setting high efficiency performance standards (HEPS) and minimum efficiency performance standards (MEPS) for energy efficiency (Pattana et al. 2017). A sample of 70 products was measured, of which 66 were analysed. It was assumed that MEPS should be set so that 5% of products are below the respective value while for HEPS, 20% of products should be above the threshold, it recommended the following thresholds:

Table 165: Proposed hair dryer HEPS and MEPS for Thailand. Source: Pattana et al. (2017)

Rated input power (W)	MEPS (Wh/g/min)	% of products below MEPS	HEPS (Wh/g/min)	% of products above HEPS
<1300	5.9	4.8	4.5	28.6
1301-1900	7	0	5.4	18.2
1901-2800	7.5	8.7	5.7	34.8

The current status of implementation is unknown. The CLASP policy database does not list MEPs or the application of the voluntary Thai Energy Label to hair dryers.

[459] https://www.energylabel.org.tw/englishlabel/application_en/efficiency/upt.aspx?Cid=10&subID=139
[460] http://www.tei.or.th/greenlabel/application-electric.html

If the Taiwanese requirement is converted into the Wh/g/min metrics used by the Blue Angel and Thai study, the requirements can be compared as follows:

Table 166: Comparison of energy efficiency requirements for hair dryers. Sources: Pattana et al. (2017); Bureau of Energy (2018); RAL gGmbH (2019)

Source	MEPS (Wh/g/min)	HEPS (Wh/g/min)
Blue Angel (RAL gGmbH 2019)	n/a	5.2
Taiwanese Ecolabel (Bureau of Energy 2018)	n/a	3.66
Thai HEPS / MEPS study (Pattana et al. 2017)	5.9 – 7.5	4.5 – 5.7

13.1.4 Standards

Currently, harmonized standards exist for measuring drying rate, power, electricity consumption, and noise emissions.

Drying rate per minute is measured according to standard EN IEC 61855:2003, "Household electrical hair care appliances - Methods of measuring the performance." Drying rate is defined according to the formula DR = M1 – M2, where M1 is the amount of water before drying and M2 the amount of water after one minute of drying and five seconds of waiting[461].

In the stakeholder consultation in the course of the WP 3 study, stakeholders have pointed out potential shortcomings of the standard:

- The test arrangement dos not reflect actual use:
    - the test material (a sheet of soaked cotton) acts differently from a tress of hair;
    - the hair dryer is held in the same place for one minute in the test arrangement which is not the case for real life; and
    - the ring holding the cloth does not correspond to the output area of the hair dryer.
- No justification is given for the required drying temperature of 75 °C;
- The use of a fixed drying time of 1 minute is an issue if the hair dryer dries in less time.

Some stakeholders therefore called for a new standard. However, no change has taken place since then. The standard mentioned in the previous section is still in use.

Power and electricity consumption can be measured according to IEC 60335-2-23:2003 + Cor. 1:2004 + Cor. 2:2008 + A1:2008 + Cor. 3:2007 + A2:2012: Household and similar electrical appliances - Safety - Part 2-23: Particular requirements for appliances for skin or hair care (RAL gGmbH 2019, Section 3.1, p.5).

Noise emissions can be measured according to EN 60704-1:2010/A11:2012: Household and similar electrical appliances - Test code for the determination of airborne noise - Part 1: General requirements; EN 60704–2-9:2003: Household and similar electrical appliances - Test code for the determination of airborne acoustical noise: Particular requirements for

[461] CENELEC (2003). Household electrical hair care appliances – Methods of measuring the performance (IEC 61855:2003).

electric hair care appliances and EN 60704-3: 2019: Household and similar electrical appliances - Test code for the determination of airborne acoustical noise - Part 3: Procedure for determining and verifying declared noise emission values.

13.2 Market

13.2.1 Sales

For hair dryers, Prodcom code 27.51.23.10 "electric hair dryers" is in use since 2011. It replaces the former Prodcom codes 27.51.23.15 "electric hair dryers (excluding drying hoods)" and 27.51.23.15 "electric hair drying hoods". Apparent consumption has been calculated for EU-27 from production plus import minus export data. As the new code 27.51.23.10 groups drying hoods and hand-held hair dryers under one code, an estimation had to be made to arrive at an approximate figure for hand-held hair dryers. For this purpose, the average of the 2008-2010 apparent consumption of drying hoods (321,000) has been subtracted from the total apparent consumption of hair dryers. Data are presented in Table 167.

Table 167: EU-27 apparent consumption of hair dryers (in 1000). Source: Own calculations from Prodcom.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Prodcom code	27.51.23.15	27.51.23.10	27.51.23.10	27.51.23.10	27.51.23.10	27.51.23.10	27.51.23.10	27.51.23.10	27.51.23.10	27.51.23.10
No. (in 1000)	25,761	23,737	22,782	22,520	23,322	23,558	25,556	28,824	34,745	30,991

These sales figures are consistent with the estimations of CECED, which used to represent the manufacturers of domestic appliances in Europe, made in 2015 for the WP 3 study: "According to internal market estimations – which are based on GfK figures and internal member's sales data – we estimate that the market size of hair dryers in the European continent could amount to 24-25 Million units"[462]. The 2018 figure seems somewhat implausible though.

13.2.2 Stock

For stock estimates, two complementary approaches are used. In the first approach, we base our estimates on the number of EU households and hairdressers.

According to Eurostat, there were about 195 million households in the EU-27 in 2019.[463] The ownership rate of hair dryers is not available at EU level. However, according to Statista, 93% of German women owned a hair dryer in 2017.[464] If we apply a total ownership rate of 85% across the EU, this would mean 165.8 million hair dryers in private households in the EU.

[462] Stakeholder comment to the first stakeholder meeting, WP 3 study.

[463] https://ec.europa.eu/eurostat/databrowser/view/lfst_hhnhtych/default/table?lang=en

[464] https://de.statista.com/prognosen/799320/umfrage-unter-frauen-in-deutschland-zum-besitz-von-haarstylingprodukten

In addition, there were about 400,000 hairdresser shops in the EU-28 in 2014 (European Agency for Safety and Health at Work 2014). In the UK, the number of hairdressers and beauty salons has grown by 45% in the past five years to reach 45,000 in 2019.[465] If we conservatively assume a 30% growth EU-wide over that period, there would be 520,000 hairdressers in 2019, minus the 45,000 in the UK, resulting in a number of 475,000. If each of them owns three professional hairdryers, this adds up to roughly 1.5 million professional hairdryers. Taken together, we end up at a stock of 167.3 million.

The second approach is to estimate the stock from sales and average service life. If we assume an average service life of 5 years[466], we arrive at a very similar number of 155 million in 2019.

For the following calculations, we will assume a middle number of 160 million in 2019; thereof 1.5 million professional hair dryers.

13.2.3 Forecast

Hairdryer sales declined on average by 4% annually from 2008-2013, and started to grow again in 2014. If we exclude the implausible figure of 2018, we can observe an average annual growth rate of 6.7% between 2014 and 2019. We assume a more conservative 4% for 2020-2025, slowing down to 2% from 2026-2028, and constant sales in 2029 and 2030 as the number of hairdryers approaches the total number of households. We apply this to a stock estimate of 160 million in 2019, and an average service life of 5 years. The resulting sales and stock forecasts are presented in Table 168. The stock figure in 2030 is somewhat higher than the current number of households plus enterprises, but it is plausible in the light of an expected further increase in number of households due to decreasing household sizes. Furthermore; there may be more than one unit per household.

Table 168: EU-27 sales and stock forecast for hair dryers. Source: Own calculations

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Sales (1,000)	32,231	33,520	34,861	36,256	37,706	39,214	39,998	40,798	41,614	41,614	41,614
Stock (1,000)	160,231	161,705	164,225	167,636	171,814	176,665	181,330	185,863	190,304	193.858	196.700

13.3 Usage

The main uncertainty with respect to usage is daily usage time. Representative data does not exist, and estimates differ widely. The situation has not changed much since the WP 3 study. WP 3 study cites three different estimates which are rather old, and not directly comparable either:

- In a **study for the Blue Angel label,** Gattermann und Manhart (2012) assumed an average daily usage time of **12 minutes** with reference to a Stiftung Warentest test of 2009. However, no such statement can be found in the respective Stiftung

[465] https://www.nhbf.co.uk/about-the-nhbf/what-we-do/industry-research/

[466] As no studies are available on the actual service life of hair dryers, we rely on consumer recommendations given by test websites such as https://www.haartrocknertests.com/haartrockner-entsorgen/

Warentest publication (Stiftung Warentest 2009). The information is probably based on personal communication and its evidence base in unclear.

- In the **study for the 2nd Working Plan**, VHK estimate a daily use of 10 minutes in households and 2 hours in the professional sector, both 260 days a year. They note that it is their own estimate based on “a few anecdotal sources of information and inhouse estimates of usage patterns” (van Elburg et al. 2011, p. 235). Given the figures above, this would amount to **7.8 minutes daily use** on average in 2019.
- A 2012 study of the **Energy Saving Trust** (Owen 2012), based on the monitoring of 89 households with hairdryers, finds an annual electricity consumption of 20 kWh / year per device. The exact methodology is not reported; the figure seems to be based on an estimate based on a per-room breakdown of total household electricity use. At a power of 1800 W, which was common at the time, this would correspond to a daily usage time of **1.8 minutes**.

To these figures from the literature, we would like to add the following considerations:

For households, anecdotical self-tests have shown that it takes about 5-6 minutes to dry medium-long hair. In the following, we will assume 6 minutes per drying session. In addition, a 2017 survey among British women found that 19% use shampoo (considered as equivalent to washing hair) every day, 63% do so several times a week, 13% once a week and 5% less often.[467] Even considering different habits throughout the EU, it is therefore considered a reasonable estimate that people wash hair 3-4 times a week, on average. If they use a hair dryer 3 times a week, and there are 2 persons sharing a hairdryer in a household, this would amount to 5.1 minutes average daily use per hairdryer. This figure is close to what can be derived if 200 hours motor running time (as required in Stiftung Warentest (2015) and 5 years service life and for private hairdryers are assumed (this would render 6.5 minutes / day). **For the following calculations, we will take a value of 6 minutes per day for private use,** also to better reflect the higher estimates made before.

For the professional sector, we assume that a hairdresser shop that is open 8 hours per day can serve 20 clients per seat and day. Drying sessions are probably shorter than in the household due to higher drying efficiency of the professional hairdryers; set at 4 minutes per session. This amounts to 80 minutes per opening day and hairdryer. If the shop is open 5 days a week (260 days a year), this would amount to 20,800 minutes per year or an average of 57 minutes per day and hairdryer. This also suits very well with an assumed service life of 5 years and 2000 hours motor running time for a professional device (rendering 65.8 minutes per day). **We will assume a medium value of 60 minutes / day for professional devices.**

The WP3 study states, based on a literature analysis and stakeholder input, that differences between household and professional hair dryers are blurring, since more and more professional devices are used by individuals. Stratmann (2018) confirms that this trend is continuing. This means that devices with higher wattage, but also better durability are increasingly used in private households. This trend can be confirmed by an Idealo search. The rated power distribution of the hairdryers of offer is shown in Table 169. The lowest rated power is 850 W, but this is extremely rare; most models have at least 1,100 W.

[467] https://www.statista.com/statistics/715522/frequency-of-shampoo-usage-in-the-united-kingdom-uk/

Table 169: Rated power of hair dryers on offer at idealo.de

Rated power	Number of devices	Share
below 1,500 W	198	21.5%
1,500-2,000 W	168	18.3%
2,000 - 2,500 W	545	59.2%
above 2,500 W	9	1.0%
Total	920	100.0%

13.4 Technologies

13.4.1 Current technologies

Professional devices often run with AC motors, whereas household hair dryers are usually equipped with DC motors. Professional hand-held hairdryers have higher air flow rates. They have at least two heat settings and one cold setting (also known as the cool-shot button). The cold setting is important to give the hair the necessary strength during the last step of the drying process. It also protects the hair from heat stress. Furthermore, professional devices may have different speed settings. The basic equipment includes a diffuser attachment (creates an indirect airflow that gives the hair more volume) and a styling nozzle (focuses the heat to straighten the hair). Professional handheld hair dryers are available in different versions for right- and left-handed users. They are easier to operate because the switches / buttons are on the ergonomically correct side. However, there are also units available with the switches in the middle, so that they can be used by both left- and right-handed people. Professional handheld hair dryers are often of higher quality and better workmanship, which promises a longer life and is also reflected in the price difference compared to the handheld hair dryers used privately. Motors of professional devices have a running time of up to 2000 hours whereas the motors of household devices are more in the range of 200 hours. However, the higher weight of professional devices or an uneven distribution of weight can have a negative effect on their manageability (Stratmann 2018).

Ionic technology means that the dryer emits negative ions which break up the water molecules. This is assumed to make the hair smoother and add volume as well as electrostatic charging. However, Stiftung Warentest suggests that ionic technology seems to be more suitable for people with thick hair than with fine hair, leaving the latter lying flat (Stiftung Warentest 2009). In a later test, it reports that ionic technology is no guarantee for preventing electrostatic charging, and and on the other hand, some models without ionic technology also perform well in this respect (Stiftung Warentest 2015).

Ceramic dryers use ceramic as a material for the body or as a coating for internal elements. They emit infrared heat which is assumed to be less damaging to the hair. Tourmaline dryers use a coating of finely ground tourmaline crystals for the air outlet or other parts.

This maximises the output of negaitve ions. They promise smoother hair and less frizz as well as a speeding up of the drying process.[468],[469]

13.4.2 Innovative developments

In 2020, recently, cordless hairdryers are being introduced.

Also in 2020, Tineco introduced devices that use sensors "that detect hair moisture levels and automatically adjust the heat and air speed for a smart hair drying experience."[470] Also, one manufacturer presented a cordless dryer with sensor equipment and smartphone connectivity to deliver firmware updates that are meant to improve the "smartness".[471]

13.4.3 Weight and material composition

The most detailed data on the bill of materials can still be derived from Oeko-Institute's 2012 study (Gattermann und Manhart 2012). It does not reflect the use of new materials such as ceramics or tourmaline in some hairdryers. However, no recent information is available on the amount on the latter materials. Furthermore, hair dryers are small appliances, which do not use a lot of material anyway, and whose main impact is in the use phase. Therefore we neglect these developments and use the detailed BOM presented in the Oeko-Institute's study (Table 170).

[468] https://www.huffpost.com/entry/hair-dryer-guide_n_4316330?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAG25P7D5S4ZHFNLDXe8IzXplZs3eULfty8ZIpFKNMBFWoFXGJ1IgTnq4AzE4Mue0gpZ_cPyP9AeXiBZC4mvIWuOtAaDSPidPIh3naKSH9yLnNgOfYijIO3_GV8r2iLeuGDQ4s4FtRtbqrFl6CDSOzsPp1-A8-KPRF-pJ_o5U3yGK

[469] https://www.modernsalon.com/362482/ceramic-ionic-tourmaline-what-does-it-all-mean

[470] https://klinegroup.com/ai-technology-invades-hair-tools-and-appliances/

[471] https://aerdryer.com/

Table 170: Bill of materials for a hand-held hairdryer. Source: Gattermann and Manhart (2012)

Material	Weight [g]	Share [%]
Polypropylene	103.5	12.9%
Polyamide	78.0	9.7%
Polycarbonate	2.0	0.2%
Acrylonitrile butadiene styrene (ABS)	1.0	0.1%
Nylon	3.0	0.4%
Polyvinyl chloride (PVC)	11.0	1.4%
Aluminium	1.0	0.1%
Copper	156.9	19.5%
Iron-nickel-chrome alloy	14.0	1.7%
Steel	145.0	18.0%
Inductors	6.0	0.7%
Capacitors	3.0	0.4%
Resistors	1.0	0.1%
Ferrite	2.0	0.2%
Diode	1.4	0.2%
Copper-PVC-Cable	16.5	2.1%
Coated paper	23.0	2.9%
Graphite	1.0	0.1%
Cable	205.0	25.5%
Plug	30.0	3.7%
Total	**804.3**	**100.0%**

13.5 Energy, Emissions and Costs

13.5.1 Energy consumption and GHG emissions

13.5.1.1 Individual product level

Rated power of hair dryers varies between 1,000 and 2,400 watts, professional hair dryers ranges between 1,600 and 2,400 watts, while household hair dryers can start at about 1,000 Watts. Stratmann (2018) analyses some measured data from a 2015 test by Stiftung Warentest (Stiftung Warentest 2015) which will be re-analysed here.

The test covered 11 hair dryers in the range of 1,900 – 2,300 watts. The energy consumption per minute can be calculated from the measured drying rate and energy efficiency (energy consumption / drying rate) provided by Stratmann (2018). It is generally somewhat below what can be expected from the rated power, and varies between 29.2 and 26.3 Wh/min, with an average of 31.3 Wh/min.

These hair dryers are rather in the upper power range. We assume that this is representative for professional hairdryers.

To arrive at a figure for household hair dryers, we assume that the offer at Idealo is representative for what is sold to households. According to Table 169, about 60% of the market is in the power range measured by Stiftung Warentest. The other 40% are distributed about evenly across the power ranges "below 1,500 W" (generally between 1,000 and 1,500) and "between 1,500 and 2,000 W). We therefore assume an average input power of 1,500 W and a calculated energy consumption of 25 Wh/min. This produces a weighted average of 28.8 Wh/min for household hair dryers.

If we apply these two figures to the usage hours presented in section 13.3, we arrive at the following figures for annual energy consumption:

- 63 kWh/year for a hairdryer in private use, and
- 686 kWh/year for a hairdryer used professionally in hairdressers' shops.

The Gross Energy Requirement (GER) has been calculated with the EcoReport tool over the whole life cycle of the product, considering the production phase based on the bill of materials included in
 and assuming a lifetime of 5 years. The resulting GER per product is

- for a privately used hairdryer: 2,567 MJ, thereof, 2,382 MJ from the use phase. Per year, this adds up to 513 MJ GER, thereof 476 MJ from the use phase.
- for a professionally used hairdryer: 26,117 MJ, thereof, 25,931 MJ from the use phase. Per year, this adds up to 5,223 MJ GER, thereof 5,186 MJ from the use phase.

13.5.1.2 EU-27 aggregate

Aggregate energy consumption, based on the individual product consumption calculated in section 13.5.1.1 and the stock data presented in section 13.2.3 is presented in Table 171. GER figures are broken down per year to be comparable with the use phase figures. Greenhouse gas emissions are given for use phase energy consumption but not for GER as the fuel mix used in the production is unknown.

Table 171: EU-27 aggregated annual energy consumption. Source: Own calculations

	2020			2030		
	Privately used hairdryers	Professionally used hairdryers	Total	Privately used hairdryers	Professionally used hairdryers	Total
Over the life cycle						
Primary energy over the life cycle (GER) per year (PJ)	81.6	7.1	88.7	100.1	8.8	108.9
In use phase						
Electricity (TWh)	10.0	0.9	11.0	12.3	1.2	13.5
Primary energy (PJ)	75.8	7.1	82.8	93.0	8.7	101.7
Greenhouse gas emissions (1,000 t)	3,808	356	4,164	4,182	391	4,573

13.5.2 Other resource consumption

To calculate EU-27 aggregate annual resource consumption, we multiply the figures provided in Table 170 with the annual sales provided in Section 13.2.3.

Table 172: Total EU-27 annual resource consumption for hair dryers. Source: Own calculation

Material	Total EU 2020 (t)	Total EU 2030 (t)
Polypropylene	3,335.9	4,307.1
Polyamide	2,514.0	3,245.9
Polycarbonate	64.5	83.2
Acrylonitrile butadiene styrene (ABS)	32.2	41.6
Nylon	96.7	124.8
Polyvinyl chloride (PVC)	354.5	457.8
Aluminium	32.2	41.6
Copper	5,057.1	6,529.3
Iron-nickel-chrome alloy	451.2	582.6
Steel	4,673.5	6,034.1
Inductors	193.4	249.7
Capacitors	96.7	124.8
Resistors	32.2	41.6
Ferrite	64.5	83.2
Diode	45.1	58.3
Copper-PVC-Cable	531.8	686.6
Coated paper	741.3	957.1
Graphite	32.2	41.6
Cable	6,607.4	8,530.9
Plug	966.9	1.248.4
Total	**25,923.3**	**33,470.2**

13.5.3 Cost

The price range of hairdryers found at Idealo is as follows:

Table 173: Price range of hairdryers. Source: Idealo[472]

Price class	No. models
Under 40 EUR	5,362
Between 40 and 80 EUR	1,188
Between 80 and 300 EUR	952
Between 300 and 700 EUR	191
More than 700 EUR	93
Total no. models	7,786

[472] https://www.idealo.de/preisvergleich/ProductCategory/3234.html?q=haartrockner&qd=haartrockner

If the average price of the "more than 700 EUR" model is set at 900 EUR, this renders an average price of 70 EUR in terms of models. However, we assume that the average price in terms of sales is considerably lower, as more units are sold in the lower price ranges. Given that the 2012 estimate of Oeko-Institute was 41 EUR, we calculate the following simplified life cycle cost assessment with two variants, an average cost of 55 EUR and 70 EUR.

A simplified Life Cycle Cost assessment with an average household electricity price of 0.216[473] EUR / kWh and a savings potential of 15% (see Section 13.6.1.1) shows the following results:

Table 174: Simplified LCC of hair dryers. Source: Own calculation

	Scenario 1	Scenario 2
Average purchase price (EUR)	70	55
Energy consumption / year (kWh)	68	68
Lifetime (years)	5	5
Average EU electricity price (domestic)	0.216	0.216
Energy costs over lifetime	73.44	73.44
Energy savings potential in use phase (kWh)	15%	15%
Economic savings potential (EUR)	11.02	11.02
Relation (economic savings / purchase price)	16%	20%

This means that, as long the average sales price does not increase more than 16-20%, the average product life cycle is likely to remain cost-neutral.

13.6 Saving potential

13.6.1 Energy consumption

13.6.1.1 Individual product level

To classify the energy efficiency of hair dryers, the drying rate DR according to DIN EN 61855 and the energy consumption of the appliances can be used as parameters. Energy efficiency can be expressed as energy consumption per drying rate.

Hair dryers have been manufactured and sold for a longer time now, with no major technological change with respect to energy efficiency so far. From this point of view, it seems unlikely that a brand new technology emerges in the next coming years. Still, there are a few technical options see Stratmann 2018):

- Improving the airflow and thereby the drying rate;
- Brushless motor: One manufacturer, advertises a new brushless direct current motor technology, a so-called BLDC motor. According to the manufacturer, their appliance with such a motor dries up to 25% faster than a hair dryer with an AC

[473] https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics#Electricity_prices_for_household_consumers

motor and up to 50% faster than a hair dryer with a conventional DC motor. This motor technology also has a very long service life, as the graphite carbon brushes of conventional motors, which are subject to wear and tear due to friction on the rotor, are replaced by neodymium iron boron magnets. The manufacturer thus guarantees an operating time of 10,000 hours and the avoidance of environmental pollution through carbon dust emission.

Existing differences in measured energy efficiency between different models confirm that savings are possible. Another aspect is the rated power. If this is larger than average, suggesting to consumers that the device will be more effective, the latter device may use more energy than a lower power rating design. At the same time, as Stratmann (2018) has shown, the wattage is not decisive for the drying rate. The latter depends largely on the interaction of the air flow (fan) with the heating power. The tables below, based on the measurements by Stiftung Warentest (2015) and calculations by Stratmann (2018), show the range of performance. Table 175 presents the raw data, Table 176 the improvement potential.

Table 175: Measured data from 15 hair dryers. Source: Stiftung Warentest

Device No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Rated Power (W)	1,900-2,100	2,000	2,200	2,000	2,100	2,200	2,200	2,000	2,000	2,200	2,200	2,300	2,100	2,200	2,000-2,200
Drying rate g / min (without nozzle)	6.48	5.7	5.17	4.45	5.95	5.8	5.67	5.3	6.14	5.84	6.29	6.16	5.68	6.26	6.05
Drying rate g / min (with nozzle)	5.74	5.32	5.59	5.57	5.75	6.1	6.15	5.69	5.69	6.03	5.84	6.28	5.78	6.04	5.95
Energy efficiency (w/o nozzle) [Wh / g/min]	4.5	5.5	6.1	6.9	5.3	5.7	5.4	5.6	4.9	5.4	5.1	5.9	5.4	4.9	5.1
Energy consumption (Wh/min)	29.2	31.4	31.5	30.7	31.5	33.1	30.6	29.7	30.1	31.5	32.1	36.3	30.7	30.7	30.9

Table 176: Improvement potential for Drying Rate, Energy Efficiency, Energy consumption. Source: Own calculation based on data from Stiftung Warentest

Drying rate without nozzle	lowest vs. highest value	31%
	lowest vs. average value	23%
Drying rate with nozzle	lowest vs. highest value	15%
	lowest vs. average value	9%
Energy efficiency without nozzle	lowest vs. highest value	35%
	lowest vs. average value	17%
Energy consumption	lowest vs. highest value	20%
	lowest vs. average value	15%

A comparison of these figures with the requirements of existing Ecolabels is also interesting. None of the devices would fulfil the requirements of the Taiwanese Ecolabel. The latter requires an Energy Efficiency Index value of 19.5% at least, while the tested devices achieve between 12.5% and 15.9% (if the metrics are converted to the Taiwanese metrics). However, five of the 15 devices reach the Blue Angel threshold (≤ 5.2 Wh/g/min) and all but two reach the Thai High Efficiency Performance Standard (≤ 5.7 Wh/g/min).

Based on this data, we will assume a potential reduction in energy consumption of 15%. Although it may seem somewhat ambitious to assume that an average product is exchanged for the best available product, potential savings by reducing rated power are also taken into account.

13.6.1.2 Overall EU-27 savings potential

If all stock were exchanged at once, and the 15% savings were realised, the following energy and GHG emission savings result for EU-27:

Table 177: EU-27 energy savings potential. Source: Own calculations

	2020			2030		
	In use phase					
	Privately used hairdryers	Professionally used hairdryers	Total	Privately used hairdryers	Professionally used hairdryers	Total
Electricity (TWh)	1.5	0.1	1.6	1.8	0.2	2.0
Primary energy (PJ)	11.4	1.1	12.4	13.9	1.3	15.3
GHG emissions (1,000 t)	571	53	624	627	59	686

These savings are in line with the medium scenario of the WP 3 study (2 TWh for both 2020 and 2030). However, we consider them to be much more reliable. The uncertainty range could be reduced considerably thanks to more detailed assessments of usage scenarios and measured data for energy consumption.

13.6.2 Other resource consumption

Durability and repairability

Due to better materials and a more durable AC motor, professional devices are more durable than household devices, which are constructed from lighter plastics and usually have a DC motor (which is also reflected in a higher price).

In its 2015 test, Stiftung Warentest conducted an endurance test of hair dryers. The devices were subject to an endurance test of all in all 400 hours, thereof 200 hours motor running time. The hair dryers were operated alternately for 15 minutes at the highest heating level with nozzle and then paused for 15 minutes. Two of the 15 devices failed the test. The heat deformed the plastic housing of both devices and the blower began to make noise. In addition, they and one other device failed the cable bending test: the cables broke in all three devices after the endurance test (Test 01/2015). The results show that such a test is feasible and that a meaningful requirement could be formulated. The Blue Angel requires that a product must pass the test conducted by Stiftung Warentest.

Furthermore, products' useful life could be prolonged if they were better repairable. For example, manufacturer Rowenta guarantees 10 years availability of spare parts for its products; missing spare parts may be reproduced using 3D printing[474].

In the attempt to increase the useful life, the advent of connected products and typical issues associated with this trend would also have to be considered, such as the availability of software updates, possibility to use products offline etc.

If the average useful life was improved by 10% by eliminating the worst performing devices and improving repairabilty, while the increase in total stock remains more or less constant, the following differences in sales would result (in 1,000):

Table 178: Differences in sales by increasing durability by 10%. Source: Own calculations

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Sales		32,231	32,779	33,336	33,903	34,479	35,065	35,662	36,268	36,884	37,511	38,149
Stock	160,000	163,431	166,792	170,106	173,390	176,659	179,926	183,201	186,492	189,808	193,154	196,535
Difference in sales		-	741	1,525	2,353	3,226	4,149	4,337	4,530	4,730	4,103	3,465
Cumulative difference		-	741	2,266	3,877	5,579	7,375	8,485	8,867	9,260	8,833	7,568

If the cumulative number of "saved" sales in 2030 is multiplied with the resource consumption presented in Table 170, the following material savings are achieved:

Table 179: Cumulative material savings in 2030, EU 27, by increasing lifetime by 10%. Source: Own calculations

Material	Weight (t)
Polypropylene	783
Polyamide	590
Polycarbonate	15
Acrylonitrile butadiene styrene (ABS)	8
Nylon	23
Polyvinyl chloride (PVC)	83
Aluminium	8
Copper	1,187
Iron-nickel-chrome alloy	106
Steel	1,097
Inductors	45
Capacitors	23
Resistors	8
Ferrite	15
Diode	11

[474] https://www.rowenta.de/reparierbarkeit

Copper-PVC-Cable	125
Coated paper	174
Graphite	8
Cable	1,551
Plug	227
Total	**6,087**

Using the energy intensity figures from the Ecoreport Tool, this translates into 0.6 PJ energy savings.

Recyclability
Recyclability could be improved by reducing the numer of polymers used in the housing. The Blue Angel therefore requires that plastic housings may only consist of two separate polymers or polymer blends. One manufacturer advertises that its hair dryers are made of 95 percent recyclable materials.

Furthermore, plastic marking could improve recyclability. The Blue Angel requires that plastic components weighing more than 25 grams shall be marked according to ISO 11469.

13.6.3 Main other environmental issues

Main other environmental issues include

- potential presence of hazardous substances in plastics,
- potential use of post-consumer recycled material.

A detailed discussion of such aspects is reserved for Task 4, given that energy and resource savings are large enough to consider the product group for regulation. See the assessment of the horizontal post-consumer recycled content in this report.

13.6.4 End user cost savings

If the projected electricity savings are multiplied with an average electricity price of 0.216 ct/kWh for household consumers and 0.1173 EUR/kWh for non-household consumers (static price, 2019)[475], the following cost savings result:

Table 180: Potential electricity cost savings, EU-27

	2020			**2030**		
	Privately used hairdryers	Professionally used hairdryers	Total	Privately used hairdryers	Professionally used hairdryers	Total
Electricity (TWh)	1,5	0,1	1,6	1,8	0,2	2,0
Electricity cost EUR / kWh	0,216	0,1173		0,216	0,1173	
Savings (Mio. EUR)	**324.6**	**16.5**	**341.1**	**398.5**	**20.2**	**418.8**

As explained in section 13.5.3, as long the average sales price does not increase more than 16-20%, the average product life cycle is likely to remain cost-neutral.

[475] https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

13.7 Summary

Table 181 presents a summary of the product group "Hair dryers".

Table 181: Summary – Hair dryers (TWh for final energy and PJ for primary energy). Source: Own calculations

	Year		Confidence in the savings estimates (from + to +++)
Market data			
Sales (1,000)	2020	32,231	
	2030	41,614	
Stock (1,000)	2020	160,231	
	2030	196,700	
EU-27 Resource consumption			
Primary energy over the life cycle (GER) per year (PJ)	2020	88.7	
	2030	108.9	
Electricity per year in use phase (TWh)	2020	11.0	
	2030	13.5	
Primary energy per year in use phase (PJ)	2020	82.8	
	2030	101.7	
Resource consumption per year (t)	2020	6,607	
	2030	8,531	
GHG emissions (1,000 t)	2020	4,164	
	2030	4,573	
EU-27 resource savings			
Electricity per year in use phase (TWh)	2020	1.6	+++
	2030	2.0	+++
Primary energy per year in use phase (PJ)	2020	12.4	+++
	2030	15.3	+++
Resource consumption per year (t)	2020	-	
	2030	6	++
Energy savings from saved resource consumption (PJ)	2030	0.6	+
GHG emissions (1,000 t)	2020	624	+++
	2030	686	+++

13.8 Stakeholder comments

Stakeholders pointed out that a more comprehensive discussion of durability would have to include an in-depth assessment of repairability issues and issues related to connected products. Furthermore, hair dryers could be considered together with other hair care products which would make potential savings more significant.

Stakeholders recommended to include the potential use of post-consumer recycled plastics into the list of relevant environmental impact. This has been implemented. However, no detailed analysis could be made at this stage of the study. For a more general discussion of recycled content, please see the chapter in this report.

14 Street lighting systems with PV

14.1 Scope, policy measures and test standards

14.1.1 Scope

Commission Regulation (EC) No 245/2009[476] defined public street lighting as *"a fixed lighting installation intended to provide good visibility to users of outdoor public traffic areas during the hours of darkness to support traffic safety, traffic flow and public security".*

The more recent (2016) Lot 37 Ecodesign preparatory study on lighting systems[477] expanded this definition, adding: *"…according to standard EN 13201 on road lighting including similar applications as used for car parks of commercial or industrial outdoor sites and traffic routes in recreational sports or leisure facilities"*. This definition excludes e.g. signage displays, traffic signals, 'city beautification', tunnel lighting, and professional sports events.

The scope of the current study follows the above definition, with the implied exemptions, but is further limited to road lighting installations equipped with photovoltaic panels (PV), including both battery-operated (off-grid) and hybrid (grid-connected) solutions.

Recently, PV technologies have seen a significant cost reduction while at the same time becoming more efficient due to innovative technologies, enlarging the type of applications and markets of solar technologies – including street lighting[478].

Lighting installations with PV typically comprise the following components (see also section 14.4):

- light source[479] (most commonly LED);
- luminaire (light source and luminaire can be integrated);
- lighting control gear (LED driver, can be integrated with light source or luminaire);
- PV panel (can be integrated with the luminaire or with the pole);
- battery (e.g. Li-ion, gel);
- control system for battery charging (e.g. Maximum Power Point Tracking, MPPT);
- sensors (e.g. daylight, temperature, traffic intensity);
- (smart) control system for the light source(s) (e.g. on/off or dimming depending on sensors, possibly remote control);
- means of luminaire fixation depending on the location (e.g. pole including foundation, suspension wires, attached to a building);
- cabling for power supply from the grid (for hybrid solutions).

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476 Commission Regulation (EC) No 245/2009 of 18 March 2009, OJ L 76, 24.3.2009, p. 17–44.

477 Preparatory study on lighting systems 'Lot 37', 15 December 2016, VITO et al. for DG ENER C.3, http://ecodesign-lightingsystems.eu/documents

478 See for example https://www.signify.com/global/our-company/news/press-releases/2020/20200227-signify-expands-solar-lighting-potential-to-northern-countries-using-new-hybrid-charging-technology and https://theconversation.com/how-a-new-solar-and-lighting-technology-could-propel-a-renewable-energy-transformation-133658

479 In the sense of Commission Regulation (EU) 2019/2020 this can be a replaceable light bulb or LED module, but also an integrated luminaire from which no smaller light source can be removed.

Considering that the pole (and its foundation) could be integrated with the PV panel and/or with the battery, it will probably have to be considered as part of the product in scope.

In addition, as shown in the Lot 37 study, road lighting efficiency does not only depend on the single lighting 'pole' but on the entire lighting installation for the piece of road considered, consisting of a combination of 'poles'.

In both cases, follow-up studies will have to address the definition of the product boundary. Thereby also the recently published preparatory study on solar photovoltaic modules, inverters and systems will be taken into account, which proposed to exclude street lighting from its scope[480]. Either way, (the combination of) the product boundary, system approach and subsequently possible policy measures will need to be investigated thoroughly in follow-up studies.

14.1.2 Policy measures

Although the Lot 9 Ecodesign preparatory study dealt with street lighting, the resulting Commission Regulation (EC) No 245/2009 mainly sets requirements on the light sources traditionally used in street lighting (fluorescent lamps without integrated control gear and High-Intensity Discharge (HID) lamps). It only marginally addresses street lighting luminaires (ballast compatibility, information requirements) or systems[481].

The Lot 8/9/19 Ecodesign review study concerned all light source types, and resulted in Commission Regulation (EU) 2019/2020[482], applying Ecodesign requirements from September 2021. From the same date, the new regulation repeals the three existing Ecodesign lighting regulations 244/2009 (non-directional household lamps)[483], 245/2009 (fluorescent lamps without integrated control gear and high-intensity discharge lamps), and 1194/2012 (directional lamps and LEDs)[484]. Regulation 2019/2020 mainly sets requirements on light sources, but integrated luminaires (from which no smaller light source can be removed) are also considered to be light sources. The generic requirement that contained light sources in principle should be replaceable[485] also applies to street lighting luminaires, but there are no specific requirements for street lighting luminaires or systems.

Regulation 2019/2020 phases out Linear Fluorescent Lamps (LFL) T8 of 2/4/5-foot length (from September 2023), but continues to allow on the market most light sources traditionally used in street lighting, in particular high-pressure sodium (HPS), metal-halide (MH), compact fluorescent lamps (CFL) without integrated control gear, LFL T5, and FL T8 non-

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[480] Dodd, Nicholas; Espinosa, Nieves, Van Tichelen, Paul Peeters; Karolien, Soares; Ana Maria, *Preparatory study for solar photovoltaic modules, inverters and systems,* EUR 30468 EN, Publications Office of the European Union, Luxembourg, 2020, Science for Policy, ISBN 978-92-76-26345-6, doi:10.2760/852637, JRC122431, available at https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-12/jrc12431preparatory_study_for_solar_photovoltaic_modules_kj-na-30468-en.pdf

[481] In parallel, the Lot 8 Ecodesign preparatory study addressed office lighting, but also here, Commission Regulation (EC) No 245/2009 actually sets requirements on the light sources traditionally used in office lighting.

[482] Commission Regulation (EU) 2019/2020 of 1 October 2019, notified under document C/2019/2121, OJ L 315, 5.12.2019, p. 209–240.

[483] Commission Regulation (EC) No 244/2009 of 18 March 2009, OJ L 76, 24.3.2009, p. 3–16.

[484] Commission Regulation (EU) No 1194/2012 of 12 December 2012, OJ L 342, 14.12.2012, p. 1–22.

[485] Unless there is a good reason to design them otherwise.

linear or of other lengths. These other types more or less keep the same energy efficiency requirements that they had under CR 245/2009.

"*Light sources and separate control gears in battery-operated products […]*" are exempted from Regulation 2019/2020[486], whereby 'battery operated' is defined as *"a product that operates only on direct current (DC) supplied from a source contained in the same product, without being connected directly or indirectly to the mains electricity supply"* [487]. This means that light sources in off-grid battery operated street lighting products are not within the scope of the Regulation, unless the battery is not contained in the same product as the light source.

Parallel to the Lot 8/9/19 study on light sources, the Lot 37 Ecodesign preparatory study on lighting systems was performed, delivering the final report in December 2016[488]. This study concerned lighting systems, rather than light sources, both for indoor (office) lighting and for outdoor (street) lighting, and thus had a broader approach. The study identified potential policy measures, among others the calculation of an Annual Energy Consumption Indicator (AECI, in kWh/m^2/a) for a lighting system. Together with measures to encourage the inclusion of life cycle costing in tendering[489]; this was expected to clarify the value proposition of efficient lighting systems to service procurers and therefore could be a major stimulus to a demand for more efficient systems. However, the study also stated that more work would be needed to develop a comprehensive set of AECI limit values that are sufficiently well-adapted to the array of roadway application types found across the EU. The Lot 37 study did not specifically consider street lights with PV panels.

A life-cycle cost, performance and/or efficiency rating of streetlights comparing types of street lighting (e.g. with and without PV) could provide valuable insights concerning different lighting installations and the potential energy and cost savings.

14.1.3 Test standards

For road/street lighting, standards are developed by CEN/TC 169 (light and lighting) and specifically WG 12. This working group is a Joint Working Group with CEN/TC 226 (road equipment) and specifies lighting requirements for all classes of roads and road users which meet the needs of visual performance, comfort and safety.

Road lighting is dealt with by CEN in the EN 13201-series[490]:

- CEN/TR 13201-1:2014: *Road lighting – Part 1: Guidelines on selection of lighting classes*[491].

[486] CR 2019/2020, Annex III, article 2 (c).
[487] CR 2019/2020, Annex I, definition (44).
[488] Ibid. footnote 477.
[489] e.g. present life-cycle costs for the planned lighting system installation and compare the designed installation to the existing installation (if any) and to at least one more solution.
[490] See https://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:772821,25&cs=1A89E3BC9C41C9ADCD6DAD6B3BA39763D
[491] The standard gives guidelines on the selection of the most appropriate class for a given situation, being: M class: motor powered vehicles, S class: slow moving vehicles, C class: intended for drivers of motorized vehicles, but for use on conflict areas, P class: pedestrians.

- EN 13201-2:2015: *Road lighting – Part 2: Performance requirements*[492].
- EN 13201-3: 2015: *Road lighting – Part 3: Calculation of performance.*
- EN 13201-4: 2015: *Road lighting – Part 4: Methods of measuring lighting performance.*
- EN 13201-5:2015: *Road lighting – Part 5: Energy performance indicators.*

Another standard pertaining to CEN/TC 169/WG 12, EN 13032-5:2018, defines the presentation of utilances or utilization factors for luminaires used for road lighting. A non-exhaustive list of other standards applying to road and street lighting can be found in Annex I.

Besides CEN also CIE (Commission Internationale de l´Eclairage) is active with developing standards and technical reports in the field of light and lighting, colour and vision, photobiology and image technology. A non-exhaustive list of their standards can also be found in Annex I, but one of the most important related to street/road lighting is CIE 115-2010[493]. It is a revision and update of CIE 115-1995 *"Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic"*. After it was issued in 1995, power consumption and environmental aspects have become more important. At the same time, the improved performance of luminaires and light sources – especially the introduction of electronic control gear and the increased use of LEDs – has made it possible to introduce adaptive lighting for roads for motorised traffic, conflict areas and areas for pedestrians.

14.2 Market

Table 182 provides an estimate of the installed stock of road lighting luminaires in the EU27. In 2015 there were around 57 mln road lighting luminaires operating in EU27. However, as shown in Table 183, only a minor part of the roads in 2015 were lit.

Table 182: Estimated stock of road lighting luminaires in EU27[494]

Country	Population 2015	Total stock luminaires 2005	Total stock luminaires 2015
Austria	8 551 081	1 000 000	1 033 494
Belgium	11 336 943	2 005 000	2 154 280
Bulgaria	7 199 931		910 708
Croatia	4 244 995		536 943
Cyprus	873 003	88 000	90 948
Czech Republic	10 536 043	300 000	1 300 000
Denmark	5 649 584	780 000	806 126
Estonia	1 311 505	50 000	51 675
Finland	5 478 486	400 000	1 100 000
France	66 175 754	9 000 000	9 000 000
Germany	80 709 056	9 250 000	9 250 000
Greece	10 977 945	900 000	930 145
Hungary	9 863 193	600 000	620 097
Ireland	4 602 854	401 000	414 431
Italy	60 944 960	9 000 000	9 301 449
Latvia	1 985 887	85 000	87 847
Lithuania	2 901 039	125 000	129 187

492 The standard defines performance requirements which are specified as lighting classes for road lighting aiming at the visual needs of road users, and it considers environmental aspects of road lighting. Classes are: ME, CE, S, A, ES and EV.

493 http://cie.co.at/publications/lighting-roads-motor-and-pedestrian-traffic

494 Adapted for EU27 from final report preparatory study on lighting systems 'Lot 37', 15 December 2016, pp. 154.

Luxembourg	562 848	61 000	63 043
Malta	426 144	45 000	46 507
Netherlands	16 876 904	2 500 000	3 652 286
Poland	38 499 953	4 200 000	4 340 676
Portugal	10 367 550	1 100 000	1 136 844
Romania	19 909 323		2 518 300
Slovakia	5 416 851	200 000	206 699
Slovenia	2 066 511	74 000	76 479
Spain	46 390 269	4 200 000	4 340 676
Sweden	9 721 642	2 500 000	2 545 366
EU27	**443 580 254**		**56 644 206**

Table 182 shows that there is a significant stock of road lighting luminaries. It includes lighting systems with and without PV, of which the former currently forms a very small part of the market.

Table 183: Estimated share of lit roads in 2015[495]

	Motorways	Main or national roads	Secondary or regional roads	Other roads
EU27 road length [km]	67 751	239 073	1 482 341	3 340 301
2015 share lit	12%	12%	18%	37%

Some examples of EU-manufacturers of street lighting systems with PV are: Signify (former Philips Lighting, the Netherlands), Sunna Design (France), Mawo Solarteur (Germany), FlexSol Solutions (the Netherlands), EKIONA Solar Lighting (Spain). Examples of non-EU manufacturers are SolarOne Solutions (USA), Jiangsu Sokoyo Solar Lighting (China), Solar Lighting International (USA). At first sight, there are very large differences in price and quality.

Due to the rising potential of solar technologies coupled with growing demand for clean energy sources it is expected that the industry of solar powered street lighting will grow. A market forecast estimates a growth towards 360 million streetlights (all types) worldwide by 2026[496]. There is a general trend to curtail greenhouse gas emissions, and prices of solar panels (and batteries) have reduced substantially and are expected to reduce more, making solar powered street lighting an attractive option compared to incumbent systems. It is estimated that (both non-solar and solar-powered) LED and smart streetlights will reach 89% and 42% of the total streetlight market, respectively, by 2026. This means a market opportunity of €5-6 billion per year[497].

14.3 Usage

For street lighting energy calculations, 4 000 operating hours per year are typically used as an average for the EU[498].

[495] Adapted for EU27 from final report preparatory study on lighting systems 'Lot 37', 15 December 2016, pp. 149.

[496] http://www.northeast-group.com/reports/Brochure-Global%20LED%20and%20Smart%20Street%20Lighting%20Market%20Forecast%202016-2026%20-%20Northeast%20Group.pdf

[497] Ibid. footnote 496.

[498] See e.g. the Lot 8/9/19 study and the associated MELISA model.

Public lighting requirements are traditionally dominated by road traffic safety concerns and the perceived security feeling especially in densely populated areas. However, the absolute reduction of crime by public lighting is not proven (several studies show that lighting can displace criminality from higher lit places to lower lit places). Dimming related to traffic density is not a mainstream technology as of yet, but the method is included in guideline CEN/TR 13201-1.

There is however a trend towards smarter street lighting, fuelled by the rise of LED and smart technologies. Although CR 2019/2020 still allows traditional light sources for street lighting on the market (e.g. HPS, MH, CFL, LFL T5, non-linear FL), the fast majority of new installed streetlights now uses LED because this offers lower life-cycle costs.

Solar powered street lighting is the logical next step. It has the advantage that it consumes solely renewable energy when it functions off-grid, but also provides flexibility when used in hybrid form (i.e. grid-connected solar powered streetlight). The most advanced streetlights use smart technologies, contain algorithms, and are equipped with wireless remote monitoring, management and control[499]. This makes the usage of street lighting more dynamic and flexible; a trend expected to continue in the future.

Considering that more options and technologies are becoming available, it is important to have a proper (rating) system to compare the different options with regard to certain criteria, for example AECI or GPP criteria[500]. Buyers at community/city level (usually not lighting specialists and certainly not in this new technology) would benefit from a(n) (energy label) system to guide them both in efficiency and performance[501].

14.4 Technologies

Solar streetlight uses solar PV modules to convert sunlight into electricity, which can be stored for lighting the streets when needed. A solar powered street lighting system includes different components that should be selected according to the system type, location and application. Figure 42 shows the main typical parts for solar streetlight systems: the solar panel(s), control system, battery, and LED. These components will be discussed individually below.

[499] E.g. https://flexsolsolutions.com/soluxio-solar-light-pole/

[500] Green Public Procurement (GPP) criteria are available at https://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm. The most recent technical report and criteria proposal for road lighting and traffic signals can be found at https://op.europa.eu/en/publication-detail/-/publication/1692805e-237b-11e9-8d04-01aa75ed71a1/language-en.

[501] For example, the EN 13201 standards seem to be encouraging light levels that are much higher than currently is the case. They set high maximum light levels for different road classes and a lot of procurers/designers sometimes simply copy those maximum values. However, road classes are also defined by traffic volume, which is dynamic, thus making the road class dynamic. The lighting level therefore should be dynamic too, and not simply be designed for the peak traffic volume (which leads to extra electricity consumption).

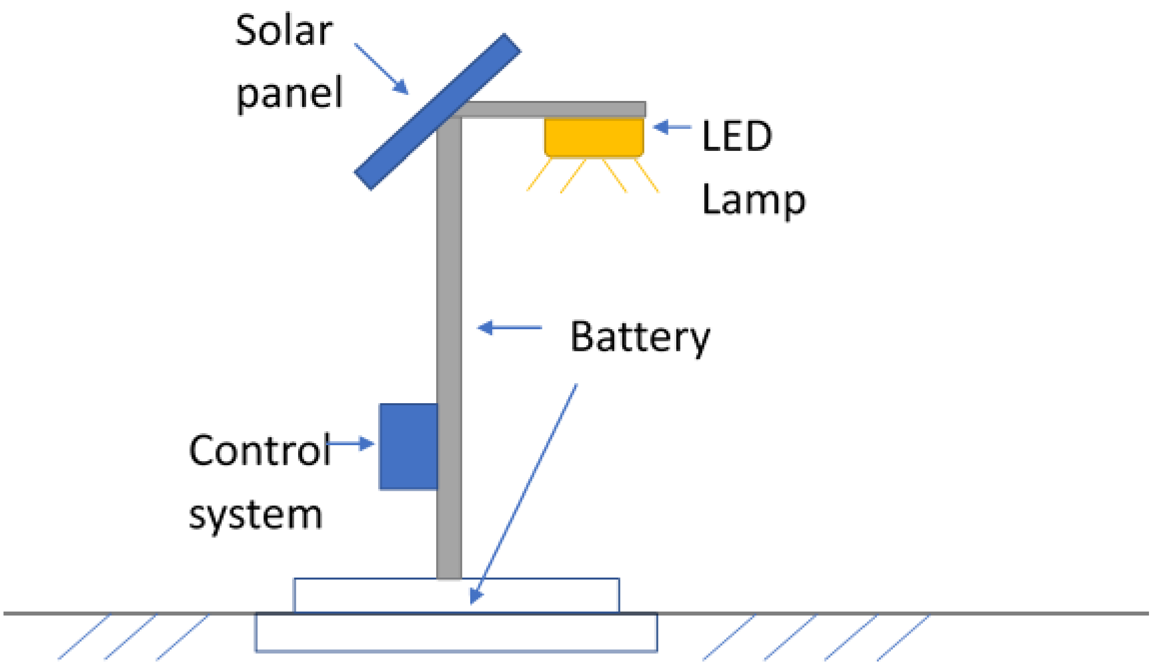

Figure 42: Schematic representation of a street lighting system with PV

14.4.1 Solar panel

An important component of a solar powered streetlight is the solar panel[502]; the most commonly used PV cells are mono-crystalline and polycrystalline. The maximum yield of a PV cell depends among others on the following factors: solar radiation (insolation); weather conditions and panel orientation (i.e. cardinal direction and tilt angle). Figure 43 shows the most commonly used positions of the PV panel on a streetlight.

[502] It should be noted that the scope of the ongoing preparatory study for solar photovoltaic modules, inverters and systems does not include streetlights. See https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/462/home.

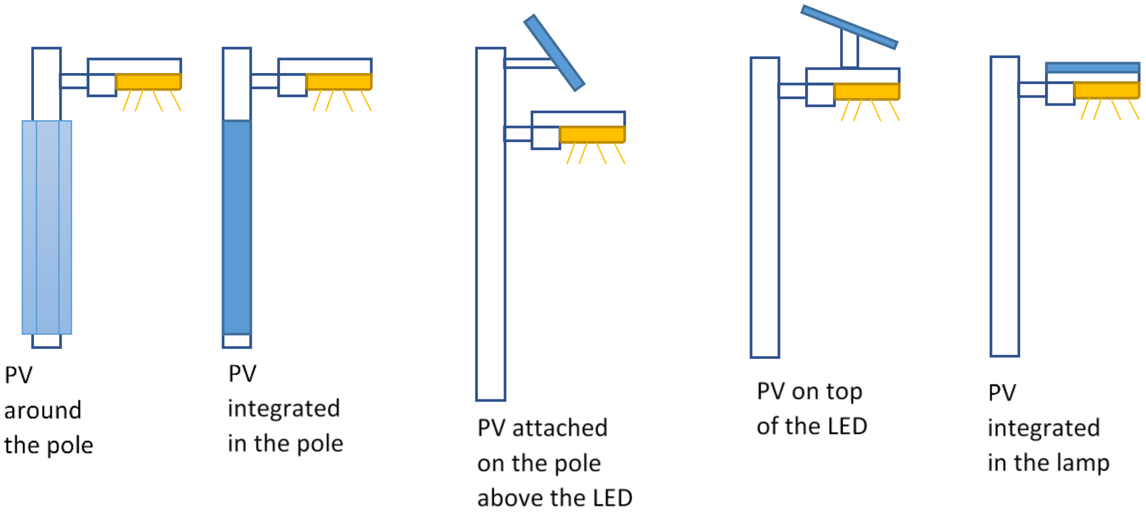

Figure 43: Examples of PV positions of a street lighting system with PV 503

14.4.2 Battery

Batteries can be located underneath the solar panel, in the pole or in the concrete base of the pole. Depending on the LED, 12 V (120Ah[504]) or 24 V lithium-ion batteries are commonly used. Gel batteries belong to the family of lead-acid batteries and are also used, but the lithium-ion batteries have more advantages (e.g. smaller, higher temperature tolerance, more efficient). On average a lithium battery service lifespan is 8-10 years[505], while the gel batteries have a service lifespan of 2-3 years[506].

14.4.3 Control system

The control system consists of at least a solar charge controller to control the charge of the battery and extend the battery lifespan. The charge controller can make use of maximum power point tracking (MPPT); this is a technique to maximise the power extraction from the PV panel under all conditions. Furthermore, it contains an internal clock/timer or a light sensor to make the light turn on and off automatically at dusk and dawn, respectively.

More advanced 'smart' streetlights can include other technologies in the control system, e.g. dimming can be done via pulse width modulation (PWM), and motion detection can be used for dynamic dimming. Other smart streetlight technologies include weather prediction features, wireless monitoring, remote management and (performance) control (e.g. information about lamp status for proactive maintenance and early detection of failures, temperatures, reading of power consumption and operating times, etc.).

[503] Adapted from https://metsolar.eu/applications/solar-for-lighting/
[504] https://www.luxmanlight.com/how-to-choose-batteries-for-your-solar-street-light-project/
[505] https://flexsolsolutions.com/soluxio/advantages-lithium-batteries/
[506] https://www.luxmanlight.com/how-to-choose-batteries-for-your-solar-street-light-project/

14.4.4 Light source

LEDs are the main light source in solar powered street lighting, as LED has a lower energy consumption.

14.5 Energy, emissions and costs

Traditional on-grid streetlights (with among others HPS lamps) consume approximately 625 kWh per year[507]. Streetlights equipped with LED and appropriate luminaire can achieve savings in energy consumption of 30% or more[508]. With more intelligent streetlights (e.g. dynamic dimming) these savings could be higher. Below is a cost-comparison of traditional streetlights and solar powered LED streetlights[509].

14.5.1 Acquisition cost

A rough estimation is that hybrid solar streetlights cost approximately 30% more than traditional streetlights, €1 056 versus €1 373 for a hybrid solar powered streetlight. An off-grid solar powered streetlight is estimated to be 50% more expensive (€1 584) because of a larger battery. It should be noted that there exist large differences between solar powered streetlights from very simple to complex, both off-grid and hybrid. Hybrid solar powered streetlights have the advantage that a smaller battery is required (reducing material and cost), since they use the electricity grid as a back-up.

14.5.2 Installation cost

In case of new installations traditional streetlights require cabling and trenching to connect to grid lines. The additional cost of cabling and trenching is approximately €770 per streetlight[510]. Off-grid solar powered streetlights do not require cabling (which offsets the higher acquisition cost); hybrid solar powered streetlights still require cabling but save on operational costs compared with traditional streetlights.

14.5.3 Maintenance cost

It is estimated that high pressure sodium bulbs have a lifespan of approximately 5 years[511], which means that at least once every 5 years a traditional streetlight requires maintenance.

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[507] See https://www.streetlight-epc.eu/the-project/. An estimated yearly electricity consumption of 35 TWh, divided by 56 mln luminaires = 625 kWh per luminaire.

[508] Based on an estimation from several streetlight-EPC projects (https://www.streetlight-epc.eu/). Replacing the HPS lamp with a LED lamp results in energy savings in the range of 20% to 30%; when the luminaire and controls are adapted to the LED lamp, energy savings of 30% to 70% can be achieved.

[509] Based on Lightinus (2017) - Ultimate guide for solar street lights (https://www.lightinus.com/wp-content/uploads/2017/06/Ultimate-Guide-for-Solar-Street-Lights.pdf) and https://www.streetlights-solar.com/cost-comparison-between-solar-vs-traditional-lights.html

[510] One meter of cabling and trenching costs €22; along a rural road with streetlights 35 m apart, this results in €770 (see also Table 185, data based on CIE 115-2010 and final report preparatory study on lighting systems 'Lot 37', 15 December 2016. Other estimates indicate higher costs, see for example https://www.streetlights-solar.com/cost-comparison-between-solar-vs-traditional-lights.html.

[511] Based on MELISA model and Sutopo et al. (2020) - A model to improve the implementation standards of street lighting based on solar energy: A case study*. Energies* 2020, 13(3), 630; https://doi.org/10.3390/en13030630

The lifetime of a LED is estimated at 12.5 years – assuming a LED lamp has 50 000 hours of service life[512].

14.5.4 Operational cost

Traditional streetlights can accumulate to approximately €375 electricity cost over 5 years[513] per streetlight. Since solar powered streetlights gather their energy from the sun, there are no electricity costs involved in the case of off-grid streetlights. In the case of hybrid streetlights, the electricity costs involved can largely be reduced, possibly only 10% of those of a traditional streetlight since it only uses electricity from the grid as a back-up.

The figure below shows a comparison of the AECI of High-Intensity Discharge (HID) lamps, 'standard' LED (LED with best fit luminaire) and 'smart' LED (with the best smart controls as defined in EN 13201-5).

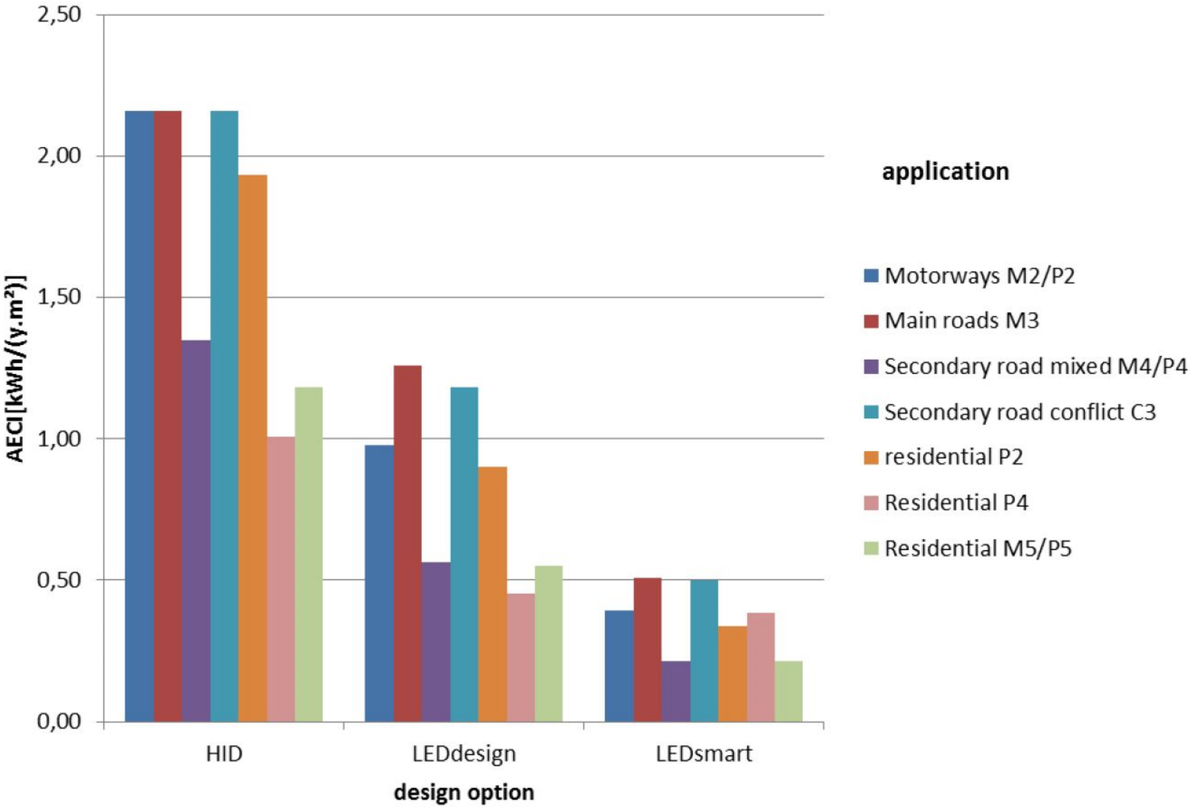

Figure 44: Calculated AECI values per reference road for various lighting design options[514]

Table 184 shows the design calculation data for HPS, LED and LED 'smart' designs, based on data from Lot 37 preparatory study on lighting systems.

[512] 50 000 hrs / 4 000 hrs/year = 12.5 years.
[513] 625 kWh/year x 0.12 €/kWh x 5 years = €375.
[514] Source: final report preparatory study on lighting systems 'Lot 37', 15 December 2016, p. 253.

Table 184: Road lighting applications with design calculation data[515]

	Motorways			Main or national roads			Rural roads or mixed with residential		
Design	**HPS 250 W**	**LED de-sign**	**LED smart**	**HPS 150 W**	**LED**	**LED smart**	**HPS 100 W**	**LED**	**LED smart**
Maximum lumi-naire Power, PI [W]	270	122	122	170	99	99	118	49.5	49.5
Road zone class	M2	M2	M2	M3	M3	M3	M4	M4	M4
Pole distance [m]	50	50	50	45	45	45	35	35	35
PE (AECI) [kWh/(y.m2)]	2.16	0.98	0.39	2.16	1.26	0.51	1.35	0.57	0.21
Lamp cost per lu-minaire for repair [€]	30	200	200	15	200	200	15	100	100
Control gear cost per luminaire for repair [€]	50	50	50	50	50	50	30	30	30
Luminaire unit cost [€]	400	800	1000	250	500	600	250	300	350

These data serve as input for the operating cost (C_{op}), life-cycle costs (C_{lc}) and average annual costs (C_{aa}), a calculation method used in CIE 115-2010. The results of which are shown in Table 185 below. Estimations of PV hybrid and PV off-grid have been added; the electricity costs of both are (almost) zero.

Table 185: Cost calculations of different lighting designs on rural roads

	HPS 100W	**LED**	**LED smart**	**LED smart + PV (hybrid)**	**LED smart + PV (off-grid)**
S spacing of the poles [m]	35	35	35	35	35
t_1 annual burning time [h]	4000	4000	4000	4000	4000
t_2 lifetime of the lamp [a]	5	12.5	12.5	12.5	12.5
t length of period [years]	20	20	20	20	20
P_{lu} power of the luminaire [kW][516]	0.12	0.05	0.05	0.05	0.05
C_{en} cost of energy [€/kWh][517]	0.12	0.12	0.10	0.012	0
C_{co} cost of the pole and the foun-dation per unit [€]	1056	1056	1162[518]	1373	1584

[515] Source: final report preparatory study on lighting systems 'Lot 37', 15 December 2016, pp. 249-252.

[516] For simplicity, the maximum luminaire power of Table 184 has been used.

[517] To mimic the minimal grid electricity consumption of a hybrid streetlight, the cost of energy is set at 10% of the non-residential electricity cost per kWh (0.12 €/kWh), resulting in 0.012 €/kWh. The energy cost of an off-grid streetlight is 0 €/kWh. Energy savings due to smart controls (e.g. dynamic dimming, off-peak dimming) are estimated at 20%, to mimic this, the electricity cost per kWh is reduced with 20% to 0.10 €/kWh.

[518] Smart controls are estimated to add 10% to the system costs, see for example http://www.northeast-group.com/reports/CityLab-Northeast%20Group%20-%20the-benefits-of-led-and-smart-street-lighting.pdf

C_{lu} cost of the luminaire and the first lamp(s) per unit [€]	250	300	350	350	350
C_{ps} cost of the power supply mains [€/m]	22	22	22	22	0
C_{in} installation costs [€/m]	59.31	60.74	65.19	71.22	55.26
C_{op} operating costs of the first year [€/m]	2.8	2.3	2.2	1.7	1.6
C_{aa} is average annual costs [€/m]	9.28	8.73	8.95	8.73	7.23
C_{lc} is present value of life cycle costs [€/m]	97.3	93.5	96.7	96.9	80.2
EU27 average annual costs [mln €]	2 477	2 330	2 388	2 328	1 930

When comparing the total costs of traditional street lighting and solar powered street lighting, the higher acquisition cost of solar is offset by its lower installation cost, and/or lower operational cost.

Since the EU27 has 266 821 km of lit rural road (see Table 183) the average annual costs can be calculated, as shown in the table above. It shows that solar powered lighting systems lead to cost savings of €149 mln per year (hybrid) and €547 per year (off-grid) – on rural roads in the EU27; savings on all roads are subsequently higher.

It should be noted that these cost calculations are estimates and not complete; for example, there also exists the possibility to retrofit existing traditional street lighting systems with PV panels to become solar powered[519].

14.6 Saving potential and other environmental aspects

14.6.1 Saving potential

As noted by the Streetlight-EPC project[520], with more than 56 million street lighting luminaires in operation and an estimated electricity consumption of 35 TWh, street lighting consumes a significant amount of electricity. With current technologies 30-70% energy savings are generally possible. This savings potential has been recognised and incorporated into European policies, e.g. Regulation (EC) No 245/2009 and Regulation (EU) 2019/2020 set requirements for a range of frequently used light sources.

With for example high-pressure mercury lamps not available on the market anymore, street lighting refurbishment with LED and other innovative solutions are economically more attractive; LED technology for street lighting offers high savings with comparatively

[519] https://www.engoplanet.com/post/solar-street-light-price-and-costs-involved. In addition, there are several online calculation tools, e.g. Premium Light Pro offers a lot of information (http://www.premiumlightpro.eu/), and a very simple tool can be found at https://solarlighting.com/applications/solar-street-lights/

[520] https://www.streetlight-epc.eu/, where EPC stands for Energy Performance Contracting.

short payback times. Thus the 35 TWh per year could be reduced by 50%[521] to 17.5 TWh. With smart controls (e.g. dynamic dimming) significant additional savings are possible; a conservative estimation is 20%[522]. Either way, from a life-cycle cost perspective, solar-powered street lighting systems are the better option compared to HID streetlights such as high-pressure sodium. These solar-powered street lighting systems are especially interesting options where there is no electricity grid yet, where the grid is due for replacement, or the grid is above ground[523]. Furthermore, if the complete stock of 56 mln streetlights were replaced by hybrid solar-powered streetlights, it is estimated that 31.5 TWh of electricity consumption from the grid could be saved, and CO_2-emission would be reduced by approximately 12 Mt per year[524].

14.6.2 Other environmental aspects

Besides the energy saving potential, it is important to acknowledge that there are other environmental aspects concerning street lighting. It should be noted that these concern street lighting systems in general and are not limited to street lighting systems with PV. These aspects include (but are not limited to) light pollution and material use. Light pollution issues attract more and more attention; see also the most recent GPP criteria report which includes sections on light pollution, the ratio of upward light output and ecological light pollution. The latter addresses two major issues, firstly the potential harm it may cause to animals such as insects, and secondly the human health effects of blue light emitted by street lighting.

From a material efficiency perspective – with the rapid emergence and evolution of LED in street lighting – it appears that the optimum product configuration has not been achieved yet. This makes standardisation difficult, though the industry is looking at reparability aspects at the level of the luminaire[525].

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[521] Average of 30-70%.

[522] See for example http://www.northeast-group.com/reports/CityLab-Northeast%20Group%20-%20the-benefits-of-led-and-smart-street-lighting.pdf

[523] Above ground electricity grids are more susceptible to failure, and aesthetically not very attractive.

[524] Assuming a hybrid solar-powered streetlight consumes 10% of electricity from the grid in comparison with a regular streetlight; this results in an energy consumption of 3,5 TWh/a. With 0.380 kg CO_2 eq/kWh (source: Ecodesign Impact Accounting) means a reduction of $((35-31.5)*10^{12}) * (0.380*10^{-3}) = 11.97*10^{9}$ kg CO_2/a = 11.97 Mt CO_2/a.

[525] See for example https://www.led-professional.com/resources-1/white-papers/lightingeurope-white-paper-serviceable-luminaires-in-a-circular-economy

14.7 Annex 1 – Non-exhaustive list of possible relevant lighting standards

EN 12464-2: Light and Lighting-Part 2: Lighting of outdoor work places

EN 12665: Light and lighting - Basic terms and criteria for specifying lighting requirements

EN 13032-1: Light and lighting — Measurement and presentation of photometric data of lamps and luminaires — Part 1: Measurement and file format

EN 13032-2: Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 2: Presentation of data for indoor and outdoor work places

EN 13032-3: Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 3: Presentation of data for emergency lighting of work places

EN 1838(2013): Lighting applications. Emergency lighting

EN 50102: Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)

EN 50294: Measurement Method of Total Input Power of Ballast-Lamp Circuits

EN 60081: Double-capped fluorescent lamps - Performance specifications

EN 60529: Degrees of protection provided by enclosures (IP Code)

EN 60598-1: Luminaires Part 1: General requirements and tests

EN 60598-2-3: Luminaires –Part 2-3: Particular requirements – Luminaires for road and street lighting

EN 60662: High pressure sodium vapour lamps – Performance

EN 60901: Single-capped fluorescent lamps – Performance specifications

EN 60921: Ballasts for tubular fluorescent lamps – Performance requirements

EN 60923: Auxiliaries for lamps. Ballasts for discharge lamps (excluding tubular fluorescent lamps). Performance requirements

EN 60927: Auxiliaries for lamps - Starting devices (other than glow starters) - Performance requirements

EN 60929: AC-supplied electronic ballasts for tubular fluorescent lamps – Performance requirements

EN 60968: Self-ballasted lamps for general lighting services - Safety requirements

EN 61048: Auxiliaries for Lamps - Capacitors for Use in Tubular Fluorescent and Other Discharge Lamp Circuits - General and Safety Requirements

EN 61049: Capacitors for Use in Tubular Fluorescent and Other Discharge Lamp Circuits Performance Requirements

EN 61167: Metal halide lamps - Performance specifications

EN 62035: Discharge Lamps (Excluding Fluorescent Lamps) - Safety Specifications

EN 62386-209: Digital addressable lighting interface - Part 209: Particular requirements for control gear - Colour control (device type 8)

EN 62471: Photobiological safety of lamps and lamp systems

EN 62532: Fluorescent induction lamps - Safety specifications

EN 62639: Fluorescent induction lamps - Performance specifications

IEC 62386-101: Digital addressable lighting interface - Part 101: General requirements – System

IEC/TR 62778: Application of IEC/EN 62471 for the assessment of blue light hazard to light sources and luminaires (Technical report)

IEC/TR 63037 'Electrical interface specification for self ballasted lamps and controlgear in phase cut dimmed lighting systems’

IES TM-25-13 Ray File Format for the Description of the Emission Property of Light Sources (Is a guideline, not yet a standard.)

prEN 13032-4: Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 4: Presentation of data for LED lamps, modules and luminaires

The following non- limitative list summarises the *CIE*[526] *documents* concerning street lighting (for a scope please consult CIE website on http://cie.co.at/):

01-1980: Guidelines for minimizing urban sky glow near astronomical observatories (Joint publication IAU/CIE)
17.4-1987: International lighting vocabulary, 4th ed. (Joint publication IEC/CIE)
23-1973: International recommendations for motorway lighting
31-1976: Glare and uniformity in road lighting installations
32-1977: Lighting in situations requiring special treatment (in road lighting)
33-1977: Depreciation of installation and their maintenance (in road lighting)
34-1977 Road lighting lantern and installation data: photometrics, classification and performance
47-1979: Road lighting for wet conditions
66-1984: Road surfaces and lighting (joint technical report CIE/PIARC)
84-1989: Measurement of luminous flux
93-1992: Road lighting as an accident countermeasure
100-1992: Fundamentals of the visual task of night driving
115-1995: Recommendations for the lighting of roads for motor and pedestrian traffic
121-1996: The photometry and goniophotometry of luminaires
126-1997: Guidelines for minimizing sky glow
129-1998: Guide for lighting exterior work areas
132-1999: Design methods for lighting of roads
136-2000: Guide to the lighting of urban areas
140-2000: Road lighting calculations
144:2001: Road surface and road marking reflection characteristics
CIE 150: 'Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations.'
154:2003: Maintenance of outdoor lighting systems

[526] CIE: Commission Internationale de l'Eclairage (International Commission on Illumination)

15 GREENHOUSE COVER MATERIALS

15.1 Scope, policy measures and test standards

15.1.1 Background

In the "Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC" (WP 3 study) (BIO by Deloitte et al. (2015), Task 3 and 4), greenhouses were evaluated for their suitability for Ecodesign and Energy Labelling measures.

The following types were in scope:

- Pre-manufactured greenhouses for professional use, equipped with heating, lighting and ventilation;
- Pre-manufactured greenhouse modules for heated, lighted greenhouses; and
- Polytunnels.

In contrast, the following were out of scope:

- Purpose-built/individual designed greenhouses;
- Small-scale pre-manufactured greenhouses for domestic use;
- Cold frames and hotboxes[527];
- Row covers (plastic sheets, plastic foil, fleece, netting).

Greenhouses were identified as complex systems made up of different components. There is usually an insulated grounding that stabilizes the greenhouse and protects plants against ground frost. To a wooden, metal or brickwork structure, transparent cover materials or elements made from glass, hard plastic or plastic foil are attached. Depending on purpose and climate, greenhouses may be equipped with varying configurations of heating, ventilation, lighting, shading and irrigation systems, with sensors and devices for regulating O_2/CO_2 concentrations. Some greenhouses are pre-manufactured while others are custom-built.

It was concluded that greenhouses exhibit relevant energy consumption and savings potentials. Primary energy savings of 7.6 PJ in 2020 and 25.5 PJ in 2030 were thought possible, although with a rather low degree of certainty (Fischer et al. 2015, Task 3, p. 114). However, "greenhouses as a whole are available in diverse designs and adapted to local climates and to required growing conditions for plants and hence not suitable for setting uniform Ecodesign requirements." (ibid.)

As it was assumed that energy-using equipment such as heating, lighting or ventilation would fall under other lots, the study recommended that "a possible preparatory study should focus on cover materials used for greenhouses and their energy-related and durability characteristics." (BIO by Deloitte et al. (2015), Task 3, p.114). "

[527] Cold frames are small wooden or brick structures with a glass cover that contain one vegetable patch to keep it somewhat warmer than the environment and protect it from wind. Adding a heating element such as heating cables, makes it a hotbox.

There is a diversity of user needs, which in turn depend on different crops and climatic conditions. Furthermore, cover materials themselves vary widely. Therefore, specific Ecodesign requirements for greenhouse covers did not seem appropriate. However, "information requirements could potentially provide benefits in terms of energy savings and increased durability [of] cover materials." (BIO by Deloitte et al. (2015), Task 3, p. 114).

They could cover characteristics such as U-values, light transmission, light diffusion, insulation, durability, and life cycle costs. Such information could contribute to "reducing information asymmetries in the market and provide a level playing field for the just comparison of different greenhouse cover materials." (BIO by Deloitte et al. (2015), Task 4, p. 104). It could also "help users of greenhouse cover materials to make the best choice for their purpose and also more easily consider total lifetime costs of each cover material considered." (ibid., p. 103). The Construction Products Regulation and to a lesser degree the EPBD were considered to be the most appropriate frameworks to achieve these goals. However, it was recommended to consider energy labelling in case greenhouse covers were not adequately covered by these instruments.

In addition to this recommendation by the previous Working Plan study, Ecodesign information requirements could be another suitable tool.

In spite of this recommendation, the Ecodesign Working Plan 2016-2019 did not include greenhouse covers. In the light of the estimated large potential energy savings as well as the increased focus on material efficiency, the current study is taking up greenhouse covers again, thereby also trying to fill some gaps that the previous study has left. Its purpose is to:

- revise the scope, given the focus on cover materials;
- update previous information on policies, standards, markets, technologies, environmental impact, and savings potentials, to the extent that the former is outdated
- amend previous information and improve database, where possible (e.g. with respect to markets and savings potentials)
- examine in greater depth the comparative suitability and merits of different policy instruments (CPR / EBPD / energy labelling / ecodesign information requirements; to be assessed in Task 4)

The chapter is partly based on prior own work, that is, Task 3 report, chapter 11 and Task 4 report, chapter 12 of the WP 3 study. It therefore includes sentences and paragraphs with identical or very similar wording. For ease of reading, these sections have not been specifically highlighted as citations.

15.1.2 Scope

The study focuses on greenhouse cover materials as other energy-using equipment in greenhouses, such as heating, lighting or ventilatio,n would fall under other lots. Cover materials are sold as separate products on the market or as part of larger greenhouse systems. "Cover materials" refers to the transparent glass or plastic elements that form the shell of the greenhouse. Three types of cover materials exist which are all covered in this analysis:

- flexible plastic film;
- rigid plastic panes;
- horticultural glass.

Flexible plastic film is mostly used in warm climates. Its main function is to protect the crop from drought, sunburn, or wind, and to keep condensing water inside. Greenhouses in warm climates are seldom heated.[528] In contrast, glass and rigid plastic are used more in cooler climates. Their main function is to collect and keep the warmth inside. Greenhouses in cooler climates are more often heated, which requires good insulation.

All three materials are covered by this assessment.

As the materials do not, in principle, differ between private and professional use, all uses are included in this assessment, although sales and stock data could only be retrieved for professional use.

15.1.3 Policy measures

The REACH Regulation applies to greenhouse cover materials. Hence, hazardous substances are best regulated through this regulation.

The EPBD Directive applies to all buildings, where a "building means a roofed construction having walls, for which energy is used to condition the indoor climate" (Art. 2 (1)). This definition would apply to greenhouses with heating systems or climate control. However, Member States implementing the Directive "may decide not to set or apply the requirements referred to … non-residential agricultural buildings with low energy demand and non-residential agricultural buildings which are in use by a sector covered by a national sectoral agreement on energy performance" (Art. 4(2) (c)). Hence, specific requirements may be in place in different Member States.

Further, "Member States shall take the necessary measures to ensure that minimum energy performance requirements are set for building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are replaced or retrofitted, with a view to achieving cost-optimal levels." (Art. 4(1)).

Therefore, the EPBD Directive provides a framework for setting minimum energy performance requirements for greenhouse building elements. Focus is, however, the reference building in which a building element is used and not the characteristics of the material itself. Also, implementation in Member States may vary.

The Construction Products Regulation (305/2011) defines conditions for the marketing of construction products and defines criteria for assessing the performance of such products. A construction product is defined as "any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works" (Art. 2 (1)). The perfor-

[528] Valera et al. (2017) report a share of 8.4% heated greenhouses for the Almería region.

mance of a construction product describes "the performance related to the relevant essential characteristics, expressed by level or class, or in a description" (Art. 2(5)). The regulation explicitly reference characteristics such as insulation, durability or the sustainable use of natural resources. Currently the Construction Products Regulation does not seem to be applied to greenhouse covers, however, we cannot see any reason why it could not be the case.

15.1.4 Standards

Specifically with respect to greenhouses or greenhouse covers, the following standards exist[529]:

- EN 13031-1: Greenhouses. Design and construction. Commercial production greenhouses
- EN 13206: Plastics - Thermoplastic covering films for use in agriculture and horticulture
- EN ISO 12017: Plastics - Poly(methyl methacrylate) double- and triple-skin sheets - Test methods
- DIN SPEC 18072 (German technical specification): Sales greenhouses.
- DIN SPEC 18071: Commercial production greenhouses.
- ABNT NBR 15560-1 (Portuguese standard): Covering plastic films for use in agriculture Part 1: Greenhouse
- ABNT NBR 16032: Structure of greenhouse and nursery farms - Requirements for design, construction, maintenance and restoration

A review of technical specifications by various manufacturers revealed that greenhouse cover materials are sometimes tested according to the following (predominantly US) standards:

- EN ISO 489: Plastics. Determination of refractive index.
- ASTM D 1003: Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
- ASTM D 882: Standard Test Method for Tensile Properties of Thin Plastic Sheeting
- ASTM D 1709a: Standard Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method
- ASTM D 1494: Standard Test Method for Diffuse Light Transmission Factor of Reinforced Plastics Panels
- ASTM C 177: Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

Many other standards referring to specific properties of plastic materials and glass could also be relevant.

[529] A search at beuth.de, the German standards portal, has been performed with the keywords "greenhouse AND NOT gas / gases" (as the keyword "greenhouse" renders several hundred standards related to greenhouse gases).

15.2 Market

No Prodcom data is available on sales of greenhouse cover materials. No other publicly available data could be identified either. Therefore, sales data will be derived from stock data available from Eurostat.

15.2.1 Stock

Eurostat statistics for area of crops "under glass or other (accessible) protective cover" (Reg. (EC) No 1166/2008; Reg. (EU) No 715/2014) are used to make estimates for the stock. It is assumed that the term "glass or other (accessible) protective cover" more or less describes greenhouses made from different materials while it excludes structures that are not accessible to humans such as cold frames, hotboxes, or row covers. The data is based on a mandatory farm structure survey to be carried out by all EU member states according to the above regulations. It generally covers all farms above one hectare agricultural area.[530] Smaller farms are also covered if they exceed certain thresholds in terms of area for specific crops or number of specific animals. Therefore, the data covers most commercial farms, but not greenhouses used privately or in the retail sector. Actual stock and sales are therefore underestimated.

The indicator "crops under glass or other (accessible) protective cover" covers (a) permanent crops (shrubs, trees, and other plants that do not need to be replanted every year), (b) fresh vegetables, melons and strawberries, and (c) flowers and ornamental plants. It does not cover plant nurseries.

Therefore, the data represents the lower edge of actual greenhouse use.

The data is presented in Table 186. Since 2014 when the same data was retrieved from Eurostat for the WP 3 study (BIO by Deloitte et al. 2015), the Eurostat database has been updated. Relevant changes in absolute numbers occurred for Spain, Italy, and France (in 2005) and, to a lesser degree, for Bulgaria, Greece, Romania (in 2005) and the United Kingdom. In sum, both the 2005 and 2010 EU totals have been corrected downwards by 9%.

Table 187 compares the figures retrieved in 2014 and 2020 for selected countries, where relevant changes occurred, and for the reference years 2005 and 2010 (which were the only ones available for comparison). Some uncertainty stems from the fact that 2014 data has been rounded to 1000 ha. For the following discussions, we will use the data retrieved in 2020, assuming that they represent the most recent knowledge.

Table 186 shows that Spain, Italy, France, the Netherlands and Poland are by far the biggest countries in terms of greenhouse covered area. Together, they accommodate for around 83% of the EU-27 (without UK) area under glass or other protective cover. The two largest contributors, Spain and Italy, together account for 62%. The biggest individual production region is Almería in Spain, with about 30,000 ha. crop area under protective cover (almost one fourth of EU-27 total) (Valera et al. 2017).

[530] Member States can fix thresholds of more than one hectare, if the farms excluded contribute no more than 2% to total agricultural area and no more than 2% to total livestock production.

Total greenhouse area appears to be more or less stable. The apparent drop in 2010 is due to a missing value for France. There seems to be a small increase for 2013. It could not be confirmed whether this is a trend as 2016 data is still not out in 2020.

Table 186: Area of commercial crops under glass or other (accessible) protective cover in Europe (in ha.). Source: https://ec.europa.eu/eurostat/web/products-datasets/-/ef_poglass

Member States	2005	2007	2010	2013
Belgium	2,140	2,120	2,060	1,800
Bulgaria	900	1,140	1,090	1,080
Czechia	180	190	0	0
Denmark	450	470	460	400
Germany	3,370	3,430	3,170	3,110
Estonia	60	60	40	40
Ireland	60	30	60	180
Greece	4,670	5,340	4,290	4,730
Spain	52,170	52,720	45,700	45,200
France	9,620	9,790	n/a	11,190
Croatia	n/a	250	410	500
Italy	28,640	26,500	39,100	38,910
Cyprus	420	430	450	420
Latvia	110	80	50	40
Lithuania	1,010	450	310	330
Luxembourg	0	10	0	0
Hungary	1,910	1,760	1,960	2,260
Malta	70	70	80	100
Netherlands	10,540	10,370	9,820	9,330
Austria	290	580	620	720
Poland	7,170	7,560	6,630	8,080
Portugal	2,310	2,220	2,360	2,490
Romania	2,790	3,250	3,020	3,300
Slovenia	170	180	170	160
Slovakia	250	190	150	100
Finland	450	440	420	400
Sweden	420	180	200	260
United Kingdom	1,650	1,790	1,560	2,420
Total EU-28	**131,820**	**131,600**	**124,180**	**137,550**
Total EU-27 w/o UK	**130,170**	**129,810**	**122,620**	**135,130**

Table 187: Area of commercial crops under glass or other (accessible) protective cover - Comparison of selected Eurostat data retrieved in 2014 and 2020. Source: https://ec.europa.eu/eurostat/web/products-datasets/-/ef_poglass; own calculations

Member States	2005			2010		
	2014 data (ha., rounded to 1000)	2020 data (ha.)	Difference (%)	2014 data (ha., rounded to 1000.)	2020 data (ha.)	Difference (%)
Bulgaria	2,000	900	-55.0%	2,100	1,090	-48.1%
Greece	3,500	4,670	33.4%	5,300	4,290	-19.1%
Spain	65,200	52,170	-20.0%	63,300	45,700	-27.8%
France	0	9,620	n/a	0	n/a	n/a
Italy	41,600	28,640	-31.2%	34,600	39,100	13.0%
Romania	1,100	2,790	153.6%	3,300	3,020	-8.5%
United Kingdom	2,000	1,650	-17.5%	2,000	1,560	-22.0%
Total EU-28	n/a	131,820		n/a	124,180	
Total EU-27 w/o UK	n/a	130,170		n/a	122,620	
Total EU-27 w/o Slovenia[531]	142,100	131,650	-9.0%	135,500	124,010	-9.1%

In the following, we estimate the distribution of this area across different cover materials. Valera et al. (2017) provide some figures for the share of plastic material in greenhouses in different countries. The sources are rather old (1992-2000) but will be used here for lack of newer data. We apply the shares provided by the authors to the total covered area and calculate the resulting sizes of areas covered with plastic materials resp. glass (Table 188). For countries where no share is available, the generic share provided by the authors for EEC countries (74%) is used.

[531] Data for Slovenia were not available in the 2014 version.

Table 188: Shares of plastic and glass material in greenhouse covers in Europe. Sources: Valera et al. (2017), own calculations

Member States	Covered area 2013 (ha.)	Plastic share (%)	Plastic covered (ha.)	Glass covered (ha.)
Belgium	1,800	5%	90	1,710
Bulgaria	1,080	74%	799	281
Czechia	0	74%	0	0
Denmark	400	2%	8	392
Germany	3,110	10%	311	2,799
Estonia	40	74%	30	10
Ireland	180	74%	133	47
Greece	4,730	95%	4,494	237
Spain	45,200	99%	44,748	452
France	11,190	70%	7,833	3,357
Croatia	500	74%	370	130
Italy	38,910	91%	35,408	3,502
Cyprus	420	74%	311	109
Latvia	40	74%	30	10
Lithuania	330	74%	244	86
Luxembourg	0	74%	0	0
Hungary	2,260	74%	1,672	588
Malta	100	74%	74	26
Netherlands	9,330	2%	187	9,143
Austria	720	20%	144	576
Poland	8,080	74%	5,979	2,101
Portugal	2,490	98%	2,440	50
Romania	3,300	74%	2,442	858
Slovenia	160	74%	118	42
Slovakia	100	74%	74	26
Finland	400	74%	296	104
Sweden	260	74%	192	68
United Kingdom	2,420	15%	363	2,057
Total EU-28	**137,550**		**108,790**	**28,760**
Total EU-27 w/o UK	**135,130**		**108,427**	**26,703**

No differentiation between plastic film and rigid plastics is provided by Valera et al. (2017) for the countries cited. However, they conducted a representative survey among farmers in the Almería region and identified the distribution of greenhouse types in 2013 (see for the explanation of greenhouse types Section 15.4). With about 30,000 ha. of crops under glass or other protective cover, the region covers two thirds of the Spanish total, and almost one quarter of the EU total. It is therefore highly relevant, Table 189 presents the distribution of greenhouse technologies together with the typical material for each type.

Table 189: Shares of greenhouse types and materials in Almería, Spain. Source: Valera et al. 2017

Type	Typical material	Percentage
“Raspa y amagado” (“ridge and valley”)	Plastic film	76.4
Flat top	Plastic film	11.3
Asymmetric	Plastic film	6.6
Multi-span cylindrical	Plastic film or rigid plastic	3.8
Multi-span gothic	Plastic film or rigid plastic	1.4
Others (mesh, gabled, venlo)	Mesh, plastic film or glass	0.5

Taken together, one can assume a share of plastic film of at least 95% of all greenhouses, and 95.5% of all plastic greenhouses in Almería. We assume that the situation is more or less the same across the Mediterranean countries (that is, for the rest of Spain, Portugal, Italy, Greece, Cyprus, Malta, Slovenia, and Croatia). For France, about 60% of greenhouse cultures are located in Mediterranean regions, about 40% in more Northern regions. A share of 65% plastic film of all plastic greenhouses is therefore assumed. For the other countries, a respective share of 20% is assumed. This gives the following overall shares of the various materials shown in Table 190.

Table 190: Covered area by greenhouse cover material in Europe. Source: Own calculations

Member States	Plastic covered (ha.)	Thereof: plastic film (ha.)	Thereof: rigid plastic (ha.)	Glass covered (ha.)
Belgium	90	18.0	72.0	1,710
Bulgaria	799	159.8	639.2	281
Czechia	0	0	0	0
Denmark	8	1.6	6.4	392
Germany	311	62.2	248.8	2,799
Estonia	30	6.0	24.0	10
Ireland	133	26.6	106.4	47
Greece	4,494	4,291.8	202.2	237
Spain	44,748	42,734.3	2,013.7	452
France	7,833	4,699.8	3,133.2	3,357
Croatia	370	353.4	16.7	130
Italy	35,408	33,814.6	1,593.4	3,502
Cyprus	311	297.0	14.0	109
Latvia	30	6.0	24.0	10
Lithuania	244	48.8	195.2	86
Luxembourg	0	0	0	0
Hungary	1,672	334.4	1,337.6	588
Malta	74	70.7	3.3	26
Netherlands	187	37.4	149.6	9,143
Austria	144	28.8	115.2	576
Poland	5,979	1,195.8	4,783.2	2,101
Portugal	2,440	2,330.2	109.8	50
Romania	2,442	488.4	1,953.6	858
Slovenia	118	112.7	5.3	42
Slovakia	74	14.8	59.2	26
Finland	296	59.2	236.8	104
Sweden	192	38.4	153.6	68
United Kingdom	363	72.6	290.4	2,057
Total EU-28	**108,790**	**91,303**	**17,487**	**28,761**
Total EU-27 w/o UK	**108,427**	**91,231**	**17,196**	**26,704**

In a next step, we estimated the total amount of cover materials that would be needed to cover a land area of this size (including side walls and taking into account roof shapes of greenhouses).

For the sake of simplicity, we assumed a "house shape", as it represents a simplified version of the most common greenhouse shapes for both plastic film and glass greenhouses.[532] (see Figure 1, with H=maximum height, E = eaves height, W=width, L = length). We made

[532]We also made some sensitivity calculations for "tunnel shaped" greenhouses, with the result that the difference is small as long as the core dimensions remain the same.

assumptions for typical dimensions that are taken from the literature and internet websites of sellers[533]. We also made assumptions about the number of greenhouses that are arranged in a row. This is highly relevant as for greenhouses that are assembled next to each other (see Figure 2), no side walls need to be erected.

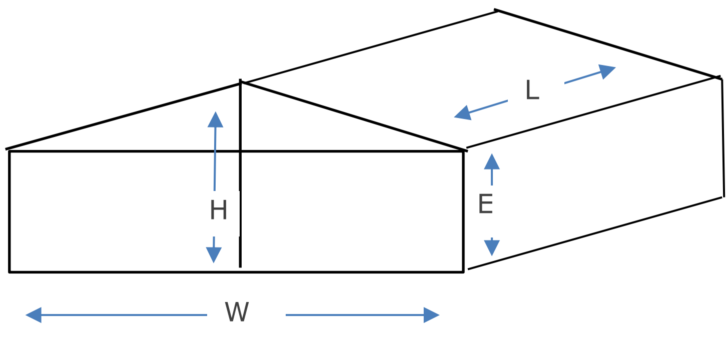

Figure 45: "House shape" greenhouse with dimensions. Source: Own calculations

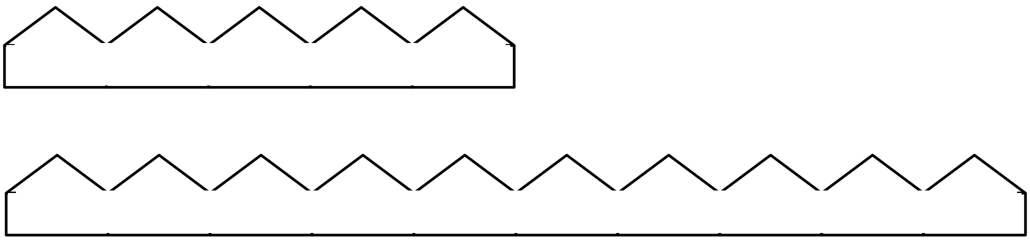

Figure 46: Two arrangements of a house-shaped greenhouse (groups of 5 and 10). Source: Own calculations

[533] Valera et al. (2017), p. 65; Sophianopoulos und Katsoulas (2011); https://www.novagric.com/es/component/tags/tag/3; https://www.integra-at.com/en/invernaderos-raspa-y-amagado; https://www.venloinc.com/greenhouses/venlo ; https://www.growspan.com/

In Table 191, the assumptions for the dimensions are presented, and the needed amounts of cover material are calculated for the three greenhouse types.

Table 191: Area of cover material for typical greenhouses, per material. Source: Own calculations

Material	Most common greenhouse type	Assumed shape	Size (H/E * W * L) (m)	Individual cover area (m^2)	Cover area: group of 5 (m^2)	Cover area: group of 10 (m^2)
Plastic film	„Raspa y amagado“	„House“	4 / 2.80 * 8 * 60	891.5	3,113.7	5,891.4
Rigid plastic	Unknown	„House“	4 / 3 * 12 * 24	520.0	2,023.9	3,903.7
Glass	Venlo	„House“	5.50 / 4.60 * 3.20 * 60	804.6	1,815.1	3,078.1

In a final step, we calculated the number of greenhouse "groups" that fit onto the land area covered with greenhouses of each material, as presented in Table 190. By way of multiplication, we arrived at the total area of each cover material.

Table 192: Stock of greenhouse cover materials in the EU-27 (in ha. of cover material) (data from 2013). Source: Own calculations

Green-house cover material	Available land (ha).	Arranged in groups of 5				Arranged in groups of 10			
		Ground area per group (m^2)	Cover area per group (m^2)	No. groups	Total EU-27 cover area (ha.)	Ground area per group (m^2)	Cover area per group (m^2)	No. groups	Total EU 27 cover area (ha.)
Plastic film	91,231	2,400	3,114	380,128	118,359	4,800	5,891	190,064	111,973
Rigid plastic	17,196	1,440	2,024	119,419	24,169	2,880	3,904	59,709	23,309
Glass	26,704	960	1,815	278,167	50,489	1,920	3,078	139,083	42,811
Total EU-27	**135,131**				**193,017**				**178,094**

As a result, between 179,000 and 193,000 ha. of greenhouse cover materials are currently in stock in the EU-27 (without UK). The distribution across the different materials is, depending on the assumption, as follows in Figure 47.

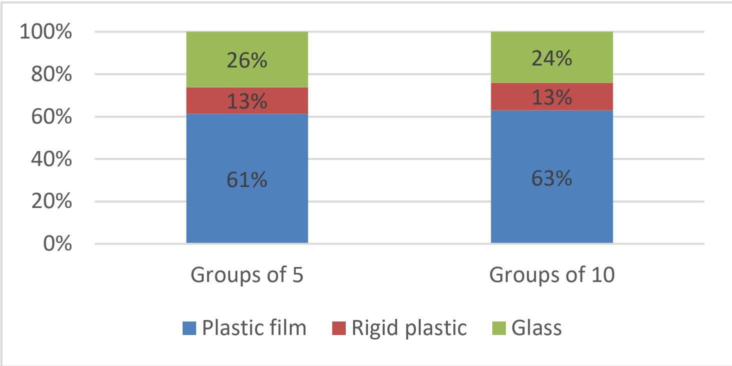

Figure 47: Distribution of greenhouse cover materials across EU-27 (for two greenhouse arrangements). Source: Own calculations

The actual stock is higher, as the calculation does not include greenhouses used in the private and retail sector.

15.2.2 Sales

Greenhouse covers for replacement or self-assembly are sold individually. Flexible plastic films come in form of rolls with varying width and length. Rigid plastic is sold as sheets and panels of varying sizes, glass in form of panels. On the other hand, cover materials are also sold in packages together with the greenhouse frame and equipment (see Section 15.3).

As there are no sales data available for any of these distribution channels, approximate sales data of greenhouses in EU-27 were derived from the stock and average lifetime of products. The "minimum" variant results from the stock that can be expected if greenhouses are arranged in groups of 10, which is more resource efficient as it requires less outer walls. The "maximum" variant results from the stock that can be expected if greenhouses are arranged in groups of five (see Table 192). Lifetimes were assumed to be 3 years for plastic film, 10 years for rigid plastic, and 15 years for glass.[534] The shares of the three basic materials are assumed to remain about the same. No significant move away from the dominance of plastic film was reported at least for the Almería region, because it is cheap and well suited for warm climates (Valera et al. 2017, p. 275). For the other materials, also no significant change is expected, as glass panes tend to break individually, and would probably not be replaced by individual rigid plastic panes in an overall glass greenhouse. On the other hand, a replacement of rigid plastics by glass is also unlikely because of the higher price of glass and the ongoing improvement of the technical properties of rigid plastic.

The resulting sales are presented in Table 193, and assumed to remain stable[535].

[534] Valera et al., p. 300, https://www.gothicarchgreenhouses.com/blog/glass-or-polycarbonate-greenhouse/¸https://ceresgs.com/how-to-choose-a-glazing-material-for-a-year-round-greenhouse/. Although glass can last in principle infinitely, we account for its breakability.

[535] This assessment does not take into account potential critical events such as the exhaustion of ground water in Almería which might render large-scale cultivation unfeasible.

Table 193: Greenhouse cover sales in EU-27 (without UK). Source: Own calculations

Greenhouse cover material	Stock in ha (2020)	Sales (replacement) per year (in ha.)
Plastic film (min)	111,973	37,324
Plastic film (max)	118,359	39,453
Rigid plastic (min)	23,309	2,331
Rigid plastic (max)	24,169	2,417
Glass (min)	42,811	2,854
Glass (max)	50,489	3,365
Total (min.)	**178,094**	**42,509**
Total (max.)	**193,017**	**45,236**

The actual sales are higher, as the calculation does not include greenhouses used in the private and retail sector.

15.3 Usage

Greenhouse cover materials are used in a variety of climates. In warm and dry climates, their main function is to protect the crops against drought, wind, and dust, and to keep humidity inside while preventing the formation of droplets of condensed water. Droplets reduce light transmission and could fall onto the crops and diminish overall transmissivity for light while at the same time causing burning of leaves due to a burning glass effect. In colder climates, greenhouses must primarily collect and retain warmth in order to prolong the growing season. Possible crops for greenhouse cultivation comprise fruit, vegetables, flowers and ornamental plants. Different crops have different needs for example with respect to temperature, humidity, or which wavelengths of light are best absorbed. Therefore, technical properties of greenhouse cover materials (see Section 15.4.3) must be adapted to the respective climate and crop.

Greenhouse cover materials are used in all sectors: In the professional sector, by horticultural farms large and small, in the commercial (retail) sector both as storing and sales area, and in the residential sector in private gardens. Large greenhouses for commercial and professional purposes are often custom made by specialized firms who assemble the frame, cover material and any equipment such as heating, ventilation, or climate controls, according to the needs of the customer. Smaller greenhouses, used in the residential sector (but sometimes also in retail), are often sold as pre-manufactured kits for self-assembly by garden centers, hardware stores, or via the internet.

Given the wide variety of materials and their properties (see Sections 15.4.2 and 15.4.3), users – especially non-professional ones - need adequate information on suitable materials for their specific purpose.

15.4 Technologies

15.4.1 Greenhouse structures

Different greenhouse cover materials are suitable for different greenhouse structures. Valera et al. (2017) give a typology of greenhouse structures for the region of Almería, Spain. The typology is in principle valid for all greenhouses, even if the distribution of the different types varies strongly between regions:

- "Almería Type": flexible structure of wires and braids covered by plastic film. Three subtypes exist: flat top (Figure 4), "raspa y amagado" ("ridge and valley"; several relatively flat house-shaped structures in a row) (Figure 49) and asymmetric shapes;
- Multi-span greenhouse (tunnel shaped, cylindrical or gothic). The cover material here is plastic film or rigid plastics (Figure 50)
- "Gabled" greenhouse (wide house-shaped structure with a flat-angled roof) (Figure 51), also with plastic film;
- "Screenhouse": similar to the "raspa y amagado" type, but covered with mesh (Figure 52);
- Venlo greenhouse: metal structure covered with glass panes or (more rarely) rigid plastic, several relatively steep and narrow house-shaped structures in a row (Figure 53).

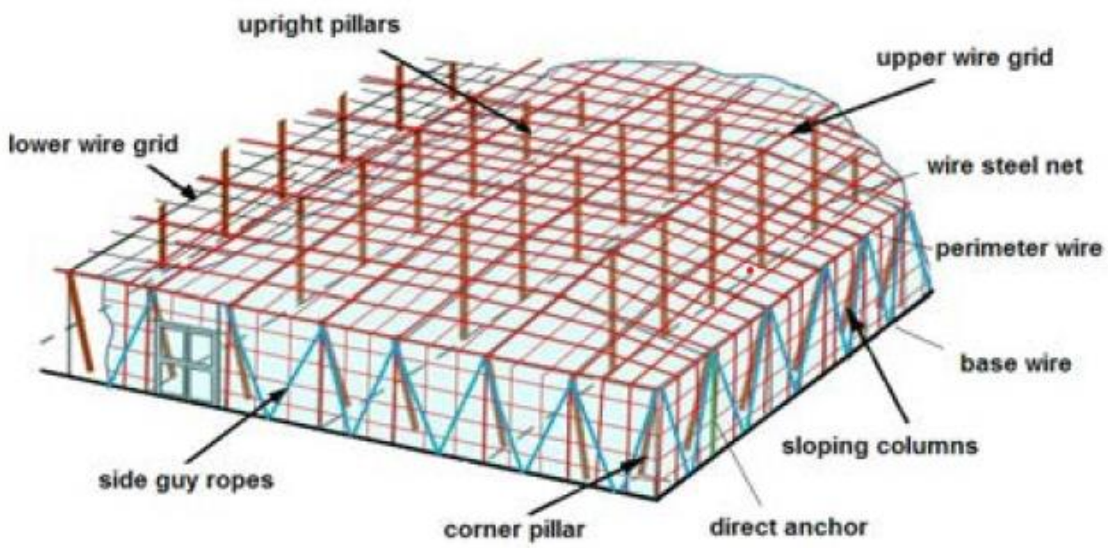

Figure 48: Almería type greenhouse (flat top). Source: Valera et al. (2017), p.57

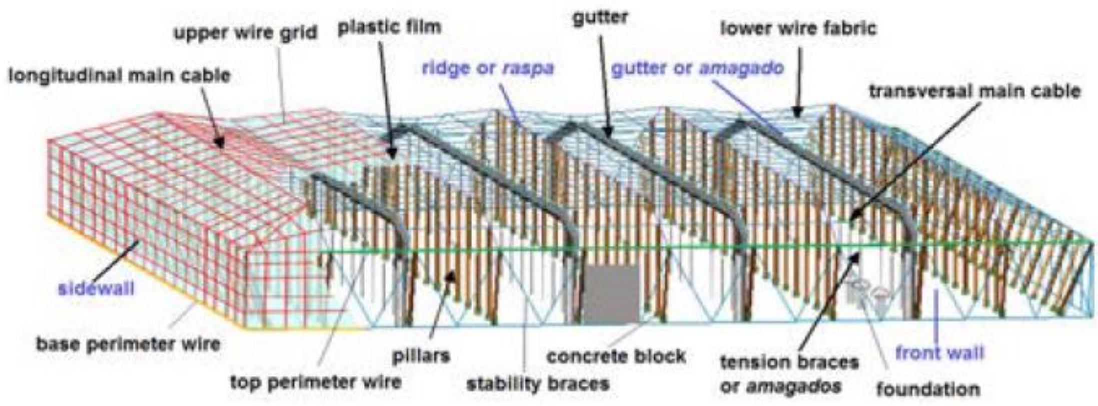

Figure 49: Almería type greenhouse "raspa y amagado". Source: Valera et al. (2017), p. 65

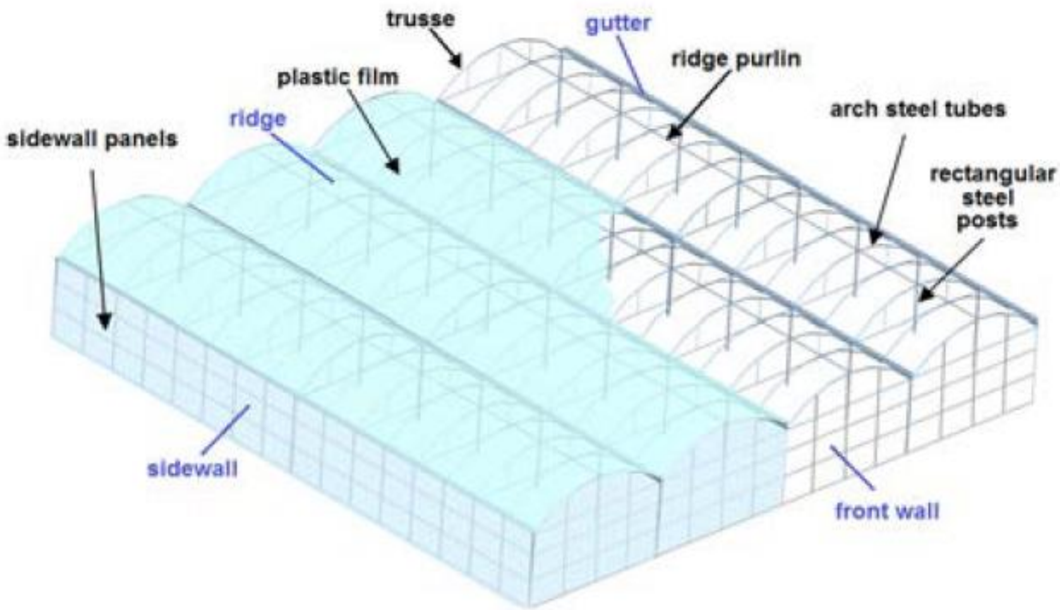

Figure 50: Multi-span greenhouse. Source: Valera et al. (2017), p. 68.

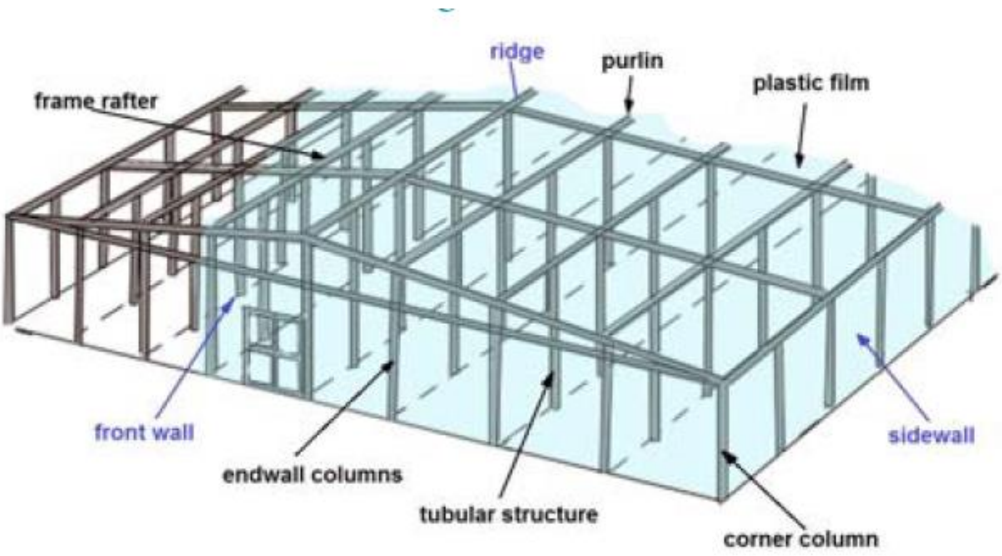

Figure 51: "Gabled" greenhouse. Source: Valera et al. (2017), p. 74

Figure 52: Mesh-covered "screenhouse". Source: Valera et al. (2017), p. 74

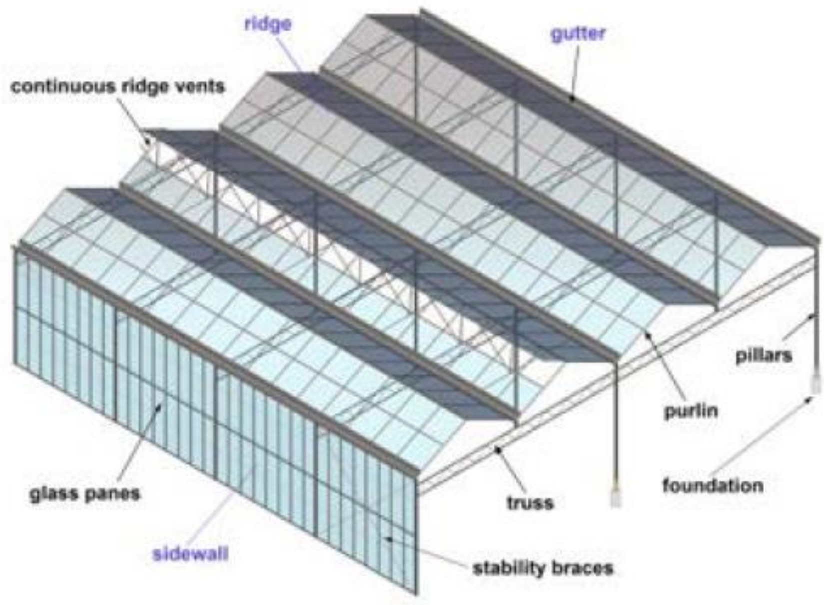

Figure 53: Venlo greenhouse. Source: Valera et al. (2017), p. 72

15.4.2 Weight and material composition

The three basic types can be made from a multitude of different materials with different properties (see Schockert (2015), Valera et al. (2017); Ahamed et al. (2019); Maraveas (2019)).

Flexible plastic film

According to Valera et al. (2017), p. 79 f, "[n]umerous flexible plastic films are available as greenhouse covers, including low density P[oly]E[thylene] (...), ethylene [tetrafluorethylene] copolymers and vinyl acetate [ETFE, EVA]; coextruded films; plasticised polyvinyl chloride (PVC) (assembled or unassembled); polypropylene (PP); and permeable high density PE screens." Plastic films today are often multi-layered products made from different plastics, and may contain various additives, with functions such as increasing durability, minimising heat loss, diffusing light, dispersing heat. Thickness is between 0.1 and 1 mm; density between 0.91 and 1.3 g/cm^3 (ibid., p.83; various internet stores). Their lifespan is between 6 months and 4 years according to manufacturers. Farmers surveyed by Valera et al. (2017) report generally three years or less (ibid.; see also Schockert (2015)).

Rigid plastic panes

Rigid plastic panes include "glass-fiber reinforced polyester (GRP), rigid [...] polyvinyl chloride (PVC), polymethyl methacrylate (PMMA) [plexiglass or acryl glass], and polycarbonate (PC)" (Valera et al. (2017), p. 82). Thickness is between 1 and 18 mm, density between 0.17 (polycarbonate) and 1.5 g/cm^3 (reinforced polyester fiberglass) (ibid., p.83; various internet stores). They last 10-12 years. (ibid). They are also available as double or triple panes to improve heat retention.

Horticultural glass

Horticultural glass may be clear, textured, or treated with various coatings. The goal of textures and some coatings is to diffuse the light. This avoids burning of leaves and is more effective in transmitting light to lower leaves that would otherwise be shaded by upper leaves. Other coatings reduce heat loss. Glass is also available in tempered and laminated qualities (layers of glass and plastic film) to make it more temperature or shock resistant. Also, insulation glass (double pane, filled with inert gases) exists. Glass can in principle last infinitely, however is breakable for example from snow load, or items that may fall onto it. (see Schockert (2015); https://www.greenhomegnome.com/greenhouse-glass/)Thickness is about 4 mm, density 2.4 g/cm^3 (Valera et al. (2017), p.83).

15.4.3 Relevant properties

Greenhouse cover materials vary in different parameters, which are relevant to plant growth as well as energy efficiency and durability. As different crops require different conditions, and there are also tradeoffs between parameters, no optimum exists for an individual parameter, but it is a matter of multi-factor optimization (Vanthoor et al. 2008).

- **Weight**, measured for example in g/cm^2, is relevant for the ease of handling in the construction process. Heavier materials such as glass also require more stable and therefore generally more expensive constructions.
- **Light transmission** (or transmittance) is the penetrability of the material for light in the visible spectrum, between 380-760 nm). Especially relevant is the transmission in the range of 400-700 nm. that can be used by plants for photosynthesis, called photosynthetically active radiation (PAR). High transmission in the PAR spectrum is beneficial to plant growth. Light transmittance is measured in %. It is not always clear whether this value relates to the whole visible spectrum or only the PAR (Vanthoor et al. 2008; Tantau et al. 2012). Typical variation is between 60% and 90% (Valera et al. 2017); various internet sources. It can deteriorate over time when dust accumulates.
- **Near infrared radiation (NIR)** transmission is the penetrability for radiation in the near infrared spectrum (wavelength 700-2500 nm). This kind of radiation warms the greenhouse. Depending on the crop, this effect may be desired or not. Some greenhouse covers deliberately reflect NIR in order to prevent the inside from heating up too much (Kempkes et al. 2008; Tantau et al. 2012). It is measured in %.
- **Light diffusion (haze):** The diffusion of light means that incoming light is scattered in different directions. This may be a desired effect for crops with a dense canopy: diffuse light may increase the portion of light that reaches the lower leaves while at the same time preventing the upper leaves from burning (Al-Helal et al. 2020). It can be measured as diffusion coefficient, the fraction of the light that is diffused during transmission, which may be between 1% (for clear glass) and 65% (SolaWrapFilms 2020).
- **UV stability:** Ultraviolet radiation (wavelength 100-380 nm) is high-energy radiation that causes especially plastic materials to deteriorate. Materials are more or less sensitive to such degradation (Sánchez-Valdés et al. 2018; Mourad und Dehbi 2014).

- **Heat retention / heat loss** describes how well the material insulates, that is, how well it performs in keeping heat (from solar gains or heating) inside the greenhouse. High heat retention / low heat loss is especially desired in cold climates and when greenhouses are heated. In heated greenhouses, it translates directly into energy efficiency. Its unit is the heat transfer coefficient or U-value in $W/m^2 \cdot K$. It can vary strongly; for example, Valera et al. (2017) report U-values between 3.2 for double glazing, 3.4 and 3.8 for rigid plastics, 6.4 for simple glazing, and 6.5 – 16.2 for films (ibid., p. 83). The reverse of the U-value is the insulating value "R".

Even if the exact technical specifications may be somewhat outdated (the website has remained unchanged since 2014), Table 194 - compiled by a US American greenhouse builder - gives a good impression of the wide range of different technical properties associated with greenhouse cover materials.

Table 194: Comparison of different greenhouse covering materials. Source: http://www.igcusa.com/Technical/coverings.html, last accessed 25 August 2020

Covering	Advantages	Disadvantages	Light transmission	"U" value	Insulating value "R"	Estimated lifetime	Cost (EUR/m²)[536]
Single Polyethylene Film	Inexpensive Easy to install	Short life	85 %	1.2	0.83	1 to 4 years	0.77
Double Polyethylene Film	Inexpensive Saves on heating costs Easy to install	Short life	77 %	0.7	1.43	1 to 4 years	1.55
Corrugated Polycarbonate	High transmittance High impact resistance	Scratches easily	91 %	1.2	0.83	15 plus years 10 year warranty	11.85
Glass Double Strength	High transmittance High UV resistance Resists scratching	High cost Difficult installation Low impact resistance High maintenance	88 %	1.1	0.91	25 plus years	27.35
Glass Insulated	High transmittance High UV resistance Resists scratching	Very high cost Difficult installation Low impact resistance	78%	0.7	1.43	25 plus years	54.70
8mm Twin Wall Polycarbonate	High impact resistance Saves on heating costs	Requires glazing system to install Scratches easily	80%	0.61	1.64	15 plus years 10 year warranty	15.13
10mm Twin Wall Polycarbonate	High impact resistance Saves on heating costs	Requires glazing system to install Scratches easily	80%	0.56	1.79	15 plus years 10 year warranty	22.79
16mm Triple Wall Polycarbonate	High impact resistance Saves on heating costs	Requires glazing system to install Scratches easily	78%	0.42	2.38	15 plus years 10 year warranty	36.46

15.4.4 Innovation

Besides improvement of the factors described above, innovations include, for example, integration of photovoltaic modules (Friman Peretz et al. 2019), insecticide-releasing films (Seven et al. 2019), films with switchable properties (Baeza et al. 2020), and the use of nanomaterials to increase photostability (Sánchez-Valdés et al. 2018).

[536] Based on costs given on original website and converted into EUR and m² (conversion factors 0.847 €/$ and 0.0929 m²/ft²).

15.5 Energy, Emissions and Costs

15.5.1 Energy consumption

Greenhouse cover materials do not in themselves consume energy in the use phase, but they have an influence on the energy needed for crop cultivation (i.e. they are energy-related products), particularly:

- Energy use for heating, often natural gas;
- Electricity use for lighting;
- Electricity use for ventilation;
- Energy use for CO_2-enrichment;
- Energy use for irrigation; and
- Energy use for cooling.

Therefore, information on overall energy consumption of greenhouse cultivation is given in this section. Furthermore, we deal with "embedded energy", that is, energy consumption for the production and end-of-life treatment of cover materials.

In Section 15.6.1, we will discuss the potential contribution of cover materials to energy savings in this sector.

Energy use can be measured per area (e.g. ha) or per amount of produce. The latter provides a more accurate assessment of efficiency but also disguises absolute energy consumption. Here, an area based model is used as area data is available from Eurostat and yields of different crops are dependent upon various further factors that could not be taken into account here.

In the WP3 study (BIO by Deloitte et al. 2015, chapter 11) total EU gross energy consumption by greenhouses has been estimated as follows: Use-phase energy consumption (in GWh/ha) has been calculated from 2004 benchmarks provided by the UK Carbon Trust for four typical cultivation methods in the UK (Carbon Trust 2004), and from 2011 results of the EUPHOROS project that provided information on energy consumption of polytunnels in Spain and glass greenhouses in the Netherlands for growing tomatoes (Montero et al. 2011).

Based on the bill of materials provided by Montero et al. (2011), gross energy requirements per hectare were calculated with the EcoReport tool. Primary energy consumption was calculated assuming that heat was provided entirely by natural gas (hence, final and primary energy are the same) and for electricity a conversion coefficient (PEF, Primary Energy Factor) of 2.5 was applied at that time.

These figures were applied to the previously estimated sales and stock data of greenhouses, resulting in the data presented in Table 195. For polytunnels, according to the EcoReport analysis tool, three fourth of the embedded energy can be attributed to the steel structure.

Table 195: Annual business-as-usual energy consumption of greenhouses in the EU-27 (without Slovenia), according to WP 3 study with PEF: 2.5. Source: Adapted from BIO by Deloitte et al. (2015), p. 106

	2010	2015	2020	2025	2030
Use-phase energy consumption (PJ/a)					
Hardcover greenhouses	397.5	426.7	455.3	483.4	510.9
Polytunnels	0.05	0.05	0.05	0.05	0.05
Total	397.5	426.7	455.3	483.4	510.9
Embedded energy (PJ/a)					
Hardcover greenhouses	19.0	20.4	21.7	23.1	24.4
Polytunnels	39.5	38.8	38.0	37.2	36.5
Total	58.5	59.1	59.7	60.3	60.9
Total life cycle energy consumption (PJ/a)					
Hardcover greenhouses	416.5	447.1	477.0	506.5	535.3
Polytunnels	39.5	38.8	38.0	37.2	36.5
Total	456.0	485.8	515.0	543.7	571.8

In the present study, we attempted to corroborate and update these findings with newer data on energy consumption and with the updated sales and stock data from Section 15.2.

While there are many studies for energy consumption and savings potential of individual greenhouses with specific configurations, aggregate data is more rare. Relatively recent data could only be retrieved for use-phase energy consumption in Finland.[537]

However, the 2012 FP7 Project "AgrEE" (Agriculture and energy efficiency, Golaszewski et al. 2012) provides a more comprehensive and detailed picture of total life cycle primary energy consumption than do the sources analysed before. Using an LCA method, life cycle primary energy consumption (per hectare and per ton of crop) is calculated for four countries and three crops, although not every crop was analysed in every country. For tomatoes in Portugal and cucumbers in Greece, two different production methods were included. The scope includes the total process of agricultural production in the greenhouse, including the upstream chain, which is mainly dominated by fertilizer and pesticide production. Results are given in Table 196.[538] The reference year is not provided.

Table 196: Specific life cycle primary energy consumption of greenhouse production in different countries (GJ/ha). Source: Golaszewski et al. (2012)

Crop	Netherlands	Germany	Greece	Portugal
Tomatoes	15,110	12,654	257	99 / 446
Cucumbers	14,360	13,053	212 / 285	
Sweet peppers	11,539			
Average per country	**13,673.1**	**12,842.0**	**253.4**	**272.5**

[537] http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE__02%20Maatalous__04%20Tuotanto__20%20Puutarhatilastot/22_Kasvihuoneyritysten_energiankulutus.px/?rxid=001bc7da-70f4-47c4-a6c2-c9100d8b50db

[538] Averages have been calculated by the authors of this study, taking into account the area shares of the different crops where available. They were unavailable for the different production methods of tomatoes in Portugal and cucumbers in Greece.

The study also revealed that the shares of use phase energy consumption are negligible in Southern countries whereas they account for the largest part of the life cycle primary energy consumption in the cooler climates.

Table 197: Shares of use phase energy consumption of total life cycle primary energy consumption for greenhouse production of different crops and countries. Source: Golaszewski et al. (2012)

Crop	Netherlands	Germany	Greece	Portugal
Tomatoes	99.3%	99.7%	26.8%	38.9%
Cucumbers	99.2%	99.6%	33.3%	
Sweet peppers	99.0%			
Average per country	**99.2%**	**99.6%**	29.5%	**38.9%**

We applied these values to the area production of the EU countries, with the following assumptions:

- The Mediterranean countries Croatia, Cyprus, Greece, Italy, Malta, Portugal, Slowenia and Spain were classified as countries with "warm" climate. All other countries except France were classified as countries with "cool" climate.[539] France was classified as mixed (60% of production in warm, 40% in cool climate).

For "warm" climates the average specific energy consumption of Greece and Portugal from AgrEE was applied. For "cool" climates, the average of Germany and the Netherlands was applied. For France, a weighted mix was applied.

- The values were multiplied with the 2013 "area under glass" values to calculate total GER.
- To obtain use phase energy consumption,
  - for Finland, the empirical data available was used;
  - for the Netherlands, Germany, Greece and Portugal, the exact shares of use-phase energy consumption (averages over all crops) were used;
  - for countries with "warm" climate, the average use-phase share of Greece and Portugal was applied;
  - for countries with "cool" climate, the average use-phase share of the Netherlands and Germany was applied;
  - for France, a weighted mix of "cool" and "warm" climate data was applied.

This approach renders the results presented in Table 198. The main countries in terms of primary energy consumption are the Netherlands, Poland, and France, and to a lesser degree Romania, the UK, Hungary, Germany, and Belgium.

[539] Inexactitudes in the classification do not have a great impact as most countries that cannot be easily classified do not have an important reenhouse production anyway.

Figure 54 illustrates the strong differences in both total life cycle energy consumption and shares of use phase energy between EU countries.

Table 198: Total primary energy consumption over the life cycle for greenhouse production in EU countries (PJ/a) Source: Own calculations based on Golaszewski et al. (2012)

Country	Climate	Asssumed GJ/ha	Area (ha)	Total PJ/a	Thereof: use phase	Thereof: production phase
Belgium	Cool	13,257.5	1,800	23.9	23.7	0.2
Bulgaria	Cool	13,257.5	1,080	14.3	14.2	0.1
Czechia	Cool	13,257.5	0	0.0	0.0	0.0
Denmark	Cool	13,257.5	400	5.3	5.3	0.0
Germany	Cool	13,257.5	3,110	41.2	41.1	0.2
Estonia	Cool	13,257.5	40	0.5	0.5	0.0
Ireland	Cool	13,257.5	180	2.4	2.4	0.0
Greece	Warm	263.0	4,730	1.2	0.4	0.9
Spain	Warm	263.0	45,200	11.9	3.8	8.1
France	Mixed	5,460.8	11,190	61.1	35.9	25.2
Croatia	Warm	263.0	500	0.1	0.0	0.1
Italy	Warm	263.0	38,910	10.2	3.3	7.0
Cyprus	Warm	263.0	420	0.1	0.0	0.1
Latvia	Cool	13,257.5	40	0.5	0.5	0.0
Lithuania	Cool	13,257.5	330	4.4	4.3	0.0
Luxembourg	Cool	13,257.5	0	0.0	0.0	0.0
Hungary	Cool	13,257.5	2,260	30.0	29.7	0.2
Malta	Warm	263.0	100	0.0	0.0	0.0
Netherlands	Cool	13,257.5	9,330	123.7	122.7	1.0
Austria	Cool	13,257.5	720	9.5	9.5	0.1
Poland	Cool	13,257.5	8,080	107.1	106.3	0.8
Portugal	Warm	,263.0	2,490	0.7	0.3	0.4
Romania	Cool	13,257.5	3,300	43.7	43.4	0.3
Slovenia	Warm	263.0	160	0.0	0.0	0.0
Slovakia	Cool	13,257.5	100	1.3	1.3	0.0
Finland	Cool	13,257.5	400	5.3	5.3	0.0
Sweden	Cool	13,257.5	260	3.4	3.4	0.0
United Kingdom	Cool	13,257.5	2,420	32.1	31.8	0.2
Total EU-28			**137,550**	**534.2**	**489.1**	**45.1**
Total EU-27 w/o UK			**135,130**	**502.1**	**457.3**	**44.8**

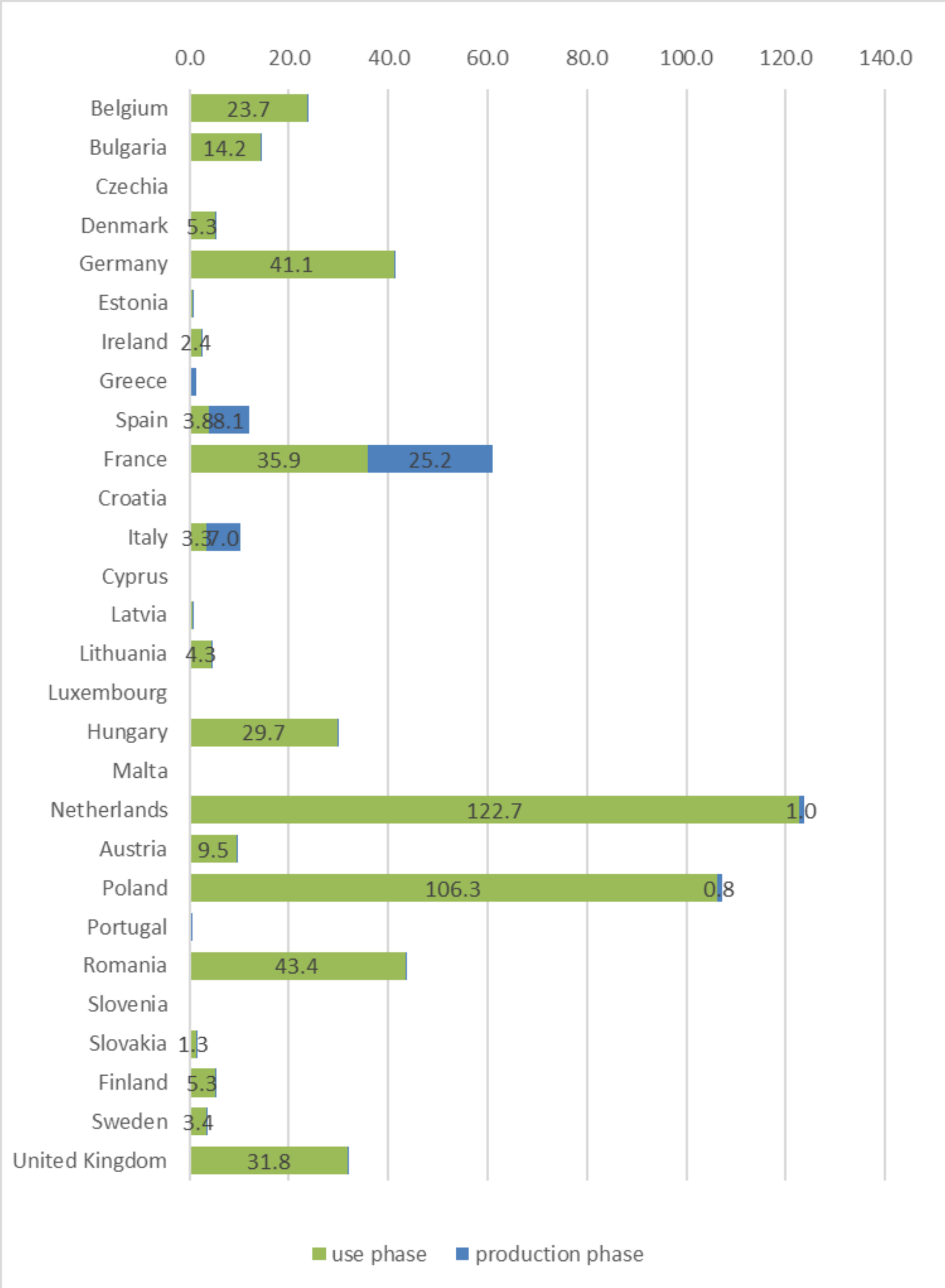

Figure 54: Life cycle energy consumption of use phase and production phase of greenhouse agriculture in European countries. Source: Own calculations

In a last step, we compare these figures with those obtained by the WP 3 study.

Table 199: Comparison of WP 3 study and present study assessments of energy use of greenhouse (covers). Source: Own calculations

Study	Present study	WP 3 study				
Year / status	2013 (status quo)	2010 (status quo)	2015 (projection)	2020 (projection)	2025 (projection)	2030 (projection)
EU-27 life cycle energy use (PJ/year)						
with UK, without Slovenia	534.2	456,0	485.8	515.0	543.7	571.8
with Slovenia, without UK	502.1	n/a	n/a	n/a	n/a	n/a

It shows that the magnitudes are reasonably similar although the present study does not assume much change over the years. A trend towards more cultivation in hardcover greenhouses, as assumed by the WP 3 study, could not be verified for the moment.

The higher initial figure for the status quo as estimated in the present study may be due to the extended scope of the underlying LCA (Golaszewski et al. 2012) which also included fertilizer and pesticide production. Still, we will continue using this data because it provides detailed country accounts which are useful for calculating savings potentials.

It is also important to note that the WP 3 study used a conversion factor (PEF) of 2.5 to convert electrical energy to primary energy, while the conversion factors used by Golaszewski et al. (2012) are based on the respective national energy mixes and are not given in detail (ibid., p.15)

15.5.2 Greenhouse gases

It is not possible to estimate EU-wide greenhouse gas emissions caused by the indirect and direct energy input into greenhouse cultivation, as data on the respective fuel mixes are missing. In addition, fuel mixes are quite different between Member States, and fuel mixes for production of materials that have been produced in third countries are different again.

To give an impression of potential greenhouse gas emissions in use phase, we use data from Cornell University, based on measurements of the energy consumption of 164 greenhouses, in 2014. With a total floor area of 1,3 ha., the greenhouses consumed 11.7 GWh of annual heat equivalent, causing greenhouse gas emissions of roughly 1,500 tons.[540]

15.5.3 Other resource consumption

In the WP 3 study, other resource consumption was calculated by applying the bills of materials of specific greenhouse types from the EUPHOROS project (Montero et al. 2011) to the calculated areas covered with greenhouses. The bills of materials referred to whole greenhouses including their structure. The greenhouse types did not include a greenhouse with rigid plastic shell, only polytunnels with plastic film and glass greenhouses. In the calculation, it was assumed that all hardcover greenhouses are made from glass; rigid plastics was neglected.

[540] https://cuaes.cals.cornell.edu/greenhouses/sustainable-greenhouses/energy-use/

In the present study, the findings shall be corroborated and updated using recent information from manufacturer websites and the more detailed sales and stock data broken down to the three cover materials from section 15.2.

Table 200 shows examples for the weight of selected cover materials taken from various retailer websites. The figures have been normalized to g/m^2 and kg/ha. The sub-rows represent varying figures from different sources. In Table 201, an average weight from the different sources has been calculated and applied to the estimated EU minimum and maximum annual sales (cf. Table 193) to provide total material consumption per year.

Table 200: Weight of different greenhouse cover materials. Sub-rows represent variations given in different sources. Sources: Various manufacturers

Material	g/m²	kg/ha
Polyethylene	125.6	1,256.3
	142.2	1,422.3
Polycarbonat (rigid)	700.0	7,000.0
PC Twin wall	777.0	7,770.0
	1300.0	13,000.0
	1500.0	15,000.0
	1700.0	17,000.0
PC Triple wall	1700.0	17,000.0
	1990.0	19,900.0
	2670.0	26,700.0
Acrylic glass	3400.0	34,000.0
	3,300.0	33,000.0
Float glass	7,500.0	75,000.0

Table 201: Total material consumption of greenhouse covers per year, EU-27. Source: Own calculations

	EU-27 annual sales (ha.)	Weight (kg/ha)	Total weight EU-27 annual sales (w/o UK, 1000 t)
Plastic film (min)	37,324	1,300	48.5
Plastic film (max)	39,453	1,300	51.3
Rigid plastic (min)	2,331	15,000	35.0
Rigid plastic (max)	2,417	15,000	36.3
Glass (min)	2,854	75,000	214.1
Glass (max)	3,366	75,000	252.4
Total (min.)			**297.5**
Total (max.)			**340.0**

In the next step, we did a breakdown per country. We assumed the annual sales of each country to be proportional to their stock area and multiplied those annual sales with the specific weight for each material. shows the results based on an average of the maximum and minimum stock area. Again, the Netherlands stand out with a high consumption of glass (which would however significantly go down if we assume a longer lifetime than 15 years). Other countries with significant glass consumption are France, Germany, Poland, the UK and Belgium. Consumption of plastic film is significant in Spain and Italy. See Figure 55.

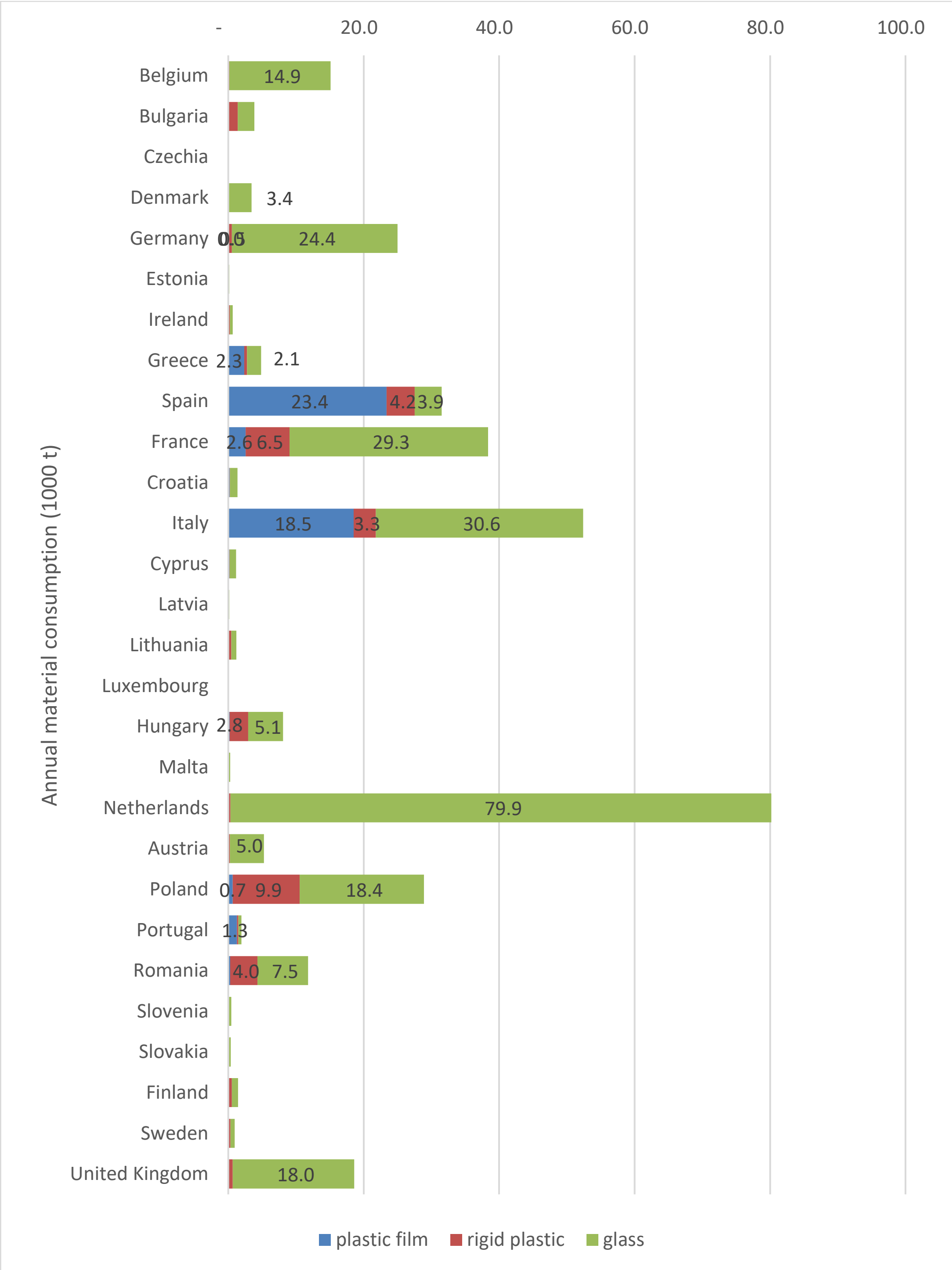

Figure 55: Material consumption of greenhouse covers per EU country. Source: Own calculations

Finally, we compare results to those of the WP 3 study (BIO by Deloitte et al. 2015) (note that in the WP 3 study, the UK is included while no data was available for Slovenia). For the results, see Table 202). The figures for total material consumption are quite similar, so there can be reasonable confidence in them. It is remarkable though that the figures for plastic film in the present study are only half those of the WP3 study while the figures for glass are about similar (even though the WP 3 study assumed that all hardcover greenhouses were made from glass, and therefore should have overestimated the amount of glass).

The basic reason is that in the WP 3 study, for lack of detailed data, the share of "polytunnels" (plastic film greenhouses) was overestimated in assuming 40% of polytunnel area in the cool climates, while in reality it is much lower (from under 1% up to maximum 15%) (see Table 190). In the following, we will therefore use the more recent estimates for the calculation of savings potentials.

Table 202: Comparison of WP 3 and WP4 study results for material consumption of greenhouse covers (1000 t/year). Source: Own calculations

Study	**Present study -EU without UK**	**Present study - EU with UK, without Slovenia**	**WP 3 study**				
Year / status	**2013 / Status quo**		**2010 (status quo)**	**2015 (projection)**	**2020 (projection)**	**2025 (projection)**	**2030 (projection)**
Low-density Polyethylene	n/a	n/a	68	67	65	64	63
Polyethylene	n/a	n/a	29	29	28	28	27
PVC	n/a	n/a	22	22	21	21	20
total plastic film	48.5 – 51.3	48.5 – 51.3	119	118	114	113	110
rigid plastic	35.0 – 36.3	35.5 – 36.9	n/a	n/a	n/a	n/a	n/a
glass	214.1 – 252.4	230.2 – 271.5	228	245	261	277	293
total hardcover	249.1 – 288.4	265.7 – 308.4	228	245	261	277	293
Total all materials	297.6 – 340.0	314.2 – 359.7	347	363	375	390	403

15.5.4 Main other environmental issues

Main other environmental issues include:

- Use of additives in plastic materials and their potential effects on biodegradability, eco- and human toxicity, recyclability etc.;
- Waste / recycling;
- Release of microplastics into the environment;
- potential use of post-consumer recycled material.

A detailed discussion of such aspects is reserved for Task 4, given that energy and resource savings are large enough to consider the product group for regulation. A horizontal discussion of post-consumer recycled content is provided in another section in this report.

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15.6 Saving potential

There are two main areas for improvement of resource consumption in greenhouse cover materials:

- contribution to greenhouse energy efficiency, in order to reduce use phase heat consumption in heated hardcover greenhouses. This applies to rigid plastic and glass materials.
- improved durability, in order to reduce material and indirect energy consumption. This applies to plastic films, as glass does in principle last infinitely as long as it does not break, and no specific methods for improving the durability of rigid plastics have been identified.

15.6.1 Improving greenhouse energy efficiency

In a recent review article on energy efficiency measures for greenhouses, Ahamed et al. (2019) concluded that "high transmissivity to the short-wave solar radiation and low transmissivity to the longwave radiation, as well as low thermal conductivity are important properties for greenhouse coverings used for energy conservation in winter greenhouses" (p. 13). Furthermore, the cover materials must avoid water condensation as water drops can lower solar heat gain (ibid., p. 13 f). Some figures cited in the review article include:

- the heat transfer coefficient (U-value) of double-layer glass is about 16% lower than that of single layer glass;
- heat demand of a double layer PE covered Venlo-type greenhouse in a simulation was about 27% less than that of a single layer glass-covered greenhouse, but 21% higher than in a double-layer glass covered greenhouse;
- heat demand of a twin-wall polycarbonate greenhouse in a simulation was 30-35% lower than that of a single-layered glass greenhouse;
- for improved double-layer glass; 53% resp. 82% lower heat transfer coefficients as compared to traditional single layer glass, were measured in experiments, while light transmissivity was retained. This translated into up to 60% energy savings without affecting productivity.

Based on these figures, we model a development in which, starting from 2021, each year an additional 10% of the sales volume of glass and rigid plastic panels are materials, which reduce energy consumption by 20%. As a basis, we assume a specific use phase energy consumption of 13,200 GJ/ha/a for greenhouse cultivation in glass and rigid plastic greenhouses, which is the average of the Netherlands and Germany values from Golaszewski et al. (2012) (see section 15.5.1) and also in line with the LCAs in Montero et al. (2011) (as cited in BIO by Deloitte et al. (2015), p.106, table 66). Results are shown in Table 203. The "savings newly sold" column shows the savings that will be achieved by the installation of the newly sold efficient panels in the respective year. However, as these remain in stock for at least 10 years, the annual savings as compared to business as usual add up each year for at least 10 years. After that, a lower curve is expected as efficient panels start being replaced.

Table 203: Use phase energy savings potential for rigid cover materials. Source: Own calculations

	Annual sales (ha.)	Energy consumption of newly sold (PJ/a)	Savings newly sold (PJ/a)	Savings 2025 (PJ/a)	Savings 2030 (PJ/a)
Rigid plastic (min)	2,330.9	30.8	0.6	3.1	6.2
Rigid plastic (max)	2,416.9	31.9	0.6	3.2	6.4
Glass (min)	2,854.1	37.7	0.9	3.8	7.5
Glass (max)	3,365.2	44.4	0.9	4.4	8.9
Total (min)			**1.4**	**6.8**	**13.7**
Total (max)			**1.5**	**7.6**	**15.3**

The results cannot directly be compared to the results of the WP 3 study, as the latter calculated savings potentials for the total greenhouse system.

15.6.2 Improving durability of greenhouse cover materials

Durability of plastic films can be improved, for example, by stabilizing them against UV radiation (Maraveas 2019), by using multi-layer films (Dehbi und Mourad 2016) or by using composite materials with nanoclays (Sánchez-Valdés et al. 2018). We assume that the average lifetime of 3 years as used in this study can be increased to up to 4 years, as claimed by some manufacturers. No specific method for improving the durability of rigid plastics has been identified (apart from UV protection, which is already applied).

We model a development in which, due to durability labelling and starting from 2021, each year 10% of the newly bought plastic film is film that lasts 4 years instead of 3 years. As a basis, we take an average of the low and high end of annual sales. Results are shown in Table 204. These savings will continue to increase although more slowly as the share of more durable plastics increases.

Table 204: Material savings potential for greenhouse covers for increased durability. Source: Own calculations

Stock & sales for improved durability	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock 3 years durable (ha)	115,166	111,328	108,480	106,369	104,803	103,641	102,780	102,141	101,667	101,315
Stock 4 years durable (ha)	-	3,839	6,686	8,798	10,364	11,525	12,387	13,026	13,500	13,851
Sales 3 years durable (ha)	34,550	34,262	34,049	33,890	33,773	33,686	33,621	33,573	33,537	33,511
Sales 4 years durable (ha)	3,839	3,807	3,783	3,766	3,753	3,743	3,736	3,730	3,726	3,724
Total stock	115,166	115,166	115,166	115,166	115,166	115,166	115,166	115,166	115,166	115,166
Total sales	38,389	38,069	37,832	37,656	37,525	37,428	37,357	37,303	37,263	37,235
Annual savings (ha)	**-**	**320**	**557**	**733**	**864**	**960**	**1.032**	**1.086**	**1.125**	**1.154**
Annual savings (1000 t)	**-**	**0.4**	**0.7**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.5**

For the saved plastic film, we apply the shares of PE and PVC as in Table 202. Taking the energy intensity figures from the Ecoreport Tool, the following annual energy savings result, for 2025 and 2030:

	2025			2030		
	Savings (1000 t)	Energy intensity (PJ/1000 t)	Savings (PJ)	Savings (1000 t)	Energy intensity (PJ/1000 t)	Savings (PJ)
LDPE	0.6	0.119	0.08	0.9	0.119	0.1
HDPE	0.3	0.117	0.03	0.4	0.117	0.04
PVC	0.2	0.097	0.02	0.3	0.097	0.03
Total	**1.1**		**0.13**	**1.5**		**0.17**

15.7 Summary

The following table presents a summary of the product group greenhouse covers.

Table 205: Summary - Greenhouse covers. Source: Own calculations

	Year	Plastic film	Rigid plastic	Glass	Total
Market data (ha of utilized cover material)					
Sales	**2013 – min.**	37,324	2,331	2,854	42,509
	2013 – max.	39,453	2,417	3,365	45,236
Stock	**2013 – min.**	111,973	23,309	42,811	178,094
	2013 – max.	118,359	24,169	50,489	193,017
EU-27 annual primary energy consumption (PJ)					
Life cycle GER	**2013**	n/a	n/a	n/a	502.1
thereof: Use phase	**2013**	n/a	n/a	n/a	457.3
thereof: embedded	**2013**	n/a	n/a	n/a	44.8
EU-27 annual primary energy savings (use phase, heated greenhouses) (PJ)					
	2025	n/a	3.1 – 3.2	3.8 – 4.4	6.8 – 7.6
	2030	n/a	6.2 – 6.4	7.5 – 8.1	13.7 – 15.3
EU-27 annual material consumption (1000 t)					
	2013	48.5 – 51.3	35.0 – 36.3	214.1 – 252.4	297.6 – 340.0
EU-27 annual material savings (plastic film) (1000 t)					
	2025	1.1	n/a	n/a	1.1
	2030	1.5	n/a	n/a	1.5
EU-27 annual embedded energy savings by saved plastic film (PJ)					
	2025	0.13	n/a	n/a	0.13
	2030	0.17	n/a	n/a	0.17

15.8 Stakeholder comments

Stakeholders recommended to include microplastic release into the environment as well as the potential use of recycled plastics into the list of relevant environmental impact. This has been implemented. However, no detailed analysis could be made at this stage of the study. For a more general discussion of recycled content, please see chapter on this topic in the report.

Stakeholders also pointed out that resource savings could be up to ten times higher if durability requirements were implemented instead of durability labelling, so that each year 100% of the sales would be more durable. This would depend on the technical feasibility of such an instrument.

16 UNMANNED AIRCRAFTS (DRONES)

16.1 Scope, policy measures and test standards

16.1.1 Background

This product group has been included in Task 3 assessments due to an increasing market. Publicly available data on sales and stock, environmental impacts, and improvement options is currently still scattered and unsystematic. Stakeholders have been invited to provide more detailed data on markets, energy consumption, environmental impact and improvement potentials, but have not been able to do so. Therefore, the following section is to be understood as a first preliminary assessment.

16.1.2 Product definition and scope[541]

Unmanned aircraft (UA), also known as unmanned aerial vehicles (UAVs) or, in common language, as drones, are unmanned, workload (or: "payload")-carrying, flying devices that include multicopters and remote airplanes of various designs, sizes and utilisation, and may be operated with different degrees of autonomy. 542 The UA itself is sometimes referred to as a "platform"; to distinguish it from the "payload" it carries.[543]

Drones are components of a wider system, the so-called UAS (unmanned aerial system, or unmanned aircraft system). A UAS, "in addition of the drone, also includes the predictor for controlling the drone, the sensors, systems for data transmission (ground/air or other recipients of exploration results) as well as components for operation, maintenance and transportation."[544]

UAs may be (and have been) classified according to different criteria such as size and weight, performance, autonomy, various constructive properties, and payload. Based on these properties, a variety of functions can be performed.

With respect to **size and weight**, UA can vary between weights of 0.005 g and 15 tons, and wingspans between 1 mm and over 60 m, giving rise to terms such as "smart dust" for the most tiny variants.

With respect to **performance**, UA can be classified according to a combination of endurance and altitude**,** leading to terms such as HALE (high altitude, long endurance) or

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[541] Main sources for this chapter are: Hassanalian M. and Abdelkefi, A. (2017): Classifications, applications, and design challenges of drones: A review. *Progress in aerospace sciences* 91, 99-131; Shakhatreh, H.; Sawalmeh, A.; Al-Fuqaha, A.; Dou, Z.; Almaita, E.; Khalil, I.; Othman, N.S.; Khreishah, A.; Guizani, M. (2018): Unmanned Aerial Vehicles: A Survey on Civil Applications and Key Research Challenges. IEEE Access 7: Preprint. https://arxiv.org/pdf/1805.00881.pdf; Vergouw, et al. (2016), ibid.; Vergouw, B.; Nagel, H.; Bondt, G., and Custers, B. (2016): Drone Technology: Types, Payloads, Applications, Frequency Spectrum Issues and Future Developments. In: Custers, B. (ed.) (2016): The Future of Drone Use. Information Technology and Law Series 27, 21-45.

[542] See for example: Introduction to Technical Rule VDI 2879:2018-09: "Inspection of installations and buildings with UA (unmanned aerial vehicles)." https://www.normadoc.com/english/vdi-2879-2018-09.html; Shakhatreh et al. (2018); ibid.

[543] Vergouw, et al. (2016), ibid.

[544] Introduction to Technical Rule VDI 2879:2018-09, ibid.

LASE (low altitude, short endurance). Drones can fly at altitudes of below 50 m (e.g. for leisure and photography) or up to 10,000 m and more (for telecommunication purposes).[545] Endurance is mainly determined by the fuel source. Small battery-powered UA are restricted to about 30 min. flight time due to limited storage capacity, while fuel-powered or solar-assisted ones can fly for several hours to days. Also, hybrid drones are being developed that combine batteries and fuel to last several hours.[546]

The **autonomy** can vary from remote piloting to automatic systems (which follow a pre-programmed routine) and autonomous systems (which can react to unexpected situations thanks to onboard software).[547]

With respect to **constructive properties**, drones vary mainly with respect to the way they are able to take off and land, wing type, and propulsion system. More detail can be found in section 16.4, "Technologies".

The **payload** can include, for example, cameras and microphones, different types of sensors (e.g. infrared, biological sensors to trace microorganisms, chemical sensors to identify substances), measurement equipment (e.g. for meteorological data), radars / LIDARs, communications equipment, weapons, freight, and even persons.

With respect to **function**, UA have been originally developed for military purposes. Meanwhile, a number of different civil functions have evolved, that are described in more detail in section 16.3, "Usage".

In this report, military applications will be excluded, as they are generally excluded in Ecodesign and Energy Labelling Regulations due to security considerations. Furthermore, it must be borne in mind that Ecodesign and Energy Labelling requirements cannot be applied to drones that are designed specifically for the transport of persons or goods, as the instruments not apply to means of transport. However, datasets used in this report often do not allow to distinguish between drones used for transport and those used for other purposes. Furthermore, the boundaries between types are sometimes blurring, and it remains to be legally clarified which types of UA could be in scope of Ecodesign and Energy Labelling legislation. This is an aspect that needs to be considered if, and when, designing policy instruments.

16.1.3 Policy measures

Regulation and legislation with respect to UA exists on different levels. This section will give a brief overview of European Union law, national law, and attempts at international harmonization.

[545] European Commission: Drone operations now and in the future. https://ec.europa.eu/transport/sites/transport/files/drone-operations-now-and-in-the-future.pdf

[546] For example https://www.quaternium.com/uav/hybrix-drone/ (a Horizon 2020 sponsored project).

[547] See also International Civil Aviation Organization (ICAO) (2016): Unmanned Aircraft Systems (UAS). Circular Cir 328 AN/190. http://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf

16.1.3.1 European Union Law

Until recently, UA of less than 150 kg weight did not fall under aviation law and where therefore regulated individually by EU member states.[548]

In 2018, a process of European harmonisation started. The new **Aviation Safety Basic Regulation (Regulation (EU) 2018/1139)**[549] layed the legal basis for the European Commission to issue Implementing Acts that would specify certification requirements for the operation of unmanned aircraft, and Delegated Acts to regulate the design. Furthermore, the EASA received a mandate to prepare rules for civil drones of all sizes and to harmonize standards for the commercial drone market.

In 2019, two Commission Delegated Regulations went into force: Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems[550] and Commission Delegated Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft.[551] These regulations combine product and aviation policies.

The core aim of all these policies is to enable safe operation of UAS; there is no specific focus on the environment.

Regulation 2019/947 is in force since June 2019, but should originally only apply from July 1st, 2020. Due to the COVID 19 crisis, the application date has been reported to 31/12/2020. It lays down rules for the operation of UAS and for the personnel operating them. UAS are classified into one of three categories: "open", "certified" or "specific", according to the level of risk. The risk does not only depend on the technical properties of the drone, but also on the mode of operation (for example, the "open" category requires, that is it operated within sight, while the "certified" category applies when a drone carries people, dangerous goods, or is operated over assemblies of people.) UAS in the "open" category can be operated without prior authorisation. The "specific" categoy requires an authorisation by the competent authority, which will be designated by the Member States. The "certified" category requires a certification of the UAS itself and its operator, as well as a registration of the pilot and device.

For each of the categories, operational limitations and also requirements for the pilots are layed down. Some of the requirements (for example with respect to minimum age of the pilot) may be modified by the Member States.

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548 Santamarina Campos, V. (2018): European Union Policies and Civil Drones. In: de Miguel Molina, M.; Santamarina Campos, V. (2018): Ethics and civil drones. European policies and proposals for the industry. Springer Open, p. 35-41; and: EASA (2018): Safe operation of drones in Europe. Leaflet; https://www.easa.europa.eu/sites/default/files/dfu/217603_EASA_DRONES_LEAFLET%20%28002%29_final.pdf

549 Regulation (EU) 2018/1139 of the European Parliament and the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1139&qid=1593090064608&from=EN

550 https://eur-lex.europa.eu/legal-content/AUTO/?uri=CELEX:32019R0945&qid=1593089521663&rid=1

551 https://eur-lex.europa.eu/legal-content/AUTO/?uri=CELEX:32019R0947&qid=1593089665851&rid=1

Regulation 2019/945 is in force since April 2019. It lays down rules for the design and manufacture of UAS; specifically for the "open" category.[552] For the latter, it requires that the health and safety requirements of the Machinery Directive[553] are respected. Furthermore, the devices are divided into different classes (CO – C4) defined by their weight, speed, maximum attainable height, and power source. For each class, the regulation specifies criteria the device has to comply with. Compliance is documented by the manufacturer's or importer's self-declaration and the devices are subject to CE marking.

Criteria relate to:

- safety functions (e.g. controllability, avoidance of injury (e.g. by sharp edges or rotating blades), mechanical strength, electric security, lighting, battery level warning, or geo-awareness systems that prevent breaches of airspace limitations)
- information requirements (technical information to be given, user's manual);
- remote identifiability;
- and, as the only environmental criterion, sound power level for classes C1 and above.

Certain exemptions are made for UAS that are toys.

Under the CE marking regime, ROHS, RED, Battery Directive and WEEE, also apply to the drones regulated by Regulation 2019/945. The existing CE marking framework could facilitate the integration of Ecodesign requirements for this group.

In addition, a regulatory framework for a so-called "U-space" is under production.[554] The "U-space" denotes a set of management services that shall enable the safe operation of a great number of UAS within limited airspace.

16.1.3.2 National law

In the European Union, national law complements Union law. Member states may lay down regulations for aircraft that fall outside the scope of Regulation (EU) 2018/1139.[555] They may also define additional requirements, for example with respect to environmental protection, public security, and privacy[556]complement or modify certain provisions, for example minimum age of the pilot.[557]

Outside the EU, a broad range of drone legislation exists. The ICAO website provides a set of links to national websites explaining the respective legislation.[558] The focus here is on

[552] It also specifies that for the "specific" category, a certification may also be needed if the competent authority deems it necessary.

[553] Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006L0042&qid=1593093023838&from=EN

[554] EASA (2020): Opinion No 01/2020. High-level regulatory framework for the U-space. https://www.easa.europa.eu/sites/default/files/dfu/Opinion%20No%2001-2020.pdf

[555] Reg. (EU), 2019/947; recital (18)

[556] Ibid.; recital (21)

[557] Ibid.; Art. 19

[558] https://www.icao.int/safety/UA/UASToolkit/Pages/State-Regulations.aspx

safety, too. A 2017 review of 19 states (including 12 non-EU states) does not identify any environmental criteria.[559]

16.1.3.3 International harmonisation

The International Civil Aviation organisation (ICAO) aims at harmonizing national rules. For this purpose, it provides a toolkit to help states to elaborate their respective set of rules[560], and even provides model regulations.[561]

16.1.4 Standards

Table 206 presents applicable international standards and EU standards as well as selected US standards, as the latter provide releative specific technical requirements as well as rules for compliance audits for UA. The table does not attempt to give an exhaustive overview of national standards. Note that some standards have been deleted and are under review, or are still under development.

Table 206 - Standards affecting UA. Source: Own compilation

Scope	Name	Content (if provided)	
International	ISO / DIS 21384-1: 2019-04-12: Unmanned aircraft systems. Part 1. General specification		Deleted
International	ISO/CD 21384-2 Unmanned aircraft systems — Part 2: Product systems		Under development
International	ISO 21384-3:2019-11: Unmanned aircraft systems - Part 3: Operational procedures	Specifies the requirements for safe commercial UAS operations	In force
International	ISO 21384-4:2020-05 Unmanned aircraft systems – Part 4: Vocabulary	Defines terms and definitions relating to unmanned aircraft systems that are widely used in science and technology.	In force
International	ISO 21895: 2020-02: Categorization and classification of civil unmanned aircraft systems	Classification according to configuration, mode of take-off and landing, engine and energy source, controle mode, maximum height, speed, indurance, C2-link coverage, kinetic energy, and identification mode.	In force
International	ISO/DIS 16119-5:2016: Agricultural and forestry machinery - Environmental requirements for sprayers - Part 5: Aerial spray systems	Technical specifications of aerial sprayers	Deleted

[559] Stöcker,C.; Bennett, R.; Nex, F.; Gerke, M., and Zevenbergen, J. (2017): Review of the Current State of UAV Regulations. Remote sensing 9(5), [459]. https://www.researchgate.net/publication/316820424_Review_of_the_Current_State_of_UAV_Regulations

[560] https://www.icao.int/safety/UA/UASToolkit/Pages/default.aspx

[561] https://www.icao.int/safety/UA/UAID/Pages/Model-UAS-Regulations.aspx

Scope	Name	Content (if provided)	
European Union	prEN 4709-001:2019-02-15: Aerospace series - Unmanned Aircraft Systems - Product requirements and verification for the Open category	Specifies criteria laid down in Reg. (EU) 945/2019	Draft
USA	ASTM F 3005a:2014: Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)		In force
USA	ASTM F 3298:2019: Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)		In force
USA	ASTM F 3365:2019: Standard Practice for Compliance Audits to ASTM Standards on Unmanned Aircraft Systems		In force

16.2 Market

16.2.1 Data sources

There is no publicly available detailed data on unit sales of UA in Europe.

UA probably fall under Prodcom code 30.30.32.00; "Aeroplanes and other aircraft of an unladen weight ≤ 2 000 kg, for civil use". But as the code does not differentiate between conventional and unmanned aircraft, PRODCOM does not provide reliable information on UA sales. For 2018, it gives EU-28 production of only 2,059 units for the above code, meaning that UA are most likely not included.

The following information is taken from publicly available previews of commercial market reports and statistics and from more in-depth reports about the Danish and German market. They do not allow to distinguish between drones used as means of transport and for other purposes.

16.2.2 Sales

Table 207 shows a comparison of global market forecasts (in USD) from various sources. While some sources are more cautious than others, the figures show a rather consistent pattern of growth. Differences between sources can also stem from differences in the scope, as it is not always clear what is covered e.g. by "commercial" drones.

Table 207: Comparison of global commercial drone market forecasts. Source: Own compilation

Source	Million USD											Scope
	2015	2016	2017	2018	2019	2020	2022	2024	2025	2028	CAGR (%)	
562				14,000				43,000			20.5	Commercial drones
563										129,300		Non-military
564						23,367			47,760		15.4	Non-military
565	2,145						10,738				26.2	0Commerci
566					16,925			43,100			20.0	al drones
567			9,710						40,310		17.0	Small drones

Among this global market, according to a 2018 analysis, "the USA and China are the largest drone markets. Together, they account for around two-thirds of the worldwide commercial drone market. The three European countries France, Germany and Great Britain follow behind the USA and China with a considerable gap." 568 Europe as a whole, according to this source, is the second largest market after North America, making up for 20 percent of the world market.

While it is not entirely clear what is comprised by "Europe as a whole", we use this figure in order to very roughly estimate the volume of the EU-28 market in 2020. When we apply the 20% share to the market value of 23,367 Million USD (or 20,497 Million EUR) for 2020 from Table 207, we arrive at a market value of 4,099.5 Million EUR for Europe in 2020. This figure fits reasonably well with the market value of 573 million EUR that has been reported for Germany in 2018 in source [568]

However, only a fraction of the drone-related market is the actual UA itself. For Germany, it has been shown that about 51.5% of the market is drone-related services, 6.5% is software (e.g. for flight planning), and only 42% is the hardware, i.e. the aircrafts themselves including components.[569] If we apply the 42% to the calculated market size, we arrive at 1,722 Million EUR for drone hardware sales in Europe in 2020.

To estimate unit sales from this, we rely on a source[570] that focuses on hardware only and gives estimates on distribution of UA types and unit sales for the global market in 2016 and 2017. They are summarised in Table 91.

562 https://www.droneii.com/project/drone-market-report#1
563 https://www.marketresearchfuture.com/reports/drones-market-1124
564 https://www.mordorintelligence.com/industry-reports/drones-market
565 https://www.alliedmarketresearch.com/commercial-drone-market
566 https://iot-analytics.com/product/commercial-drone-market-report-2019-2024/
567 https://www.marketsandmarkets.com/Market-Reports/small-uav-market-141134567.html
568 Kortas, M.; Rzegotta, I. (2018): Analysis of the German Drone Market. Bundesverband der deutschen Luftverkehrswirtschaft. https://www.bdl.aero/en/publication/analysis-of-the-german-drone-market/
569 Kortas and Rzegotta (2018); ibid.
570 https://www.gartner.com/en/newsroom/press-releases/2017-02-09-gartner-says-almost-3-million-personal-and-commercial-drones-will-be-shipped-in-2017

Table 208: Global unit sales and market value of civil drones, 2016-2017. Source: Own calculation

	2016			2017		
	Unit sales (Mio.)	Market value (Mio $)	Unit value ($)[571]	Unit sales (Mio)	Market value (Mio $)	Unit value ($)[572]
Personal	2.04	1,705.85	835.42	2.82	2,362.23	838.47
Commercial	0.110	2,799.27	25,378.71	0.17	3,687.13	21,178.22
Total	**2.15**	**4,404.12**	**2,046.33**	**2.99**	**6,049.36**	**2,022.25**
In EUR (historic exchange rate)		**3,918.25**			**5,425.43**	

Again, the global market of 5,425 million EUR for hardware in 2017 fits reasonably well with the calculated 1,722 million for Europe in 2020, given market growth.

If we assume, for Europe, a similar distribution between personal and commercial UA than in Table 91, and therefore a similar average unit price, we can divide 1,722 million EUR by 2,022 EUR and very roughly estimate **EU unit sales for 2020 at 0.85 million.**

16.2.3 Stock

Stock information could be collected for Germany: In 2018, the stock was almost 500,000. Of these, 455,000 were used privately and 19,000 drones. The stock was predicted to reach 721,000 private and 126,000 commercial drones in 2030.[573]

From the data above (573 Million market value in 2018, 42% hardware, 2,022,25 EUR average unit price), we can calculate German sales for 2018 to be about 119,000. This gives us a sales / stock ratio of 4.2. Applying the same ratio to Europe-28 in 2020, we arrive at a **stock of about 3.6 million in 2018.**

16.2.4 Forecast

For the forecast we make the simplified assumption of a constant annual growth rate. From the data provided for Germany, we can derive an annual growth rate of 4.49%.

If we apply the same growth rate to the EU-28 stock, we arrive at the following stock forecast:

Table 209: Stock forecast EU-28. Source: Own calculation

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock (1,000 units)	3,600	3,762	3,931	4,107	4,291	4,484	4,685	4,896	5,116	5,345	5,585

[571] Calculated by the author
[572] Calculated by the author
[573] Kortas and Rzegotta (2018); ibid.

If we further apply the same growth rate to the sales data calculated for 2020, we can estimate the following figures for sales, number of drones going out of stock, and average lifetime, which do not seem unreasonable:

Table 210: Calculation of sales, departures from stock, and average lifetime, EU-28. Source: Own calculation

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Sales (1,000)	851	890	930	971	1,015	1,061	1,108	1,158	1,210	1,264	1,321
Difference to stock in previous year		162	169	176	184	193	201	210	220	230	240
No. going out of stock		728	761	795	831	868	907	948	990	1,035	1,081
Share going out of stock	20.2%										
Calculated lifetime (years)	4.95										

The real numbers could, in fact, be somewhat lower due to the Brexit. On the other hand, the effects of the Covid-19 crisis, for which some analysts assume that it has spurred interest in drones[574,575,576], have not been taken into account either because the effects are still too unsure.

16.3 Usage

Civil drones are used for a variety of purposes:

- remote sensing, monitoring, inspection and surveillance (e.g. in the areas of environmental monitoring, meteorology, disaster management, road traffic monitoring, infrastructure and building site inspection, border surveillance, mining, firefighting, space missions, and others;
- photography and filming;
- providing wireless coverage (including in emergency situations where traditional networks are broken down).
- precision farming (in addition to monitoring functions, e.g. for crops, moisture, soil properties, diseases or weeds, UA can also distribute pesticides, herbicides or products for biological pest control);
- search and rescue of missing persons;
- transport and delivery of goods (including in disaster relief and for medical purposes);

574 https://droneanalyst.com/2020/09/17/covid-19-drives-interest-in-consumer-drones

575 https://www.prnewswire.com/news-releases/drone-industry-powers-on-in-a-post-covid-19-world-to-be-worth-us92-billion-by-2030-301143603.html

576 https://www.amsterdamdroneweek.com/news/articles/the-benefits-of-aerial-mobility-during-covid19

- hobby and leisure, including as a toy.[577]

Figure 56, Figure 57 and Figure 58 show the most important areas of use, according to different sources.

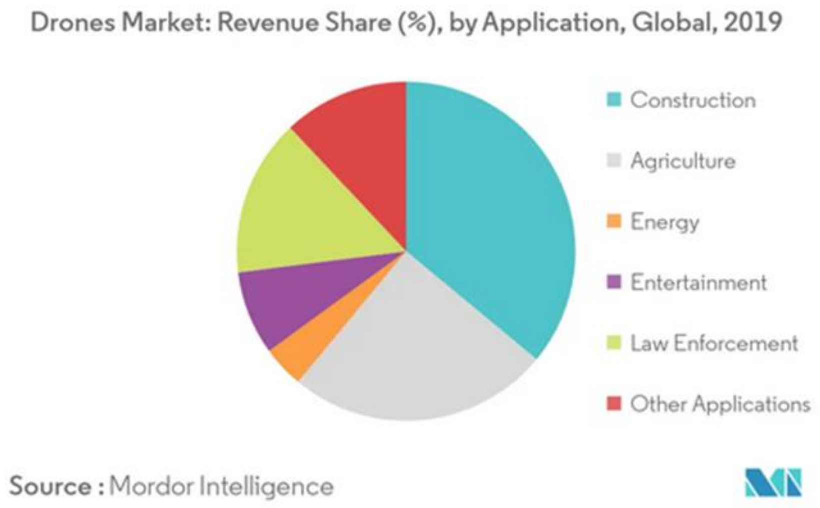

Figure 56: Revenue share by application. Source: Mordor Intelligence[578]

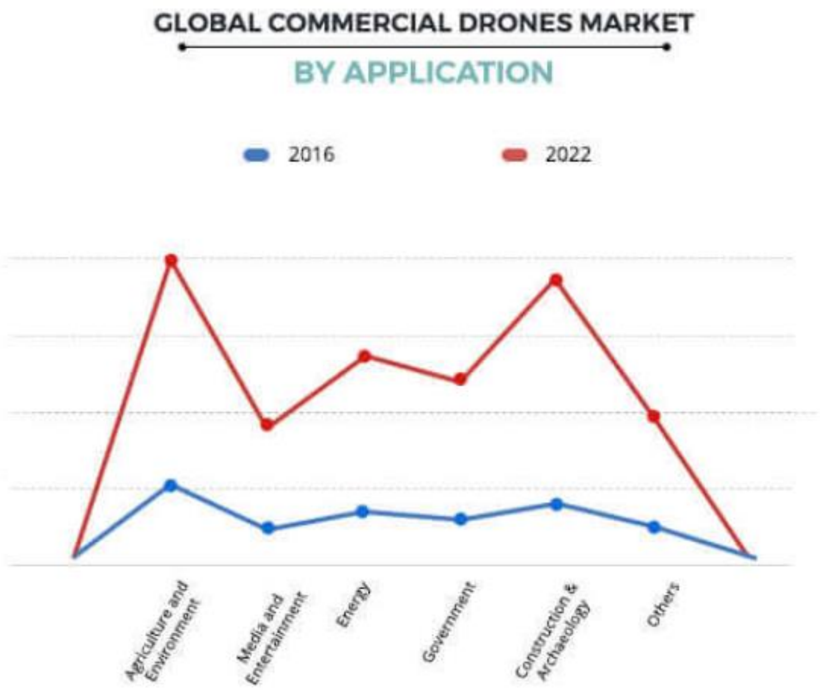

Figure 57: Revenue share by application. Source: Allied Market Research[579]

[577] For a thorough review of all mentioned functions, except leisure, see Shakhatreh at al. (2018), ibid.
[578] https://www.mordorintelligence.com/industry-reports/drones-market
[579] https://www.alliedmarketresearch.com/commercial-drone-market

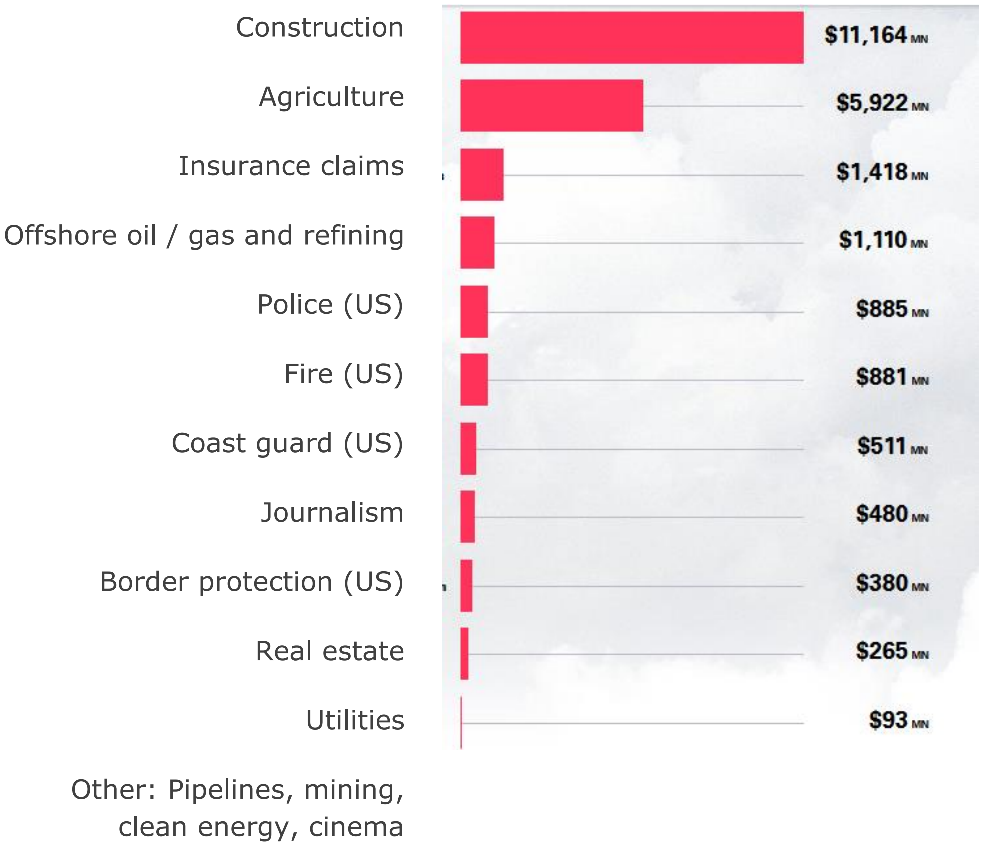

Figure 58: Revenue share by application 2016. Source: Goldman Sachs[580]

Although with varying shares, the construction and agriculture sector seem to dominate. A somewhat different picture emerges, if the shares are not differentiated according to sectors but functions.

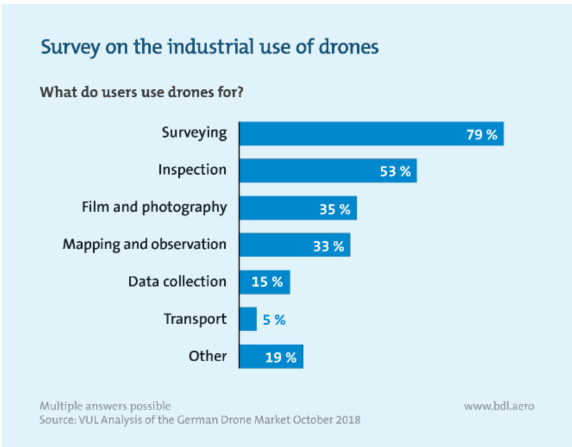

Figure 59: Drone usage by function. Source: Kortas and Rzegotta[581]

580 https://www.goldmansachs.com/insights/technology-driving-innovation/drones/
581 Kortas and Rzegotta (2018), ibid.

Ecodesign and Energy Labelling requirements could only be designed for drones that are not exclusively used as means of transport, because means of transport are out of scope.

16.4 Technologies

16.4.1 Types of UAs[582]

Apart from their size and weight, drone types may be distinguished according to the way they take off and land, to wing type and propulsion system.

- **Take-off and landing type:** *Horizontal take-off and landing (HTOL*) devices need a runway much like an airplane. *Vertical takeoff and landing (VTOL)* systems are able to take off and land on the spot like a helicopter does. There are also *hybrid drones* which combine the advantages of being able to take off and land vertically, and the higher cruise speed of HTOL. Among them are tilt-rotor, tilt-wing, tilt-body and ducted fan types.
- **Wing type:** *fixed-wing types* resemble an airplane with a fuselage and fixed wings; *flapping-wing types* that imitate a bird's flight, or *rotor systems*. Among the latter, types with one or several rotors and corresponding motors exist, up to twelve rotors / motors. They are called monocopters, twin-copters, tricopters, quadrocopters etc. Also with respect to wing type, *hybrids and unconventional types* exist such as "heli-wings" that can use their wing both as a rotating blade or fixed wing, or "ornicopters" that can flap their helicopter blades.
- **Propulsion system:** A propulsion system consists of fuel, engine, and, for flapping wing types, an actuator. It is closely related to size and wing type. Large fixed-wing UA usually use propulsion systems that resemble those of an airplane, e.g. using a motor and propeller, or a jet engine. Engine types for large UA include various types of fuel engines (piston engine, jet engine, gas turbine engine, wankel engine, injected engine, etc.), as well as electrical motors (brushed and brushless). Fuels may include kerosene, gasoline, diesel, methane, and hydrogen. Smaller UAs most commonly use battery- or fuel-cell powered electric motors (especially for flapping-wing types). Over 90% of batteries are Lithium ion batteries. Alternatively, smaller UAs may also be equipped with micro gas turbine or micro-diesel engines. Solar panels or energy harvesting can be used as an additional energy source to increase endurance or power sensors and cameras.

Hassanalian and Abdelkefi (ibid.) propose a classification by size, and, in a second step, various wing types for each size. A simplified overview of their typology[583] is given in Table 211. (Note that the terminology is not consistent across literature. Specifically, Hassanalian et al. reserve the term "UAV" for a certain subgroup of large vehicles, a decision that is not shared by other authors and is not followed in the remainder of this report)

[582] See Hassanalian M. and Abdelkefi, A. (2017): Classifications, applications, and design challenges of drones: A review. *Progress in aerospace sciences* 91, 99-131; Vergouw, et al. (2016), ibid.; and Shakatreh et al. (2018) (ibid.)

[583] The table excludes unconventional types, types that are in an experimental stadium such as "bio-drones" that make use of living or taxidermed insects or birds, and summarizes several subtypes under "hybrid".

Table 211: Simplified drone typology. Source: Hassanalian and Abdelkefi (2017)

Name	Size		Take-off and landing			Wing type			
	Weight	Wingspan	HTOL	VTOL	Hybrid	Fixed-wing	Flapping wing	Rotor system	Hybrid
UAV	5 g – 15 t	2 – 61 m	x	x	x			x	x
µUAV	2 – 5 kg	1 – 2 m	x	x	x		x	x	x
MAV	50 g – 2 kg	15 cm – 1 m		x	x	x	x	x	x
NAV	3 – 50 g	1.5 – 15 cm				x	x	x	
PAV	0.5 - 3 g	0.25 - 2.5 cm					x	x	x
SD	0.005 - 0,5 g	0.1 - 0.25 cm							

Figure 43, Figure 44, Figure 45, Figure 46 and Figure 47 show different examples. The source for all pictures is Hassanalian et al. (2018).

Figure 61: Fixed-wing HTOL

Figure 60: Fixed-wing VTOL

Figure 62: Flapping-wing MAV

Figure 63: Quadrocopter

Figure 64: Dodekacopter

Industry stakeholders provided the following overview of technical specifications and use cases of commercial drones:

Table 212: Technical specifications and use cases of commercial drones. Source: Stakeholder input.

Model (Manufacturer)	Matrice 300 RTK (DJI)	Inspire 2 (DJI)	WingtraOne (Wingtra)	eBee x (senseFly)	eBee SQ (senseFly)	AgBot (Aerial Technology International)	InDago AG 3 (Lockheed Martin)	Freefly ALTA 8 (Viper Drones)
Weight	3.6kg (without batteries) 6.3kg (with 2 batteries) 9kg (max take-off weight) + 2.7kg (max payload)	3.44kg / max take-off weight 4.25kg	3.7 kg / Max. payload weight 800 g	1.3 kg - 1.5 kg (depending on camera and battery)	1.1 kg (incl. supplied camera & battery)	4.7 kg (incl. sensor and battery)	2.05 kg with payload	Maximum Gross for Takeoff 18.1 kg Maximum Payload 9.1 kg Typical Standard Empty Weight 6.2 kg
Flight time (approx.)	55 minutes	23-27 minutes	59 minutes	90 minutes	59 minutes	26 minutes	50 – 75 minutes	15 minutes
Use cases (examples)	Search and rescue missions; inspections	Filmmaking	Precision aerial surveys	Mapping	Agricultural mapping	Agriculture	Agriculture, inspections	Filmmaking

16.4.2 Types of sensors

Sensors are, besides cameras and microphones, the most common type of payload. Shakatreh et al. introduce a distinction that is relevant for energy consumption: active vs. passive remote sensing systems. "In active remote sensing system[s], the sensors are responsible for providing the source of energy required to detect the objects. The sensor transmits radiation toward the object to be investigated, then the sensor detects and measures the radiation that is reflected from the object. […] In passive remote sensing system, the sensor detects natural radiation that is emitted or reflected by the object."[584]

16.4.3 Materials and manufacturing

UA may be manufactured from a great variety of different materials, both between and within devices. Low weight is a core criterion in the choice of materials. For the body, strength is also important.

Fixed-wing drones "usually consist of wing, fuselage, booms, vertical and horizontal tails. Each part of the drone is fabricated with different materials and methods. The applied materials in fixed wing drones can be metallic materials, such as aluminum which are used in huge UA, composite materials including kevlar, fiberglass, fiber carbon and other materials including wood, Styrofoam, and plastics (PVC). Nowadays, composite materials are considered as popular materials. Unlike metallic materials, the actual material properties of composites are generally not available because their properties are dependent on the manufacturing process."[585] Composite materials are, according to the author, also the most popular choice for most µUAV and MAV. Other authors point to thermoplastics such as nylon, polystyrene, or polyester for the frame.[586]

For flapping wing types, manufacturing techniques and methods are dependent on the class (i.e. size) of the flapping wings. "Flapping wing drones usually consist of wing, fuselage, tails, and actuation mechanism. The wing that constitutes the main part of flapping wing drones consists of a structural part (spars and ribs) and a membrane. The light-weight materials used in the building of the wing and tails of the flapping wing MAVs are foam, wood, composite materials, such as fiberglass and fiber carbon, and flexible membranes, such as mylar or plastic tissues. Composite materials and foam are usually utilized for the fabrication of the fuselage."[587]

16.4.4 Areas of research

Almost all aspects of UAs are subject to rapid innovation. A core concern is the **increase of efficiency and reduction of fuel consumption** and therefore the increase of flight time. More information can be found in section 16.6.1.

Furthermore, **manufacturing methods** are refined, including the use of 3D printing and inflatable drones.[588]

Some larger trends include:

- further miniaturisation;
- further increase of the autonomy;

[584] Shakatreh et al. (2018), ibid., p.9
[585] Hassanalian and Abdelkefi, ibid.; p. 117
[586] Wade, L. (2019): What are drones made of? October 23, 2019. https://matmatch.com/blog/what-are-drones-made-of/
[587] Ibid.
[588] Hassanalian and Abdelkefi, ibid.; p. 119

- Swarms: The cooperation between drones in so-called swarms "may widen the range, flight duration, and maximum payload for particular applications. For instance, using drones in swarms, one drone may take over a task from another drone with an exhausted battery. […] Heavy payloads may in some cases be distributed over several drones, […]. Swarms of drones may be used as sensor networks.[589]
- biomorphic and bio-hybrid drones. Biomorphic drones imitate structure and function of live animal bodies. For example, propulsion systems of flapping-wing drones may imitate the muscles of birds and insects. Bio-hybrid drones are constructed by integrating artificial components into the bodies of taxidermically prepared insects or birds, or even by controlling live animals such as beetles or pigeons via electrodes.[590]

16.5 Energy, Emissions and Costs

16.5.1 Energy consumption during operation[591]

As has been mentioned, energy consumption in drones is a major concern for developers and users, as it translates directly into flight range. It can be divided into the energy consumption of the payload (sensors, cameras, etc.) and the energy consumption of the motor(s). Main energy consumption is by the motor(s).

As has been shown, different fuels are used for different UA sizes and purposes. Liquid or gaseous fuels have higher energy densities than electric motors (Figure 65). On the other hand, they have lower conversion efficiencies and the respective motors are louder. They are therefore mainly used for large, aircraft-like UAs that fly long distances or carry heavy payloads.

[589] Vergouw et al. (2016); ibid.; p. 42

[590] Hassanalian and Abdelkafi, ibid.; p. 108 f.

[591] Severals studies deal with the comparison of drone use and ground vehicle use for goods delivery. These are not considered here, as drones that are means of transport are out of scope.

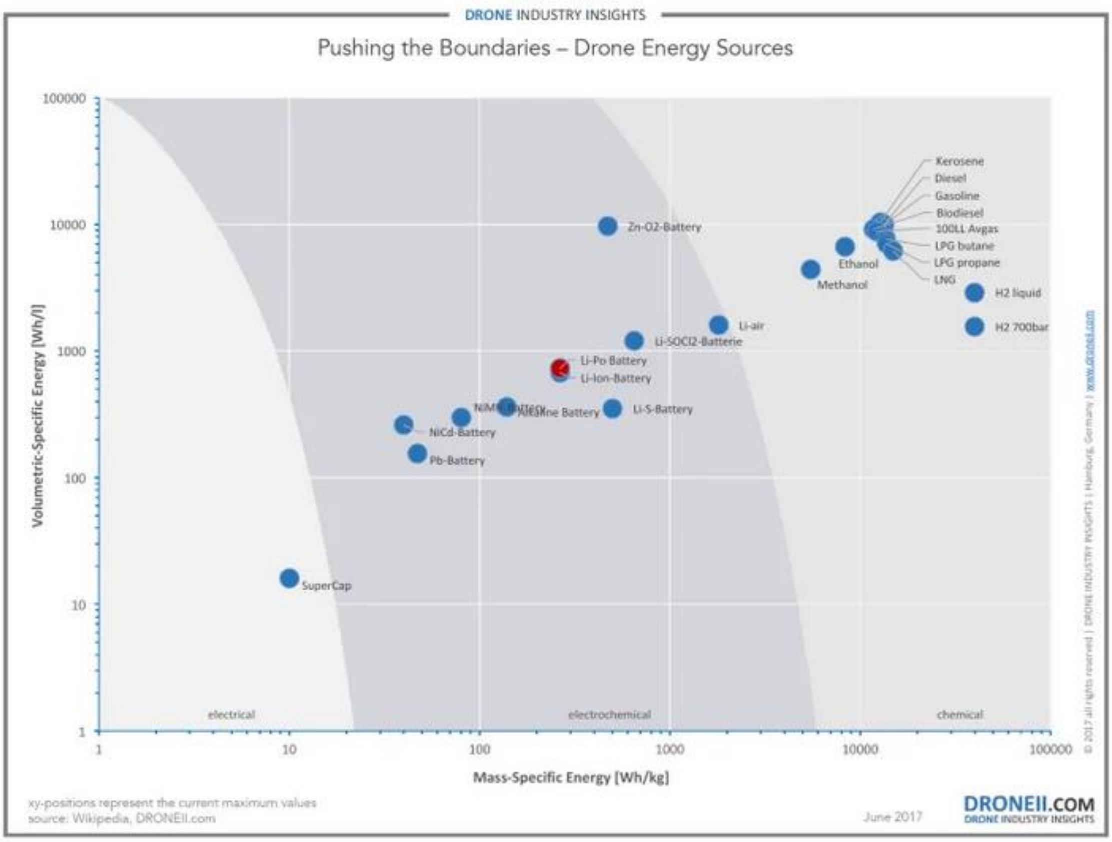

Figure 65: Mass-specific and the volumetric specific energy of different fuels. Source: DroneII.com[592]

Energy consumption during operation depends on:

- UA design, for example weight; motor efficiency; propeller / wing design (aerodynamics). Generally, fixed-wing UA are more efficient than rotor UA just like a traditional aircraft is more efficient than a helicopter. However, rotor design is often needed for manoeuvrability.[593]
- the weather (e.g. flying with the wind, or battery performance being affected by temperature), flying speed and payload.
- energy management and routing.

Two figures for selected base cases may illustrate a range for energy consumption of medium-sized multicopters with electric motors:

- Dietrich at al. (2017) determined an energy consumption of about 38 Wh for a 10 minute steady hover flight of a 1,8 kg multicopter.[594] This is rather typical for private / leisure use. Lifetime for this type of drone is assumed to be about 800 flying

[592] https://www.droneii.com/drone-energy-sources

[593] Öhlund, R. (2017): Drones and energy efficiency. http://smartplanes.com/drones-and-energy-efficiency/

[594] Dietrich, T.; Krugy, S., and Zimmermann, A. (2017): An Empirical Study on Generic Multicopter Energy Consumption Profiles. 11th IEEE Int. Systems Conference (SysCon 2017), Montreal, April 2017, pp. 406-411. https://www.tu-ilmenau.de/fileadmin/public/sse/Veroeffentlichungen/2017/SysCon17-DietrichKrug-EmpiricalEnergyProfilesMulticopter.pdf

hours.[595] If the device was always in hover flight, this would render 182.4 kWh over the lifetime.

- Koiwanit (2018) assumed 25,8 Wh for a 10 kg multicopter to transport a package for 1 km (the weight of the package is not given). 596 This case represents rather a commercial use. Multiplied by a lifetime travel distance of 250,000 km (see section 16.5.3), this would render 6450 kWh.

For lack of data on parameters such as energy consumption of other drone types, overall fuel mix across drone types, or distribution of drone sizes and types across the market, no information on primary energy consumption, lifecycle energy consumption, GHG emissions or EU aggregated values can be given.

16.5.2 Cost

A schematic overview of design and manufacturing cost for different drone types is given in Figure 66.

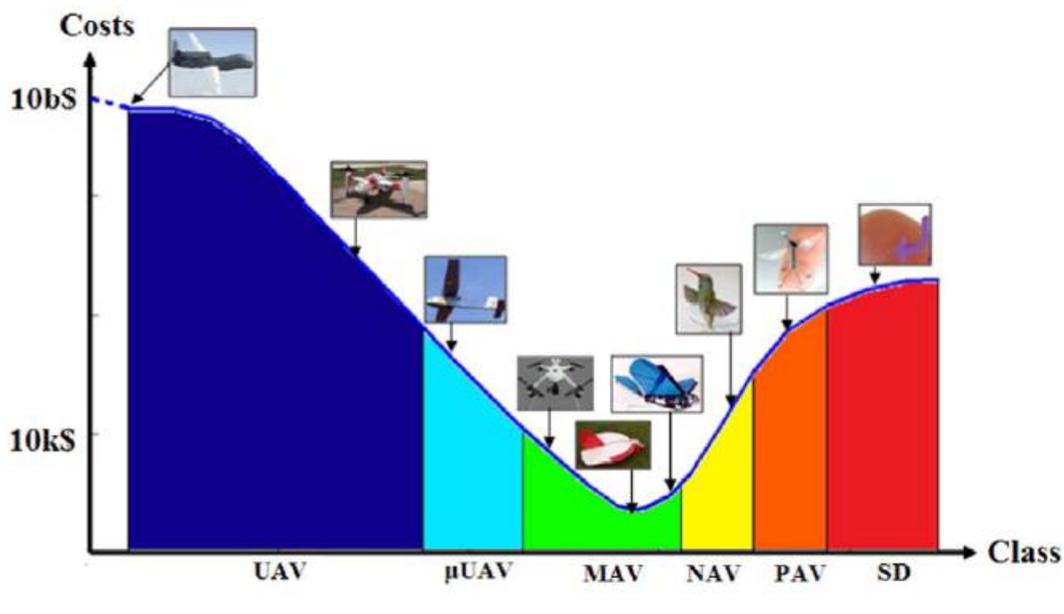

Figure 66: A schematic view of design and manufacturing cost of different types of drones. Source: Hassanalian et al. (2017).[597]

No reliable information on operating cost may be given, as it depends fully on the type of drone, use case, intensity of use, country of use (e.g. licenses, insurance), etc.
If energy costs alone are considered, consideration of the two base cases in section 16.5.1, at an electricity cost of 0.22 EUR / kWh, renders

- for the private case, energy costs of 5 ct per hour and 40.13 EUR over the lifetime;
- for the commercial case, energy costs 0.56 ct per km, and 1419.00 EUR over the lifetime.

[595] https://www.thedroneu.com/adu-0704-life-expectancy-drone/

[596] Koiwanit, J. (2018): Analysis of environmental impacts of drone delivery on an online shopping system. Advances in climate change research 9 (2018), 201 – 207.

[597] Hassanalian et al. (2017); ibid.; p. 115

In both cases, lifetime energy cost would be only a fraction of purchase cost.

No EU-wide figures can be given for lack of data.

16.5.3 Emissions and overall environmental impact

Koiwanit (2018) conducted a Life Cycle Analysis of drone delivery in Thailand as compared to road delivery.[598] Although the study deals with a delivery drone, it will be used here as it is one of the few sources of reliable data.

The author was faced with serious data limitations concerning the manufacturing and composition of the UA, so data from different sources across the globe (Europe, Canada, USA) was used. Nevertheless, the study allows to estimate the environmental impact of a certain base case. The author studied a rotor UA of 10 kg (empty, but including six batteries) and 15.5 kg including payload, with an electric motor and six Li-Po batteries. Energy use per package and kilometre was assumed to be 25,8 Wh. Lifespan was set at 5000 h or around 250,000 km. Table 213 gives an overview of the materials used.

Table 213: Material composition of base case UA. Source: Koiwanit (2018)

Part	Weight (g)	Materials	%	Weight (g)
Frame	8,768[599]	Carbon fiber	85	7,452.8
		Plastic	10	876.8
		Aluminium	5	438.4
Motor	230	Steel	55	126.5
		Copper	35	80.5
		Magnet	10	23
Propeller	232[600]	Plastic	100	232
Electronic speed controller	90	Copper (cables), resistor, transistor, CU etc.		90
Batteries	680	LiPo		680
Transport box	181.4	Carbon fiber	100	181.4

Results indicate that parts production is the most important life cycle phase in terms of environmental impact, and that drone operation is negligible.

[598] Koiwanit, J. (2018), ibid.

[599] Calculated from 10,000 total weight minus the weight of the other components (excluding transport box).

[600] The author only gives the weight of an individual propeller. He mentions that there are several propellers, but the number is nowhere indicated. It is therefore assumed that there are four propellers, as this is the most common case.

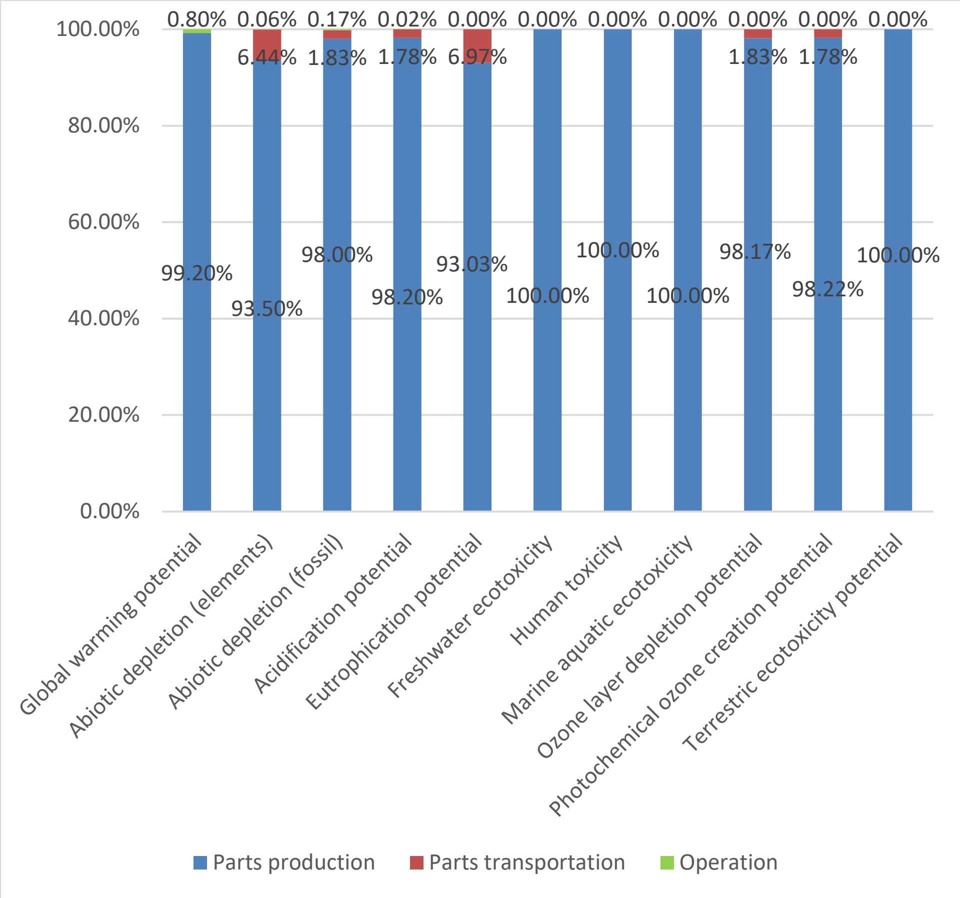

Figure 67: Contribution of life cycle phases of a drone to various environmental impacts, according to Kowainit (2018)[601]

Industry stakeholders argue that delivery drones are heavier than other types, so the actual impact for other types may be somewhat lower. But the core finding that the main impact is in the manufacturing phase holds nevertheless.

EU-wide impact cannot be quantified reliably for lack of data.

16.6 Saving potential

16.6.1 Energy

Several paths are already being pursued to increase the flight range of UAs.[602] Some aim at improving energy efficiency, such as:

- lightweight construction. For example, already in 2015, researchers at HRL laboratories, California, developed a fabrication process for a microsandwich structure with areal densities from 0.04 g/cm^2 down to 0.005 g/cm^2.[603] Incentives

[601] Ibid.

[602] See https://www.dronezon.com/learn-about-drones-quadcopters/drone-components-parts-overview-with-tips/; Wade, L.. (2019), ibid.; Hassanalian and Abdelkefi, ibid.; https://www.droneii.com/drone-energy-sources; Shakatreh et al. (2018); ibid.

[603] https://www.hrl.com/news/2015/07/10/lightweight-sandwich-structures-lay-the-groundwork-for-micro-drones

to invest in lightweight products are also set by regulations 2019/945 and 2019/947, which tie operational requirements to the weight of the drone.

- propeller design;
- motor efficiency. The newest electric drones generally use brushless motors, which are more efficient, more reliable, and quieter than a brushed motor;
- energy management (including battery management, management of the communications and sensor equipment, flight planning and routing, and the utilisation of machine learning techniques for these purposes). Energy consumption and battery life models are calculated, taking into account the mission, route, and external conditions, and optimum routes are planned as well as battery replacement and charging cycles;

Others approaches rather try to improve the availability of energy sources, such as:

- improved battery technology. The most important breakthrough might have been the development of lithium ion batteries. Also, Lithium polymer (Li-Po) batteries are commonly used. Future developments might include Lithium-Thionyl-chloride batteries (Li-SOCl2), Lithium-Air-batteries (Li-air), and Lithium-Sulfur-batteries (Li-S) with higher energy densities;
- solar cells (which are however seldom used as the only power source because they do not provide sufficient power when drones fly under clouds or in the dark). Solar hybrids therefore integrate solar cells and battery systems. Also, ground charging systems are explored that charge solar cells in UAs via laser beams from the ground;
- wireless charging, based on a system of charging stations or energy harvesting from power lines.
- fuel cells.

16.6.2 Resources

As manufacturing dominates by far the environmental impact, and energy efficiency is already a core concern of manufacturers and operators, improvement options should focus on resource-saving. Lightweight design is already an important area of research. Furthermore, according to industry stakeholders, manufacturers try to enhance the flexibility of the platforms to be used for multiple use cases with different types of sensors and cameras, or other payloads to create a “multi-use” drone for different types of operations instead of a single purpose drone. This would contribute to material savings.
Remaining topics are therefore durability, repairability, and recyclability.

Another issue is the avoidance of hazardous substance, especially given the risk that UA may crash or get lost in remote areas, releasing substances into the environment.

Industry stakeholders argue that crashes are rare, given that 80% of drone flights take place within sight, and technology on board such as GPS avoids collisions. However, crashes can occur for multiple causes that are unaffected by the above factors, e.g. human error of the pilot, GPS signal outages, battery exhaustion, interference, software errors, or the weather.[604] Widespread discussions about crashes among both amateur users and the military, as well as scientific papers indicate that the risk is not negligible.[605] While certain hazardous substances are regulated by the RoHS Directive, the latter only applies to CE-marked drones, and it does not cover for example Lithium from disintegrating batteries.

Also, biodegradability might be an issue to avoid littering by crashed drones. A recent student demonstration project showed that it was possible, using a 3D-printer, to produce a drone from biodegradable plastics that could fly 30 m high at a speed of 9 km/h, and carry 100 g of payload.[606]

Resource savings potentials can, for lack of data, not be quantified at the moment.

16.7 Summary

Table 214 gives an overview of market data for drones.

Table 214: Overview of drones (market data). Source: Own calculation

	2020	2025	2030
EU-27 annual sales (1,000 units)	851	1,061	1,321
EU-27 stock (1,000 units)	3,600	4,484	5,585

For lack of data, no EU-wide figures for energy consumption, other resource consumption, or savings potentials can be gives. As there are already intrinsic incentives to improve energy efficiency and lightweight design of drones, potential requirements – if any – might focus on issues such as durability, repairability, or hazardous substances.

16.8 Stakeholder comments

Industry stakeholders highlight the unsatisfactory data base (especially in terms of markets), the nascent state of the industry and the challenges in adapting to an instable and yet evolving regulatory environment (see section 16.1.3). Against this background, they recommend to postpone Ecodesign and Energy Labelling requirements until the industry is more mature.

With respect to durability and repairability, they claim that these are already guaranteed by the use of high-quality materials and the "do it yourself" principle prevalent in the drone operator community. It must, however, be avoided that drones become obsolete by the introduction of new regulation that they cannot fulfil.

[604] Allouch, A.; Koubaz, A.; Khalgui, M.; Abbes, T. (2019): Qualitative and Quantitative Risk Analysis and Safety Assessment of Unmanned Aerial Vehicles Missions Over the Internet. IEEE Access 7/2019, 53392-53410.

[605] e.g. https://store.dji.com/guides/drone-crash/, https://www.thedroneu.com/adu-0984-report-drone-crash/ ; https://sofrep.com/fightersweep/why-are-the-drones-crashing-so-often/ ; Susini, Alberto (2015): A Techno-critical Review of Drones Crash. Risk Probabilistic Consequences and its Societal Acceptance. *Risk Information Management, Risk Models, and Applications,* Vol. 7, 27-38; Fish, Adam (2020): Crash Theory: Entrapments of Conservation Drones and Endangered Megafauna. *Science, technology, and human values*, May 2020.

[606] Sponder, A. (2019): Student group develops eco-friendly drone using 3-D printing. http://blog.cdnscien-cepub.com/student-group-develops-eco-friendly-drone-using-3-d-printing/

Furthermore, they point to the high variability of drones which makes it unfeasible to apply “one size fits all” requirements. If drones should nevertheless become the object of regulation, they suggest that potential requirements should focus on larger drones outside the “open” category (above 25 kg), as the savings potentials are larger in this category.

On the other hand, it needs to be verified to what degree larger drones actually fall under the scope (because a significant share might be used for military or transport purposes).

17 ENTERPRISE NETWORK EQUIPMENT

17.1 Scope, policy measures and test standards

17.1.1 Scope

The overall scope of the product group enterprise network equipment is network equipment and specifically routers and switches used in enterprises and hyper-scale data centres, except smaller offices using more household-like equipment, which has been assessed separately.

Server and storage related network equipment were studied in a preparatory study on enterprise servers and data equipment[607], but only for Task 1-4, with the following conclusion provided in the Task 7 report:

During the first tasks of the preparatory study (Tasks 1-4) it was shown that networking equipment is an important product group, but that the complexity of these products made it unfeasible for the Lot 9 study to cover them in an adequate manner. For this reason it is suggested to conduct a separate preparatory study on networking equipment, based on preliminary information provided in Tasks 1-4 of the Lot 9 study.[607]

The regulation (EU) 2019/424 adopted after the preparatory study and a combined follow-up study and impact assessment covers servers and storage equipment and not network equipment[608].

Since then, measurement methods have been developed for network equipment and an Energy Star certification for Large Network Equipment[609] has been launched covering routers and switches. Furthermore, additional studies of the product group have been carried out such as the development of product specific criteria under the Type I Ecolabel "TCO Certified"[610], which is using the mentioned Energy Star specification for the energy efficiency requirements.

Enterprise network equipment mainly consist of switches and routers, but additional equipment such as security appliances and access point controllers are also network equipment.

The assessments in this section are focusing on the market, energy consumption, material consumption, emissions and improvement opportunities related to switches and routers, because they constitute the majority of the products in enterprise network equipment and correspond to the scope of the Energy Star specification. However, security appliances,

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[607] Ecodesign Preparatory Study on Enterprise Servers and Data Equipment. Bio by Deloitte with Fraunhofer IZM
July 2015.

[608] Commission Regulation (EU) 2019/424 of 15 March 2019 laying down ecodesign requirements for servers and data storage products pursuant to Directive 2009/125/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 617/2013

[609] ENERGY STAR® Product Specification for Large Network Equipment. Eligibility Criteria. Version 1.0. March 2016.

[610] https://tcocertified.com/files/certification/tco-certified-generation-8-for-network-equipment.pdf

access point controllers and possibly other equipment may be considered to include in the scope in possible preparatory study.

The preparatory study Task 1 describes enterprise network equipment as a device that is providing connectivity and passing data through wired or wireless network interfaces. The same types of network equipment can be operated in different networks under different operative conditions and quality of service requirements. E.g. the Wide Area Network (core), Metro Area Network (aggregation), Access Network (fixed/mobile) or Local Area Network (wired/wireless).

Energy Star certification for Large Network Equipment[609] defines switches and routers as devices whose primary function is to pass Internet Protocol traffic among various network interfaces/ports. Furthermore, Energy Star defines enterprise network equipment (referred to as large network equipment by Energy Star), as network equipment that is mountable in a standard equipment rack, support network management protocols and contains more than eleven physical network ports and the total aggregate port throughput of the product is greater than 12 Gb/s.

Some of the enterprise network equipment are modular and accepts modules or are up-gradable, which can e.g. increase or decrease the number of ports or add/remove func-tionality for the product. Other types of enterprise network equipment are considered fixed product that cannot accept modules that modify the capability of the device or are not upgradable.

The definitions provided in the Energy Star certification have been adopted in this study.

Figure 68 illustrates how enterprise network equipment may connect to each other and to other devices in the network. UAs may be (and have been) classified according to different criteria such as size and weight, performance, autonomy, various constructive properties, and payload. Based on these properties, a variety of functions can be performed.

With respect to **size and weight**, UA can vary between weights of 0.005 g and 15 tons, and wingspans between 1 mm and over 60 m, giving rise to terms such as “smart dust” for the most tiny variants.

With respect to **performance**, UA can be classified according to a combination of endurance and altitude**,** leading to terms such as HALE (high altitude, long endurance) or LASE (low altitude, short endurance). Drones can fly at altitudes of below 50 m (e.g. for leisure and photography) or up to 10,000 m and more (for telecommunication purposes). Endurance is mainly determined by the fuel source. Small battery-powered UA are restricted to about 30 min. flight time due to limited storage capacity, while fuel-powered or solar-assisted ones can fly for several hours to days. Also, hybrid drones are being developed that combine batteries and fuel to last several hours.

The **autonomy** can vary from remote piloting to automatic systems (which follow a pre-programmed routine) and autonomous systems (which can react to unexpected situations thanks to onboard software).

With respect to **constructive properties**, drones vary mainly with respect to the way they are able to take off and land, wing type, and propulsion system. More detail can be found in section 16.4, "Technologies".

The **payload** can include, for example, cameras and microphones, different types of sensors (e.g. infrared, biological sensors to trace microorganisms, chemical sensors to identify substances), measurement equipment (e.g. for meteorological data), radars / LIDARs, communications equipment, weapons, freight, and even persons.

With respect to **function**, UA have been originally developed for military purposes. Meanwhile, a number of different civil functions have evolved, that are described in more detail in section 16.3, "Usage".

In this report, military applications will be excluded, as they are generally excluded in Ecodesign and Energy Labelling Regulations due to security considerations. Furthermore, it must be borne in mind that Ecodesign and Energy Labelling requirements cannot be applied to drones that are designed specifically for the transport of persons or goods, as the instruments not apply to means of transport. However, datasets used in this report often do not allow to distinguish between drones used for transport and those used for other purposes. Furthermore, the boundaries between types are sometimes blurring, and it remains to be legally clarified which types of UA could be in scope of Ecodesign and Energy Labelling legislation. This is an aspect that needs to be considered if, and when, designing policy instruments.
 provides definitions of the products in scope and the considered security appliances and access point controllers.

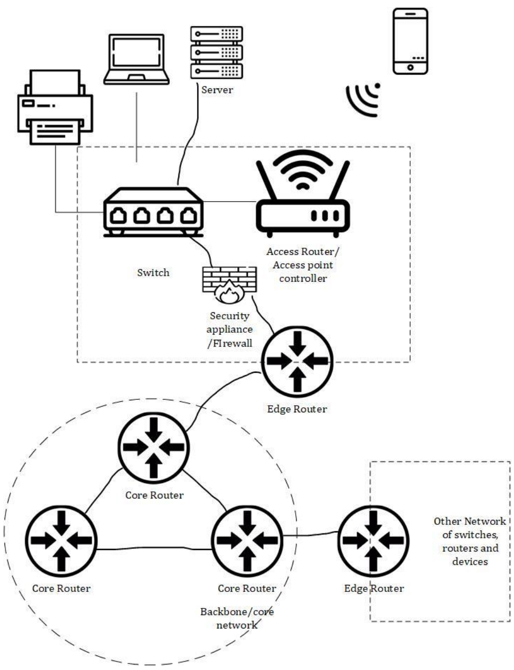

Figure 68: Illustration of enterprise network devices
Source: Viegand Maagøe

Table 215: Scope and product definitions[609,611,612]

Product	Definitions
Router	A network device that routes network packets from one logical network to another, along a predefined or dynamically discovered path, based on network layer information embedded in the network packet header (OSI layer 3)[609]. Routers have different applications and can be classified into core, edge and access routers[612]. • A core router is wired or wireless and it distributes data packets within networks, but not between multiple networks. They are designed to become the backbone of the local network and can transfer large amounts of data[613]. • An edge router distributes data packets between one or more networks, but not with in a network. As their name indicates, edge routers are placed at the edge or boundary of networks, and typically connect to internet service providers (ISPs) or other organisations' networks[613]. • An access router (sometime referred to as access point, with built-in router) is a router that allows devices to connect to the network[614]. Routers in small offices and in homes, often combined with a Wi-Fi access point and a switch with up to about 5 ports, are not included.
Switch	A network device that delivers packet data frames to specific physical ports on the device, based on the destination address of each frame from the Data Link (OSI layer 2) within a logical network[609]. The switches can be categorised according to types: • Modular managed: A system able to be modified regarding the capability and able to configure, manage and monitor the local area network (LAN) • Fixed managed: As modular managed, but without the modular capability • Fixed unmanaged: As fixed managed, but without the capability to manage etc. the LAN and according to maximum bandwidth: 100 Mbps, 1 Gbps, 10 Gbps and 40 Gbps. Switches may also have routing capability (L3 switches) and therefore function both as router and switch.
Security appliance	A stand-alone network device whose primary function is to protect the network from unwanted traffic (e.g. secure tunnel and firewall appliances). This includes products whose primary function is to provide virtual private network (VPN) services. These are not in scope of this assessment.
Access Point Controller	A network device whose primary function is to manage wireless local area network (WLAN) traffic through one or more wireless access point devices. These are not in scope of this assessment.

[611] ICT Impact study. Final report. VHK and Viegand Maagøe for the European Commission. July 2020.

[612] https://www.etsi.org/deliver/etsi_es/203100_203199/203136/01.02.01_60/es_203136v010201p.pdf

[613] https://www.cisco.com/c/en/us/solutions/small-business/resource-center/networking/types-of-routers.html#~choosing

[614] https://techterms.com/definition/accesspoint

17.1.2 Policy measures and test standards

Enterprise switches and routers are not included in a separate Ecodesign product regulation but they are for specific categories in scope of two horizontal regulations, see below. Additionally, there are several standards and other initiatives available. The relevant regulations, standard and other initiatives are:

d) Regulations

1. Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for standby and off mode, and networked standby, electric power consumption of electrical and electronic household and office equipment. Only EMC Class B equipment is in scope.
2. Commission Regulation (EC) No 2019/1782 of 1 October 2019 laying down ecodesign requirements for external power supplies pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulation (EC) No 278/2009. The regulation set ecodesign requirements to external power supplies used for powering electronic equipment up to 250 watts. Thus, focusing on equipment used in household and smaller ICT equipment. Furthermore, only external power supplies for EMC Class B equipment are in scope.

e) Standards

1. EN 50564:2011 Electrical and electronic household and office equipment - Measurement of low power consumption[615] specifies methods of measurement of electrical power consumption in standby mode(s) and other low power modes (off mode and network mode), as applicable. It is applicable to electrical products with a rated input voltage or voltage range that lies wholly or partly in the range 100 V a.c. to 250 V a.c. for single phase products and 130 V a.c. to 480 V a.c. for other products.
2. ETSI EN 303 423 Environmental Engineering (EE); Electrical and electronic household and office equipment; Measurement of networked standby power consumption of Interconnecting equipment specifies methods of measurement of electrical power consumption in networked standby and the reporting of the results for interconnecting equipment.
3. ITU-T L.1310 / 07/2017 Telecommunication standardization sector of ITU, Energy efficiency metrics and measurements methods for telecommunication equipment.
4. ETSI ES 203 136 V1.2.1 (2017-10), Environmental Engineering (EE); Measurement methods for energy efficiency of router and switch equipment.
5. ETSI ES 203 184, Measurement Methods for Power Consumption in Transport Telecommunication Networks Equipment
6. ATIS 0600015.03.2016, Energy Efficiency for Telecommunications Equipment: Methodology for Measurement and Reporting for Router and Ethernet Switch Products. This document specifies the definition of router and Ethernet switch products based on their position in a network, as well as a methodology to calculate the Telecommunication Energy Efficiency Ratio (TEER). The standard will also provide requirements for how equipment vendors shall

[615] https://www.cenelec.eu/dyn/www/f?p=104:110:119075597197560 1::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1257245,45888,25

respond to a TEER request based on a specific application description by making use of relevant data from internal and independent test reports.

7. Verizon 2009: Verizon Network Equipment Building System (NEBS) Compliance: Telecommunication Equipment Energy Efficiency Rating (TEEER)
8. ECR 2010: ECR Initiative Network and Telecom Equipment Energy and Performance (Assessment Metrics, Test Procedure and Measurement Methodology), Draft 3.0.1, December 14, 2010
9. IEEE 802.3az Energy Efficient Ethernet (EEE): It is a standard that allows physical layer transmitters to consume less power during periods of low data activity for Ethernet networks.
10. ETSI TS 103 199 V1.1.1 (2011) Life Cycle Assessment (LCA) of ICT equipment, networks and services: General methodology and common requirements
11. ITU-T L.1410 (2014): Methodology for environmental life cycle assessments of information and communication technology goods, networks and services.

f) Other initiatives

1. ENERGY STAR[609] specification for large network equipment. The specification sets requirements on efficiency of the power supply, adaptive active cooling that reduce energy consumption proportionate to the cooling needs of the unit, compliance IEEE 802.3 clause 78, etc.
2. Triple E program Ireland is a program that set minimum criteria that products are required to meet to be listed[616]. The aim of the program is to ensure that 10-15% of the most energy efficient products are used. The program includes routers, switches, firewalls and optical transmission equipment.
3. TCO Certified certification of network equipment[610].

17.2 Market

Market data on enterprise network equipment (not only routers and switches) from various sources show high dispersions (all data are for worldwide sales):

- Mordor Intelligence values the market at 9.83 billion USD in 2020 and an expected increase to 15.48 billion USD by 2026[617]
- Fraunhofer[618] reports the market based on IDC data to be totally 43 billion USD in 2020, of which 22.5 billion USD are switches (incl. L3 switches) and 3.4 billion USD are routers.
- Free ICT Europe[619] reports sales based on data from ITCandor of 18.5 billion USD for LAN switches (i.e. L2 switches) and 11.8 billion USD for routers for 2019.

Based on the two latter sources, the global market size of routers and switches is assumed to be 26-30 billion USD and with an EU share of about 25-30%, the corresponding EU sales for 2020 is about 6 billion EUR. Due to the uncertainty of the figures and the overlap between the router and switch devices when including L3 switches with routing capabilities, the following assessments are based on merging routers and switches into one group.

[616] https://www.seai.ie/publications/ICT_Communications.pdf

[617] https://www.mordorintelligence.com/industry-reports/enterprise-network-equipment-market

[618] State of sustainability research for network equipment – Large Network Equipment - Enterprise Switches and Routers. Final Report. Fraunhofer IZM. April 2019.

[619] Personal information from Free ICT Europe to the study team.

Unit sales in 2019 were about 1.5 million and total stock same year was about 15 million, assuming an EU share of 27.5%.

Sales data from Fraunhofer[618] shows a small decline in the router sales, but increasing sale of switches (+10% from 2017 to 2020). Based on these data, an annual increase in sales of switches and routers is estimated at 2.4%.

Table 216 shows the calculated sales and stock data for routers and switches for 2020, 2025 and 2030 based on the above sources and assumptions. A lifetime of 10 years is assumed, see next section.

Table 216: Sales and stock data for routers and switches

Million units	2020	2025	2030
Sales	1.6	1.8	2.0
Stock	15	16	17

The total stock of routers and switches reported in the ICT Study for 2014 based on data from the Ecodesign Preparatory Study on Servers and Data Equipment is 7.4 million units. Extrapolating this to 2020 based on annual sales growth of 2.4% and 10 years lifetime, the resulting stock is 7.7 million units, where Table 216 reports 15 million units. Both figures involve many uncertainties, however, the figures in Table 2 are based on newer data and therefore used in the following. However, the study team recommends taking the uncertainty of this figure into account when assessing the overall saving potential and look further into sales and stock data, if a preparatory study should be carried out.

17.2.1 Product lifetime

The preparatory study presenting the lifetime of enterprise network equipment distinguishing between an economic lifetime and a technical lifetime. The two lifetimes are defined by the preparatory study as follows:

- The economic lifetime, which refers to the time after which equipment is renewed by the owner/operator for economic and business reasons (even if it is still functional); and
- The technical lifetime, that refers to the time after which the product does not function anymore and cannot be repaired.

For enterprise network equipment the preparatory study estimates that the economic lifetime is between 5-7 years and the technical lifetime is 15-20 years. A stakeholder informed that an economic lifetime of 10 years is typical, which also correlates well with the sales and stock data from previous section.

The most common reason for replacement before the end of technical lifetime is technological development regarding speed, functionality, capacity, etc.

According to the preparatory study, enterprise network equipment replacement before end of life should not take place on a regular basis, but should rather depend on the following four factors, which are thus determining the economic lifetime:

- Market innovation: In some cases existing product might become obsolete, because a technology upgrade is required. On the other hand, in the case of an increasingly standardized market or when facing a product with a small number of software features, it is more likely to observe extended product lives.
- Vendors' end-of-life (EOL) policies: The end of the support for hardware and software of the network equipment constitutes an issue for the operator, but it does not necessarily imply replacement of equipment given that the operator can turn to third parties for support.
- Operating costs: The introduction of more energy-efficient products, as well as of new lifetime warranties, among others, provides companies with a strong incentive to purchase new equipment; consequently, decreasing economic lifetime.
- Level of risk: Risks include downtime and security functionality.

17.3 Usage

Network equipment is a device that is providing connectivity and passing data through wired or wireless network interfaces. The enterprise network consists of physical and virtual networks and protocols that serve the dual purpose of connecting all users and systems on a local area network (LAN) to applications in the data centre and cloud well as facilitating access to network data and analytics[620].

Enterprises often run VPN software that encrypts user data when connecting with devices outside of a LAN. In addition, firewall software is used to inspect and control network traffic, both between the LAN and the wider world and with the network itself.

Enterprise networking relies on high-speed switching and routing devices that mediate data transfers between desktop computers, servers, applications, and services. A modern enterprise network consists of a common networking and security platform that provides a variety of networking services such as switching, routing, load balancing, firewalling, Wi-Fi, and service mesh for modern application. See previous Figure 68 for an illustrative sketch of the connecting equipment.

17.3.1 Performance

The performance of switches and routers is typically expressed in typology, bandwidth and ports.

Due to increasing demand in network speeds, there is a similar increasing demand in routers and switches supporting more bandwidth, especially 25 GbE (Gigabit Ethernet), 100 GbE and even up to 400 GbE.

Typical number of ports is 24 and 48 ports, where the latter is more common in larger enterprises.

17.3.2 Usage hours

Typically, network equipment is always on but with varying traffic load, which also result in variations on power draws, though this depends highly on the capability of reducing the

[620] https://www.vmware.com/topics/glossary/content/enterprise-networking

power draw with the amount of traffic passing through and of reducing power for unused ports.

A utilisation of the equipment is therefore estimated. The preparatory study on enterprise servers[607] did not specifically investigate the utilisation of routers and switches, however, they did investigate the utilisation of servers. Servers are accessed through routers and switches and the same utilisation is therefore assumed for enterprise network equipment. The preparatory study found that enterprise servers are in active mode for 16 hours a day with a 30% utilisation and in idle mode for 8 hours with 0% utilisation. The level of utilisation cannot directly be transferred from servers to network equipment, because a server can have a high utilisation factor without network traffic and the opposite. However, in lack of better data, we use these assumptions as an approximation of the network traffic.

17.4 Technologies

17.4.1 Types of equipment and functionality

Routers and switches are designed for different purposes depending on where they are placed in the network. In general, both routers and switches are inter-connecting devices in networking. The main objective of a router and a switch with routing capabilities is to connect various networks simultaneously, while the main objective of a switch is to connect various devices simultaneously[621].

A switch or a router placed in the core network will transfer much more data than access routers used to connect a few devices locally. The performance and thereby efficiency is therefore quite different for the different types of equipment. The energy efficiency rating (EER) is a metric generally defined as a functional unit divided by the energy used. The ETSI standard 203 136 use the unit Gbps/Watt, whereas ITU-T L.1310 use Mb/J. A higher EER corresponds to a better energy efficiency.

The different types of router and switches and the related typical efficiency is found in the ITU-T recommendations[622] and reported by the ICT Study as seen in Table 217 and Table 218.

The ICT Study also found that newer information that suggest core router efficiency has reached around 1000 Mb/J in 2017[623].

Table 217: Router efficiency[611]

Equipment	Sub type	Typical efficiency (Mb/J)
Router	Access router	12-50
Router	Edge router	35-100
Router	Core router	50-300

[621] https://www.geeksforgeeks.org/difference-between-router-and-switch/

[622] https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-L.1310-201707-I!!PDF-E&type=items

[623] Nokia 7950 Extensible Routing System

Table 218: Switch efficiency[611]

Equipment	Sub type	Typical efficiency (Mb/J)
Switch	Access switch	20-300
Switch	High speed	20-300
Switch	Distribution/aggregation	20-200
Switch	Core	50-400
Switch	Data centre	50-400

17.4.2 Barriers to lifetime extension

A recent study from Fraunhofer on enterprise network equipment[618] has investigated the lifetime and circular economy potential of the equipment. They stated that the evolving technologies can render the devices obsolete before their physical components wear down.

Some of the reasons for the early replacement are:

- Periodical (fixed) IT hardware update cycles (approx. every three years)
- Taxation or internal company policies
- High technological demands that the devices can no longer handle. This is often the case with cloud data centre operators or telecommunication providers.

However, the discarded hardware is not necessarily obsolete and there is typically still a demand for it on the market[624,625,626]. Other companies that require a lower bandwidth or computational power can still use the hardware and acquire refurbished products for a reduced price.

Most manufactures have already developed their own end-of-life polices[618] and have established a remanufacturing business (e.g. Cisco Refresh), offering certified remanufactured products[627]. According to Cisco CSR report 31% of their models are refurbished, resold, or reused[628]

There exist at rather large aftermarket (which include software and hardware maintenance, consultancy, repair and resale), in Europe for ICT equipment, which is estimated to be worth more than 39.3 billion EUR, which corresponds to 16% of the total market for IT services in Europe, according to a study carried out by Deloitte at the request of Free ICT[625]. According to the study requested by Free ICT, about 45% of companies used third party maintainers (TPM) in 2015 to maintain their routers and switches. Furthermore, according to the study, TPMs play a vital role in supporting end-of-life-services when OEMs no longer support series, either primary or extended. According to the study from Free ICT, OEMs do not have any incentives to extend the life of equipment, as they often want to push new products to the market. A survey carried out in the Free ICT study, showed that TPM prices are 80% lower than OEM prices after seven years. This is supposedly due to OEMs increasing the price for support of older equipment to incentivize companies to switch to new products.

[624] https://www.greenit-solution.de/refurbished-so-wird-gebrauchte-hardware-wieder-fit
[625] ICT Aftermarkets in Europe, prepared by Deloitte at the request of Free ICT. July 2019.
[626] https://www.aliternetworks.com/
[627] https://www.cisco.com/c/en/us/products/remanufactured.html#~stickynav=1
[628] https://www.cisco.com/c/dam/assets/csr/pdf/CSR-Report-2018.pdf

The Free ICT study carried out a survey that pointed at the following obstacles that limits the extension of lifetime of the network equipment and other circular economy options:

- Restricted access (or delayed access) to input needed for the maintenance of hardware and software (firmware, microcode, spare parts, documentation etc.)
- Limited access to diagnostics tools
- Manufactures maintaining reinstatement fee penalties
- Disclosed limited information on products sold.

The obstacles mentioned above can lead to serious reductions in the potential of reusing the equipment. In a survey carried out by the study requested by Free ICT, two thirds of companies have reported that they would have kept at least 25% of their equipment if the OEMs would have continued to support it.

17.5 Energy, Emissions and Costs

17.5.1 Energy consumption

Fraunhofer IZM has investigated the energy consumption of enterprise switches and routers in April 2019[618] in a report for the Green Electronics Council and TÜV Rheinland and found that current products only report maximum rated power and not operational energy consumption data. The actual energy consumption depends on various factors such as configurations and traffic load. Furthermore, many enterprise switches support PoE (Power over Ethernet) i.e. supplying power to e.g. Wi-Fi access points in the organisation, but this power draw should naturally not be included in energy consumption figures for the switches. However, the efficiency of the power supply is relevant to reduce the conversion losses.

Fraunhofer identified the energy consumption as being reliable on the following factors:

- Switches and routers are typically run in active or idle mode 24/7.
- Use of sleep modes is not very common. However, power savings are possible, when using the IEEE 802.3az standard, the Energy Efficiency Ethernet (EEE) standard providing a Low Power Idle (LPI) mode for copper-based Ethernet connectivity.
- Power consumption is influenced by the conversion efficiency of the power supply unit. The standard 80 Plus provides a basis for energy efficiency requirements[629]. For switches and routers, a good practice is 80 Plus Gold certified power supply units allowing for high power efficiency even in the lower partial load range when a product is idling.
- Power consumption is often not scaling with the installed number of ports or throughput capacity and different types of ports draw different amounts of power.
- Power consumption is influenced to a considerable extent by the network controller (compute capacity) and buffer (memory capacity) configurations, which can vary substantially.
- Power consumption is also influenced by the fan unit configuration. Large diameter fans are typically more efficient due to the lower number of revolutions. The form factor (height) of the switch chassis determines the dimensions of the fans. Load adaptive fans are state of the art.

[629] https://www.plugloadsolutions.com/80PlusPowerSupplies.aspx

- Power consumption is influenced by the ambient (inlet fan air) temperature. The thermal conditions under which an IT equipment including switches can be safely operated are standardised by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). Higher allowed temperatures in the data centre where the units are placed reduces the data centre cooling needs, but at the same time increases typically the active fan cooling for the switches and routers by requiring a higher speed of the fan units.

For assessing the energy consumption of switches and routers at EU level, the study team has used data from the ICT Impact Study[611], which recently analysed the energy consumption of data centre equipment using data from acknowledged studies, such as US research[630] reported among others in Science[631].

The energy consumption of network port usage was investigated for network equipment in data centres only. The network port usage (energy consumption related to switches and routers) can be seen in Table 219.

Table 219: Annual energy consumption in use phase of data centre switches and routers. Source: ICT Study. Figure for 2030 is extrapolated by the study team with the development 2020-2025.

	Energy consumption, TWh/year			
Product	**2015**	**2020**	**2025**	**2030**
Routers and switches in data centres only	0.53	0.74	1.06	1.52

To verify these data, the energy consumption for network equipment (0.74 TWh/year, 2020) can be compared to the total energy consumption for data centres the same year (also reported in the ICT Impact Study), 39.5 TWh/year. The proportion for network equipment is around 2%. This is close to what other sources report for network equipment[632,633].

In addition to being an energy consuming product, network equipment is also an energy related product when placed in a data centre, where the equipment impacts the energy consumption for cooling, UPS units and power distribution. Network equipment placed in enterprises may also be cooled and be connected to UPSs. If adding the overhead of cooling etc., the total energy consumption for 2020 increases from 0.74 TWh/year to 1 TWh/year (average PUE=1.39)[611] for 2020.

The Ecodesign Preparatory Study on Enterprise Servers and Data Equipment[607] found that around 18% of the shipped ports for switches are installed in data centres. The energy consumption found in the ICT Impact Study is therefore scaled up from 18% to 100% to reflect the energy consumption of all the switches and routers in the market, see Table 220. The table also shows the total energy consumption including for cooling and UPSs. Overhead for cooling etc. is assumed for 1/3 of devices used outside data centres[634]. The PUE for 2020 is extrapolated from 2020 to the other years presented in the table.

[630] Researchers from Lawrence Berkeley National Labs, Stanford (Jonathan Koomey), Northwestern University, University of California. Support from the US Dept. of Energy.

[631] https://science.sciencemag.org/content/367/6481/984

[632] https://energyinnovation.org/2020/03/17/how-much-energy-do-data-centers-really-use/ (3% for network equipment).

[633] United States Data Center Energy Usage Report. 2016. (2% for network equipment)

[634] Study team's own estimation based on expert experience.

Table 220: Annual energy consumption in use phase of all enterprise and data centre switches and routers. Sources: ICT Study and Ecodesign Preparatory Study on Enterprise Servers and Data Equipment. Figure for 2030 is extrapolated with the development 2020-2025.

	Energy consumption, TWh/year			
Product	**2015**	**2020**	**2025**	**2030**
All routers and switches	2.94	4.11	5.89	8.44
All routers and switches, incl. cooling etc.	3.61	4.84	6.83	9.59
PUE	1.50	1.39	1.35	1.30

17.5.2 Material efficiency

The study team has based the assessments of material efficiency aspects on the Fraunhofer IZM study carried out in 2019[618]. It concluded that no comprehensive and up-to-date LCA studies on lifecycle impacts for enterprise switches and routers were available. Instead, Fraunhofer used LCA data for a similar network product for fibre-optic communication (a wavelength-division multiplexing (WDM) device)[635], which is considered to be a comparable product to enterprise switches and routers from a material perspective (PCB, ports, chassis etc.).

The overall result from this study of the LCA can be seen in Figure 69 showing that for most of the environmental performance factors, the use phase is the largest contributor in a lifetime perspective.

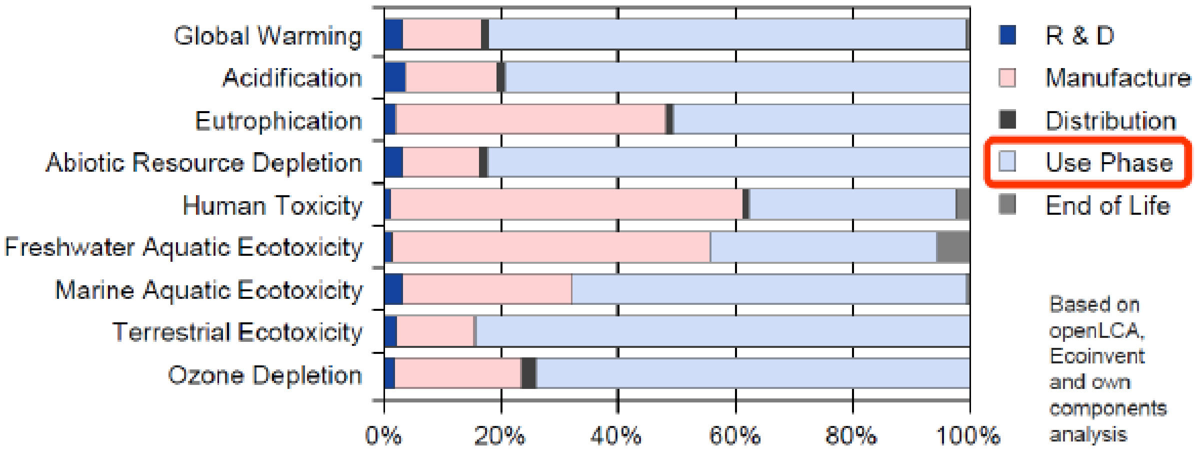

Figure 69 - LCA of a network product comparable to enterprise switches and routers[635]

The percentage distribution of GHG gasses (Global Warming) on manufacture (incl. materials) and use phase from Figure 69 have been used to estimate the amount of GHG related to materials for the switches and routers, which is 14%. This corresponds to approximately 43 PJ/year for 2030.

[635] Source: Dr. Klaus Grobe, Director Global Sustainability, ADVA Optical Networking, Improved Sustainability in WDM Transport-Network Elements, presented at Electronics Goes Green 2016+, Berlin, September 2016; https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7829807

In the next section this percentage has been applied on the total GHG emissions for the lifetime use phase.

17.5.3 Total energy consumption and GHG emissions

The annual electricity and primary energy consumption for routers and switches without and with cooling etc. are presented in Table 221.

Table 221: Annual electricity and primary energy consumption for routers and switches without and with cooling etc. EU-27, 2030.

Product	ENERGY INPUT (use phase 2030)	
	Electricity	Primary energy[636]
	TWh/year	PJ/year
All routers and switches	8.44	64
All routers and switches, incl. cooling etc.	9.59	73

GHG emissions based on the electricity consumption in the use and embedded in stock material (14% of 10 years lifetime emissions, see previous section) can be found in Table 222.

Table 222: GHG emissions related to primary energy for electricity consumption and embedded in stock material (not incl. equipment for cooling etc.). EU-27, 2030.

Product	GHG EMISSIONS	
	From the electricity consumption Mt CO_2e/year	From the materials (stock) Mt CO_2e
All switches and routers	3.2	4.5
All routers and switches, incl. cooling etc.	3.7	4.5

17.6 Saving potential

Saving potentials have been assessed for both energy consumption in use and materials.

17.6.1 Energy in use phase

Many opportunities exist to improve the energy efficiency of switches and routers. Lack of regulations apart from the US Energy Star certification for large network equipment and lack of test standards until recently may have resulted in less focus on energy efficiency of these products.

In the following, we present energy efficiency options from various sources followed by quantification of the options.

[636] CC factor 2.1

Energy efficiency design options
Main requirements in the Energy Star specification include:

- Power supply efficiency criteria
- Energy efficiency feature requirements (remote port administration, adaptive active cooling, energy efficient Ethernet)
- Active state data reporting
- Standard performance data measurement and output requirements

Fraunhofer recommends in their study[618] the following measures on energy efficiency:

- Power supply efficiency requirements (with high conversion effectiveness also in partial load)
- Low power idle
- Other power management options for load-adaptive equipment utilization
- Hardware configuration that allows for higher operating/inlet temperature (less cooling on room level) combined with more effective internal cooling by load-adaptive and highly energy-efficient fans.
- Energy efficiency performance indicators (metrics) assessing the overall energy efficiency.

As energy efficiency performance indicators, Fraunhofer recommends considering an energy efficiency metric like the existing TEER[637] (Telecommunications Energy Efficiency Ratio) and improved methodologies based on ETSI standards.

Cisco has also created recommendations on energy efficient networking solution:

- Optimized power supplies – efficient and right-sized for the deployment
- Intelligent power management
- Maximising the number of PoE (Power over Ethernet) devices supported per switch
- Optimized use of power across the entire network
- Power consumption as it relates to networking services provided
- Features that can foster sustaining behaviours and operational practices.

Based on the above, the following main energy in use saving design options are considered as very relevant as a basis for potential Ecodesign implementing measures for enterprise switches and routers:

- Power supply efficiency criteria, also taking power supply to PoE devices into account, aiming at reducing losses in the power supply.
- Active state minimum efficiency requirement based on a performance efficiency indicator, aiming at reducing the overall power consumption in active state.
- Power management requirements such as adaptive active cooling, and energy efficient Ethernet, aiming at powering down circuitries etc. partly or fully in dependency of the traffic load.

Energy efficiency quantification
The study team has quantified the energy efficiency design options at an overall level by assessing opportunities for the active state and for powering down at low loads. Reducing power supply losses will impact both areas.

[637] ITU-T L.1310 Energy Efficiency metrics and measurements methods for telecom equipment (including routers and switches).

Only few measured data were available for this quantification, however, these provide illustrative examples of the level of energy savings to be achieved.

The main dataset is the Energy Star database for certified products, which only contains 39 switches that so far have been Energy Star certified in USA; all Dell and Dell EMC. This may be an indication of no interests from manufacturers and/or clients in energy efficiency; or difficulties in complying with the requirements.

The switches have been tested according to the Energy Star test method for large network equipment[609] and power and traffic load data were reported for 19 of them. We have used these data as part of the input for assessing the savings.

Energy Star certified products should represent the most efficient products on the market i.e. savings estimated in the following based on the Energy Star data, should reflect the minimum achievable and for the average products in the market, the savings would be larger.

Active state

Figure 70 shows the active state intensity (W / Gb/s) for each of the 19 switches with full port configuration and full load throughput.

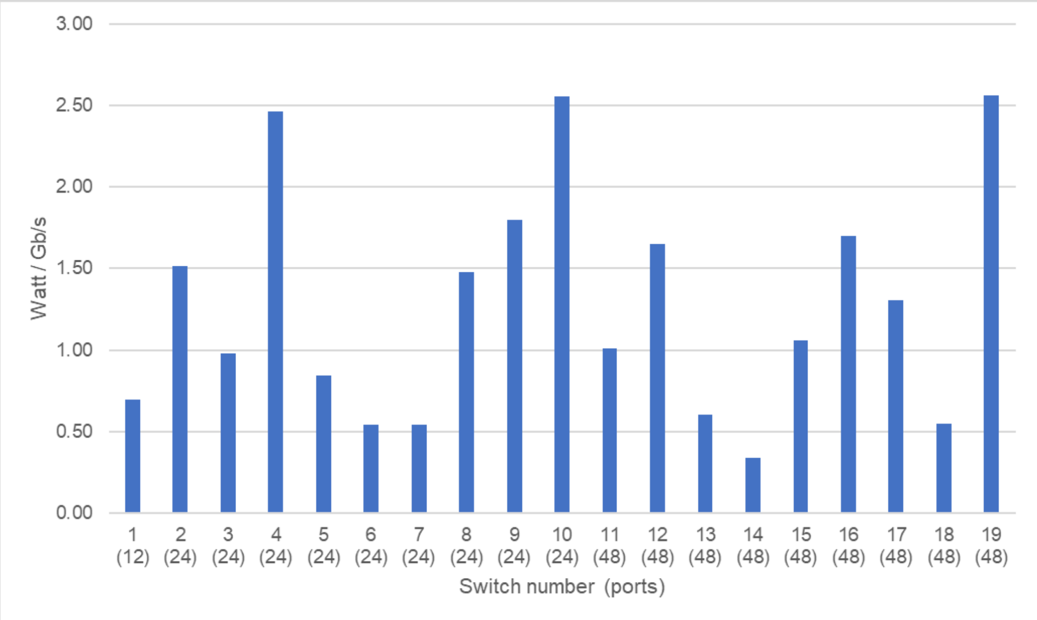

Figure 70: Active state intensity (W / Gb/s) for each of the 19 switches. Port numbers for each switch is indicated. Full port configuration and full load throughput.

It can be seen that there is a large variation in power consumption per traffic unit. It has not been possible to verify if other features have impacted the power consumption. The average active state intensity is 1.27 W / Gb/s. If the most consuming products were improved e.g. by setting a cap at 1.5 W / GB/s, the average would be reduced to 1.08 resulting in average savings of 16%. If the cap was set at 1 W / GB/s, average savings would be 21%.

Another example from the literature review is from Cisco, who has reported results of 24 hours test comparing energy consumption of similar enterprise switches to show differences in energy consumption between similar products on the market. Tests were made for three groups of switches and configurations, so the two or three switches tested for each group had the same technical specifications and the power consumption could be compared. They were tested in idle and under load to simulate a typical day and night. See results in Table 223.

Table 223: Energy consumption comparison of switches[638]

Model switch	Power (Watts)		Index (power current / power highest)	
	Idle	Under load	Idle	Under load
Cisco Catalyst 6509E	2,259	2,279	1.00	-
Nortel ERS 8610	1640.8	-	0.73	-
Cisco Catalyst 4507R-E	658	658	0.78	0.72
Nortel ERS 8310	845	915	1.00	1.00
Cisco Catalyst 3750E-48PD	116.1	138.2	0.85	1.00
Nortel ERS 5520-48T-PWR	137	137.1	1.00	0.99
Nortel ERS 4548GT-PWR	96.6	97.7	0.71	0.71

The table shows that selecting the switch with the lowest consumption compared to the one with highest consumption in each group would save from 22% to 29% depending on the group and the load (idle or full load).

The large difference in energy consumption is also supported by a blog post written by RouterSwitch Tech in 2015[639] reporting test results from Miercom that Cisco Catalyst 2960-X and XR switches saved over 50% in annual energy operating costs compared to the industry average.

Power management

One main saving opportunity for switches and routers is reducing the power consumption when less performance is needed i.e. reduced traffic load. This is a development that has been ongoing for years for mobile devices such as laptops, tablets and mobile phones aiming at increasing battery lifetime. In recent years, the development has also taken place for desktop computers and servers. However, it seems that the development has still not broadly come to large network equipment.

One measure to reduce the power consumption at low load is the Energy Efficient Ethernet (EEE) standard introduced by IEEE in 2010. It aims to reduce the power consumption of EEE ports by transitioning Ethernet ports into a low power mode when traffic is not present[640]. A study on assessing the impact of EEE standard on energy consumed by commercial grade network switches found that the average utilization rate of Ethernet links is 30% in data centres and the saving potential of EEE at port level is very large[640].

The test in the EEE standard study shows that an EEE port runs at 12-15% of its total power at full load when in low power mode. Therefore, the power savings can exceed 80%

[638] https://www.cisco.com/c/dam/en/us/solutions/enterprise-networks/C02-502519-00_GreenNrg_BR_v5a.pdf

[639] https://blog.router-switch.com/2015/04/ws-c2960x-48td-l-ws-c2960xr-48td-i-tested-from-miercom/

[640] Assessing the Impact of EEE Standard on Energy Consumed by Commercial Grade Network Switches - January 2019 https://www.researchgate.net/publication/327975786_Assessing_the_Impact_of_EEE_Standard_on_Energy_Consumed_by_Commercial_Grade_Network_Switches

when there is no traffic. However, the study also found that the power consumption of a single port represents less than 1% of the total power consumption of the switch, i.e. about 24% or 48% for a 24-port and 48-port switch as a rough estimate. Based on these figures, 80% savings of the power consumption for the ports would give almost 20% savings for a 24-port switch and almost 40% for a 48-port switch.

The study team has further analysed the data in the Energy Star database for certified switches (see above) reporting measured power data for full load, 30% load and very low utilisation for full-port configuration. See Figure 71. Lowest power reduction is 1% and highest 15%. Weighted average reduction is 6%. The conclusion is that not many of the products scale down power consumption at low traffic loads and that the reduction is quite low.

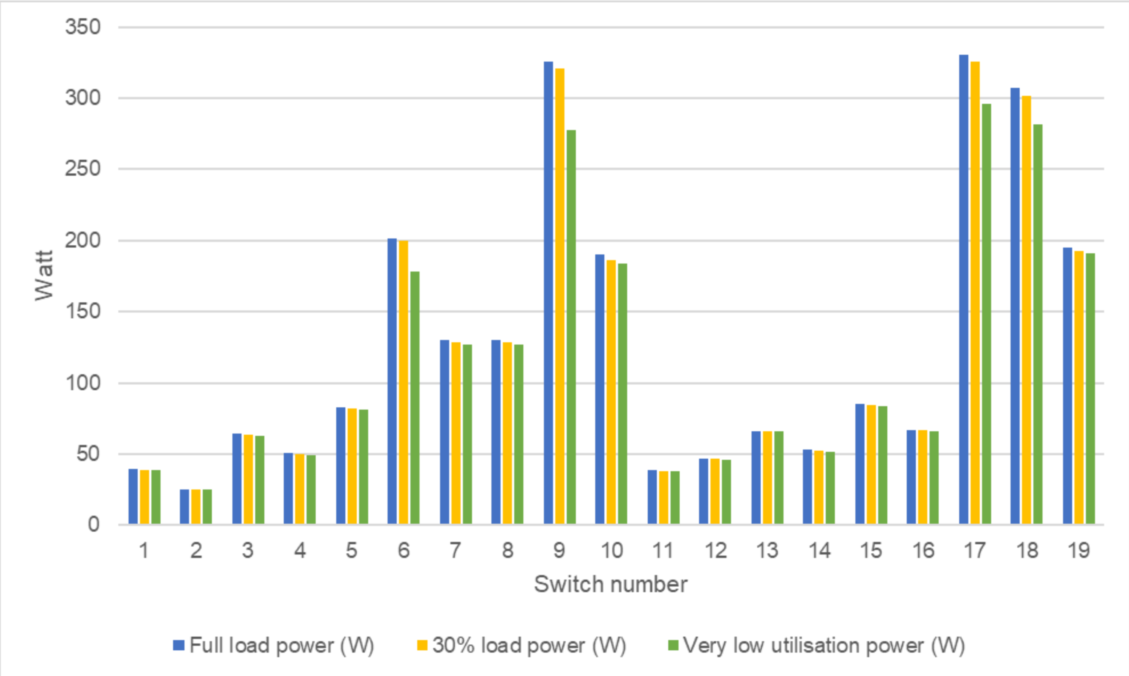

Figure 71: Measured power draw at three load levels for 19 switches in the Energy Star database.

No power data for half-port configurations were report and it was therefore not possible analyse possible power reductions through powering down ports.

<u>Total energy saving potential</u>

Based on the assessment above, the study team has estimated that 30% energy savings can be achieved in average for this product group. Applying this percentage on the energy consumption for the product group provided in Table 6, estimated annual savings are presented in Table 10. The savings will be achieved for the power consumption of the switches and for the related cooling etc.

Table 224: Estimated annual savings related to in use energy consumption of all enterprise and data centre switches and routers, EU-27, 2030

	ENERGY INPUT	GHG EMISSIONS

Product	Annual electricity savings TWh/year	Annual primary energy savings PJ/year	Annual CO2 savings Mt CO2e/year
All switches and routers, incl. cooling etc.	2.9	21.9	1.1

17.6.2 Materials

An opportunity for material related savings exists for product lifetime extension of enterprise switches and routers, since there is a large gap between the economic product lifetime and the technical lifetime (50%-100% longer technical lifetime compared to economic lifetime), as described in Section 17.2.1. Extending the lifetime of enterprise switches and routers can therefore significantly reduce the emissions related to materials. The level of increased product lifetime and the benefits achieved has however to be balanced against typically higher energy in-use energy consumption for older products compared to newer products. Furthermore, the technological development may require newer and more performing products, though there may still be areas where older, and lower performing products are still useful.

In section 17.4.2 some of the problems related to aftermarket sales were identified. These obstacles limit the possibilities for reaching the potential of the technical lifetime of the products. The Fraunhofer study and material requirements set in the some of the latest regulations are suggesting the following initiatives to prolong the lifetime of equipment:

- Easy disassembly
- Availability of spare parts and software (for repair and reuse) and short delivery times
- Exchangeability of drives and mass storage devices
- Data deletion
- Product take-back systems

Regarding increased recycling of enterprise switches and routers it requires disassembly of the products with commonly available tools with the following benefits:

- Facilitate the separation of components requiring selective treatment in accordance with Annex VII of the WEEE Directive (e.g. printed circuits boards larger than 10 cm2);
- facilitate the separation of components that could be prepared for reuse / remanufacturing; and of
- components with valuable CRM that would need a dedicated recycling process.

As mentioned already in section 17.4.2 there is already quite a large aftersales market for switches and routers. One example is the German company Green IT solutions[641], who sells refurbished hardware and provide up to 10 years guarantee on the refurbished products.

[641] https://www.greenit-solution.de/refurbished-so-wird-gebrauchte-hardware-wieder-fit

Based on the above, the following material saving design options are considered as very relevant for potential Ecodesign implementing measures for enterprise switches and routers:

- Easy disassembly for repair or reuse purposes
- Availability of firmware and security updates for a number of years after placing the product on the market, e.g. eight years as it is for servers and data storage products in scope of the Ecodesign regulation
- Availability of spare parts and short delivery times, e.g. for eight years as mentioned above
- Exchangeability and upgradability for relevant component such data storage, ports, etc.
- Availability of functionality for secure deletion of data contained in data storage
- Information on presence of critical raw material for the purchasers, recyclers, etc.

In lack of other sources on average material saving potential, based on stakeholder input, the study team has estimated that 5%-10% material savings can be achieved in average for this product group. Applying average of this percentage (7.5%) on the primary energy and GHG emissions related to input of materials, the result is presented in Table 225.

Table 225: Estimated primary energy and GHG emission savings related to stock material. EU-27, 2030

Product	MATERIAL	
	Primary energy savings	CO2 savings
	PJ	Mt CO2e
All switches and routers	3.2	0.34

17.7 Stakeholder comments

Comments were received from the following stakeholders:

- BAM and UBA
- Danish Energy Agency
- ECOS-EEB-Coolproducts-CLASP
- Free ICT

The following comments were provided; the study team's answers are provided for each of them:

- Request to include WAN Optimisers in the scope: WAN (Wide Area Network) optimization comprises technologies (hardware and cloud-based solutions) for increasing efficiency of data transfer across the WAN e.g. for connecting organisations different locations including the organisation data centre. WAN Optimisers have not been included here because the focus was on routers and switches. WAN Optimisers comprise both hardware and software solutions and it may therefore be more difficult to define a scope for. In any case, if a preparatory study should be carried out, WAN Optimiser hardare could be considered.

- For products with PoE (Power over Ethernet) functionality, the efficiency of the energy supply by the switch should also be in the focus: The power supply was already included, however, text has been added to make it clearer.
- The scope should be clearer regarding network equipment for hyper scale data centres: The scope includes hyper scale data centres and the text has been revised to make it clearer.
- Calculation of the total energy use of network equipment appears to be too uncertain: The study team has updated the calculations based on further inputs and correlated with several sources.
- Assumption for GHG and material estimates appears very fragile: The assumptions have been rechecked, however, no further sources were identified. Within the scope of this study, it has not been possible carry out further assessments.
- Energy saving potentials are uncertain: The study team has updated the calculations based on further inputs and correlated with several sources.
- Material saving potentials are uncertain: The assumptions have been rechecked, however, no further sources were identified. Within the scope of this study, it has not been possible carry out further assessments.
- The market seems to be one of least open markets as there is hardly any public available data for example about the number of products placed on the market and figures and minimal product information about energy consumption. The inclusion within Ecodesign is of high importance: The study team agrees that public data on this product group is very scarce.

18 SMALL NETWORKING EQUIPMENT FOR HOME AND OFFICE USE

18.1 Scope, policy measures and test standards

Small networking equipment such as modems, gateways, routers, switches and access points was a part of the Working Plan study 3[642]. In this study, the focus was on on-mode consumption as standby was already regulated, and the study was performed before the first Circular Economy Action Plan was published. The conclusion was that only gateways had a significant energy consumption; energy consumption for all other equipment network equipment was negligible. Gateways (home network equipment) were therefore carried on to further assessments in the Working Plan study Task 4 and recommended for regulation. The actual Working Plan included this product group for a further ICT study ("The ICT Study") together with other ICT product groups. The first part of the study has been finalysed.[643]

In the current working plan study, the name "gateway" is used for products that connect IoT devices e.g. light bulbs and thermostats to the home network (when they are not connected durectly to a a Wi-Fi access point, which is less tupical) and not as gateways from the home network to the internet. This follows current practice.

With recent advancements in smart homes, high-speed internet connections, technologies such as mesh networks and increased use of internet connections for streaming, use of cloud services etc., it is assumed that more households will have more products that are connected to a local network and the internet and will need high quality wireless connections from all locations in the home and in the offices. Furthermore, IoT devices are coming into the homes and offices and they are typically connected to the local area network via gateways (often Zigbee or Z-wave). There is a risk that multiple gateways are needed to connect different products such as blinds, thermostats or light bulbs of different brands, increasing energy consumption and consumption of other resources.

Additionally, small networking equipment consists of a high share of electronics, which includes valuable and scarce resources in varying amounts depending on the grade of the printed circuits boards.

The networking equipment is a diverse group of products, and it can be difficult to group them in representative base cases. In Table 226 the defined products group in the ICT Study is presented.

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[642] Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC. Task 3 Final Report. 2015

[643] ICT Impact study. Prepared by VHK and Viegand Maagøe for the European Commission. July 2020.

Table 226: Product groups in the ICT study

Product	Description
Home Network Attached Storage equipment (NAS)[644]	One or more dedicated storage devices that are connected to a network and provide file access services to remote computer systems.
Home/Office Network Equipment[645]	A device whose primary function is to pass Internet Protocol (IP) traffic among various network interfaces/ports intended for use in residential and small business settings. The equipment provides a Local Area Network (LAN) where devices such as computers can connect to a Wide Area Network (WAN) such as the internet.
	Modem: A device that transmits and receives digitally–modulated analogue signals over a wired or optical network as its primary function. **Router/wireless router:** A network device that determines the optimal path along which network traffic should be forwarded as its primary function. Routers forward packets from one network to another based on network layer information. Devices fitting this definition may provide both Router functionality and wireless network capability.
	Switch: A network device that filters, forwards, and floods frames based on the destination address of each frame as its primary function. The switch operates at the data link layer of the OSI model.
	Integrated access device (IAD): A network device with a modem and one or more of the following functions: wired network routing, multi-port Ethernet switching and/or access point functionality.
IoT Cellular Gateway[646]	An IoT cellular gateway is a data communication device that provides a remote network with connectivity to a host network. The IoT Cellular Gateway is connected to the host network through the mobile network, also known as Radio Access Network (RAN).
IoT home/office Gateway	An IoT home/office gateway is a data communication device that provides a remote network with connectivity to a host network. The IoT home/office Gateway is connected to a Local Area Network through the Home/Office Network Equipment. Several wireless protocols exist, such as Zigbee and Z-Wave.
Internet of Things (IoT) (not in scope)	Computing devices embedded in everyday objects that can access and be accessed via a local area network and often also the internet. E.g. a smart-light bulb, washing machine, speaker or IoT equipment used for industrial purposes or smart city solutions.

In addition to the products in the table above, a broad range of products exists:

- Single-purpose products to extend the Wi-Fi coverage such as homeplugs/ Power-Line adapter (internet over powerlines) with passthrough, different types of Wi-Fi extenders/boosters and products to create a wireless connection for IPTV set-top boxes (bridge mode) and indoor and outdoor cells to improve 4g/5g coverage[647]
- Multipurpose products such as Google Nest Wi-Fi/Orbi Voice Smart Speaker (Mesh router with a built-in speaker and Google Assistant/Alexa), travel routers with built-in power banks, light bulbs with a built-in Wi-Fi extender and complex set-top

[644] Definition taken from Energy Star: https://www.energystar.gov/ia/partners/product_specs/program_reqs/StorageV1.0_Program_Requirements.pdf?cb43-b421

[645] Definitions taken from Energy Star: https://www.energystar.gov/products/office_equipment/small_network_equipment/key_product_criteria

[646] Definition from Techopedia: https://www.techopedia.com/definition/5358/gateway

[647] https://www.ericsson.com/en/networks/offerings/urban-wireless?gclid=Cj0KCQjwz4z3BRCgARIsAES_OVdAf7HOHYRUhtm8ZNhckkzacKTJs_RgGHFnL6O55ML_mYSekqeykRAaAi97EALw_wcB&gclsrc=aw.ds

boxes. Also, some products such as a laptop or a Raspberry Pi can function as an IoT home/office Gateway by adding a Zigbee or Z-wave dongle.

Most of these products already fit with the definitions suggested in the ICT study. Hence, the products groups for the ICT study form the scope of the current assessment. However, the combined number of products may be even greater than reported in section 18.2.

Of other relevant regulations, standard and other initiatives, the following is considered relevant for the products in scope:

g) Regulations

1. Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for standby and off mode, and networked standby, electric power consumption of electrical and electronic household and office equipment

h) Standards

1. EN 50564:2011[648] specifies methods of measurement of electrical power consumption in standby mode(s) and other low power modes (off mode and network mode), as applicable. It is applicable to electrical products with a rated input voltage or voltage range that lies wholly or partly in the range 100 V a.c. to 250 V a.c. for single phase products and 130 V a.c. to 480 V a.c. for other products. The objective of this standard is to provide a method of test to determine the power consumption of a range of products in relevant low power modes.
2. EN 50643:2018/A1:2020 specifies methods of measurement of electrical power consumption in networked standby and the reporting of the results for edge equipment. Power consumption in standby (other than networked standby) is covered by EN 50564, including the input voltage range. This European Standard also provides a method to test power management and whether it is possible to deactivate wireless network connection(s).

i) Other initiatives

1. EU Code of Conduct on Energy Consumption of Broadband Equipment V 7.1 (2020)[649]. This Code of Conduct sets out the basic principles to be followed by all parties involved in broadband equipment, operating in the European Community, in respect of energy efficient equipment. Expectations are that broadband equipment will contribute considerably to the electricity consumption of households in European Community in the near future. Depending on the penetration level, the specifications of the equipment and the requirements of the service provider, a total European consumption of at least 50 TWh per year was estimated for the year 2015 for broadband equipment. With the general principles and actions resulting from the implementation of this Code of Conduct the (maximum) electricity consumption could be slightly reduced or kept constant compared to a business as usual scenario with growing usage and penetration of broadband equipment in the EU.

[648] https://www.cenelec.eu/dyn/www/f?p=104:110:1190755971975601::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1257245,45888,25

[649] https://e3p.jrc.ec.europa.eu/publications/eu-code-conduct-energy-consumption-broadband-equipment-version-7-0

Voluntary Industry Agreement to improve the energy consumption of Complex Set Top Boxes within the EU. This Voluntary Agreement aims at reducing the potential electrical load represented by this equipment and at ensuring that the electrical efficiency of equipment required to support digital TV and related services is maximised. This Voluntary Agreement lays down energy consumption requirements for CSTBs. It is complemented by a Code of Conduct on Digital TV which should be endorsed by any Signatory to this Voluntary Agreement aspiring to the best possible outcomes in the area of energy consumption. The voluntary agreement is foreseen to be terminated.

2. ENERGY STAR for Small Network Equipment provides specifications that will help to differentiate more efficient products across six types of network equipment found in great numbers in homes and small offices. The six types of network equipment are broadband modems, IAD's, optical termination Devices (ONT), access points, routers and switches. In addition to recognising equipment that meets rigorous low traffic rate efficiency criteria, this specification incentivises the implementation of two energy-saving capabilities, Energy Efficiency Ethernet and External Network Proxy, that further product and network system efficiency. When testing small network equipment, the following test methods shall be used: ENERGY STAR Test Method for Small Network Equipment, Rev. Nov-2013. In addition, it should be noted that only one product is available on the product finder on ENERGY STAR homepage.

18.2 Market

The market data is based on data from the ICT study and crosschecked with the Eurostat PRODCOM statistics, which were used in the previous working plan study[650]. In the Eurostat PRODCOM statistics, two relevant data sets are available:

- 26.30.23.20: "Machines for the reception, conversion and transmission or regeneration of voice, images or other data, including switching and routing apparatus"; and
- 26.12.20.00: "Network communications equipment (e.g. hubs, routers, gateways) for LANs and WANs and sound, video, network and similar cards for automatic data processing machines".

These two categories are not clearly defined and are not considered to cover the entire market. Also, a lot of data gaps is present in the statistics, and only data from a few countries are available and only data from production. No data were available regarding import and export, which indicates that the Eurostat PRODCOM statistics underestimates the sales of small networking equipment for home and office use as a high share of these products are assumed to be produced outside of Europe. In Table 227 the available sales data from PRODCOM is presented.

Table 227: Sales data from PRODCOM

Year	Sales (units x 1000)				
	2010	2015	2016	2017	2018

[650] Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC. Task 3 Final Report. 2015

26122000 - Network communications equipment (e.g. hubs, routers, gateways) for LANs and WANs and sound, video, network and similar cards for automatic data processing machines	1770	8516	8646	6511	6950
26302320 - Machines for the reception, conversion and transmission or regeneration of voice, images or other data, including switching and routing apparatus	52176	35729	37009	33004	30967
Total	**53945**	**44245**	**45655**	**39515**	**37917**

The sales values from the ICT study are based on the Ecodesign Impact Accounting (EIA) status report[651], forecasted values reported by ABI Research on IoT home/office gateways, and estimations. Table 228 shows the estimated unit sales of small networking equipment for home and office use from the ICT study.

Table 228: Sales data from the ICT study

	Sales (units x 1000)				
Year	**2010**	**2015**	**2020**	**2025**	**2030**
Home Network-attached storage equipment (NAS)	2814	4824	6834	8844	10854
Home/office network equipment (modems, routers IAD's and switches)	30914	39858	48803	57747	66692
IoT Cellular Gateway	n.a.	n.a.	5284	n.a.	n.a.
IoT Home/Office Gateway	n.a.	n.a.	17276	n.a.	n.a.
Total			**78198**		

In 2020, small networking equipment for home and office use is assumed to represent a sales volume of 78 million units per year according to the ICT study. From the PRODCOM data, it seems that the sales are falling and assumed to be in the range of 30-40 million units (only half of the sales from the ICT study). The difference in sales values could be due to the missing information in PRODCOM (import, export and data gaps from the majority of the European countries). Hence, the data from the ICT study is assumed to be representative of the current situation with increasing sales. The stock from the ICT study is used, which is presented in Table 229. It should be noted that the average lifetime is assumed to be 5 years.

Table 229: Stock from the ICT study

	Stock (units x 1000)				
Year	**2010**	**2015**	**2020**	**2025**	**2030**
Home Network Attached Storage equipment (NAS)	10050	20100	30150	40200	50250
Home/office network equipment (modems, routers IADs and switches)	136580	181403	226125	270848	315570

[651] https://ec.europa.eu/energy/sites/ener/files/documents/eia_status_report_2017_-_v20171222.pdf

IoT Cellular Gateway	n.a.	n.a.	19355	n.a.	n.a.
IoT Home/Office Gateway	n.a.	n.a.	60159	n.a.	n.a.
Total			**335789**		

In 2020 the installed stock of small networking equipment for home and office use is assumed to be 335.8 million units from the ICT study, which will increase towards 2030 due to the expected increase in sales. However, not all products in scope are represented in the ICT study. Regarding the stock of other relevant products, the following stock is assumed:

- Complex set-top boxes – a stock of 113 million is assumed in 2020[652]
- Wi-Fi extenders, powerline adapters and other small products are assumed to have a sales and stock similar to IoT Home/Office Gateway with a stock of approximately 60 million in 2020.

The combined stock is assumed to be 509 million pieces of equipment.

The average prices of these products are based on the previous working plan study and estimations based on the price of common products in the product category. The assumed average prices are:

- Home Network Attached Storage equipment (NAS) – 300 EUR
- Home/office network equipment – 75 EUR[653]
- IoT Cellular Gateway – 50 EUR
- IoT Home/Office Gateway – 100 EUR
- Complex set top boxes – 100 EUR[654]
- Other equipment (Wi-Fi extenders, powerline adapters and other small products) – 30 EUR

18.3 Usage

The typical user of small networking equipment for home and office use is in principle all residents in Europe as the stock indicates that the penetration rate is approximately 2.3 meaning that the average household owns more than one type of equipment that can be considered as part of the scope. However, some households may have a mesh network with multiple routers, different IoT gateways, a complex set-top box and a NAS device ("superuser"). In contrast, other households may only have an integrated access device (casual user) or no equipment at all.

The products are typically only in active mode (payload traffic passing) for a limited time during the day. When the products are not in active mode, they are rarely switched off. Instead, the products are assumed to be in idle mode, standby or networked standby. Most of the products (all products except NAS) are expected to have the same use pattern and approximate level of energy consumption[655]. The use pattern and power consumption are presented in Table 230 and Table 231 based on data from the ICT study.

[652] Review study on Standby Regulation, Study on the Review of the Regulation (EC) No 1275/2008 available at: https://www.ecostandbyreview.eu/downloads/Review%20study%20standby%20regulation%20-%20final%20report%20april%202017.pdf

[653] Note that the price can vary greatly within this product group and up to 300 EUR

[654] Note some complex set top boxes are sold at a low price as part of a subscription

[655] Based on the data from the ICT study

Table 230: Use patterns and energy consumption home/office network equipment (modems, routers IADs and switches). Based on the ICT study.

	2010	2020	2030	2040	2050
	Hours of use				
Active mode [h/d]	7	7	7	7	7
Standby [h/d]	8.5	0	0	0	0
Networked standby [h/d]	8.5	17	17	17	17
	Power draw				
Active mode [W]	12	9	7	5	2
Standby [W]	5	0	0	0	0
Networked standby [W]	10	8	6	4	2
	Energy consumption per day				
Active mode [Wh/day]	84	63	49	35	14
Standby [Wh/day]	42.5	0	0	0	0
Networked standby [Wh/day]	85	136	102	68	34
Total energy consumption per year [kWh/year]	**77.2**	**72.6**	**55.1**	**37.6**	**17.5**

Table 231: Use patterns and energy consumption of NAS. Based on the ICT study.

	2010	2020	2030	2040	2050
	Hours of use				
Active mode [h/d]	3	3	3	3	3
Standby [h/d]	19	19	19	19	19
Networked standby [h/d]	2	2	2	2	2
	Power draw				
Active mode [W]	19	16	12	8	4
Standby [W]	5	4	3	2	1
Networked standby [W]	15	12	9	6	3
	Energy consumption per day				
Active mode [Wh/day]	57	48	36	24	12
Standby [Wh/day]	95	76	57	38	19
Networked standby [Wh/day]	30	24	18	12	6
Total energy consumption per year [kWh/year]	**66,4**	**54,0**	**40,5**	**27,0**	**13,5**

The time in active mode is used in the following assessments, but it is considered as a conservative estimation taking into account e.g. the heavy use of smartphones, streaming devices and IOT products.

In addition, the following assumptions are made:

- Gateways – assumed to have an average power draw of 1.5 W resulting in an annual energy consumption 13.1 kWh[656]
- Complex set-top boxes are assumed to have an annual energy consumption of 46 kWh[657]. Note that the product with the highest reported annual energy consumption was 226 kWh and the product with the lowest annual energy consumption is 8 kWh.

[656] Based on the ICT study

[657] http://cstb.eu/wp-content/uploads/2013/02/2017-10-24-Report-Independent-Inspector-2015-2016_final.pdf

- Other equipment (Wi-Fi extenders, powerline adapters and other small products) are assumed to have an average power draw and use pattern similar to home/office network equipment from the ICT study[658]

18.4 Technologies

The pictures below show several products in this group: IoT gateway, a HomePlug/powerline adapter, a mesh[659] system and a NAS .

Figure 72: (From left-to-right) IoT gateway[660], powerline adapter[661], mesh system (with speaker and voice assistant in router[662], NAS server[663]

All products are widely available today and are getting more user friendly. Previous, it could be a challenging task to provide sufficient internet coverage for the entire household in all rooms. Today it is almost a plug and plays solution to install a MESH network and to set up a QoS (Quality of Service). This means that technology is assumed to become more available for more users. Also, more homes will get access to high-speed internet connections, as this is included in the European Commission's strategy on connectivity, with the following three main strategic objectives for 2025:

- Gigabit connectivity for all of the main socio-economic drivers,
- uninterrupted 5G coverage for all urban areas and major terrestrial transport paths, and
- access to connectivity offering at least 100 Mbps for all European households.

When more homes get access to high-speed internet, the need for more network equipment is expected to increase. With higher internet speed, the requirements for the equipment also increases to ensure that the equipment is not creating a bottleneck regarding internet speed. Today most equipment in the stock is considered to be either Wi-Fi version 4 or 5, but the new Wi-Fi version 6 will perform better in smart homes with higher speed and better coverage. With technological advancements, there is a risk that well-functioning products are discarded prematurely.

All products in scope differentiate in size and the composition of materials. However, all products are assumed to have an average composition (type of materials and percentage

[658] Based on the energy consumption of the following two devices: WiFi extender - https://www.tp-link.com/us/home-networking/range-extender/re450/#specifications and powerline adapter - https://www.tp-link.com/dk/home-networking/powerline/tl-wpa8630p-kit/#specifications

[659] Mesh is a network topology in which devices are connected with many redundant interconnections between network nodes.

[660] https://www.samsung.com/dk/smartthings/smartthings-hub-gp-u999sjvlg/

[661] https://www.tp-link.com/uk/home-networking/powerline/tl-wpa8630p-kit/

[662] https://store.google.com/dk/product/nest_wifi

[663] https://www.synology.com/da-dk/products/DS218+

content for each material of total content) as a laptop without a screen and batteries. The only way the products differentiates is in the average weight, which are:

- Home Network Attached Storage equipment (NAS) – 1.3 kg[664]
- Home/office network equipment – 0.5 kg[665]
- IoT Cellular Gateway – 0.2 kg[666]
- IoT Home/Office Gateway – 0.2 kg[666]
- Complex set top box – 0.15 kg[667]
- Other equipment (Wi-Fi extenders, powerline adapters and other small products) – 0.2 kg

The assumed average material composition is presented in Table 232.

Table 232: Material composition (based on a laptop computer[668] without a screen and batteries)

Description of component	%	Material group	Material
Plastic polymers - Plastics (including those from storage systems, ODD and cables)	34%	1-BlkPlastics	11 -ABS
PCBs (motherboard, RAM, CPU, others) Various (*)	18%	6-Electronics	51 -PWB 6 lay 4.5 kg/m2
PCBs (storage systems and ODD) Various (*)	5%	6-Electronics	52 -PWB 6 lay 2 kg/m2
Metals components Steel and ferrous	15%	3-Ferro	26 -Stainless 18/8 coil
Metals components Aluminium	14%	4-Non-ferro	27 -Al sheet/extrusion
Metals components Magnesium alloy	12%	4-Non-ferro	34 -MgZn5 cast
Metals components Copper	1%	4-Non-ferro	30 -Cu wire
Metals components Rare earth element (in magnets)	0%	4-Non-ferro	33 -ZnAl4 cast
Others Various (**) (in fan, small LCD, speakers and lamps)	2%	6-Electronics	45 -big caps & coils

18.5 Energy, Emissions and Costs

Energy, emission and simple LCC calculations are presented in following three tables. The stock presented in Section 18.2, the energy consumption in Section 18.3 and material composition in Section 18.4 are used to calculate the annual primary energy consumption of the stock and the primary energy from the materials. Note that EcoReport tool has been used to calculate the primary energy consumption of the materials in the current stock.

664 https://www.synology.com/da-dk/products/DS218#specs

665 https://www.amazon.com/TP-Link-Archer-C60-Ac1350-Wireless/dp/B01LX8Z8TP

666 https://www.amazon.co.uk/Philips-Bridge-Works-Alexa-White/dp/B0152WXHVE

667 https://www.amazon.com/BUILT-CABLE-REMOTE-POWER-ADAPTER/dp/B07DXFB2JR/ref=sr_1_1?crid=3K529A2UJI3VR&dchild=1&keywords=set+top+box&qid=1591984597&sprefix=set+top+%2Caps%2C274&sr=8-1

668 https://publications.jrc.ec.europa.eu/repository/bitstream/JRC105156/20180115_-_jrc_technical_report_online_v02.pdf

Table 233: Annual energy consumption of the stock and the combined embedded energy in the materials in the stock

Annual input EU-27 2020 Product type	ENERGY INPUT Annual electricity TWh	 Annual primary energy[669] PJ	MATERIAL INPUT Combined weight (stock) Kt	 Primary energy (stock) PJ
Home Network Attached Storage equipment (NAS)	1.6	12.3	39.2	8.2
Home/office network equipment	16.4	124.2	113.1	23.7
IoT Cellular Gateway	0.3	1.9	3.9	0.8
IoT Home/Office Gateway	0.8	6.0	12.0	2.5
Complex set top boxes	5.2	39.3	16.95	3.6
Other equipment (Wi-Fi extenders, powerline adapters and other small products)	4.4	33.0	12.0	2.5
TOTAL	**28.7**	**216.7**	**197.1**	**41.3**

Table 234 gives greenhouse gas emissions (in CO2 equivalent GWP-100).

Table 234: CO2 emission from small networking equipment for home and office use

EU-27 2020	GHG From the electricity consumption [kt]	 From the materials [kt]
Home Network Attached Storage equipment (NAS)	618.9	431.6
Home/office network equipment	6241.3	1245.1
IoT Cellular Gateway	96.6	42.6
IoT Home/Office Gateway	300.4	132.5
Complex set top boxes	1975.2	186.7
Other equipment (Wi-Fi extenders, powerline adapters and other small products)	1660.5	132.5
Total	**10893.0**	**2171.1**

From Table 233 and Table 234 it can be seen that small networking equipment for home and office use in the stock consumes 217 PJ of primary energy each year, resulting in a CO_2-emission of 9250 kt. Also, the combined stock includes materials with embedded primary energy of 41 PJ, resulting in a CO2-emission of 2170 kt (for the entire stock in one year). However, if the lifetime of CO2-emission from the materials is distributed over the lifetime of the equipment, the annual emission is 434 kt.

The end-user expenditure in Table 235 is calculated based on the stock, purchase price and the energy consumption presented in previous sections.

Table 235: End-user expenditure

End-user expenditure, EU 2020 (stock)	**Running costs** bn euros	**Acquisition (stock)** bn euros	**Total** bn euros

[669] A CC factor of 2.1 is used

Home Network Attached Storage equipment (NAS)	0.3	9.0	9.4
Home/office network equipment	3.3	17.0	20.3
IoT Cellular Gateway	0.1	1.0	1.0
IoT Home/Office Gateway	0.2	6.0	6.2
Complex set top boxes	1.1	11.3	12.4
Other equipment (Wi-Fi extenders, powerline adapters and other small products)	0.9	1.8	2.7
Total	**5.8**	**46.1**	**51.9**

The total stock of small networking equipment for home and office use has an approximate value of 46 billion euros. Each year the end-users spend 5.8 billion euros in running cost.

18.6 Saving potential

The standby regulation already regulates standby and networked standby, which is responsible for approximately half of the energy consumption. This means that the active mode of small networking equipment for home and office use is responsible for a consumption of 14 TWh electricity (108 PJ of primary energy) each year. Hence, even minor energy improvements can have a significant impact. Based on data from The Power Consumption Database, it seems that a product such as a router can have an energy consumption of 1 watt to 10 watts[670] and even up to 20 watts or higher. Based on these numbers, it seems that there is a potential for a significant energy saving by setting a limit on the active mode power consumption and push the manufactures to produce energy-efficient BAT (Best Available Technology) products. If the products reduce their active mode consumption with 1 watt, the annual savings would roughly be 3.2 TWh electricity and 1200 kt of CO_2, i.e. due to high sales, even small improvements can be significant.

Also, it is essential to consider the power allowances in standby and networked standby. When products gradually move from standby to network standby, the annual energy consumption is expected to increase.

According to the Energy Star specification for small network equipment, the base power allowance is 3.1 W for routers, and 4.0 W for ADSL modems and 2.0 W for a switch. In addition to the power allowance, Energy Star provides additional functional adders such as 0.7 W for Wi-Fi and 0.3 W per gigabit ethernet port. Based on Energy Star, the VA for complex set-top boxes and the EIA, the following potential efficiencies are estimated in Table 236. In Table 237, the estimated annual energy savings and CO2 savings are presented.

[670] http://www.tpcdb.com/list.php?type=11

Table 236: Current annual energy consumption of the different base cases and a "BAT" which indicates the assumed obtainable energy consumption

Product type	Annual energy consumption KWh		Saving potential [%]
	BAU	BAT	
Home Network Attached Storage equipment (NAS)	54.0	41[671]	24%
Home/office network equipment	72.6	55.1[672]	24%
IoT Cellular Gateway	13.1	9.9[673]	24%
IoT Home/Office Gateway	13.1	9.9[673]	24%
Complex set top boxes	46	23[674]	50%
Other equipment (Wi-Fi extenders, powerline adapters and other small products)	72.6	55.1[673]	24%

Table 237: Energy saving potential for current stock

Product type	Energy saving		CO2 saving Kt CO2
	Annual electricity savings TWh	Annual primary energy savings[675] PJ	
Home Network Attached Storage equipment (NAS)	0.4	3.0	152
Home/office network equipment	4.9	36.8	1862
IoT Cellular Gateway	0.1	0.5	38
IoT Home/Office Gateway	0.2	1.5	76
Complex set top boxes	2.6	19.6	988
Other equipment (Wi-Fi extenders, powerline adapters and other small products)	1.1	8.0	418
TOTAL	**9.2**	**69.3**	**3496**

In addition, by applying resource efficiency requirements such as minimum requirements for firmware and software updates (to secure as a minimum security updates) and in some cases upgradeable design (software[676] and hardware), the lifetime can be improved. If the lifetime of each product can be improved by an average of one year, the approximate savings in CO2 would annually be additional 75 kt.

[671] Based on the EIA 2030 values. It is expected that networked standby and active mode can be improved. This improvement corresponds approximately to the same energy saving of 25% as for home/office network equipment

[672] Same use pattern, but the power draw is changed to 7 W in active mode and 6 W in networked standby. The 7 W in active mode is estimated based on Energy Star.

[673] Same assumptions as for home/office network equipment. The estimated saving is primarily assumed to be achieved by a reduction of networked standby

[674] Based on numbers from the VA for CSTB´s where there is a large difference between the most and least efficient boxes: http://cstb.eu/wp-content/uploads/2013/02/2017-10-24-Report-Independent-Inspector-2015-2016_final.pdf

[675] A CC factor of 2.1 is used

[676] According to a stakeholder there have been examples where fully functioning appliances had to be replaced as the cloud service of the manufacturer/supplier was not provided anymore.

18.7 Stakeholder comments

DIGITALEUROPE commented on the suitability of the first draft name of the product group and suggested to name it “Small networking equipment for home and office use”, which the study team agrees in and has changed it accordingly. DIGITALEUROPE further commented that industry strongly believes that for a proper enforcement of regulations set up under the framework of the Ecodesign Directive, products shall be in the scope of only one regulation. Many products potentially in scope of this product group are already covered by regulation 1275/2008 (ErP lot 6/26).

ECOS-EEB-Coolproducts commented that the scope should be enlarged to capture all networking equipment (including products that were considered and excluded from the scope of the servers regulation because of perceived complexity of the product group at the time) i.e. to include professional network equipment. The study team informs that a separate product group for enterprise network equipment already has been included in the assessments and that due to large differences between these 2 product groups, they have been assessed separately.

ECOS-EEB-Coolproducts further requested clarification regarding whether set-top-boxes are actually included in the assessment. The study team’s response is that complex set top boxes are specifically mentioned in the different tables and included in the stated saving potentials in spite of the existence of a voluntary agreement on the area. The purpose of Task 3 is to evaluate the potential for further energy savings and the stated saving potentials in the tables suggest that further energy savings can be obtained.

LightingEurope commented that home and office networking appliances, which include connected lighting equipment, cannot be placed together and fulfil the same requirements. Those are two different groups and should not be mixed up in terms of legislation. The study team informs that the focus here is on the gateway i.e. the bridge between e.g. lighting products and the rest of the network, which fits in this category. However, special attentions should also be put on the large range of products with a built in Wi-Fi extender, e.g. in some bulbs.

Netherlands Enterprise Agency commented that electronic (ICT) products cover a broad range of products, which because of both energy savings potential and resource efficiency potential, especially durability/life time, should be included in the Working Plan. Regarding Small Networking Equipment, the study does not mention the Code of Conduct for Broadband Equipment (https://e3p.jrc.ec.europa.eu/publications/eu-code-conduct-energy-consumption-broadband-equipment-version-7-0), which illustrates some of the difficulties of regulating these products regarding energy efficiency; however, solutions to overcome these difficulties exist (See: Siderius. 2020. Regulating ICT products through EU ecodesign and energy labelling measures – a new approach. Electronics Goes Green, Berlin). Regarding resource efficiency in any case and at least the same type of requirements should be introduced as in the latest ecodesign regulations. The study team has updated the text updated with brief information about the Code of Conduct.

The Japan Electrical Manufacturers' Association (JEMA) commented that they recognize that much equipment is already covered by Regulation 1275/2008 and that they think that it is extremely important that devices are regulated by only "one ErP Implementation Measures" because of ensure proper compliance of all products and proper enforcement of regulations. JEMA also commented on the naming of this product group, which the study team has changed. The study team agrees that care should be taken not to impose multiple regulations for one product group. However, the standby regulation is a horizontal regulation and multiple product groups are covered both by the standby regulation and a separate regulation.

19 INTERCONNECTED HOME AUDIO AND VIDEO

19.1 Scope, policy measures and test standards

Interconnected home audio and video service equipment were mentioned as an area of focus in the previous Working Plan Study. However, loudspeakers were excluded at an early stage, because they were evaluated to have a low energy consumption. Video projectors and amplifiers were investigated, but not chosen for further regulation, because of the expected decline in sales.

The comprehensive market of audio and video equipment today includes home audio interconnected systems (e.g. mesh[677] type speakers), portable wireless speakers (smaller & larger in- and outdoor with large batteries) and casting/streaming video devices (mostly with low consumption, though examples of products with higher consumption levels exist). Software obsolescence is also relevant (e.g. the recent Sonos case where older products were not supported for software update and recommended by the manufacturer to be replaced with new products and the old products being destroyed). In the loudspeaker segment, the volume market volume in 2023 is forecast to be 66.31 million units (data from Statista). Cloud-based voice service equipment like Alexa and Google Home may be included in this category. These consume in themselves typically 2-4 W in listening mode, but there are reports stating that some TVs connected to a voice service device increase their connected standby consumption up to 20 W[678]. All-in-all, these interconnected systems are in increase and the energy consumption as well.

The market of interconnected home audio and video services devices is comprehensive and include many products. Table 238 describes included and excluded products.

Table 238: Products

Product	Description of product[679]
Video player / recorder	A standalone device used to play or record audio/video signals. Does not have a viewing display.
Television	A product designed to display, on an integrated screen, a video signal from a variety of sources (including television broadcast signals), which optionally controls and reproduces audio signals from an external source device, that is linked through standardised video signal paths including cinch (component, composite), SCART, HDMI, and future wireless standards (but excluding non-standardised video signal paths like DVI and SDI), but cannot receive and process broadcast signals.
Video projectors/beamers	A optical device used for processing analogue or digital video image information, in any broadcasting, storage or networking format to modulate a light source and project resulting image onto an external screen.

[677] Mesh is a network structure where devices can connect to each other in the network and more efficiently route data between them. Read more: https://en.wikipedia.org/wiki/Mesh_networking

[678] https://www.cnet.com/news/alexa-and-google-assistant-make-energy-hogs-out-of-smart-tv-nrdc-report-says/

[679] Description are based on information from other regulations, and the IA Standby study.

Amplifiers	Is an electronic device for increasing the amplitude of electrical signals, used mainly in sound reproduction. It is most often used in combination with passive speakers.
Standalone home audio equipment	Defined as audio equipment that works as a standalone solution and not connected to a network (e.g. through Wi-Fi). However, the category includes audio equipment that receive radio signals.
Loudspeakers (standalone)	This product group includes medium to large sized active and passive loudspeakers that can be connected to sound sources like receivers, amplifiers and TVs. It contains the following sub segments: • Passive loudspeakers that can be used as a speaker pair for a stereo setup or as front, rear, centre or subwoofer speaker in a multi-channel home theatre setup. They are connected to an amplifier or receiver via screw or clamp terminal. • Active subwoofer speakers that are typically used in a multi-channel home theatre setup. They are connected to an amplifier or receiver via TSR or RCA input(s). • Passive or partly active home theatre speakers sets usually consisting of a set of passive front, rear and centre speakers and an active or passive subwoofer. • Active TV speakers with various form factors that are directly connected to a TV set or attached to the wall. With or without separate subwoofer. • Sound Bases (placed under TV sets)
Docking mini speaker (standalone)	Docking mini speaker – the mini speaker/speaker system has a sound source, a USB or jack connection. These speakers are generally smaller in size and connected to portable audio, IT or telecom devices.
Network connected audio products (NCAP) and portable wireless speakers	Audio equipment that is connected to a network e.g. through Wi-Fi. Products that are connected through Bluetooth are also included in this category.
Smart audio (NCAP)	Smart audio (so called multiroom or Wi-Fi speakers) (NCAP): These are component-based music systems, which exclusively use audio streaming as sound source. The music can either be streamed from the internet by providing access to a music service like Spotify, Napster etc., internet radio or from a PC, NAS (Network Attached Storage), or dedicated music server being part of the home network. Music servers may include an optical disc drive and an HDD for ripping and storing music from CDs. Smart audio and network music systems support multiroom functionality, which means that the system can play one song synchronized in different rooms as well as playing different rooms originating from the same source. Smart audio systems do not have traditional sound sources like CS, analog/digital radio or turntables. Examples are: Sonos product family, Philips Streamium family (except CD/DVD micro systems), Yamaha Musiccast, Linn, Olive Audio, Denon Heos, Harman Omni etc.
Docking mini speaker (NCAP)	Same product as docking mini (standalone), but can be connected through Wi-Fi, Bluetooth, or other wireless connection.
Media box and media sticks	Small movie streaming device that plugs into an HDMI port on a TV or A/V receiver and accepts digital media wirelessly from mobile devices, computers or the internet. E.g. Chromecast, Apple TV, Roku or Fire TV[680].

[680] Definition taken from: https://www.yourdictionary.com/streaming-stick

Other products which are used to connect audio to other devices also exist, but it is difficult to determine the magnitude of the market, and there are currently no reliable public market data available. E.g. a new product standard called WiSA products, ensuring that products can connect and work seamlessly with other WiSA Certified products[681]. Of the listed products it should be noted that the sales of projectors and video players are assumed to move towards zero in 2030[682]. Hence, these products are not further considered.

Of relevant regulations, standards and other initiatives, the following is considered relevant for the products in scope:

j) Regulations

1. Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for standby and off mode, and networked standby, electric power consumption of electrical and electronic household and office equipment. All audio and video equipment described are included in the standby regulation and shall fulfil the requirements for standby, and networked standby. The only exception is televisions where it is clearly specified that the products covered by Commission Regulation (EC) No 642/2009 are excluded.
2. Commission Regulation (EC) No 642/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for televisions meaning that televisions is already regulated.

k) Standards

1. EN 50564:2011 Electrical and electronic household and office equipment - Measurement of low power consumption[683] specifies methods of measurement of electrical power consumption in standby mode(s) and other low power modes (off mode and network mode), as applicable. It is applicable to electrical products with a rated input voltage or voltage range that lies wholly or partly in the range 100 V a.c. to 250 V a.c. for single phase products and 130 V a.c. to 480 V a.c. for other products.
2. EN 50643:2018/A1:2020 Electrical and electronic household and office equipment - Measurement of networked standby power consumption of edge equipment specifies methods of measurement of electrical power consumption in networked standby and the reporting of the results for edge equipment. Power consumption in standby (other than networked standby) is covered by EN 50564, including the input voltage range. This European Standard also provides a method to test power management and whether it is possible to deactivate wireless network connection(s).
3. EN 62087-1:2016 Audio, video, and related equipment - Determination of power consumption - Part 1: General specifies the general requirements for the determination of power consumption of audio, video, and related equip-

681 https://www.wisaassociation.org/about-wisa/our-technology/

682 Based on the ICT impact study task 1 2020.

683 https://www.cenelec.eu/dyn/www/f?p=104:110:1190755971975601::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1257245,45888,25

ment. Requirements for specific types of equipment are specified in additional parts of this series of standards and may supersede the requirements specified in this standard. Moreover, this part of IEC 62087 defines the different modes of operation which are relevant for determining power consumption. This first edition of IEC 62087-1 together with IEC 62087-2 to IEC 62087-6 cancels and replaces IEC 62087:2011 in its entirety. This edition constitutes a technical revision. This edition includes the following significant technical changes with respect to Clauses 1 to 5 of IEC 62087:2011. It includes new information about operation modes. Equipment that includes removable main batteries are now considered. Light measuring equipment is now specified.

4. EN 62087-6:2015 Audio, video and related equipment - Determination of power consumption - Part 6: Audio equipment specifies the determination of the power consumption of audio equipment for consumer use. The various modes of operation which are relevant for measuring power consumption are defined. This first edition of IEC 62087-6 cancels and replaces Clause 9 of IEC 62087:2011. This standard together with IEC 62087-1 to IEC 62087-5 cancels and replaces IEC 62087:2011. This International Standard constitutes a technical revision. This edition includes the following significant technical changes with respect to Clause 9 of IEC 62087:2011. The definition of the input signal is changed. The output power measurement of amplifiers is changed. The measurement method for compact audio systems including loudspeakers is added. Methods for measuring On-decoding, idle and auto power down functions are added. Portions of the document related to general measuring conditions and procedures are now contained in IEC 62087-1:2015. Portions of the document related to signals and media are now in IEC 62087-2:2015. The titles have changed in order to comply with the current directives and to accommodate the new multipart structure of IEC 62087.

l) Other initiatives

1. ENERGY STAR[684] for audio/video equipment in version 3.0 establishes an allowance for multiple networking and control protocols (including Gigabit Ethernet or WiFi protocols) implemented in a single product, and adds definitions for Consumer and Commercial Amplifiers to the specification to allow EPA to establish future efficiency criteria once data become available. ENERGY STAR certified audio/video equipment can be up to 70% more efficient than conventional models.

19.2 Market

Table 239 shows estimated unit sales and stock of audio speakers and media sticks; the data is based on the impact study for standby products, which has based the sales on GfK data from 2010-2017. The data for 2020 and forward are forecasted.

[684] https://www.energystar.gov/products/electronics/audiovideo

The IA standby study found that in some product groups, there are products that can be either network connected audio products (NCAP) or standalone equipment (e.g. some loudspeakers have network capabilities) a share of the loudspeakers and docking mini speakers are therefore shown in the NCAP category.

From the sales and stock data, it is clear that the market is moving towards more NCAPs and sales of standalone products is decreasing rapidly and is expected to be non-existing in the market in 2030.

The projected stock made in the IA standby study seems relatively low compared to the estimated stock in 2020 made by the ICT impact study[685], which estimates a stock of 272 million NACPs alone.

No data was available for sales or stock of amplifiers, but it is assumed that the stock and sales constitute one-third of the loudspeakers, two or more speakers are typically connected to one amplifier, and some the units in the loudspeaker category work without an amplifier, e.g. active TV speakers.

Media boxes and media sticks have experienced a significant rise in stock from 2015 to 2020, and it looks like it has found a saturation level of around 49 million units.

Table 239: Sales and stock (in mil. units)

	Sales [mln. Units]				**Stock [mln. Units]**				**Average lifetime [Years]**
Product	**2015**	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**	
Loudspeakers	5.0	1.9	0.0	0.0	34.8	17.4	0.0	0.0	5.0
Docking mini (others)	7.9	3.0	0.0	0.0	54.7	27.4	0.0	0.0	5.0
Smart audio	0.1	0.0	0.0	0.0	0.4	0.2	0.0	0.0	5.0
Audio speakers (standalone)	**13.0**	**5.0**	**0.0**	**0.0**	**90.0**	**45.0**	**8.0**	**0.0**	**5.0**
Loudspeakers	0.4	1.0	1.2	1.2	0.8	3.8	6.0	6.3	5.0
Docking mini (others)	0.1	0.1	0.2	0.2	0.1	0.5	0.8	0.8	5.0
Smart audio	2.2	5.8	6.5	6.5	4.7	21.7	34.0	35.4	5.0
Docking mini bluetooth	12.3	32.5	36.6	36.6	26.1	121.7	190.8	199.0	5.0
Audio speakers (NCAP)	**15.0**	**39.0**	**44.0**	**44.0**	**32.0**	**148.0**	**232.0**	**242.0**	**5.0**
Amplifier	**1.7**	**0.6**	**0.0**	**0.0**	**11.6**	**5.8**	**0.0**	**0.0**	**-**
Media box, media sticks	**7.0**	**9.0**	**9.0**	**9.0**	**15.0**	**45.0**	**49.0**	**49.0**	**5.0**

The average lifetime of all the products is estimated to be 5 years, according to the IA standby study.

[685] ICT Impact study April 2020 task 1. Prepared by VHK and Viegand Maagøe for the European Commission

19.3 Usage

The typical applications of home audio and video equipment are entertainment. The products are used in the home for listening to music, radio, podcasts etc. or create an improved sound experience when watching movies.

Wireless speakers (AC powered) are accessed typically through an app on a smartphone, but many do also have a simple interface with play/pause and volume buttons. The communication can either be over Wi-Fi, Bluetooth or Airplay (Wi-Fi or Bluetooth) and alike. The convenience of wireless speakers makes them very popular. It is straightforward to set them up in the home, as they only require power and no cable for a signal. Because an app operates it on the smartphone, it is easy to stream/play music from popular music apps such as Spotify or Tidal even for visitors coming to the home.

Figure 73: Example of AC powered wireless speakers (NCAP)

Wireless speakers (movable) are provided with a built-in battery, that can be recharged, and are therefore portable. They come in all sizes and are often used to bring outside, where they can play for hours. The simple models are typically connected by Bluetooth and simply mirror what they phone is playing. However, newer and more advanced models can be controlled by apps (e.g. by Spotify), like the AC power wireless speakers.

Figure 74: Example of wireless Bluetooth speakers

Recently, hybrid models have entered the market that can be charged at a station at home, connected to Wi-Fi, but also moved outside because it has a built-in battery.

Figure 75: Example of a "hybrid"

More of these products are labelled as multiroom speakers and can, e.g. be paired to play in stereo mode or simple just play the same song in mono in several rooms. Some speakers create a mesh network, which means that one speaker connects to closest speaker next to it instead of a main unit and thereby being part of the network structure improving the data routing. Other speakers can be voice-activated or powered on by an app casting music. If the consumers are using the cast functionality the speaker will keep on playing, even if device used for the cast leaves the room. When the cast functionality is used, the speakers are connected directly to the music provider and are not dependent on presence of the device.

The IA standby study has estimated usage hours of the audio equipment and the media boxes and media sticks. The estimated usage hours have been verified by manufacturers, industry associations and a component supplier. The usage hours from the IA standby study are shown in Table 240.

Table 240: Estimated usage hours in IA standby study

	Active [h]	Standby [h]	Network standby [h]	Off mode [h]
Audio speakers (standalone)				
Loudspeakers	2.7	11.3	0.0	10.0
Docking mini (others)	2.7	11.3	0.0	10.0
Smart audio	2.7	0.0	21.3	0.0
Audio speakers (NCAP)		0.0	0.0	0.0
Loudspeakers	2.7	0.0	11.3	10.0
Docking mini (others)	2.7	11.3	0.0	10.0
Smart audio	2.7	0.0	21.3[686]	0.0
Docking mini bluetooth	2.7	0.0	11.3	10.0
Amplifier	2.7	11.3	0.0	10.0
Media box, media sticks	3.0	0.0	21.0[687]	0.0

The use pattern presented in Table 240 is expected to be representative of the current market. However, with more products on the market, consumers may in the future use

[686] Adjusted – In the IA Standby study it was assumed that NCAP/wireless equipment use 10 hours in off mode. In this study the NCAP equipment is divided into categories to differentiate between a Bluetooth speaker which is often turned off when not used and a smart audio speaker which is always in a Networked standby/idle mode, so it is ready to be activated at all times.

[687] Adjusted - In the IA Standby study it is estimated that the Media stick/Box would go into normal standby when not active. However, from online research of products such as Apple TV4k, Google Chromecast Ultra and Nvidia Shield, it was found that the products go into a Networked standby/idle mode.

each device for fewer hours. Also, it is relevant to notice that these types of products typically are in standby or networked standby the majority of the time.

19.4 Technologies

19.4.1 Technological development

The market for audio equipment is continuously experiencing technological development that outdates old products. The ICT impact study describes it well in the historic development description of the audio market:

"Audio equipment in the home in the form of radios, started almost 100 years ago. Audio furniture incorporating radio record players and speakers came into Europe in the 1950s. Portable radios and record players in the 1960s, tape recorders (for audio enthusiasts) then followed. Cassette-recorders (portable and in-systems) took off in the late 1960s. In the 1970s, HiFi stereo component systems became popular, integrated or stacked as 'towers' of single components. CD-players, being the first medium for digital music were introduced in the 1980s. In the 1990s, as mentioned above, specific sound systems for TVs entered the market, e.g. with 'surround sound' with 5+1 speakers, while nowadays 'sound bars', integrated multi-speaker systems, seem to be the more popular, less invasive sound solution. The mid-1990s also saw the beginning of streaming (digital) audio, i.e. in the form of mp3 files that was discussed the previous section. In the most recent years this developed in streaming audio also becoming popular in (wireless) network connected audio products (NCAP) that will be discussed in the next section."

The development is also clear from the market data showing that standalone speakers will soon be outdated, and the new reality is NCAPs. In addition, more products with mesh functionality will be available. With increased functionalities, the risk of premature obsolescence may become greater, e.g. the Sonos case where older products were not supported for software update and recommended by the manufacturer to be replaced with new products and the old products being destroyed. Other manufactures could potentially face the same challenges as Sonos, and it may become increasingly important to ensure updateability (software) and upgradeability (hardware). Currently, at least one manufacture has provided an upgrade kit for old speakers[688]. Security issues and related necessary software updates for networked audio devices are also becoming a more relevant topic nowadays.

Regarding amplifiers, different types of amplifiers exist with different efficiencies. The most common types of amplifiers are[689]:

- Class A Amplifier – has a low efficiency of less than 40% but good signal reproduction and linearity.
- Class AB Amplifier – has an efficiency rating between that of Class A and Class B[690] but poorer signal reproduction than Class A amplifiers.

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[688] https://www.techradar.com/news/bang-olufsen-diy-kit-lets-you-make-your-own-smart-speakers-with-raspberry-pi

[689] https://www.electronics-tutorials.ws/amplifier/amplifier-classes.html

[690] Class B Amplifier – is twice as efficient as class A amplifiers with a maximum theoretical efficiency of about 70% because the amplifying device only conducts (and uses power) for half of the input signal.

- Class D Amplifier – A Class D audio amplifier is basically a non-linear switching amplifier or PWM amplifier. Class-D amplifiers theoretically can reach 100% efficiency, as there is no period during a cycle where the voltage and current waveforms overlap as the current is drawn only through the transistor that is on.

Other amplifier classes exist, but the above-mentioned classes are the most common in consumer electronics. Hence, it could be possible to increase the energy efficiency of amplifiers by moving the market towards Class D amplifiers but at the cost of good signal reproduction and linearity from Class A amplifiers. Hence, it may not be a solution to ban certain amplifiers.

Today many products are able to be controlled by other devices or voice controls. Many media boxes and casting devices are able to power on a TV through CEC (Consumer Electronics Control). Some of the devices are also able to power off the television if the device is inactive for a certain amount of time. However, based on a simple test it the following was concluded:

- A Chromecast was able to power on a TV when a cast starts, but after an hour of inactivity the Chromecast was still on (screensaver). In addition, the TV and connected devices was on. Apparently, the TV and other connected devices did not receive any signals indicating that the Chromecast was inactive.
- A Shield was able to turn on a TV and power it off after 20 minutes. In the screensaver setting the shield was set to sleep after 20 minutes out of the box.
- A Xiaomi Mi box S (not European model) was able to power off the TV, but it was set to 3 hours of inactivity before it should enter sleep mode (out of the box)

19.4.2 Material composition

The material composition of the different products is presented in Table 241 and Table 242.

Table 241: Material composition of audio equipment (NCAP speakers)[691]

Description of component	%	Material group	Material
Copper	7%	4-Non-ferro	29 -Cu winding wire
Plastic	51%	1-BlkPlastics	4 -PP
Brass	1%	4-Non-ferro	32 -CuZn38 cast
Iron	18%	3-Ferro	24 -Cast iron
Steel	12%	3-Ferro	26 -Stainless 18/8 coil
Paper used in speaker	0.2%	7-Misc.	58 -Office paper
Polyester	0.5%	1-BlkPlastics	10 -PET
Circuit board	9%	6-Electronics	98 -controller board

[691] Based on BOM data of a set of computer speakers (https://www.cnet.com/products/sonos-play-1/specs/). The weight is scaled up to the weight of a Sonos Play 1 (1800g). The electronics/circuit board is also upscaled by a factor 2, to better reflect the increase in functionalities (e.g. WiFi) in smart audio systems.

Table 242: Material composition of media stick/box and amplifier (based on a computer[692] without batteries)[693]

Description of component	%	Material group	Material
Plastic polymers - Plastics (including those from storage systems, ODD and cables)	34%	1-BlkPlastics	11 -ABS
PCBs (motherboard, RAM, CPU, others), various (*)	18%	6-Electronics	52 -PWB 6 lay 2 kg/m2
PCBs (storage systems and ODD), various (*)	5%	6-Electronics	51 -PWB 6 lay 4.5 kg/m2
Metals components Steel and ferrous	15%	3-Ferro	26 -Stainless 18/8 coil
Metals components Aluminium	14%	4-Non-ferro	27 -Al sheet/extrusion
Metals components Magnesium alloy	12%	4-Non-ferro	34 -MgZn5 cast
Metals components Copper	1%	4-Non-ferro	30 -Cu wire
Metals components Rare earth element (in magnets)	0%	4-Non-ferro	33 -ZnAl4 cast
Others Various (**) (in fan, small LCDs, speakers and lamps)	2%	6-Electronics	45 -big caps & coils

19.5 Energy, Emissions and Costs

The total energy consumption of all products included in the scope defined in this report is estimated to be 7.6 TWh per year. The energy consumption is based on power draw estimated in IA standby study for standby, networked standby and off mode. The power draw in active mode is based on values found in the ICT impact study and other sources stated in the footnotes.

The energy consumption for the following products have been updated:

- NCAP and smart audio - A manufacturer of smart speakers stated that they have lowered the idle (networked standby) mode consumption with up to 73% from 8 W (1. generation) to 2.2 W (2. generation), while other speakers had more moderate energy savings in networked standby. However, according to the standby regulation, these products are only allowed to have an energy consumption of 2 W in networked standby (for non-HiNA products[694]) meaning that even the energy consumption has been lowered it does not comply the current regulation. This seems to be a general problem for active multiroom speakers as other manufacturers also state a power draw above the current requirement in networked standby[695]. However, some of these products may be categorised as HiNA product or with HiNA functionality because they provide Wi-Fi connectivity to multiple clients through a mesh network. In this case, the limit is 8 W.
- For NCAP and smart audio the energy consumption in idle / networked standby mode is assumed to be 6 W. It should also be noted that some NCAPs cannot be switched off unless it is disconnected from the mains.

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[692] https://publications.jrc.ec.europa.eu/repository/bitstream/JRC105156/20180115_-_jrc_technical_report_online_v02.pdf

[693] A media stick/box and a digital amplifier is assumed to have the same electronic components as a computer. In the calculation of material and energy input the composition of a computer have been with the weight of an Apple TV (425g) and the weight of a amplifier (3300g).

[694] HiNA: Networked equipment with high network availability or functionality.

[695] http://manuals.denon.com/HEOS1/ALL/DA/DRDZSYvvrhvacp.php

- Media boxes, media sticks – The energy consumption in networked standby was assumed to be 0.5 W in networked standby according to the IA standby study, which seems low. A common media box is measured to 1.9 W[696] in networked standby and is assumed to be representative for the market. 2 W is used for further calculation in networked standby (current requirement).

The power draws in each mode is multiplied with usage hours stated above resulting in annual energy consumption, see Table 243. From the table, it can be seen that the smart audio system has the highest annual energy consumption of all products. This is due to the relatively high power draw in networked standby, which the product spend 21 hours in every day.

Table 243: Estimations of energy consumption in 2020[697]

	Active [W]	Standby [W]	Network standby [W]	Off mode [W]	Annual energy consumption per device [kWh/year]
Audio speakers (standalone)					
Loudspeakers	30	0.5	0.0	0.5	33
Docking mini (others)	24	0.5	0.0	0.5	28
Smart audio	5	0.5	6.0	0.5	52
Audio speakers (NCAP)					
Loudspeakers	30	0.5	6.0	0.5	56
Docking mini (others)	24	0.5	0.0	0.5	28
Smart audio	9[698]	0.5	6.0	0.5	56
Docking mini Bluetooth	24	0.5	0.0	0.5	25
Amplifier	20	6.1	0.0	0.0	44
Media box, media sticks	4[699]	0.5	2.0	0.0	20

The total energy consumption is calculated by multiplying the stock with the energy consumption of each product, see Table 244. The table shows that docking mini Bluetooth speakers have the highest annual electricity consumption of all the products groups, even though the energy consumption per unit is less than half of the energy consumption of smart speakers. The high energy consumption of all docking mini Bluetooth speakers is caused by the large number of speakers present in the market (121 million units in stock in 2020 compared to 22 million smart audio speakers).

[696] https://www.flatpanels.dk/test.php?subaction=showfull&id=1589870953

[697] ICT study 2020 & IA Standby – note that some values have been updated and marked with a footnote

[698] Adjusted based power draw in active mode of a smart audio speaker: https://www.sonosguiden.dk/hvor-meget-strom-bruger-dit-sonos-musik-system/

[699] Based on an average consumption of Chromecast ultra, Apple TV4k and Nvidia Shield in active mode.

Table 244: Energy and material input

Input EU-27 2020	ENERGY INPUT		MATERIAL INPUT	
	Annual electricity consumption	Annual primary energy consumption[700]	Combined weight (stock)[701]	Primary energy (stock)
	TWh/year	PJ/year	Kt	PJ
Audio speakers (standalone)	**1.35**	**10.18**	**74**	**14**
Loudspeakers	0.58	4.40	29	5
Docking mini (others)	0.75	5.69	45	9
Smart audio	0.01	0.09	0	0
Audio speakers (NCAP)	**4.53**	**34.28**	**244**	**47**
Loudspeakers	0.22	1.63	6	1
Docking mini (others)	0.01	0.11	1	0
Smart audio	1.20	9.11	36	7
Docking mini Bluetooth	3.10	23.44	201	38
Amplifier	**0.26**	**1.94**	**19**	**2**
Media box, media sticks	**0.89**	**6.71**	**11**	**1**
TOTAL	**7.03**	**53.11**	**348.22**	**63.42**

The large amount of mini docking Bluetooth speakers in the market is also reflected in the representation of materials in the stock and the primary energy embedded in the materials, see Table 244. The high electricity consumption and the primary energy embedded in the materials in stock is therefore also related to the relatively high emissions coming from the mini docking Bluetooth speakers, see Table 245.

[700] CC factor 2.1

[701] The weight of all audio equipment is based on the weight of a Sonos Play 1 (1850g). The weight of amplifiers is based on the weight of a Yamaha A670 amplifier (3300g) and the weight of Media box/stick is based on the weight of an Apple TV (425g).

Table 245: GHG emissions related to electricity consumption and materials

Emissions related to inputs EU-27 2020	GHG	
	Related to the electricity consumption [kt/year]	Related to the materials [kt]
Audio speakers (standalone)	**511.6**	**1170.5**
Loudspeakers	221.1	452.7
Docking mini (others)	286.2	712.0
Smart audio	4.3	5.8
Audio speakers (NCAP)	**1723.3**	**3845.7**
Loudspeakers	81.9	99.9
Docking mini (others)	5.4	13.3
Smart audio	457.8	564.2
Docking mini Bluetooth	1178.2	3168.3
Amplifier	**97.8**	**262.4**
Media box, media sticks	**337.0**	**147.8**
TOTAL	**2669.7**	**5426.5**

19.6 Saving potential

It was not possible to find studies or data collections comparing the energy consumption of audio equipment within the same performance categories. The potential energy savings have, therefore, been estimated in alternative ways. For all products, the majority of the saving potential is linked to the consumption in standby and networked standby, as it has not been possible to pinpoint substantial energy savings in active mode. In active mode, there is a clear link between sound power and energy consumption. Improvement regarding amplifiers and standalone speakers has not been further considered, because they represent a relatively small market share and sales are decreasing rapidly.

The following three saving potentials are identified:

- NCAP - Reduction in the power consumption of non-HiNA NCAPs in networked standby from 6 W to 2 W.
- Reduction of power in consumption of media boxes in networked standby from 2 W to 1.3 W
- All products – improved lifetime due to provision of software updates preventing premature replacement of products. It could potentially also be by hardware upgrade.

Table 246 and Table 247 show the annual primary energy and CO2-eq. savings from electricity consumption and materials. If the potential savings in the use phase, described above, is achieved for the current stock, it will generate annual electricity savings of 2.3 TWh and 878 Kt CO_2-eq.

Table 246: Assumed obtainable energy savings related to the use phase for the current stock

Annual savings EU-27 2020	**Energy savings**		
	Annual electricity savings	Annual primary energy savings	**GHG emission savings**
	TWh	PJ	Kt CO_2-eq.
Audio speakers (Standalone)	**0.0**	**0.0**	**0.0**
Loudspeakers	0.0	0.0	0.0
Dockingmini (others)	0.0	0.0	0.0
Smart audio	0.0	0.0	0.0
Audio speakers (NCAP)	**2.0**	**15.4**	**771.8**
Loudspeakers	0.1	0.7	36.7
Dockingmini (others)	0.0	0.0	2.4
Smart audio	0.5	4.1	205.0
Docking mini w. Bluetooth	1.4	10.5	527.7
Amplifier	**0.0**	**0.0**	**0.0**
Media box, media sticks	**0.3**	**2.1**	**106.4**
TOTAL	**2.3**	**17.5**	**878.2**

The savings obtained by a reduction of the power consumption for non-HiNA NCAPs in networked standby account for 2.0 TWh or approximately 87 % of total saving potential. These savings should already be obtained due to the networked standby regulation. Currently, this is not the case, and a simple online search on soundbars[702] (with Dolby Atmos support) reveals that all four random investigated soundbars claim a power consumption in networked standby above the current requirement. Hence, it seems to be a general problem and should be taken care of by the market surveillance authorities.

The savings obtained by a reduction of the power consumption of media boxes are assumed to be 0.3 TWh.

If other products are included such as headphones or products for home office use, the savings may become even larger.

Extending the product group to cover also the tertiary sector (offices, restaurants, shops, etc.) may also be considered because there is also a growing sales of these products in this sector. These products have not been included in this assessment, because the only home devices were in scope.

In addition, it is estimated that another 20% of savings can be achieved from applying resource efficiency requirements, such as minimum requirements for software updates (both software functionality and security updates) and perhaps an upgradeable design that

[702] Randomly investigated soundbars with ATMOS support from well-known brands

will extend the lifetime of the product. If the lifetime is extended by one year, the approximate savings in CO2 would be 1085 kt CO_2-eq.

Table 247: Assumed obtainable energy savings related to materials

Saving – EU-27 2020 based on stock	Material saving	
	Primary energy savings	GHG savings
	PJ	kt CO2-eq.
Audio speakers (standalone)	**2.8**	**234.1**
Loudspeakers	1.1	90.5
Docking mini (others)	1.7	142.4
Smart audio	0.0	1.2
Audio speakers (NCAP)	**9.4**	**769.1**
Loudspeakers	0.2	20.0
Docking mini (others)	0.0	2.7
Smart audio	1.4	112.8
Docking mini Bluetooth	7.7	633.7
Amplifier	**0.3**	**52.5**
Media box, media sticks	**0.2**	**29.6**
TOTAL	**12.7**	**1085.3**

Regarding other products, it has been noted that some televisions have an increased energy consumption in standby (up to 23 W) if it is able to be turned on and controlled by voice controlled smart speaker[703]. However, the connected smart speakers did not increase its energy consumption in standby. This problem is currently only related to televisions, but it is important to consider the possibilities that other products could behave the same way, but this may already be reflected in the high energy consumption in networked standby for NCAP products.

A more significant problem is that some devices are able to power on but not off other products. Currently, there are no requirements ensuring that the same device is able to power off e.g. a television after predefined time limit when a streaming device stops streaming i.e. with no activity, only a requirement to power off after 4 hours. A modern television typically consumes about 100. Also, the television could be connected with multiple speakers, which all are active, also keeping the television on.

19.7 Stakeholder comments

DIGITALEUROPE has highlighted the fact that some wireless speakers and audio equipment have high network availability features (HiNA equipment or equipment with HiNA function-

[703] https://www.nrdc.org/sites/default/files/gadget_report_r_19-07-b_13_locked.pdf

alities) and that the 2 W limit in network standby only applies to other networked equipment, i.e. non-HiNA. The study team agrees that this can be the case for some of the devices exceeding the 2 W limit and text has been added to the report reflecting this comment.

ECOS-EEB-Coolproducts provided a comment on this product group related to the Task 2 report, which is included here due to the relevance: The inclusion of the product group is very important and relevant regarding e.g. software obsolescence and impacts on networked standby. Furthermore, that it is especially important to include home/office assistants and avoid that they trigger very high power demand in standby. They recommend to enlarge the focus to cover more audio/video equipment, such as loudspeakers (excluded in previous work plan because of assumed low energy consumption) and headphones/earphones (not looked into, whereas relevant from resource efficiency perspectives) and to include the tertiary sector because there is a growing number of interconnected audio/video systems in the tertiary sector (offices, public spaces, restaurants, shops, etc.). The study team agrees that potential savings may be achieved for these areas. The report text has been slightly updated with considerations on other relevant markets. However, speakers are included in the numbers if they have, e.g. Bluetooth. Passive speakers are not included. Extending the product group to cover also the tertiary sector has been included as a future consideration.

Netherlands Enterprise Agency commented that the study indicates that the main (energy) savings come from networked standby requirements which are already in force, so this might be more a question of (innovative) market surveillance than of (additional) requirements. Furthermore, that it may be useful to spend specific attention to networked home audio and video products, since a lot of new products have been placed on the market in recent years and tailoring the requirements to these products may make market surveillance more effective. The study team agrees in this point of view and refers to the Task 3 assessment on market surveillance.

20 UNIVERSAL EXTERNAL POWER SUPPLIES

20.1 Introduction

It is estimated that about 2 billion External Power Supplies (EPSs) (also called power adapters or chargers, though not all EPSs are charging batteries), in the range from 0-120 watts, are in use in EU today (data for total EU-28 stock)[704] i.e. more than 4 EPSs per EU inhabitant. This is partly due to a fragmentation of EPS e.g. it is not possible to charge an electronic shaver with a power adapter for a phone or vice versa[705]. Partly due to business practice, where it is common to bundle an EPS with each electronic device to make sure that the sold product is charged and supplied with the right power supply adapted to the specific end-product. Previously, at times, only lower priced electronic products such as simple mobile phones and wireless speakers were sold without an EPS.

A potential for material efficiency exists if EPSs and products are unbundled as a common practice and the EPS is only delivered, when the consumer does not already possess a suitable EPS or any other suitable way to power the product[706]. The EPSs would therefore typically have a longer lifetime and fewer EPSs would be needed to be produced resulting in material savings. Additional savings may exist if:

- standardised marking of chargers and cables is applied to raise awareness among consumers to highlight which chargers, cables and products that are interoperable.
- standardised connectors and minimum power delivery protocols are supported to avoid proprietary connectors;
- fast charge protocol is applied to ensure high charging performance across different brands;
- Efficient standardised wireless alternatives are implemented to avoid future differentiations resulting in multiple wireless chargers at home.

It is important to notice that the cornerstone of the potential savings is related to standardisation and harmonisation. Over the last decade several activities have taken place to harmonise chargers for mobile phones sold in the EU. Between 2009 and 2014, a Memorandum of Understanding (MoU) to harmonise chargers for data-enabled mobile phones sold in the EU was effective. Since 2014, the Commission, the Parliament and the Council have pushed for common chargers for all mobile phones. A recent activity is an impact assessment study on common chargers of portable devices with a specific focus on chargers for mobile phones performed for DG GROW[707], in the followed denoted "the common charger study". The study was carried out in 2019 and comprised extensive data collection and detailed analyses and therefore has provided much of the background for the analyses in this section[708].

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[704] EIA overview report 2017

[705] Whilst technically possible, in principle.

[706] E.g. by using a USB plug integrated in wall plates, or by using the USB plug from another products, such, e.g., a computer or a monitor.

[707] Impact Assessment Study on Common Chargers of Portable Devices. December 2019. Ipsos and Trinomics, in collaboration with Fraunhofer FOKUS and Economisti Associati.

[708] A second study, for DG GROW is ongoing on "unbundling" of products from their "chargers". Results are expected in the first half of 2021.

The aim of the current assessment of Universal EPSs is to explore opportunities and saving potentials, if EPSs delivered with products were unbundled as a common practice (mandatory or voluntarily) and only delivered, when the consumer did not already possess a suitable EPS. The product scope is EPSs, which falls under the current Ecodesign implementing measure for external power supplies[709]. Therefore, the scope is broader than the scope of the DG GROW initiative, which is chargers (not including EPSs as pure power adapter) and mainly for data-enabled mobile phones with the inclusion of considerations on the possibility to extend the scope to other portable electronic devices.

This study draws on data on sales, stock, energy consumption etc. from the IA EPS study from 2019, which includes EPS devices of all products that are sold with an EPS including both portable devices and stationary devices (e.g. a network router or a computer monitor or even a desktop computer). The assumption made for decoupling and saving potential made in the common charger study is projected to the whole EPS market. The assumption and the saving potential are explained further in Section 20.7.

The common charger study describes the current situation for the EPSs as being:

- Absence of any binding (voluntary or regulatory) requirements as regards the interoperability of chargers for either mobile phones or other portable electronic devices.

- A high but not universal degree of interoperability of different charging solutions, due to the fact that cables are almost always detachable from the external power supply (EPS), and that large parts of the market have adopted technologies (including connectors) based on USB specifications and standards.

- Potentially significant variations in charging performance between brands and devices, due to the wide range of fast charging solutions on the market, meaning that, even if the likelihood is high that any given modern EPS can be used to charge nearly all mobile phones that are currently on the market, it may not do so at the same speed.

- A market in constant evolution, with USB Type-C connectors expected to gradually replace legacy USB connectors at the phone end (within the next few years) as well as the EPS end (more slowly), and innovation in fast and wireless charging technology likely to continue at a rapid pace.

According to the common charger study, the consequences of this situation is consumer inconvenience and negative environmental effects.

The assessments in this task are purely related to opportunities and saving potentials based on analyses of market data, standards, usages and technologies. If a preparatory study were initiated following the Working Plan, further assessment of interoperability, safety, product specific requirements, impact on energy efficiency, impact on consumer convenience etc. would need to be included. These topics are to a certain extent assessed in the common charger study, however, due to the much broader and diversified product

[709] Commission Regulation (EU) 2019/1782 of 1 October 2019 laying down ecodesign requirements for external power supplies pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulation (EC) No 278/2009

scope, encompassing products from e.g. small portable loudspeakers to lawnmowers, further and more detailed assessments would be needed to be carried out. These assessments may lead to adjustments of the scope.

20.2 Scope, policy measures and standards

20.2.1 Scope and policy measures

The suggested scope is based on the existing ecodesign regulation for EPSs covering energy efficiency and no-load losses: Commission Regulation (EU) 2019/1782[709]. It defines an EPS as a device that meets the following criteria:

- (a) it is designed to convert alternating current (AC) power input from the mains power source input into one or more lower voltage direct current (DC) or AC outputs;
- (b) it is used with one or more separate devices that constitute the primary load;
- (c) it is contained in a physical enclosure separate from the device or devices that constitute the primary load;
- (d) it is connected to the device or devices that constitute the primary load with removable or hard-wired male/female electrical connections, cables, cords or other wirings;
- (e) it has nameplate output power not exceeding 250 watts;
- (f) and it is used with electrical and electronic household and office equipment included in Annex I, which contains a list of electrical and electronic household and office equipment including toys, leisure and sports equipment.

The regulation excludes the following types of power supplies:

- voltage converters;
- uninterruptible power supplies;
- battery chargers without power supply function;
- lighting converters;
- external power supplies for medical devices;
- active power over Ethernet injectors;
- docking stations for autonomous appliances;
- external power supplies placed on the market before 1 April 2025 solely as a service part or spare part for replacing an identical external power supply placed on the market before 1 April 2020, under the condition that the service part or spare part, or its packaging, clearly indicate 'External power supply to be used exclusively as spare part for' and the primary load product(s) it is intended to be used with.

This study follows to a high degree the above-mentioned scope because it covers EPSs that are currently used for a wide arrange of devices that have the potential to be powered by a universal EPS, however, with the limitations in maximum nameplate output power following the USB specifications (see next section). Furthermore, other products not in scope of the EPS regulation such as power tools, vacuum cleaners and garden equipment are neither considered in this analysis.

Beside the regulation, the European Commission has established a voluntary scheme, the Code of Conduct for External Power Supplies (CoC)[710], which was prepared by the European Commission Joint Research Centre following the discussions and decisions of an ad-hoc working group composed by independent experts, Member States representatives and representatives of industry. The CoC aims to promote and bring recognition to the top performing EPSs on the EU market.

20.2.2 Standardisation activities

Over more than 20 years, industry standards and specifications for data transfer and power supply for electronic devices, initially mainly for computers and connected peripherals, has been developed, namely based on the USB (Universal Serial Bus) specifications. Until now, there have been four generations, from USB 1.x to USB 4. The standard establishes the technical specifications for cables and connectors and protocols for connection, communication and power supply. Behind this industry standard is the USB-IF[711] (USB Implementers Forum)[712]. Furthermore, IEC and ITU-T USB standards have been developed.

USB-IF has recently finalised the definition of a number of specifications that have led to the development of standards and recommendations that makes it possible to design an EPS (or a family of complementary and interchangeable EPSs) to be used in any electric and electronic device using DC power up to 100 Watts, voltage levels between 5 V and 20 V, and supporting so-called fast charging technologies providing opportunities for using them with a broad range of products with or without rechargeable batteries.

The EPS market is influenced by many standards that concern both the EPS itself and the connectors. In Table 248, Table 249 and Table 250 a selection of relevant standards for EPSs and connector types are listed.

The Industry Forum, USB-IF have finalised specifications for the USB system called USB Power Delivery (PD) that builds on the existing USB ecosystem. The standards[713] developed by USB-IF and the IEC enable the possibility of creating a universal EPS[714]. See a detailed description of the history of the development of USB standards and common EPS in Section 20.5 Technologies.

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[710] https://ec.europa.eu/jrc/en/energy-efficiency/code-conduct/external-power-supplies (EU Code of conduct for EPS)

[711] A stakeholder has pointed out that sustainability goals need to be aligned with safety regulations and standards. In the case of External Power Supplies for Small Electrical Appliances, the harmonized safety standards (e.g. EN 60335) require the product to be placed on the market with a power supply, contradicting the intent and effect of implementing Universal External Power Supplies. The proposed USB-IF standard for all appliances up to power re-quirements of 100W further does not address appliances for use in a wet area, e.g. a bathroom. Usage of USB-IF Universal Power Supplies in such conditions will violate harmonized standards and create safety hazards for consumers.

[712] The USB-IF is a non-profit industry group. It defines itself as “the support organization and forum for the advancement and adoption of USB technology as defined in the USB specifications”, www.usb.org

[713] Standards include a communication protocol between the EPS and the powered device to negotiate voltage level and power level, permitting multivoltage EPS powering devices, with a battery or without using the different voltage levels included in the standard, i.e. between 5V and 20V

[714] https://www.usb.org/usb-charger-pd

Table 248: Standards and specifications affecting EPSs for mobile phones

Type of EPS in terms of charging capability	Standards and specifications applicable	Interoperability with low-end and old phones	Interoperability with high end phones
Common EPS, as defined in 2009 MoU	IEC 62684	Yes	Can charge high-end phones at normal speed.
USB PD (Power Delivery)	IEC 62680-1-2 IEC 62680-1-3 IEC 63002	Yes	Yes
Quick Charge v1, v2, v3	None	Yes, although safety (for user and device) is not guaranteed.	Only phones including Quick Charge
Quick Charge v4, v4+	Programmable Power Supply Compatible with USB PD and USB C specifications	Yes	Yes

Source: Impact Assessment Study on Common Chargers of Portable Devices[715]

Table 249: Maximum power and data transfer speed supported by USB connectors

Type of connector	Latest standards and specification it supports (power)	Latest specification it supports (data transfer)	Max power	Max data transfer
USB micro-B	IEC 62684	USB 2.0	7.5 W	480 Mbps
USB Type-A	USB PD (IEC 62680-1-2)	USB 3.2	100 W	20 Gbps
USB Type-C	USB PD (IEC 62680-1-2)	USB 4	100 W	40 Gbps

Source: Impact Assessment Study on Common Chargers of Portable Devices[715]

[715] https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/c6fadfea-4641-11ea-b81b-01aa75ed71a1

Table 250: Other standards concerning EPSs

Other standards	Area	Description
ITU-T L.1000 3. Edition	Recommendations for universal power adapter and charger solutions	Recommendation ITU-T L.1000 provides high level requirements for a universal power adapter and charger solution that will reduce the number of power adapters and chargers produced and recycled by widening their application to more devices and increasing their lifetime. The solution also aims to reduce energy consumption. The longer life cycle and possibility of avoiding device duplication reduces the demand on raw materials and waste. The universal power adapter and charger solution is designed to serve the vast majority of mobile terminals and other ICT devices.
International efficiency marking protocol[716]	Energy efficiency of EPSs	The International Efficiency Marking Protocol for External Power Supplies Version 3.063 developed by the U.S. Environmental Protection Agency and now maintained by the U.S. Department of Energy (DOE) provides a system for setting specific minimum energy performance of EPSs. It sets active efficiency and no-load requirements for different levels, which are marked by Roman numerals: I, II, III, IV, V, VI etc. The higher the numeral is the higher energy efficiency is required.
Measurement methods developed by CENELEC[717]	EN 50563:2011 EN50563:2011/A1:2013	The measurement standard describes the determination of the no-load power and the average active efficiency of active modes of external AC-DC and AC-AC power supplies within the scope of the current regulation.

Source: IA EPS 2018[718]

20.3 Market

Table 251 show the estimated unit sales of equipment used with an EPS in scope of the EPS regulation. The data is based on the Impact Assessment of EPSs from 2018[718], who have collected data from 41 base cases with input from GfK, Statista and Lot 6 and 26 preparatory studies and impact assessments. The Impact Assessment EPS study have combined the base cases into 10 categories of different power ranges. The largest category in terms of sales is the 6-10 W category, which includes EPSs for smartphones and tablets.

[716] https://www.regulations.gov/document?D=EERE-2008-BT-STD-0005-0218

[717] https://ec.europa.eu/growth/single-market/european-standards/harmonisedstandards/ecodesign/powersupplies_en#This%20is%20the%20first%20publication

[718] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/1955-Ecodesign-requirements-for-external-power-supplies-

Table 251: Annual sales in millions of EPSs in scope of the EPS regulation

Power range	Base case description	2010	2015	2020	2025	2030
≤ 6W	a. 5W low voltage (e.g. mobile phone and rechargeable grooming products)	77	54	37	27	14
6–10 W	b. 10W normal voltage (e.g. tablets, smart phones etc.)	220	237	251	263	277
10–12 W	c. 12W normal voltage (e.g. small network equipment and set-top boxes etc.)	122	145	155	157	158
15–20 W	d. 18W normal voltage (e.g. portable devices and portable game consoles etc.)	1	5	9	10	11
20–30 W	e. 30W normal voltage (e.g. notebook computer)	15	15	14	14	13
30–65 W	f. 36W multiple voltage output (e.g. multi-device universal chargers etc.)	0	0	2	2	3
30-65 W	g. 65 W normal voltage (e.g. high-end notebooks computers)	0	0	4	5	5
65–120 W	h. 120W normal voltage (e.g. high-end notebook computers)	5	5	1	1	0
65–120 W	i. 120W Multiple voltage output (e.g. stationary game consoles)	24	9	3	3	3
12–15 W	j. 15W normal voltage (e.g. loudspeakers and sound systems)	11	23	28	28	28
	Total annual sales (million units)	**476**	**493**	**504**	**509**	**512**

Source: IA EPS 2018

The common charger study assumed that the sale of power adapters for mobile phones is equal to the sale of mobile phones, because a mobile phone in most cases is bundled with a power adapter. The sales figures in Figure 77 are divided into categories based on most commonly connector types used for mobile phones, see Figure 76. USB micro Type B is typically used on smart phones older than 2 years, whereas Type C is typically sold with new smartphones and the lightning cable is used to charge Apple products.

Figure 76: Illustration of different USB-compatible connector types

Figure 77 shows that the market is quickly adapting to the new USB C connector, which have increased from 2 % of the sales in 2016 to 29 % of the sales in 2018. Likewise, the lightning connector continues to have large market share of 21 %. This means that a large and increasing part of the EPSs for the mobile phones are equipped with the Type C connectors.

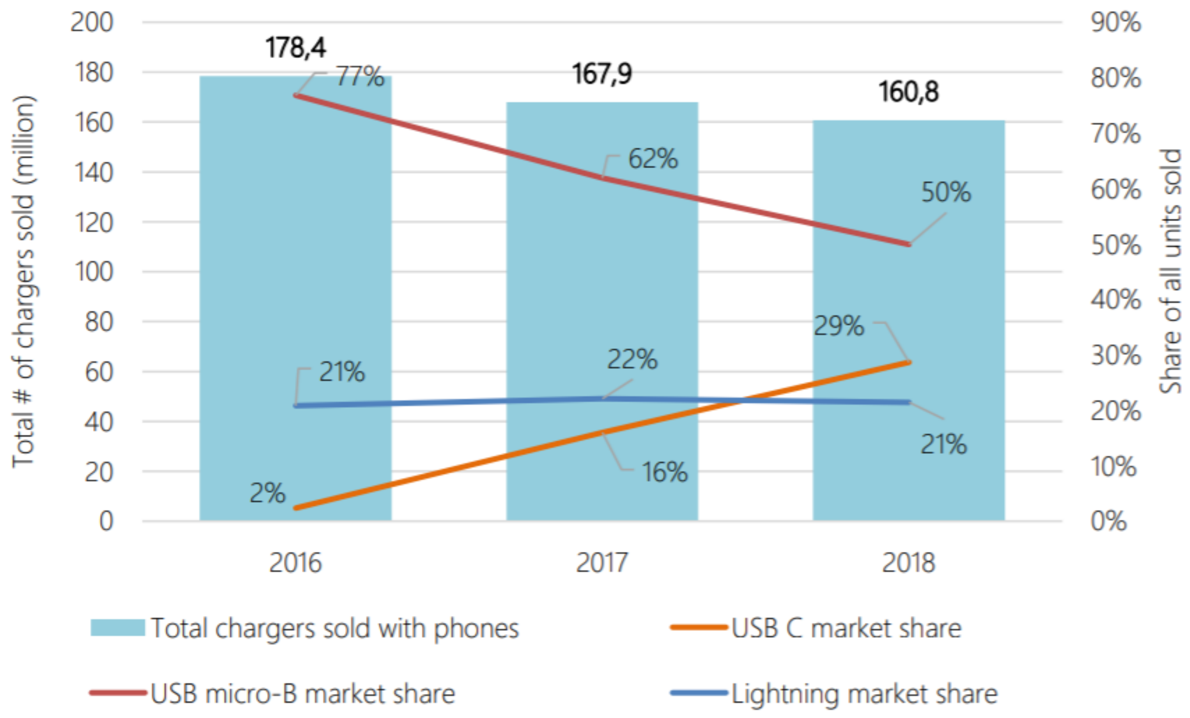


Figure 77: Mobile power adapters sold in 2016-2018 in EU28

Source: Common charger study

The common charger study also showed that the amount of fast charging solutions is increasing rapidly, see Figure 78. It is assumed that a large part of the fast charging solutions are Quick Charge v4 or v4+, which are compatible with USB PD and USB C that work across multiple product groups (the compatibility and how USB PD and USB C can be used for multiple products is described further in the technology section). The common charger study also found that 44.4 million wireless chargers were sold in EU in 2018. Furthermore, a consumer survey was carried out to determine the amount of mobile power adapters sold separately. 16.8 % of the consumers answered that they had bought a power adapter separately.

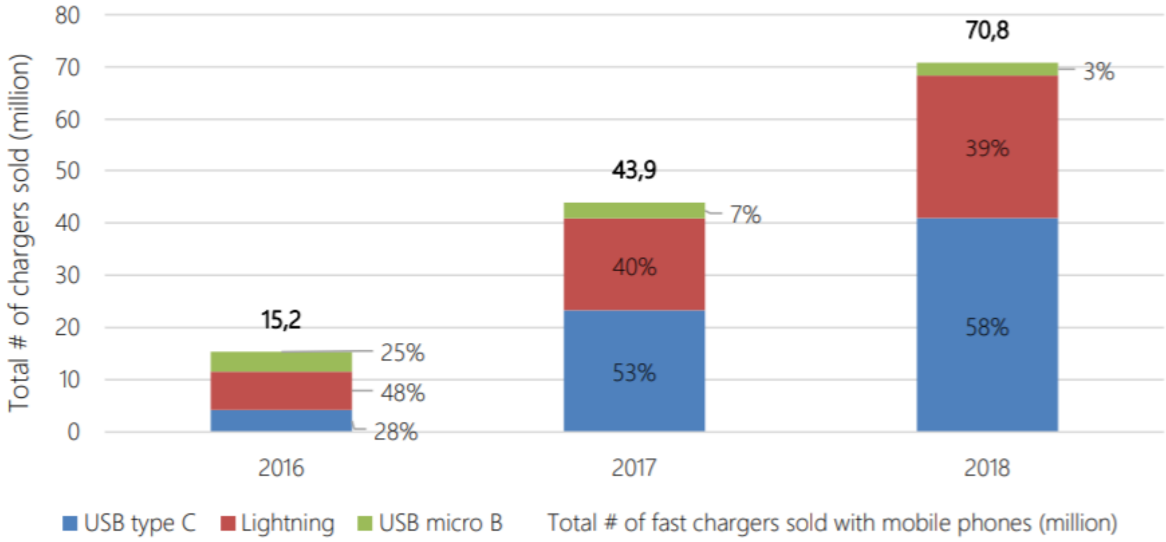


Figure 78: Fast charging solution sold with a mobile phones (EU 28, 2016-2018)

Source: IA Common Charges of Portable devices

Table 252 show the total stock estimated in the IA EPS study. In 2020, it is estimated that there will be more than 2 billion EPSs in Europe (EU28) within the scope of the EPS regulation and thereby the scope of this study. Some of the high-power demanding devices such as high-end notebook computers and stationary game consoles might not be included in scope, because it is only possible to charge with up to 100 W with the USB Type-C PD specification. The data source did not reveal the number of EPSs having output power of more than 100 W but it is assumed to be a minor part and therefore the data has not been corrected.

Table 252: Stock of EPS in millions

Power range	Base case description	2010	2015	2020	2025	2030
≤ 6W	a. 5W low voltage (e.g. mobile phone and rechargeable grooming products)	158	211	140	103	64
6–10 W	b. 10W normal voltage (e.g. tablets, smart phones etc.)	437	814	868	911	953
10–12 W	c. 12W normal voltage (e.g. small network equipment and set-top boxes etc.)	240	614	692	703	708
15–20 W	d. 18W normal voltage (e.g. portable devices and portable game consoles etc.)	1	13	29	33	37
20–30 W	e. 30W normal voltage (e.g. notebook computer)	30	82	81	76	72
30–65 W	f. 36W multiple voltage output (e.g. multi-device universal chargers etc.)	0	0	4	11	15
30-65 W	g. 65 W normal voltage (e.g. high-end notebooks computers)	0	0	13	25	27
65–120 W	h. 120W normal voltage (e.g. high-end notebook computers)	11	29	16	4	2
65–120 W	i. 120W Multiple voltage output (e.g. stationary game consoles)	51	87	22	14	14
12–15 W	j. 15W normal voltage (e.g. loudspeakers and sound systems)	21	96	147	155	156
	Total stock (million units)	**948**	**1946**	**2012**	**2034**	**2049**

Source: IA EPS 2018

Figure 79 show the stock estimation made in the common charger study, which show that the market for mobile phone power adapters is clearly moving towards the fast-charging USB C EPS. Furthermore, comparing the two sources, the figures show that EPSs for mobile phones constitute about 40 % of the total stock of EPSs within the scope of the EPS regulation.

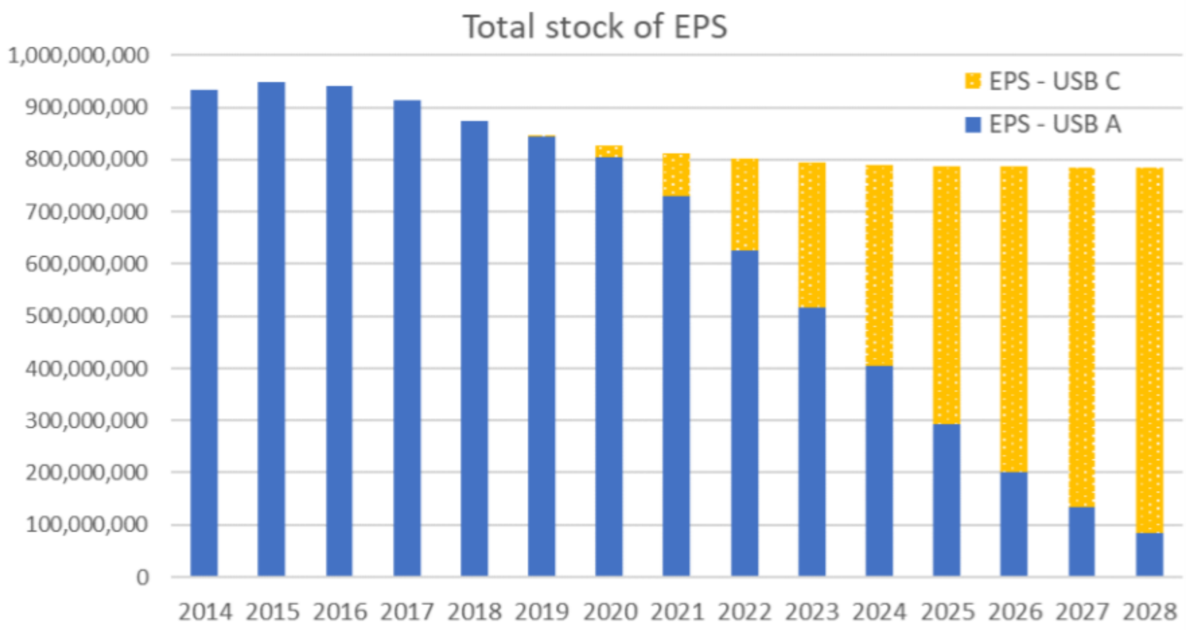


Figure 79: Stock model estimation of EPS types for mobile phones 2014-2028

Source: Common charger study

20.4 Usage

20.4.1 Usage time and lifetime

An EPS is used to power electronic and electrical devices, which cannot be connected directly to the Alternate Current (AC) mains using 230 V, but typically need Direct Current (DC) at a lower voltage, typically between 5 V and 20 V. The EPSs charge batteries in portable devices (e.g. smartphones) or supply continuous power to device without batteries (e.g. network routers).

The usage pattern for the EPS depends very much on type of appliance. Table 253 shows for the EPS categories from the IA for EPS (same categories used for the market data), where assumed time in each mode (active, no-load and unplugged) and average power level for the active mode are shown.

E.g. it is assumed that the power adapter for a smartphone is only used in active power state for 5.2 hours a day while a 12 W EPS used for powering small network equipment is used for 21.4 hours a day (assuming that some users switch it off during periods without use).

Common for all categories is that the average lifetime (i.e. lifetime of actual use) of the EPS is relatively low (3-5 years).

Table 253: Lifetime, nameplate power, active power, active hours, no-load hours and un-plugged hours per day for each base case.

EPS type	Name plate power (W)	Active power (W)	Active hours (hours /day	No-load (hours /day)	Unplugged (hours /day)	Lifetime (years)
a. 5W low voltage (e.g. mobile phone and rechargeable grooming products)	3.5	1.1	5.20	9.80	9.00	3.0
b. 10W normal voltage (e.g. tablets, smart phones etc.)	10	2.0	5.20	9.80	9.00	3.0
c. 12W normal voltage (e.g. small network equipment and set-top boxes etc.)	12	7.7	21.40	2.60	0.00	4.0
d. 18W normal voltage (e.g. portable devices and portable game consoles etc.)	18	3.1	7.00	10.00	7.00	3.0
e. 30W normal voltage (e.g. notebook computer)	30	7.6	20.72	0.00	3.28	5.0
f. 36W multiple voltage output (e.g. multi-device universal chargers etc.)	36	9.7	20.72	0.00	3.28	5.0
g. 65W normal voltage (e.g. high-end notebooks computers)	100	7.8	20.72	0.00	3.28	5.0
h. 120W normal voltage (e.g. high-end notebook computers)	120	7.6	20.72	0.00	3.28	5.0
i. 120W Multiple voltage output (e.g. stationary game consoles)	120	9.7	24.00	0.00	0.00	5.0
j. 15 W normal voltage (e.g. loudspeakers and sound systems)	9.5	2.3	24.00	0.00	0.00	5.0

Source: IA EPS 2018

20.4.2 Efficiency levels of EPS

This section describes the development of EPS efficiency[719] levels as information on the development of the market. The efficiency levels will not be impacted by a universal EPS initiative unless energy efficiency improvements will be included in this initiative, which has not been further considered in this section.

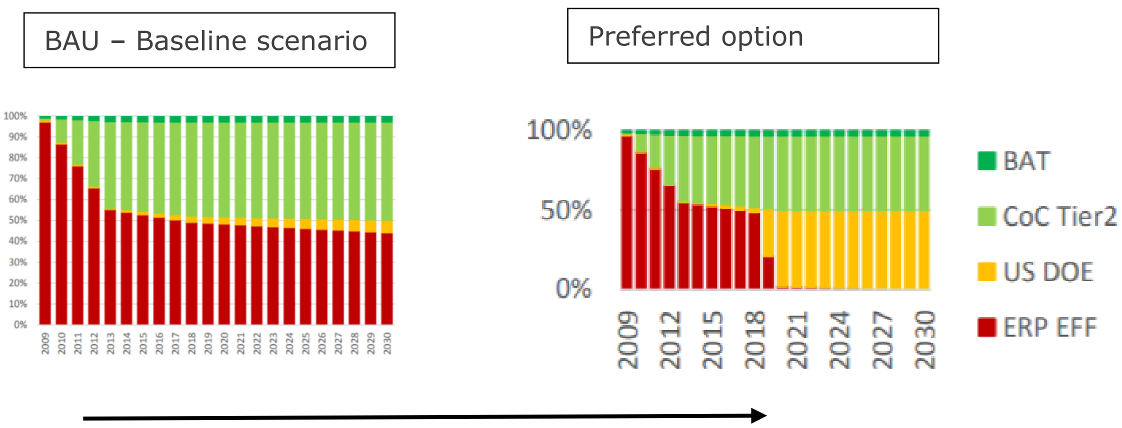
The efficiency levels of the EPSs sold in previous years and assumed in the coming years are grouped into four efficiency categories: 1) former Ecodesign 278/2009 level ("ERP EFF"), 2) US DOE[720], 3) EU CoC Tier 2, 4) mid-way between EU CoC[721] Tier 2 and BAT (or "Half BAT"), see Table 254. The data are from the IA EPS study.

The maximum efficiencies considered at different levels in Table 254 are derived using formulae from Ecodesign Regulation, US DOE rulemaking and EU CoC Tier 2 and the base case power output.

As the efficiency levels are based on the minimum requirements of the above-mentioned regulations and Code of Conduct, it means that the efficiencies of the EPS are slightly conservative as in practice the EPS on the market could be more efficient than these minimum values.

In the IA EPS study from 2018 a policy option that shift 70% of the market towards a higher efficiency in 2020 was preferred. Figure 80 illustrates the shift of efficiency for the 5 W low voltage EPSs. The pattern is the same for the other categories. The preferred policy option has an saving potential of 4.26 TWh/year and 1.45 Mt CO_2eq./year in 2030.

Figure 80: Efficiency distribution 2009 - 2030 for base case a 5W low voltage (e.g. mobile phone and rechargeable grooming products)



Source: Adapted from IA EPS 2018

[719] The term efficiency represents the share of electricity delivered to the product compared to the electricity input to the EPS (difference between input and output). Typical losses occur in the AC/DC conversion, where losses are emitted as heat.

[720] Requirements adopted by the US DOE (US Department of Energy)

[721] EU Code of Conduct on Energy Efficiency of External Power Supplies - Version 5

Table 254: Efficiency levels and no-load power for the EPS categories

	Efficiency level				No-load power (W)			
EPS type	ERP EFF	US DOE	CoC Tier 2	Half BAT	ERP EFF	US DOE	CoC Tier 2	Half BAT
a. 5W low voltage (e.g. mobile phone and rechargeable grooming products)	0.682	0.736	0.738	0.741	0.3	0.1	0.075	0.046
b. 10W normal voltage (e.g. tablets, smart phones etc.)	0.767	0.819	0.822	0.843	0.3	0.1	0.075	0.046
c. 12W normal voltage (e.g. small network equipment and set-top boxes etc.)	0.779	0.830	0.833	0.859	0.3	0.1	0.075	0.058
d. 18W normal voltage (e.g. portable devices and portable game consoles etc.)	0.804	0.850	0.855	0.859	0.3	0.1	0.075	0.058
e. 30W normal voltage (e.g. notebook computer)	0.836	0.869	0.877	0.885	0.3	0.1	0.075	0.058
f. 36W multiple voltage output (e.g. multi-device universal chargers etc.)	0.830	0.830	0.830	0.858	0.995	0.3	0.3	0.3
g. 65W normal voltage (e.g. high-end notebooks computers)	0.870	0.880	0.890	0.902	0.5	0.21	0.15	0.096
h. 120W normal voltage (e.g. high-end notebook computers)	0.870	0.880	0.890	0.902	0.5	0.21	0.15	0.096
i. 120W Multiple voltage output (e.g. stationary game consoles)	0.860	0.860	0.860	0.873	0.995	0.3	0.3	0.3
j. 15W normal voltage (e.g. loudspeakers and sound systems)	0.793	0.841	0.845	0.841	0.3	0.1	0.075	0.058

Source: IA EPS 2018

20.5 Technologies

In this section, descriptions of the different charging technologies of phones from the common charger study is presented.

20.5.1 Interoperability aspects

Following the MoU signed in 2009, CENELEC received a mandate from the European Commission to develop a harmonised standard for mobile phone chargers. In response, CENELEC created a task force to develop the interoperability specifications of a common EPS, and work was transferred into the International Electrotechnical Commission (IEC). The IEC published the standard IEC 62684 in 2011, and updated it in 2018. This standard specifies the interoperability of common EPS for use with data enabled mobile telephones. It defines the common charging capability and specifies interface requirements for the EPS[722].

According to the interviewees consulted in the common charger study, the standard (IEC 62684) was widely adopted by the industry for smartphone. However, it is not adopted in all possible products needing DC current and power below 100W such as, e.g.razors and shavers, portable vacuum cleaners, electric toothbrushes, electric knives, computer monitors and televisions, any battery charger module, etc. . As the technology evolved and smartphones required higher power than 7.5W (the maximum power allowed by the IEC 62684 is 5V at 1.5A), new technologies emerged to cover this need. For example, in 2013 Qualcomm released Quick Charge 2.0[723], which provided maximum power of 18W by increasing the current and the voltage of the common charger. Since then, Qualcomm has released Quick Charge v3, v4 and v4+. Quick Charge comes with Snapdragon devices and it has been adopted by a large number of mobile phone manufacturers, such as Samsung, Motorola, OnePlus, Oppo, LG, Xiaomi, and Sony. Other companies are also building fast charge technologies like Huawei's SuperCharge, Oneplus Dash/Warp/Oppo VOOC charge, MediaTek Pump Express, Motorola TurboPower and Samsung Adaptive Fast Charging. Of those mentioned, Quick Charge 4.0+, and Huawei Super Charge are USB PD compatible[724].

In parallel, the USB Promoter Group, formed by 100 members of USB-IF, was working to develop new battery charging specifications. In 2013, it set a cooperation agreement with IEC to support global recognition and adoption of USB technologies in international and regional standards and regulatory policies. As a result of the work carried out by the USB Promoter Group and USB-IF, IEC published in 2016 the standard series IEC 62680. This standard series set the specifications for USB Power Delivery (IEC 62680-1-2) and USB Type-C (IEC 62680-1-3). Both standards were last revised in 2018.

The USB Power Delivery (PD) specification describes the architecture and protocols to connect the battery charger and the device to be charged (e.g. a smartphone). During this communication, the optimum charging voltage and current are determined to deliver power up to 100 W. Some mobile phone manufacturers have since incorporated USB PD in their devices, such as Apple, Google, and Huawei. Samsung has recently announced new charging solutions based on USB PD.

The USB Type-C specification is intended as a supplement to the existing USB 2.0, USB 3.1 and USB PD specifications. It defines the USB Type-C receptacles, plugs and cable assemblies. This specification also sets charging requirements up to 15 W, and specifies the use of USB PD if the charge exceeds 15 W.

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[722] IEC 62684:2018 defines interoperability based on legacy USB technologies and does not cover charging interfaces that implement IEC 62680-1-3, IEC 62680-1-2 and IEC 63002

[723] Presentation prepared by Qualcomm for a meeting with the European Commission, DG GROW, on 8 September 2016

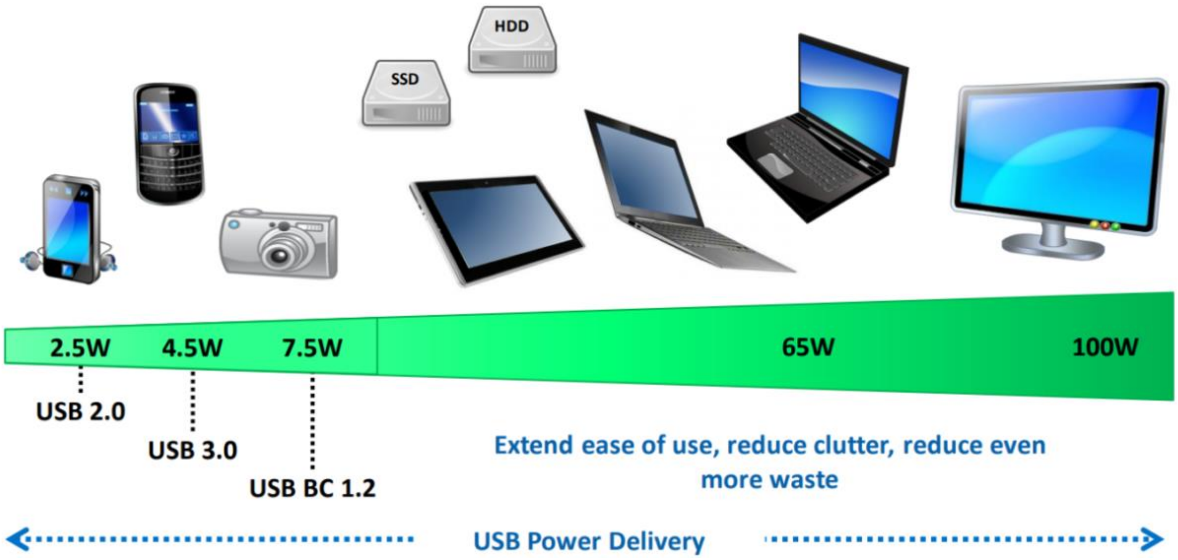
[724] https://www.digitaltrends.com/mobile/how-does-fast-charging-work/

On 8 January 2018, USB-IF announced the "Certified USB Fast Charger" which certifies chargers that use the feature "Programmable Power Supply" (PPS) of the USB PD specification. Qualcomm's Quick Charge v4 and v4+ incorporate PPS and therefore is compatible with USB PD. PPS ensures that the EPS can exchange data with the product to charge or deliver power to and dynamically adjust the output voltage and current according to the condition of the product.

Interoperability of the USB PD family is defined by the standard IEC 63002, released in 2016. This standard provides guidelines for the device and EPS to "communicate with each other", so that the EPS provides only the power that the device requires, avoiding damaging the battery and maximising performance.

Figure 81 illustrates the development of USB charging and powering capabilities since USB 2.0.

Figure 81: Illustration of the development of USB charging and powering capabilities.



Source: Android Authority[725]

20.5.2 Material composition

Table 255 shows the assumptions on material composition to model the energy consumption and related GHG emissions from manufacturing. The composition is based on data presented in the common charger study of a Samsung fast charger (15 W, weight 48 g incl. cable). This charger have been used to estimate the material composition of all base cases, under the assumption that all power adapters have similar material composition. However, a high nominal output power requires more material content (e.g. the weight of a Huawei quick charger 40 W with cable is 126 g and the weight of a Lenovo charger 65 W with cable is 343 g). However, newer low-weight type EPS using GaN (Gallium Nitride) combined with a higher switching frequency are coming on the market. Weight and size are typically half of the traditional chargers of the same nominal output.

[725] https://www.androidauthority.com/usb-power-delivery-806266/

To take these developments into account while still keeping in mind that smartphone chargers have almost half of the market share in 2020, the average weight of the EPSs used in the calculations has been adjusted from 58 g to 82 g to better reflect the market average.[726]

Table 255: Material composition used to model energy consumption and GHG from manufacturing

Description of component	Weight [%]	Weight [g]	Material group	Material
Plastic polymers - EPS	34	27.6	2-TecPlastics	11 -ABS
Metal components Steel – EPS	1	1.1	3-Ferro	26 – Stainless 18/8 coil
Metal components Copper – EPS	1	0.7	4-non-ferro	29 – Cu winding wire
Metal components Ferrite – EPS	11	8.9	3-Ferro	25 – Ferrite
Metals components Aluminium - EPS	3	2.4	4-Non-ferro	27 -Al sheet/extrusion
Unspecified materials[727] – EPS	16	12.7	6-Electronics	98-controller board
Plastic polymers – Cable	17	14.3	1-BlkPlastics	8-PVC
Metal components – Cable	6	4.5	4-Non-ferro	30-Cu Wire
Metal components Steel – cable	12	9.8	3-Ferro	26 – Stainless 18/8 coil

Source: Based on data from the common charger study.

20.5.3 Unit price

Table 256 provides the unit price as a weighted average for each EPS type.

Table 256: EPS unit price as sales weighted average for each EPS type for 2020.

EPS type	EUR/unit (weighted average)
a. 5W low voltage (e.g. mobile phone and rechargeable grooming products)	4.38
b. 10W normal voltage (e.g. tablets, smart phones etc. including USB 3.1 Profile 1)	7.22
c. 12W normal voltage(e.g. small network equipment and set-top boxes)	10.75
d. 18W normal voltage (e.g. portable devices and portable game consoles including USB 3.1 Profile 2)	8.03
e. 30W normal voltage (e.g. notebook computer)	13.82
f. 36W multiple voltage output (e.g. e.g. multi-device universal chargers including USB 3.1 Profile 4)	17.28
g. 65 W normal voltage (e.g. high-end notebooks including USB 3.1 Profile 5)	24.67
h. 120W normal voltage (e.g. high-end notebook computer)	27.08
i. 120W Multiple voltage output (e.g. stationary game consoles)	37.34
j. 15 W normal voltage (e.g. loudspeakers and sound systems)	12.21

Source: IA EPS 2018

[726] This assumption has also been made in the common charger study.

[727] Unspecified materials have been categorized as electronics/controller board under the assumption that it contained various kind of electronics.

20.6 Energy, Emissions and Costs

The energy consumption and GHG emissions related to the production of the EPSs in scope are assessed in the following. This assessment will be used in next section to calculate the savings by implementation of a universal EPSs concept. This concept will not have any impact on the in-use energy consumption for the EPSs (i.e. the conversion and no-load losses), which therefore have not been assessed. Hence, energy consumption and emissions are solely related to the assumed material content.

The primary energy consumption and GHG emissions related to materials and manufacturing are presented in Table 257 together with the total weight of the materials. The values have been calculated using the EcoReport Tool with data on sales and stock presented in Section 20.3 and the material composition presented in Table 255.

Table 257 represent the greenhouse gas emissions (in CO2 equivalent GWP-100) for all EPS equipment including cable.

Table 257: Total material weight, primary energy consumption, GHG emissions for products sold and in stock for year 2020.

EPSs	Total material weight [Kt]	Primary energy consumption [PJ]	GHG emissions [kt CO_2-eq.]	Consumer expenditure [Mill. EUR]
All EPSs sold	41	19	1,034	4,126
All EPSs in stock	165	74	4,126	16,096

Source: Stock model from IA EPS 2018 and EcoReport Tool

20.7 Saving potential

The impact in form of savings in primary energy consumption, GHG emissions, material weight and consumer expenditure have been assessed based on assumptions and assessments provided in the previous sections.

The overall assumption is that EPSs to a higher degree than now are unbundled from the product and can be used for several products and product types and can be transferred from an old product to a new product replacing the old product and thereby reducing the sale and manufacturing of EPSs.

The assumptions in reductions are based on the common charger study. The study considered two overall policy options: Increased interoperability (via several levels of increased interoperability) and decoupling of EPS and the product (via three scenarios, lower case, mid case and higher case).

Based on the study and simplifying the assessments, the following two scenarios have been established, indicating the percentage reduction in EPS sales and manufacturing compared to the baseline scenario:

- Mid case decoupling scenario combined with interoperability: 17% reduction
  This is considered as the most realistic scenario in the common charger study.

- High case decoupling scenario combined with interoperability: 37% reduction This is considered as the maximum possible scenario in the common charger study.

In the common charger study, separate reduction assumptions for EPS and cable have been established while here a weighted average based on the weight of the EPS and the cable is used.

It was not in the scope of the common charger study to consider mandatory requirement for manufacturers and distributors to decouple power adapters from phones. The decoupling rates therefore are based on the likely impacts of voluntary initiatives. The decoupling rates are thus depended on to what extent the manufacturers and distributors decide to offer phones without a charger and to what extent the consumers choose to buy phones without a charger. The decoupling rates comes with uncertainty, because no one knows how the market will react on the initiatives. However, the common charger study based the assumptions on consumer surveys and industry stakeholder consultations.

In Table 258 and Table 259 are presented the anticipated savings in total material weight, primary energy consumption, GHG emissions and consumer expenditure for 2020 sales and stock from the mid and high case decoupling scenario combined with interoperability.

Table 258: Savings obtained in 2020 sales from the mid and high case decoupling scenario combined with interoperability

Impact area	Unit	Baseline	Mid case savings	High case savings
Total material weight	Kt	41	7	15
Primary energy consumption	PJ	19	3	7
GHG emissions	Kt CO2-eq	1034	174	379
Consumer expenditure	Mill. EUR	4032	680	1478

Table 259: Savings obtained in 2020 stock from the mid and high case decoupling scenario combined with interoperability

Impact area	Unit	Baseline	Mid case savings	High case savings
Total material weight	Kt	165	28	60
Primary energy consumption	PJ	74	12	27
GHG emissions	Kt CO2-eq	4126	696	1513
Consumer expenditure	Mill. EUR	16096	2716	5902

The conclusion is that an initiative for a universal EPS could provide 3-7 PJ savings in primary energy consumption for the 2020 sales and 12-27 PJ savings for the total 2020 stock for a total replacement in addition to corresponding savings in material, GHG emissions and consumer expenditure.

In addition, it is important to consider the following savings and benefits:

- **Additional material savings –** Additional savings can be obtained if a potential universal EPS regulation also includes wireless charging to avoid potential loopholes.
- **Indirect material savings** - Indirect saving potential lies in the improved reparability of products, currently using an internal power supply (IPS), if an external one would be used: currently, IPS are frequently implemented as circuitry soldered on the main printed circuit board (PCB) or other board: a faulty IPS may easily result in the disposal of the entire product because of the labour cost for opening the products and possibly replacing an expensive internal board. A universal EPS, on the contrary, can be easily replaced by an inexperienced user and diagnosis of the possible fault would be possible by simply trying to connect another, similar universal EPS.
- **Additional consumer expenditure savings -** An additional saving potential related to consumer expenditure exists, as the cost of a mass-produced universal EPS would be progressively reduced and stimulate increased competition. Moreover, if a specific EPS production is discontinued, the consumers may decide to discard fully functional products when the EPS breaks.
- **Higher energy efficiency -** Energy efficiency may possibly be facilitated by the introduction of an energy efficiency labelling on this product category that would have comparable products: an energy scale on 3 or 5 classes may be possibly envisaged, on the line of the schemes already in place for internal adapters.
- **Other consumer benefits –** Increased consumer convenience and reducing unnecessary resource consumption, which is very visible to the consumers.

The calculated savings are based on the common charger study. A stakeholder[728] has provided a paper calculating a more optimistic saving potential 80%, with the following conclusions:

"Furthermore, assuming that a common charger policy will reduce the need for 80% of power supplies currently shipped with our smartphones and other devices, the savings brought about by a comprehensive decoupling policy would amount to approximately 29,000 tonnes of e-waste per year, as much as over 70 International Space Stations put together. In addition, the associated positive climate impacts would equal over 1,800 kilotonnes of CO2 equivalent spared, which corresponds to some 1 million cars being taken off our roads.

A decoupling policy is essential for the environmental savings to be achieved, and this will not be accomplished with standardised connectors alone – as the now expired Memorandum of Understanding clearly demonstrated. Addressing decoupling via a dedicated Ecodesign Regulation enables a wider focus beyond smartphones, reducing market fragmentation and leading to major increases in environmental benefits. While it requires a shift in consumer expectations at the time of purchase, it also offers the chance to resolve many of the current issues consumers experience with portable product chargers.

The shift to USB-C / USB 3.1+ power delivery protocols offers endless opportunities for innovation, but as is often the case, it needs to be steered in the direction of cooperation and standardisation. Our policy recommendations ensure that innovation proceeds at its

[728] ECOS - https://ecostandard.org/wp-content/uploads/2020/07/ECOS-COMMON-CHARGER-PAPER.pdf

current pace, guided in a direction that is less harmful to the environment, and ensuring a level playing field for the market. Furthermore, the suggested implementation makes it possible to bypass the shift to USB-C connectors and move straight to innovative wireless solutions when needed."

The annual savings would be approximately 1,800 kilotonnes of GHG emissions corresponding to approximately 90 PJ by applying the more optimistic saving potential.

20.8 Stakeholder comments

Comments were received from the following stakeholders:

- DIGITALEUROPE
- The Japan Electrical Manufacturers' Association (JEMA)

The following comments were provided; the study team's answers are provided for each of them:

DIGITALEUROPE comments that the industry would like to reiterate that the concept of "a single EPS" (or "one common power adapter", or "universal EPS") may be misinterpreted and does not align with the intention of the USB interoperability standards for common charging. USB technologies enable different chargers to be designed to match the requirements (power, functionality, cost, form factor etc.) and use cases of the target products while supporting charging interoperability with other products across different categories. It is strongly recommended for the Commission to consult with the USB/IEC technical experts in order to ensure accurate understanding of these international standards in order to scope the workplan appropriately.

While regulatory measures might not exist, various standards and voluntary industry initiatives do exist already that lead to increased interoperability of EPSs. The added value of regulatory interventions needs to be carefully assessed against all current initiatives and the state/evolution of the market.

Careful consideration needs to be given to the scope of any further universal EPS initiatives, in particular in light of increased interoperability and potential unbundling, which means defining EPSs in relation to the equipment would be complicated.

The inclusion of wireless charging needs to be carefully considered as this technology is evolving rapidly and it is unclear if/how regulatory requirements would automatically result in additional savings.

In addition, the feasibility section should better reflect the challenges and implications associated to implementing this recommendation:

- Mandated technical charger aspects, such as maximum output power, and the adoption of "single EPS" for different product groups could potentially decrease the long-term environmental and consumer benefits from USB technologies, as well as create obstacles for future innovations of these technologies in the EU market. The adoption of common charging interoperability, based on the IEC/USB standards, instead of a single charger solution could avoid these negative impacts.

- The implementation of one single power supply for different purposes may lead to safety issues, as the specificities of the use environment cannot be fully taken into consideration during design. Future requirements in this area should carefully consider safety, EMC and other regulations which are important requirements for EPS design.
- The implementation of one single power supply for different purposes may lead to quality issues, as consumers may be incentive to use low quality power supplies that can potentially damage electronic components in high end devices.
- The single EPS solution does not allow for a design optimization of the power consumption. And so, energy consumption can be hampered when consumers use an external power delivering more power than sufficiently required by a specific device.
- Some consumers may prefer a charger or cable to be supplied with their electronic devices. The decoupling of the charger from the products may lead to consumer dissatisfaction. Study shows that 87 percent of household report that they charge multiple devices at the same time at least sometimes per week, while over 60 percent do it on a daily basis, (Copenhagen report page 57 Figure 28). This suggests that consumers' choice to have more than one charger per location is for practical reasons and not only because of lacking interoperability between devices and chargers. For these reasons, it's not clear that even mandatory decoupling would reduce the number of chargers that consumers own.

The Japan Electrical Manufacturers' Association (JEMA) commented that the information published in task 3 report is not solid enough and contains too many inaccuracies to move to task 4. At least, the concerns on considerations to add as the product group to the task 4 selection should be further clarified:

- Safety: Different standards for safety are applicable for different categories of products, setting specific requirements pending products categories. Therefore, one single power supply may not fit all purposes. E.g., in case of IPX 4, water tightness is required for the product such as washable shavers, but a mobile phone adapter is not required any water tightness level.
- Quality: External power supplies designed with the same quality as the devices they are intended to charge. Therefore, if only one external power supply is used for many products, it may lead to quality issues. It is really concerned that consumers are incentive to use low quality power supplies that can potentially damage electronic in high end devices such as smartphones etc.

The study team is aware of the concerns and considerations of both DIGITALEUROPE and JEMA, which have also been considered by the study team during the assessments. If a preparatory study should be commissioned, the topics should be further assessed. At the same time, however, the situation is that more and more products are delivered without external power supply, where the consumer typically will use an existing power supply. In any case and in spite of unbundling efforts, it should naturally still be possible to get and use without any complexity an EPS suited for the product in terms for safety and quality.

21 UNIVERSAL BATTERIES

21.1 Scope, policy measures and test standards

The assessments in this task are purely related to opportunities and saving potentials based on analyses of market data, standards, usages and technologies. If a preparatory study should be initiated following the Working Plan, further assessments of interface with other regulations and standards, interoperability, safety, product specific requirements, impact on energy efficiency, impact on consumer convenience etc. would need to be included. Furthermore, a possible policy option may need to be seen together with possible policy options for universal external power supplies. These assessments may lead to a adjustments of the scope.

21.1.1 Scope

A broad range of cordless consumer and professional products such as power tools, cordless vacuum cleaners, gardening tools and lawnmowers use detachable rechargeable batteries that are very similar or identical, which however due to customised connectors, recharge docks, form factors and lack of data interoperability (i.e. because of non-standardised battery management circuitry and protocols), in most cases are not interchangeable between brands or even between different product series within the same brand. However, examples of cross-brand interoperability exist, demonstrating the concept that interoperability would be possible, if suitable requirements would be set.

This results in at least the following limitations and source of unnecessary and undesired waste and cost for consumers:

- Users with different products of the same category but from different brands and using them once at a time are required to buy a battery and its specific charging dock and external power supply (or charger) for every single product, unless they choose products from a single brand.
- Disposing of a broken/unrepairable tool/products results in disposing of its battery and its charger, although still perfectly usable and working unless they buy a tool of the same brand, provided that the customised connector, form factor, recharge dock and battery charging control circuitry protocols are still used and unmodified.

The consequence is that:

- the unbundling of the product from its battery and charger is rare and limited to some few cases, mostly in the professional market;
- the consumer's freedom of choice is limited even in the choice of battery most suitable to their needs, as the product is bundled to a battery with a capacity chosen by the manufacturer or distributor;
- even when unbundling is possible, there is a user lock-in, as an additional tool from a different brand would involve the purchase of an additional battery and specific charger;
- increased resource consumption because batteries, chargers and powered tools have different lifetimes, but malfunctioning of one of the three may result in disposal of all the three parts;

- reduced lifetime of the powered product in all those situations where replacement of an OEM battery or its charger outpaces the residual value of the product[729];
- high cost of batteries, as original spare parts, is seen as opposed to competition in cost and quality from interoperable batteries from different manufacturers.

Manufacturers of tools and products are unlikely to produce the battery cells themselves and they rather assembly cells from third parties with customised connectors (typically with sliding bay) and battery management control circuitry.

The aim of the concept of universal batteries assessed in this section is to reach a more sustainable use of batteries by incentivising voluntarily or mandatory common connectors and interoperability of detachable batteries for power tools and other household or gardening products using batteries similar to types used for power tools. Universal batteries and chargers are likely to create an independent competing market benefitting consumers choice and decreasing expenditure.

The batteries in scope are detachable and externally rechargeable batteries of common power tools, such as cordless drills, and of other household and professional products using detachable batteries similar to batteries used for power tools. Connectors are most often slide-in types, but stick-type batteries also exist.

The battery voltage levels may differ from product to product and have generally increased over the past years. The most commonly used voltage levels used today are:

- 12 V batteries used in small products such as light-duty screwdrivers aimed for DIY (Do It Yourself) products.
- 18 V batteries, which are the most commonly used battery in both DIY products and professional applications. They are used in most power tools and other products intended for craftsmen, gardeners, mechanics, etc., apart from the smaller and larger products described above and below. Besides power tools, these products also include radios, lamps, inflators, compressors, cordless vacuum cleaners etc.
- 36 V batteries, which are only used in larger and more powerful products such as lawnmowers, rotary hammers, crosscut and mitres etc. However, some manufacturers obtain 36 V by simply connecting in series two 18 V batteries.

It should be noted that batteries with other voltage levels also exist, such as 14.4 V[730], 20 V[731], 21.6 V[732], 40 V[733], 60 V[734] and a range of other voltages. However, the above levels are by far the most commonly seen on the market.

21.1.2 Policy measures and test standards

Power tools were included in the Working Plan Study 2 (2011-2014) and 3 (2016-2019) but excluded at an early stage because of limited energy saving potential, which means that power tools and their batteries are not included in any ecodesign or energy labelling

[729] A still working product or charger would be disposed of if the cost of an original OEM spare battery is too high, whilst an open competition on compatible batteries and chargers would lower replacement costs.

[730] https://www.bosch-professional.com/africa/en/products/gsr-14-4-v-li-060186600E

[731] https://www.dewalt.com/products/power-tools/shop-by-cordless-platform/20v

[732] https://www.amazon.com/Dyson-Battery-Replacement-Compatible-Cord-Free/dp/B07F6X8D1R

[733] https://www.amazon.com/Ryobi-40-Volt-Brushless-Chainsaw-Without/dp/B00NO7CMA2

[734] https://www.stiga.com/dk/295486868-st1-combi-48-sq-mae.html

regulation. An ecodesign preparatory study and an impact assessment for rechargeable electrochemical batteries (secondary batteries) with a primary focus on batteries for electric vehicles and electric grid support have been carried out. The scope was secondary batteries in the size of 1-1000 kWh designed for electric vehicles or for electric grid support. Batteries in an electric vehicle may seem very different than the ones used in, e.g. power tools, but some electric vehicles use the same cylindrical cells, which are also used in products in the scope of this assessment.[735][736] The outcome of the study and impact assessment fed into the work on a new battery regulation; see below.

The following regulations, standard and other initiatives are considered relevant for the products in scope in relation to the assessments carried out in this Task 3 report:

m) Regulations

1. The Battery Directive 2006/66/EC[737] applies to all types of batteries and sets rules regarding placing on the market of batteries, specifically prohibiting batteries containing hazardous substances such as lead, mercury and cadmium. A proposal for a Regulation concerning batteries and waste batteries, repealing the Batteries Directive was published during the preparation of this analysis (December 2020)[738].
   It is important to highlight the design requirements in the proposal for portable batteries, which includes strengthed obligations regarding removability and new obligations on replaceability. However, a requirement on interoperability was discarded at an early stage with the following reasoning[739]: *"a requirement on interoperability – which in theory could trigger a reduction in the number of batteries needed to operate a certain number of appliances – was not analysed in further detail because of the far-reaching consequences it would have in terms of design and product compliance obligations (including liabilities)"*

2. Commission Regulation (EU) 2019/1782 of 1 October 2019[740] laying down ecodesign requirements for external power supplies pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulation (EC) No 278/2009. The regulation on ecodesign covers external power supplies with an output power of maximum 250 W, which are intended to work with electrical and electronic household and office equipment. The rules apply to both the active efficiency and the no-load power consumption. Active efficiency is the average efficiency when a power supply is connected to a device, such as a laptop, when used. No-load power consumption is the power consumed when the supply is plugged into a power outlet but not connected to a device. Voltage converters, uninterruptible power supplies, battery chargers, halogen lighting converters and external

[735] https://batteryuniversity.com/learn/article/types_of_battery_cells

[736] The drop in cost of tools battery is also a result of the production scale of these cells, now also used in the electric vehicles or even for stationary storage (both domestic and utility level).

[737] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006L0066-20131230&rid=1

[738] Proposal: https://ec.europa.eu/environment/waste/batteries/pdf/Proposal_for_a_Regulation_on_batteries_and_waste_batteries.pdf. Annex: https://ec.europa.eu/environment/waste/batteries/pdf/Annexes-Proposal_for_a_Regulation_on_batteries_and_waste_batteries.pdf

[739] https://eur-lex.europa.eu/resource.html?uri=cellar:5ee7d299-3ad8-11eb-b27b-01aa75ed71a1.0001.02/DOC_1&format=PDF, p. 56

[740] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1572280419368&uri=CELEX:32019R1782

power supplies for medical devices are excluded from these requirements. However, some chargers may be included in the regulation if they have a power supply function and fulfils the definition of a power supply.

n) Standards

1. EN 61960-3:2017 Secondary cells and batteries containing alkaline or other non-acid electrolytes[741]. Secondary lithium cells and batteries for portable applications. Prismatic and cylindrical lithium secondary cells, and batteries made from them. Includes measurement methods for battery performance, including electrical measurements, charge measurements and endurance testing in terms of cycle times the battery can withstand.

2. A long list of different standards regarding batteries is available at www.batterystandards.info. Including standards on performance, ageing and safety tests.

o) Other initiatives

1. ENERGY STAR specification [742] for Battery Charging Systems was sunset on December 30, 2014. The old specifications had requirements regarding non-active energy ratio, which is the ratio of the accumulated non-active energy divided by the battery energy. The accumulated non-active energy is the energy, in watt-hours (Wh), consumed by the battery charger in battery maintenance and standby modes of operation over a defined period. The battery energy is the energy, in watt-hours (Wh), deliverable by the battery under known discharge conditions.

2. Memorandum of Understanding (MoU) regarding Harmonisation of a Charging Capability for Mobile Phones[743] which promotes the use of common chargers. As a result, EU's major mobile phone manufacturers agreed to adopt a universal charger for data-enabled mobile phones sold in the EU. The MoU committed the industry to provide charger compatibility on the basis of the micro-USB connector. Afterwards, the Commission authorised a study to consider an appropriate legislative approach that analysed the impact of a common charger solution on consumers, the industry and the environment with assessment and guidance for implementing different policy options[744]. EU has initiated other activities within this area. Furthermore, universal external power supplies – covering more broadly harmonisation of external power supplies - are also included in the Working Plan study. See Section xx [to be updated when all sections are included in one Task 3 report].

[741] https://www.batterystandards.info/node/920

[742] https://www.energystar.gov/products/spec?term_node_tid_depth_1%5B%5D=1089&field_status_value%5B%5D=Historical&field_status_value%5B%5D=Sunsetted&field_effective_start_date_value%5Bvalue%5D%5Bdate%5D=&field_effective_start_date_value2%5Bvalue%5D%5Bdate%5D=

[743] https://ec.europa.eu/growth/sectors/electrical-engineering/red-directive/common-charger_en

[744] https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/c6fadfea-4641-11ea-b81b-01aa75ed71a1

21.2 Market

Table 260 shows estimated unit sales and stock of batteries. The data are based on the previous working plan study assessing power tools as a product group, which were based on sales data on input from EPTA (European Power Tool Association). Based on data between 2008 and 2013, the sales pattern has been forecasted until 2030.

The previous working plan study was solely focusing on corded and cordless power tools. The data is presented in Table 260.

Table 260: Sales of power tools (corded and cordless) from the previous working plan study.

Year	2004	2006	2008	2009	2011	2013
Sales	24,000,000	27,000,000	33,000,000	24,000,000	28,000,000	31,000,000

In the previous working plan study, the assumed sales of cordless power tools were approximately 50% of the total sales, which means that in 2013, approximately 15.5 million cordless power tools were sold. Today, EPTA estimates a total sales volume of 50 million units with a 60% share of cordless products meaning that 30 million cordless products are sold today. This fits well with information from stakeholders that the market is moving towards battery-driven products, which is also a trend seen in other product areas and that is expected to accelerate due to advancements within the battery technology and the end-products as well.

The same trends are seen in other sectors as well:

- According to EGMF (European Garden Machinery Federation), the sales of battery-driven garden tools increased from 2.4 million units in 2015 to 5.7 million in 2019.
- According to the review study for vacuum cleaners, this market is also moving towards cordless products. In 2015, the sales of cordless vacuum cleaners and robots were 5.7 million, and in 2030 the expected sales of these products are almost 23 million products.

With the above-mentioned sales of power tools, garden tools and vacuum cleaners, the following assumptions are made based on stakeholder input to calculate the sales and stock towards 2030:

- The average lifetime of these battery types is 5 years.
- Approximately 20% of the sales are 12 V products, 70% are 18 V products and 10% are 36 V products.
- It has not been possible to collect data on the actual sales of batteries, but it is assumed to be 25% above the sales of the battery-driven products mentioned above. This includes batteries as spare parts when worn-out or when an extra battery is needed to cover a full working day or have a higher lifetime regarding the battery bundled with the product.
- It is assumed that a charger is sold with approximately 75% of the batteries.

In Table 261 the assumption of sales and stock data is presented.

Table 261: Sales and stock data

Product	Sales [Million units] 2015	2020	2025	2030	Stock [Million units] 2015	2020	2025	2030	Average lifetime [Years]
12 V batteries	5	9	13	17	28	53	81	108	5
18 V batteries	24	42	59	77	99	186	282	379	5
36 V batteries	5	9	13	17	14	27	40	54	5
Total batteries	**35**	**60**	**85**	**110**	**142**	**266**	**404**	**541**	**5**
Chargers	26	45	64	83	106	199	303	406	5

21.3 Usage

The products using in-scope batteries can vary greatly from a range of different power tools (grinders, drills, impact drills, multi cutters, jigsaws, screwdrivers, mixers etc.) to vacuum cleaners, lighting products, radios etc. Many of these products are intended for craftsmen and DIY consumers. A variety of different cordless products are presented in Figure 82.

Figure 82: A range of different products with 18 V detachable batteries[745]

[745] https://www.pdfmanualer.dk/thumbs/products/l/1182105-bosch-unlimited-bcs1topnc.jpg, https://encrypted-tbn0.gstatic.com/images?q=tbn%3AANd9GcRvLREldNEtFLdG86o_I8JmYiPlMojL3f0MMg&usqp=CAU

It seems like more and more household products such as cordless and robotic vacuum cleaners become available with the possibility to use the same type of batteries. The same trend is visible within powered garden tools such as lawnmowers and trimmers. Products that can use the same batteries are most often from the same manufacturer, meaning that, e.g. a Bosch 18 V battery used for a drill can be used in a Bosch cordless vacuum cleaner[746]. The same can be seen at other manufacturers, e.g. Dewalt and Makita, where the batteries can be used for multiple product types and even in radios, vacuum cleaners (cordless and robotic) and lawn mowers in the same brand (Figure 1). Some manufacturers provide batteries of different voltages to supply the needed power, e.g. an 18 V battery for a drill and a 36 V battery for lawnmowers, where other manufacturers design the product to use two 18 V of batteries simultaneously instead of one 36 V battery. E.g. Makita provides an 18 V battery that is claimed to be able to power 120 machine types (within the Makita brand), including types, which need 36 V, which is achieved by using two batteries[747].

According to a stakeholder, there is a risk that a given product using a universal battery result in a poor combination as batteries are designed for the specific application, e.g. waterproof batteries for lawnmowers and batteries with high power output for an angle grinder. This issue should be looked at during a possible preparatory study. However, there are already many products on the market, where one single battery type can be used both for indoor and outdoor products. Moreover, specific battery types, e.g. for extreme conditions[748], could use the same form-factor, connector/slide and charger of others,

Even though the need for batteries is expected to be higher for professionals, DIY consumers purchase professional products, and an increasing number of gardening and home products use already or may use the same batteries. Moreover, there is an increasing number of products not developed or even not produced anymore with the wired option and new types of products and tools invented because of the cordless possibility in a family group. Even hard discounts stores are now launching their own "brand" of products, with legacy and removable batteries (Figure 2) but not interoperable with similar tools from other brands (and requiring a specific charging cradle).

[746] Note, that it is only a limited number of Bosch cordless vacuum cleaners can use the 18V batterie from power tools.
[747] https://www.worldofpower.co.uk/blog/makita-one-battery-fits-all/
[748] High humidity, very low of very high temperatures, etc.

Figure 83: Two examples of new "families" of cordless products now available at hard discounts (Aldi-Ferrex and Lidl-Parkside in this picture).

According to a stakeholder, professionals always secure having a fully charged spare battery to avoid downtime, hence professionals use more batteries due to high usage but also to avoid downtime. However, tools rarely used are usually kept and transported without the battery.

Conversely, domestic and DIY users use a variety of tools but one at a time, so a single or a couple of batteries and one single changer may serve all tools at home (thus the opportunity of unbundling the purchase of the products from the battery and from its charger).

21.4 Technologies

21.4.1 Cell types

The market for batteries is continuously experiencing technological development. Batteries are used in more and more products and have to fulfil many product-specific requirements regarding weight, power, voltage, form-factor, interoperability, connectors, safety etc., which not always are compatible. To reach the desired voltage and/or ampere-hours, multiple cells are combined in series, parallel or a combination of series and parallel. The typical cell used is a 18650 (18 mm in diameter and 65 mm long) lithium-ion cylindrical cell with approximately 3.6-3.7 volt and the ampere-hours often varying between 1.8 ampere-hours and 3.6-ampere hours[749,750]. To reach e.g. 18 V, five of the cylindrical cells are connected in series, and to increase the store energy, cells are connected in parallel (Figure 3).

[749] https://commonsensehome.com/18650-battery/
[750] https://www.protoolreviews.com/news/voltage-vs-amp-hours/16313/

Figure 84: Exploded view of a typical battery (18V, 9Ah, courtesy of Milwakee)

To increase the ampere-hours, it is necessary to add a new series of batteries connected in parallel to reach 18 V and 4 ampere-hours. Another possibility to increase the number of ampere-hours is to use cells with higher energy density. Yet another possibility, which is seen in the industry by Metabo, Bosch and Milwaukee, is to use a 21700 cell (21 mm in diameter and 70 mm long) or even 46800 cells. A 21700 cell has the same voltage around 3.6 to 3.7 V but with 3 to 5 ampere-hours.

The typical 18650 and 21700 cell in 18 V power tools are presented in Table 262.

Table 262: Typical 18650 and 21700 cell in 18V power tools

Description	Ampere-hours	Watt-hours
Five 18650 cells in each series		
Compact Battery (1 series)	2.0Ah–3.0 Ah	36 Wh–54 Wh
General Purpose Battery (2 series in parallel)	4.0Ah–6.0 Ah	72 Wh to 108 Wh
High Capacity Battery (3 series in parallel)	9.0 Ah	162 Wh
Five 21700 cells in each series		
Compact Battery (1 series)	3.0 Ah–4.0 Ah	54 Wh–72 Wh
General Purpose Battery (2 series in parallel)	6.0Ah–8.0Ah	108 Wh–144 Wh
High Capacity Battery (3 series in parallel)	9Ah–12Ah	162 Wh–216 Wh

The 21700 cell has a larger volume but not necessarily more energy (i.e. number of ampere-hours) or energy-density, which is depending on the assembly and resources used in the cell.

A study has investigated the different types of cells and found the following conclusions[751]:

- *"The energy content per cell can be higher by ~ 50% for 21700 compared to 18650. Therefore, for certain applications, less cells have to be built and used to deliver the same amount of energy.*
- *The higher energy content on cell level leads to potentially lower effort and costs in the production of 21700 compared to 18650 type cells and their packs. The benefit of lower cell hardware costs is likely to be caused mainly by less cell housings, fewer jellyroll insertions/closings/tab welding, and less cell formations per Wh. More produced Wh per existing station might also have a trickledown effect on the cost.*
- *The energy density does not increase significantly by changing the cell format from 18650 to 21700 type. Instead, for state-of-the-art cells, the energy density is mainly a function of the anode coating thickness, i.e. high energy cells with current material combinations usually have thicker electrodes. The study showed that it is very important to use comparable coating thicknesses or electrode loadings when comparing different active materials or at least give the coating thickness for later comparison.*
- *The cell resistance is negatively influenced by the electrode thickness and positively by the electrode area. For cylindrical cells these parameters correlate with each other. This contributes to the lower performance of high energy cells. Going from the 18650 to the 21700 format, the cell resistance decreases noticeably and shows a relatively flatter correlation to anode coating thickness. The reason is the larger usable coated cathode area in the larger 21700-type cells, especially due to the outer windings of the jelly roll.*
- *Increasing electrode thickness in commercial cells has a negative impact on the discharge rate capability. Cells with thicker electrodes experience higher losses by limited transport, resulting in lower discharge energy and underutilised electrode active material. The general trend for all tested cell types was found that the rate-capability is limited by the temperature on the cell surface due to current flow."*

Based on this study, it seems that the 21700 cell has clear improvements over the 18650 cell though the energy density is not necessarily higher. Besides the shift in cell dimensions, the different manufacturers include different options to improve the power output and batteries' lifetime. The improvements can briefly be described as:

- More power output from the batteries due to improved cooling, better materials with lower internal resistance (ohms) and thereby lower losses and larger connectors[752]. Previous batteries could provide output up to 800 watts but today up to 1440 watts or more is possible from an 18 V battery[753] meaning that batteries can power more products.
- Longer battery life by better thermal management of the battery when used and when charged. The charger also adjusts the charging speed, meaning that the first 80% can be charged faster while the remaining 20% can be charged at a slower speed for better protection of the battery[754]. The higher capacity of new batteries may also imply fewer charge cycles, resulting in an experienced longer lifetime.

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[751] Jason B. Quinn et al 2018 J. Electrochem. Soc. 165 A3284, available at: https://iopscience.iop.org/article/10.1149/2.0281814jes

[752] Without hampering the exchangeability

[753] https://www.protoolreviews.com/news/21700-vs-18650-behind-the-lithium-ion-battery-battles/48042/

[754] https://www.boschtools.com/us/en/boschtools-ocs/batteries-chargers-starter-kits-bc1880-146184-p/

In future, it is expected that the energy density will improve further, and an increased focus on the durability of the batteries can be expected. Also, other types of cells may be used in the future, e.g. pouch cells, which have a higher packaging density (cylindrical cells cannot be packed without air pockets between the cells due to the geometry of the cell).

According to a stakeholder, the battery technology is generally moving towards solid-state batteries with higher voltage levels, but this may imply that the current use of, e.g. 18 V would change to, e.g. 20 V with a new cell voltage level of 5 V instead of 3.6 V. New cell formats may also become cost-efficient because of the economy of scale (i.e. because used by the automotive industry) such as the new 4680 cell format.

21.4.2 Connectors and cross-manufacturer compatibility

The change of battery cell and materials in the cell and energy density do not affect the type of connector and interoperability. Manufactures that produces the 21700 cell batteries or other types of cells can be used in products with 18650 cell batteries[755],[756]. So even with further advancements, it is expected that many of the existing connectors can be used. The most commonly used types of battery and connectors are presented in Figure 85.[757,758]

Figure 85: Commonly used types of battery and chargers (group at right)

Today the form-factor of most of the batteries from the major manufactures are slide-in batteries though previously, other types of batteries existed. For small products with a voltage below 18 volt stick type batteries still exist. The connectors often only fit one brand or one product series under a brand, though there are no technical reasons for this.

According to a stakeholder, the batteries are an important part of the innovation and the different manufactures compete on the size, weight, energy content and power output. The power output is important to ensure proper functions of even larger appliances. Additionally, the stakeholder believes that the batteries are an important part of the differentiation between different brands.

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[755] https://www.metabo.com/com/en/info/competence/battery-pack-technology/lihd-battery-pack-technology/
[756] According to a stakeholder it is possible to use e.g. batteries with a pouch cell in the current 18V products.
[757] https://www.aussiebatt.com/blog/how-to-choose-the-best-cordless-tools-and-power-tool-batteries/
[758] https://www.globalindustrial.com/g/tools/Batteries-Chargers/cord-less-batteries/milwaukee-cordless-batteries

Some manufacturers have formed an alliance for cross-manufacturer battery pack systems, the Cordless Alliance System (CAS)[759], which allows slide-in type batteries to be used across products from different manufacturers, see Figure 86. In this system, both batteries with 18650 and 21700 cells exist. It is up to the consumer to decide which combination of battery and machine are suitable for different tasks. This alliance is important as showing the concept that it is possible to harmonise the batteries for interoperability across products from different manufacturers.

Figure 86: Cordless Alliance System (CAS)

21.4.3 Charging interoperability

The batteries used in these tools are provided with a very specific and customised insertion system to ensure electrical continuous connectivity and solidity. Thus a sliding mechanism is used to firmly connect the battery being resisting to shocks etc. The electrical connectors, moreover, are legacy.

An analogous sliding and blocking mechanism is provided for recharging the battery: special purpose charging bays or cradles are needed that include an EPS (external power supply). Thus, a user needing to use different batteries for different brands of tools, has to multiply also the cradles and even the EPSs, although these may in principle be interchangeable and shared for all batteries with the appropriate interoperability standards, and a single EPS could recharge multiple batteries, even of different voltage[760].

In addition to the battery connector fitting to the product, a universal battery also requires interoperability between the battery, the charger and the product using the battery. This concerns the voltage levels, power and current delivered, charging speeds, safety measures, etc., which may depend on the product type and the environment in which it is used, e.g. indoor or outdoor and in hot or cold climates. Specific circuity in the batteries constituting a battery management system performs these communication and control functions.

[759] https://www.cordless-alliance-system.com/

[760] Similarly to what USB PD (IEC EN 62680-1-2) allows, i.e. by supporting 5, 9, 12 and 20 V at once.

During charging and discharging, communication takes place between charger and battery or battery and product, respectively, which requires that these are interoperable. There may be varying degree of interoperability, e.g. a basic level may include a low charging speed and/or low power delivery to the product but a less rudimental communication may include temperature, voltage, resistance and other parameters to ensure battery durability (again similarly to what has been done in USB by the power delivery (PD) specifications)

21.4.4 Material composition

Regarding the materials, different types of batteries exist, such as NiCd, NiMH and lithium-ion battery cells. The development is expected to go fully towards lithium-ion batteries as they have clear improvements regarding energy density, no memory and faster charging speed. Even within the different types of batteries, different material composition exists.

The materials composition of a typical lithium-ion battery is shown in Table 263.

Table 263: Material composition of the content of a typical battery cell without cell packaging, module, management system etc. shown as percentage of total content[761]

Description of component	%	Material group	Material
Cell cathode			
Cathode active material: NCM 622	6.6%	8-Extra	100-NCM622
Cathode active material: NCM 424	0.0%	8-Extra	101-NCM424
Cathode active material: NCM 111	0.0%	8-Extra	102-NCM111
Cathode active material: LMO	2.6%	8-Extra	104-LMO
Cathode active material: NMC 523	0.9%	8-Extra	103-NCM532
Cathode active material: NCA (80/15/5)	0.6%	8-Extra	105-NCA
Cathode active material: NCA (82/15/3)	4.8%	8-Extra	105-NCA
Cathode active material: LFP	3.7%	8-Extra	106-LFP
Cathode conductor: carbon	1.2%	8-Extra	107-Carbon
Cathode binder: PVDF	1.0%	8-Extra	108-PVDF
Cathode additives: ZrO2	0.0%	8-Extra	109-ZrO2
Cathode collector: aluminium foil	3.5%	4-Non-ferro	27 -Al sheet/extrusion
Cell anode			
Anode active material: graphite	12.2%	8-Extra	110-Graphite
Anode binder: SBR	0.2%	1-BlkPlastics	11 -ABS
Anode binder: CMC	0.2%	8-Extra	111-CMC
Anode collector: copper foil	7.4%	4-Non-ferro	30 -Cu wire
Anode heatresistnt layer: aluminium foil	0.3%	4-Non-ferro	27 -Al sheet/extrusion
Cell electrolyte			
Fluid: LiPF6	1.3%	8-Extra	112-LiPF6
Fluid: LiFSI	0.0%	8-Extra	113-LiFSI
Solvent: EC	3.4%	8-Extra	114-EC (Ethylene carbonate)
Solvent: DMC	3.4%	8-Extra	115-DMC (Dimethyl carbonate)
Solvent: EMC	1.5%	8-Extra	116-EMC (Ethyl methyl carbonate)
Solvent: PC	0.0%	8-Extra	117-PC (Propylene carbonate)
Cell separator			
PE 10 micron+AL2O3 6 micron coating	0.1%	4-Non-ferro	27 -Al sheet/extrusion
PP 15 micron + AL2O3 6 micron coating	0.3%	4-Non-ferro	27 -Al sheet/extrusion
PP/PE/PP	1.0%	1-BlkPlastics	4 -PP
PE-Al2O3	0.3%	4-Non-ferro	27 -Al sheet/extrusion
Auxilary materials			
Hydrochloric acid mix (100%)	31.4%	8-Extra	118-Hydrochloric acid
n-Methylpyrolidone (NMP)	12.1%	8-Extra	119-n-Methylpyrolidone (NMP)

21.5 Energy, Emissions and Costs

This section assesses the energy consumption and GHG emissions related to the production of the batteries in scope in order to be able to calculate the savings by a universal battery concept, i.e. the possibility to exchange and use batteries with different products from different manufacturers and thereby reduce sale of batteries. This concept will not impact the in-use energy consumption in the charger or the product, which therefore have not been assessed in this section. Also, energy saving opportunities for the battery charging and for the product may exist but are out of scope of this study.

[761] Data provided by the Ecodesign preparatory Study for Batteries, https://ecodesignbatteries.eu

Energy consumption, emissions and costs are solely related to the assumed material content and the cost of the batteries. The batteries exist with different voltage, ampere-hour and size adapted to the products they are used for.

For this assessment the following assumptions for three base cases are used:

- 12 volt batteries with 2.5 ampere-hours resulting in 30 watt-hours, consumer price: 40 EUR[762]
- 18 volt batteries with 4 ampere-hours resulting in 72 watt-hours, consumer price: 80 EUR[763]
- 36 volt batteries with 5 ampere-hours resulting in 180 watt-hours, consumer price: 115 EUR[764]
- Charger, consumer price: 40 EUR[765]

The most commonly used battery is by far the 18 volt battery. The total energy consumption for battery production (primary energy consumption of the materials) for the current sales and stock (assumed for 2020) is calculated by multiplying the sales and the stock with the impact of each of the battery types. The impact of the different batteries is calculated in EcoReport Tool based on the data in Section 20.5.2.

Table 264: Annual energy consumption and GHG emission related to the production of batteries sold in 2020

EU 2020 sales	**Primary energy consumption [PJ]**	**GHG [kt]**
12 V batteries	0.5	26.2
18 V batteries	5.6	286.1
36 V batteries	3.1	151.4
Charger	1.3	68.0
TOTAL	**10.5**	**531.8**

Table 265: Total energy consumption and GHG emission related to the production of all batteries in the current stock

EU 2020 stock	**Primary energy consumption [PJ]**	**GHG [kt]**
12 V batteries	3.0	151.0
18 V batteries	25.0	1268.6
36 V batteries	9.1	453.1
Charger	5.6	300.8
TOTAL	**42.8**	**2173.5**

762 https://www.amazon.com/Bosch-BAT415-Lithium-Ion-2-5Ah-Battery/dp/B015XPRS60?currency=EUR&language=en_US
763 https://www.amazon.com/gp/offer-listing/B00BQHLJ4M/ref=dp_olp_new_mbc?ie=UTF8&condition=new
764 https://www.amazon.com/dp/B015PVD9UQ/ref=twister_B07C8F3VX9?_encoding=UTF8&psc=1
765 https://www.amazon.com/MAKITA-DC18RC-Charger-7-2-18V-Output/dp/B007VM44HU/ref=sr_1_2?dchild=1&keywords=makita+battery+charger&qid=1613716734&sr=8-2

Table 266: Annual consumer expenditure

EU 2020 annual consumer expenditure based on sales	[mill. EUR]
12 V batteries	370
18 V batteries	3,359
36 V batteries	1,022
Charger	1,803
TOTAL	**6,553**

21.6 Saving potential

The saving potential exists in a reduction of the volume of batteries produced due to the universal battery concept. It was not possible to find a study or data suggesting the impact of this concept. Instead, the potential energy savings have been calculated for two scenarios with different estimated reduction assumptions.

Today, many consumers buy products from the same manufacturer, which means that it is not necessary to purchase a new battery for each new product. However, if the consumer needs to switch to a different brand[766], one or more a new batteries will have to be purchased.

By applying the universal battery concept, the following usage patterns are assumed:

- The same battery can be used with different products reducing the overall need for batteries.
- The batteries can be used for new products as well and in principle for generations or as long the battery is functioning.
- A single cradle/EPS can charge all batteries of all products

The legislative implementation of the universal battery concept has not been considered here because it would need more assessments (cf. also section 1.1.2). Previously, voluntary approaches have been used for common chargers for mobile phones, and they are also considered for further common charger initiatives. See details in the section on unversal external power supply.

Based on the above assumptions, the saving potentials have been calculated for a scenario with 20% fewer batteries and 30% fewer chargers purchased and produced. However, with future advancements in battery technology, it becomes more realistic that batteries can last multiple years and the saving potential can become even larger. Therefore, a scenario with 50% fewer batteries and 60% fewer chargers purchased and produced has also been calculated.

The savings in primary energy consumption, GHG emissions and consumer expenditure for battery production based on 2030 stock are presented in Table 267 to Table 269 for the two scenarios. All values in the tables are based on the stock values i.e. assuming the stock is replaced overnight. The corresponding annual savings would be approximately 20% of the savings presented in the tables.

[766] I.e. because that brand has not a suitable tool/product in its catalogue

Table 267: Primary energy consumption and GHG emission savings for battery production based on 2030 stock (20% fewer batteries and 30% fewer chargers)

EU 2030 stock	**Primary energy consumption [PJ]**	**GHG emissions[767] [$CO2_{eq}$ kt]**
12 V batteries	1.2	61.5
18 V batteries	10.2	516.7
36 V batteries	3.7	184.5
Charger	3.4	183.8
TOTAL	**18.6**	**946.5**

Table 268: Primary energy consumption and GHG emission savings for battery production based on 2030 stock (50% fewer batteries and 60% fewer chargers)

EU 2030 stock	**Primary energy consumption [PJ]**	**GHG emissions [$CO2_{eq}$ kt]**
12 V batteries	3.1	153.8
18 V batteries	25.4	1291.7
36 V batteries	9.3	461.3
Charger	6.9	367.5
TOTAL	**44.7**	**2274.3**

Table 269: Consumer expenditure savings

EU 2030 stock	**Battery and charger purchase [mill. EUR]**	
	20% fewer batteries and 30% fewer chargers	50% fewer batteries and 60% fewer chargers
12 V batteries	425.4	1063.6
18 V batteries	2978.0	7445.0
36 V batteries	611.6	1528.9
Charger	2393.0	4786.1
TOTAL	**6408.0**	**14823.6**

The conclusion is that based on the 20% and the 50% battery reduction scenarios, the savings achieved for the battery production are approximately 18-45 PJ in primary energy consumption, 950-2300 CO2eq kt in GHG emissions and 6,500-15,000 mill. EUR in consumer expenditure.

In addition to savings in energy and GHG emissions, there will also be an important saving potential for the chemical content of batteries providing an important reduction on environment and health.

[767] Note that the carbon footprint of the production of batteries and chargers are assumed to be stable from 2020 to 2030.

21.7 Stakeholder comments

Comments were received from the following stakeholders:

- APPLiA Europe
- BAM and UBA
- Danish Energy Agency
- ECOS-EEB-Coolproducts-CLASP

The following comments were provided; the study team's answers are provided where relevant:

APPLiA Europe provided the following comments:

- The mandatory introduction of a universal battery would hamper innovation in this fast-developing field: It is the study team's experience that it is often commented that Ecodesign implementing measures would hamper the innovation, however, the general experience is that in practice this is not the case.
- Legislation on batteries under Ecodesign could lead to double regulation with the revised Batteries Directive: A proposal on an amended battery directive was published in the final phases of the current study. It needs naturally to be ensured that there is no double regulation, if further study of the universal batteries will be launched.
- Need of clarification and specification on which products are included in the scope, specifically for household appliances. It seems that the study is quite limited with regard to household appliances (only mention of cordless vacuum cleaners): The scope is described in Section 21.1.1, however, it needs to be further refined in a possible study.
- APPLiA agrees with the reasoning provided regarding requirement on interoperability that needs further assessment.
- Each battery has its own properties for an optimal use of the product. Therefore, it implies that to provide the best use of an application, the battery should differ as well to be the most adapted one for that type of application: Batteries could be of different sizes and with different properties.
- The study claims that: "It seems like more and more household products such as cordless and robotic vacuum cleaners become available with the possibility to use the same type of battery" (p. 13). The study refers to a limited number of products where this is possible, however, this is not true for most household appliances.
- The example on p. 16 where it discusses an 18V battery able to provide 1440W output, is using a specific article to support their assertion that deploying more powerful batteries will reduce the number of batteries in circulation. We would like to signal caution on this. While this may be the case for a power tool that is used in short and intense blasts (some second), were such a solution to be used (e.g. in a vacuum cleaner), or another application with different parameters of use, the outcome could be quite different. At the best case, an overload may be caused which could kill the battery pack, at worst, there would be the potential for a hazardous event for both the containing product and user: It should naturally be ensured that safety is not impacted negatively. The Cordless Alliance System (CAS) is an example of a first step towards universal batteries.
- Sharing packs for products with similar use patterns, design and electronics, could be possible, but this should not be extended "carte blanche" across all products, as this could cause some serious safety risks: It should naturally be ensured that safety

is not impacted negatively. The Cordless Alliance System (CAS) is an example of a first step towards universal batteries.

- The study mainly refers to DIY tools/gardening tools and describes interoperability potentials in this area. However, this is not the case for household appliances, e.g. vacuum cleaners, because they have very different designs. The study shows that some tool manufacturers established a 'Cordless Alliance System' (p. 18); this is not feasible for other sectors as e.g. the 'sliding mechanism' for the battery is not the norm among household appliances: It should be further assessed how common connectors and interoperability should be ensured.
- Imposing a «universal battery» would imply changing the design of the product with potential consequences such as a higher volume required in the product and additional equipment needed for the recharge of the battery. By consequence, the impact on the environment by imposing a "universal battery" (which is rechargeable) to a wider range of products should also be considered: This should be further studied, if continueing with this product group.
- There are significant uncertainties in the data figures provided in the study (particularly on Tables 8 to 10 providing the figures on potential savings). Could you elaborate further on how the figures expressed in Tables 8 to 10 are obtained and which technological assumptions have been used for the development of the different scenarios?: The assumptions are provided in the text.
- The study states "Today, many consumers buy products from the same manufacturer, which means that it is not necessary to purchase a new battery for each new product." - As already said by APPLiA in p. 13 of the draft report, this may be true for tools but does not apply to other products groups such as household appliances: Yes, it is correct.

BAM and UBA provided the following comments:

- We agree that the universal batteries topic has to be seen in connection with the new proposal for a battery regulation. It is not clear for us from the report why interoperability is not included in the proposal and where this topic should be adressed. In the discussions regarding the battery regulation it is referred to Ecodesign as a product regulation to take care of interoperability: Interoperability is not included in the proposal for a new battery regulation and it may be difficult to propose a parallel regulation for universal batteries. However, it is still to be seen how the battery regulation eventually will be.

Danish Energy Agency provided the following comments:

- The study mentions connectors several times but does not conclude on the consequences of different types of connectors or docking solutions as related to energy losses. Please, add to chapter 1.4.2 a section on calculated or estimated energy losses or other potentials or issues related to different types of connectors: The study team has no data on losses for different types of connectors and believes that the losses are marginal.
- The savings potential does not specify if batteries of different characteristics are taken into account, e.g. indoor v. outdoor. Specify criteria behind saving potentials: The savings are calculated on the basis of overall assumptions on the reduction percentages for batteries and chargers. It has not be possible within the scope of this study to go into more details regarding impact on specific types of batteries.

ECOS-EEB-Coolproducts-CLASP provided the following comments:

- The impact analysis only investigates energy and GHG emissions related to the material content, but obviously the chemical content of batteries and its impact on the environment and health is of critical importance (even more than embedded energy). This should be mentioned and, if possible, assessed; It has not been possible to assess the reduction, but text has been added about the chemical content.
- The statement "Today, many consumers buy products from the same manufacturer" needs to be backed by a reference: This is rather emperical information and we do not have any source.
- The proposed scenarios appear very theoretical. It is not clear why a legislative/regulatory proposal to impose a universal battery has not been considered for evaluation (even if it would require more assessments, a preliminary estimate could be done, exactly in the same way preliminary estimates of potential Ecodesign requirements have been done in many other task 3 reports). If the sales of (universal) batteries & chargers were unbundled from the sales of products, consumers/professionals would only have to buy one or a couple of batteries for all their tools. This could mean a considerable rate of battery savings, maybe even beyond 50%: Due to lack of data, the calculations have been based on simple assumptions showing the amount of savings. The study team sees it as difficult to require full unbundling for this area. However, this could be assessed in a further study.

22 UNINTERRUPTIBLE POWER SUPPLIES

22.1 Scope, policy measures and test standards

Uninterruptible power supplies (UPS) were the subject of an ecodesign preparatory study by Ricardo-AEA Ltd in 2014[768] concluding there was a large energy and CO2 saving potential for standard UPS systems and that no existing measures were addressing that potential. Besides energy and CO2 savings, uninterruptible power supplies consist of different types of valuable and scarce resources in the printed circuit boards and the batteries. Since the preparatory study, there is a new relevance of uninterruptible power supplies because of increased use in base stations and in data centres, etc.

In the preparatory study and the test standard IEC 62040-3:2011[769], a UPS is defined as: *"A UPS is a combination of electronic power converters, switches and energy storage devices (such as batteries) constituting a power system for maintaining the continuity of power to a load in the case of input power failure."*

Apart from 'maintaining the continuity of the load in case of input power failure' ('black-outs') the UPS takes care of power surges and spikes. Typically, the UPS batteries work long enough to overcome a short black-out and/or give enough time to save the computer files and/or – for larger systems e.g. in data centres and hospitals – to start-up the back-up (diesel) generator set.

The preparatory study included the following base cases:

1. UPS below 1.5 kVA
2. UPS 1.5 to 5 kVA
3. UPS 5 to 10 kVA
4. UPS 10 to 200 kVA

UPS systems also exist above 200 kVA, but these are generally custom-made to fit specific requirements and could not be defined at the same level as the other base cases. In number of units, the systems above 200 kVA are estimated to account for less than 1% of the total stock. In addition, there are custom-built and non-standard UPS systems in the range of 10 to 200 kVA, which also make up less than 1% of the stock and are neither considered in this study.

The above-mentioned types of UPSs are still considered to be the most relevant as they can operate with no or only fractional time delay, and are responsible for the highest market share and deployed stock. Other types of UPS exist, such as:

- Fuel cell-based UPS (mobile communication)
- Engine/motor driven UPS (hospitals and mobile communication)
- Grid connected or isolated battery storage UPS systems deriving electrical energy from solar PV and wind generation
- Gas turbine driven UPS
- Flywheel/motor driven modules

[768] https://www.eup-network.de/fileadmin/user_upload/Lot-27-Consolidated-Final-Report.pdf

[769] As also defined in IEC 62040-3:2011.3.1.1.

- Hydro power pump storage
- Compressed air storage
- Non-grid connected UPS

In the future, grid-connected local battery systems like the Tesla Powerwall[770] may become more relevant as more manufactures are investigating both smart grid possibilities and ways to optimise the economy of, e.g. solar cells by ensuring that the majority of the production can be utilised. This may also work as a battery backup system in case of outages however without being a dedicated UPS. This type of battery system was also mentioned in the preparatory study for solar photovoltaic modules, inverters and systems[771] but not directly included in the study.

It is important to mention that tailor-made solutions, which are designed according to specific standards (e. g. 50171 in Germany or E8007 in Austria) to ensure power supply in cases where a power breakdown would be critical, dangerous or with life-threating consequences (e. g. in hospitals, critical industrial plants etc.) are not considered to be a part of the scope.

22.1.1 Policy measures

The 2014 Ecodesign preparatory study portrayed a significant potential energy saving of 11 TWh/year in 2025, mainly based on the smaller size UPS products, acting as a back-up power for desktop PCs.

However, at the Ecodesign Consultation Forum of 20 December 2017, the decision to develop Ecodesign and/or Energy Label measures was postponed. One reason was the doubts on the projected energy savings, because the market for UPS as a back-up for office PCs was moving from desktops towards notebooks (that do not need a UPS because the battery is incorporated). Due to the rapid replacement of desktop PCs by notebook PCs not needing a UPS, this UPS market was decreasing rapidly. Another reason was that – under the US-EU Agreement on the Energy Efficient Labelling of Office Equipment at the time[772] –there was also an EU Energy Star label for UPS products.[773] Finally, in 2016 JRC Ispra started a (voluntary) Code of Conduct for UPS (CoC UPS)[774], with 10 signatories.

Today, the market for UPS products is growing especially for servers of all sizes, i.e. from the single file back-up server in a small office to the UPS for large server farms in data centres. Edge Computing, i.e. bringing data as close as possible to the end-user to lower the latency, is creating a whole new market for UPSs as a power back-up for e.g. base stations. The EU Energy Star label for UPS was abolished when the aforementioned US-EU Agreement expired on 20 February 2018. Additionally, the CoC for UPS does not seem to be very active since its outset in 2016, judging from their website. However, stakeholders

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[770] E.g. powerwall: https://www.tesla.com/da_DK/powerwall

[771] https://susproc.jrc.ec.europa.eu/solar_photovoltaics/documents.html

[772] Agreement between the Government of the United States of America and the European Community on the coordination of energy-efficient labelling programs for office equipment - Exchange of diplomatic Notes
OJ L 172, 26.6.2001, p. 3–32

[773] Qualified under Uninterruptible Power Supplies specification 1.0. See https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-products/energy-star_en

[774] https://ec.europa.eu/jrc/en/energy-efficiency/code-conduct/ups and https://e3p.jrc.ec.europa.eu//communities/ict-code-conduct-ac-uninterruptible-power-systems

involved on the CoC have informed that they are working on updating the CoC. Latest news is that a new version should be publicly available from mid-May 2021.

Apart from the voluntary US Energy Star label, the US DoE has presently increased its efforts by introducing new mandatory (minimum) Energy Conservation Standards for Uninterruptible Power Supplies through the (amended) Energy Policy and Conservation Act 1975. These minimum energy efficiency standards were published on the 10th of January 2020, with effective data two years later.

The above developments indicate that now there is a good reason to revisit the UPS as a possible topic for the Ecodesign Working Plan 2020-2024.

To complete the overview of legislation, it can be mentioned that other UPS relevant European legislation includes the Low Voltage Directive (LVD) 2014/35/EU[775], the Electromagnetic Compatibility Directive (EMC) 2014/30/EC[776], the Directive on Batteries and accumulators and waste batteries and accumulators 2006/66/EC[777], the WEEE Directive[778] and RoHS[779], where appropriate.

Voluntary measures include for instance the German Blue Angel label for UPS.

Regarding circular economy, it is relevant to mention that the UPS was taken up by the Product Environmental Footprint Category Rules (PEFCR) in 2019.[780] This project was a collaboration between industry and other experts and was mainly based on inputs (Bill-of-Materials, energy, sales, etc.) from the Ecodesign Lot 27 preparatory study.

22.1.2 Standards

The main standards relevant for UPS is the European Standard series EN IEC 62040. Firstly, these standards prescribe general and safety requirements for handling and using UPS[781]. Secondly, they provide a conformity assessment, which ensures that UPS placed on the market have an appropriate level of electromagnetic compatibility (EMC)[782]. Thirdly, they establish a method to specify performance and test requirements of a UPS as a whole[783]. Finally, these standards determine harmonized requirements to declare the environmental

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[775] Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits, OJ L 96, 29.3.2014, p. 357–374

[776] Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast), OJ L 96, 29.3.2014, p. 79–106

[777] Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC, OJ L 266, 26.9.2006, p. 1–14 (latest status: https://ec.europa.eu/environment/waste/batteries/)

[778] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and elDirective 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment Text with EEA relevance
OJ L 174, 1.7.2011, p. 88–110 ectronic equipment (WEEE) OJ L 197, 24.7.2012, p. 38–71

[779] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment OJ L 174, 1.7.2011, p. 88–110

[780] https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_UPS.pdf

[781] EN IEC 62040-1:2019. Uninterruptible power systems (UPS). Safety requirements

[782] EN IEC 62040-2:2018. Uninterruptible power systems (UPS). Electromagnetic compatibility (EMC) requirements

[783] EN IEC 62040-3:2011. Uninterruptible power systems (UPS). Method of specifying the performance and test requirements

aspects relating to UPS with the aim of promoting a reduction of adverse environmental effects during the UPS entire life cycle.

These environmental requirements are reflective of other horizontal environmental standards and relate these to UPS in particular[784]. In addition to these specific UPS standards, other international and European Standards exist that are relevant to the UPS components or to the installation[785].

The following specific standards were pinpointed as relevant in the preparatory study:

- EN 62040-1:2008 - Uninterruptible power systems (UPS). General and safety requirements for UPS apply to uninterruptible power systems (UPS) with an electrical energy storage device in the DC. It is applicable to UPS which are movable, stationary, fixed or for building-in, for use in low-voltage distribution systems and intended to be installed in any operator accessible area or in restricted access locations as applicable. It specifies requirements to ensure safety for the operator and layman who may come into contact with the equipment and, where specifically stated, for the service person.
- EN 62040-2:2006 - Uninterruptible power systems (UPS). Electromagnetic compatibility (EMC) requirements is a standard intended as a product standard allowing the EMC conformity assessment of products of categories C1, C2 and C3 as defined in this part of EN 62040, before placing them on the market. The requirements have been selected so as to ensure an adequate level of electromagnetic compatibility (EMC) for UPS at public and industrial locations.
- EN 62040-3:2011 - Uninterruptible power systems (UPS). Method of specifying the performance and test requirements applies to movable, stationary and fixed electronic uninterruptible power systems (UPS) that deliver single or three phase fixed frequency AC output voltage not exceeding 1,000 V AC. and that incorporate an energy storage system, generally connected through a DC. This standard is intended to specify performance and test requirements of a complete UPS and not of individual UPS functional units.
- IEC 62040-4 Ed. 1.0 Uninterruptible power systems (UPS) - Part 4: Environmental aspects - requirements and reporting. This standard specifies the process and requirements to declare the environmental aspects concerning uninterruptible power systems (UPS), with the goal of promoting reduction of any adverse environmental impact during a complete UPS life cycle. This product standard is harmonised with the applicable generic and horizontal environmental standards and contains additional details relevant to UPS. This standard applies to movable, stationary and fixed UPS that deliver single or three-phase fixed frequency a.c. output voltage not exceeding 1 000 V a.c. and that present, generally through a d.c. link, an energy storage system and specified in IEC
- An extensive list of other standards relevant to UPS and the installation of UPS is presented in the preparatory study.

In particular for smaller UPSs, the Product Environmental Profile (PEP) appears to be popular. The PEP (Product Environmental Profile) registered under the PEP ecopassport® Program is a type III environmental declaration according to the ISO 14025 standard. It is

[784] EN IEC 62040-4:2013. Uninterruptible power systems (UPS). Environmental aspects. Requirements and reporting

[785] E.g. IEC 60146 Semiconductor Electronic Converters; EN 50171 Central power supply systems; EN IEC 60439 Low voltage switchgear and control gear assemblies; EN 50272-2 Safety requirements for secondary batteries and battery installations, stationary batteries; etc.

dedicated to electric, electronic and HVAC-R products.[786] PEPs are available for UPSs from APC/Schneider Electric, Legrand and others.

22.2 Market

The market data is based on data from the preparatory study and crosschecked with the Eurostat PRODCOM statistics. In the Eurostat PRODCOM statistics, two relevant data sets are available:

- 27.90.11.50 – Machines with translation or dictionary functions, aerial amplifiers and other electrical machines and apparatus, having individual functions, not specified or included elsewhere in HS 85 (excluding sinbeds, sunlamps and similar sun tanning equipment).
- 27.11.50.40 – Power supply units for telecommunication apparatus, automatic data-processing machines and units thereof.

Table 270: Sales from PRODCOM

Prodcom code	2010	2011	2012	2013	2014	2015	2016	2017	2018
Value of products sold (mill. EUR)									
27.90.11.50	1,966	2,087	2,232	2,233	2,122	2,286	2,199	2,208	2,180
27.11.50.40	453	447	378	358	412	401	No data	No data	No data
Products sold (mill. units)									
27.90.11.50	No data	No data	No data	No data	No data	No data	No data	No data	No data
27.11.50.40	2.4	2.3	2.7	2.4	2.8	3.1	No data	No data	No data

UPS market data for the EU are available by size-classes (in kVA or Watt, see Figure *87* and Table 271) and topology:

- VFD with Voltage and Frequency of the AC output are dependent on those of the input (a.k.a. 'Standby' topology);
- VI with the output's Voltage Independent of the input voltage (a.k.a. 'Line Interactive')
- VFI with the output's Voltage and Frequency being Independent of the input voltage and frequency (a.k.a. 'Double Conversion').

The EU unit shipments in the following table are taken from the UPS Business-as-Usual scenario in the 2018 Ecodesign Impact Accounting[787] , which is a harmonised version of the data from the 2014 preparatory study.

Table 271: Market data UPS (source: EIA 2018)

UPS	**Main topology**	**Sales (000 units)**				**Stock (000 units)**				**Load**	**Life**
Size-class		**2010**	**2015**	**2020**	**2030**	**2010**	**2015**	**2020**	**2030**	**kVA**	**years**
<1.5 kVA	VFD	1000	1041	1265	1915	4027	4065	4791	6575	0.32	4
1.5-5 kVA	VI	402	419	509	687	2994	3242	3599	5002	1.93	8
5.1-10 kVA	VFI	26	27	32	44	230	258	281	388	4.33	10
10.1-200 kVA	VFI	13	14	17	23	140	155	170	233	43.79	12

[786] http://www.pep-ecopassport.org/create-a-pep/.
[787] Wierda, L. and Kemna, R., Ecodesign Impact Accounting, VHK for the EC, 2018.

The load in the table refers to the average wattage (kVA) applied to a UPS of a certain size-class. 'Life' relates to the average service life in years, which is a parameter needed in calculating the average stock.

Figure 87: Examples of currently available UPS on the market for each size-class

Currently, there are many UPS models that exceed the 200 kVA limit of the fourth category, however - as the PEFCR study explains – these often consist of several smaller models combined.

The annual sales volume was 1.5 million units in 2015 and is estimated to double to 3 million by 2040. Each base case is expected the same growth rate towards 2050. In number of units, UPS systems below 5 kVA account for 97 % of the sales. The sales from PRODCOM is twice as high as the data from the EIA. However, the categories from PRODCOM are extensive and assumed to include other types of as well. The sales and stock from the EIA are therefore used int this assessment.

The data in Table 271 represents the best available data currently. However, stakeholders have suggested that the market for small UPS are decreasing due to the use of e.g. laptops with batteries instead of desktops. In addition, the increased use of specialised UPS in hyper-scale data centres are not included, and neither is the increase of UPS in base stations not considered to be reflected in the numbers.

End-user costs are presented in Table 272 for all four base cases covering purchase price, installation cost and repair and maintenance costs.

Table 272: End-user costs per unit UPS over the entire lifetime. 2011-prices[788].

EUR	PURCHASE PRICE	INSTALLATION COST	TOTAL REPAIR AND MAINTENANCE COST
UPS BELOW 1.5 KVA	180	0	0
UPS 1.5 TO 5 KVA	643	308	241
UPS 5 TO 10 KVA	3,502	503	1,138
UPS 10 TO 200 KVA	28,800	1,220	45,936

22.3 Usage

UPS units are commonly found in server rooms and data centres, but also in other environments with time- and/or process-critical operations like base-stations for radio networks, hospitals, financial institutions (e.g. payments), certain manufacturing, security, military, etc.

They play a significant role in maximising the availability of systems. UPS modules are often operated in parallel to increase availability and provide extra security of electrical supply to the connected equipment. One or more additional modules are included to maintain capacity in the event of a failure. This is known as operating in 'redundant configuration'. Under these circumstances, each UPS shares the supply but operates at a reduced power level. Or some modules operate at high capacity and others are inactive until needed.

For non-IT environments, the UPS are the first-line emergency devices in a micro-grid. They provide power before other back-up devices, like from diesel generators or fuel cells, become operational.

Generally, UPS of category 1-3 – i.e. up to 10 kVA – are considered to be a server back-up. For base-stations 10-20 kVA is a typical UPS size. Large UPSs in the range between 50 and 200 kVA are used in larger data centres and server rooms, as well as back-up for non-IT applications.

The UPS market is dominated by a dozen manufacturers, including ABB, Schneider Electric/APC, Eaton Corporation, Emerson Network Power Inc., Mitsubishi Electric.[789] The hardware is often sold through service providers, who also take care of the maintenance and monitoring of the UPS. Specialist data centre designers are often the specifiers for the UPS. The data centre owners pay the hardware (capex) and operating costs (opex). In cloud centres, these costs (capex write-off and opex) are paid by server operators.

The use of UPS systems may also vary between EU countries as user habits and national grid conditions differ. In northern countries, the electricity supply is considered to be

[788] ErP Lot 27 – Uninterruptible Power Supplies, Preparatory Study, 2014

[789] https://www.mordorintelligence.com/industry-reports/global-data-center-ups-market-industry

among the best in the world in terms of reliability, affordability and sustainability according to the World Economic Forum[790]. Hence, the need for a UPS in the northern countries' households and offices is considered to be low, but other countries in Europe may still use them in households and offices. The UPS sold for households and offices are mostly sold as a standard off-the-shelf product. This includes, e.g. UPS units for desktop PCs, home and small servers including NAS (Network Attached Storage) and other domestic and office purposes.

UPS systems for data centres (not hyper scale), where standardised UPS modules are rack-mounted are business to business (B2B) products. When batteries are exchangeable lead-acid cells, cells are usually recycled after 3-15 years of operation, depending on the used technology. Most complex UPS systems use an alarm system that informs about battery or system failure. Single unit UPS systems could provide such a feature as well.

The use pattern of UPS systems is given by the stability of the local grid and safety concerns related to the connected equipment. Small UPSs are often in standby and reacts if it detects any disturbance from the mains, where larger UPSs also ensures s stable energy supply.

It should also be noted that a UPS operating at a low load level will have significant losses when compared with the same UPS operating at full load. In a realistic scenario, the load level is typically between 10 and 30%, which leads to a 4-17% reduction of efficiency according to the preparatory study. The load type has also a strong influence on the achieved efficiency. The UPS efficiency is usually tested with resistive or linear loads, but several UPSs are used with non-linear loads and with poor power quality (low power factor and high total harmonic distortion). The low power factor will require a higher peak current from the UPS, decreasing its efficiency. Therefore, in order to assess the conversion efficiency, it is important to test with different load levels. Load levels and time and power draws in the different load levels are presented in Table 273 to Table 276. The source is the preparatory study 'intermediate level' as this level is slightly over levels in the newly proposed CoC.

Table 273: Average conversion efficiency, time spent and power draw for each load level and annual energy consumption of a UPS below 1.5 kVA

Tested load levels	25%	50%	75%	100%
Conversion efficiency at each load level	91.8%	92.8%	93.5%	94.1%
Proportion of time spent at each load level	0%	30%	40%	30%
Power at each load level [kW]	0.13	0.27	0.4	0.54
Annual energy consumption [kWh]	226			

Table 274: Average conversion efficiency, time spent and power draw for each load level and annual energy consumption of a UPS 1.5 to 5 kVA

Tested load levels	25%	50%	75%	100%
Conversion efficiency at each load level	91.2%	93.7%	94.3%	94.4%
Proportion of time spent at each load level	0%	30%	40%	30%
Power at each load level [kW]	0.72	1.43	2.15	2.87
Annual energy consumption [kWh]	1089			

[790] http://reports.weforum.org/pdf/gci-2017-2018-scorecard/WEF_GCI_2017_2018_Scorecard_EOSQ064.pdf

Table 275: Average conversion efficiency, time spent and power draw for each load level and annual energy consumption of a UPS 5 to 10 kVA

Tested load levels	25%	50%	75%	100%
Conversion efficiency at each load level	91.2%	93.9%	93.8%	93.4%
Proportion of time spent at each load level	0%	30%	40%	30%
Power at each load level [kW]	1.56	3.13	4.69	6.25
Annual energy consumption [kWh]	2605			

Table 276: Average conversion efficiency, time spent and power draw for each load level and annual energy consumption of a UPS 10 to 200 kVA

Tested load levels	25%	50%	75%	100%
Conversion efficiency at each load level	87.8%	91.7%	92.1%	91.8%
Proportion of time spent at each load level	25%	50%	25%	0%
Power at each load level [kW]	23.63	47.25	70.88	94.5
Annual energy consumption [kWh]	35754			

22.4 Technologies

22.4.1 Current technologies

In the preparatory study it is specified that a UPS is designed to act as an interface between the mains and particular applications, e.g. PCs and servers. They protect the application against power problems, such as power failures, power sags, power surges, under-/over-voltage, switching transients, line noise, frequency variation and harmonic distortion. The UPS does this by supplying the load with continuous, high-quality electrical power regardless of the status of the mains. The supply voltage delivered by the UPS is free from major disturbances, within specified tolerance levels. In the case of power failure, the UPS will provide a supply for a given run time, typically 5-30 minutes, to allow a backup generator to be started or systems to be shut down properly.

The preparatory study defines three main typologies used in existing UPS products:

- Passive Standby (off-line) (output voltage and frequency dependent from mains supply - VFD): These types of UPS provide power to the application direct from the mains in normal load. Where there are power cuts or fluctuations (for example, outside of pre-set tolerances), then the UPS will take over and deliver a stable supply via the battery/inverter.
- Line Interactive (output voltage independent from mains supply - VI): These types of UPS are used to protect larger applications, such as enterprise networks and IT applications. In addition to power failure, sags and surges, line-interactive UPS also protect against under-/over-voltage. The inverter provides output voltage conditioning in response to voltage fluctuations, for example outside pre-set tolerances. The output frequency is still dependent on the mains input frequency.
- Double conversion (online) (output voltage and frequency independent from main supply – VFI): This UPS topology is designed to be used for the protection of critical applications, and will provide protection against a wide range of power problems, including power failure, power sag, power surge, under-/over-voltage, switching transient, line noise, frequency variation and harmonic distortion. These types of

UPS provide a consistent power supply regardless of disturbances to the mains input.

22.4.2 Technology improvements

The preparatory study identified several Best Available Technology (BAT) and Best Not yet Available Technology (BNAT) options for UPSs presented in Table 277.

Table 277: UPS improvement options (BAT/BNAT) from the preparatory study[791]

Component	Improvement	BAT/BNAT
Intelligent multi-mode operation	Up to +2% increase in efficiency	BAT
Improved lead-acid batteries	Better performance and lifetime	BAT
Lead-carbon batteries	Increased cycle life	BNAT
Lithium-ion batteries	+20% of efficiency	BNAT
Supercapacitors	Better performance and lifetime	BNAT
Fuel cells	Better performance	BNAT
Transformer-less UPS	+3% of efficiency and 25% less weight	BAT
High-frequency transformer	Alternative to the transformer-less topology	BAT
Three-level converter	Reduction of 35% on the semiconductor losses	BAT
Transformer-less + three-level converter + elimination of active components	+3% of efficiency and 46-60% less weight	BNAT
Delta-conversion line-interactive UPSs	Better performance	BAT

The use of transformer-less designs can also apply to (rack) power distribution. By removing a number of conversions (from DC to AC and then back to DC) and filtering steps, the overall power conversion efficiency is increased from 80.75% to 91.2% (over 10% fewer losses). This avoids losses in EMI (ElectroMagnetic Interference) and PFC (Power Factor Correction).

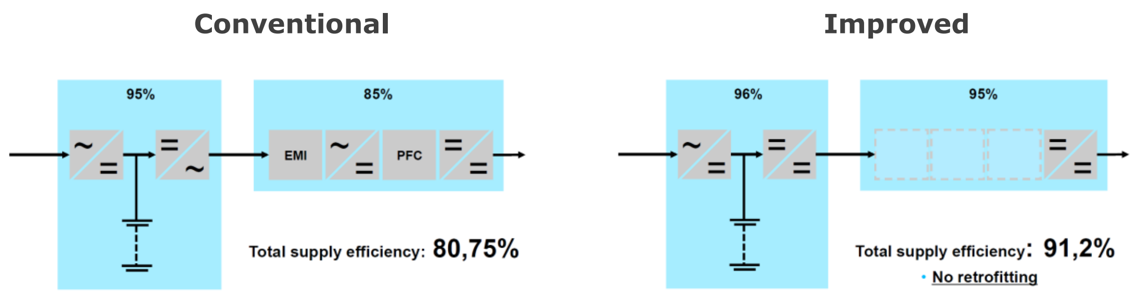

Figure 88: Power distribution improvement

Facebook and Google use the open compute project (OCP) rack design that uses 48V DC UPS battery cabinet to achieve savings of up to 20%, where the only conversion is DC to DC for sub-components of servers such as CPUs, RAM and disks in the market[792].

The latest development is the introduction of li-ion batteries, which are more efficient and have a longer product-life, instead of lead-acid batteries, short-time back-up and gas-fired fuel-cell back-ups for longer-time black-outs.

[791] Lot 27 preparatory Ecodesign study

[792] https://www.reportbuyer.com/product/5741687/data-center-ups-market-global-outlook-and-forecast-2019-2024.html

22.4.3 Developments in UPS technology

There are two major developments in UPS technology. One is the transition, for larger capacities like in data centres, from Valve Regulated Lead Acid VRLA ('Lead') batteries to lithium-ion ('Li-ion') batteries. The other development is smarter battery controls.

Batteries

Figure *89* below shows the trend of annual data centre li-ion UPS penetration in North America and Europe over the period 2016-2025, in GWh, according to Bloomberg New Energy Finance[793].

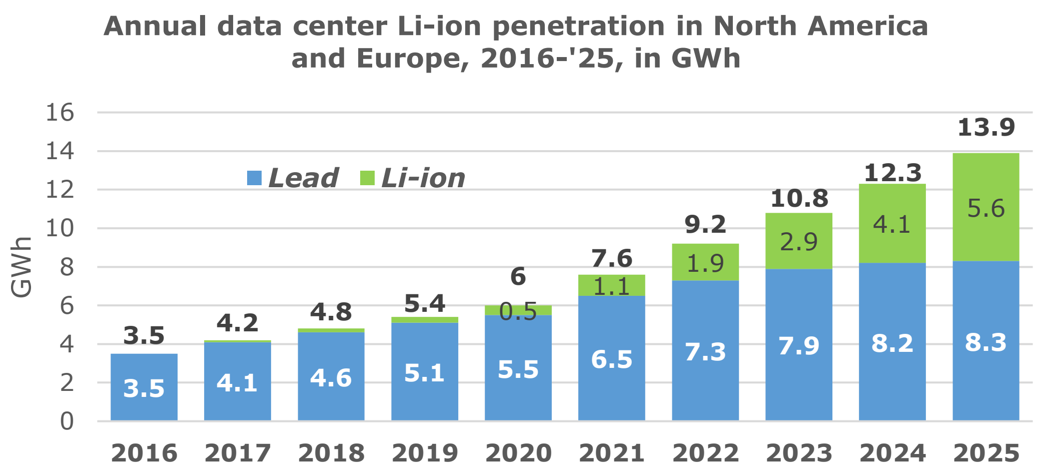

Figure 89: Data centre li-ion penetration in North America and Europe, 2016-2025.[793]

Advantages of lithium-ion over Valve Regulated Lead Acid VRLA ('Lead') batteries according to Schneider Electric are[794]:

- About three times less weight for the same amount of energy content
- Up to ten times more lifetime discharge cycles depending on chemistry, technology, temperature, and depth of discharge
- About a fourth self-discharge (i.e. slow discharge of a battery while not in use)
- Four or more times faster charging, which is key in multiple outage scenarios

Compared to VRLA, the li-ion batteries are about 1.2 to 2 times more capital expensive for the same amount of energy due to higher manufacturing cost and cost of required battery management system (see Section 5 hereafter) and there are stricter transportation regulations due to risk of fire.

In the longer term, the li-ion technology itself additionally offers still ample room for improvement.[795] [796]

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[793] https://www.datacenterknowledge.com/business/report-lithium-ion-gain-one-third-data-center-ups-market-2025

[794] Whitepaper https://download.schneider-electric.com/files?p_Doc_Ref=SPD_VAVR-A5AJXY_EN

[795] https://www.renewableenergyworld.com/2019/04/03/why-lithiumion-technology-is-poised-to-dominate-the-energy-storage-future/#gref

[796] https://ec.europa.eu/energy/sites/ener/files/technology_analysis_-ongoing_projects_on_battery_based_energy_storage.pdf

Smarter controls
Especially in the context of 5G base stations, manufacturers suggest to use the UPS battery capacity also for intelligent peak shaving, e.g. for grids with solar PV panels to use the battery capacity, when supply is low (at night) and charge when supply is high (in the daytime).[797]

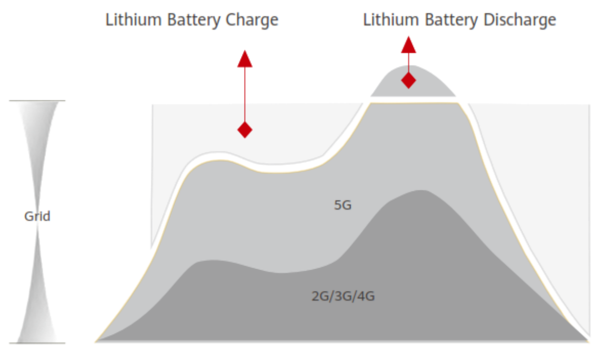


Figure 90: Intelligent peak shaving (source: Huawei[798])

22.4.4 Weight and material composition

The average weight and material composition from the preparatory study for the UPS base cases and the batteries separately are presented in Table 278 and Table 279.

Table 278: The average material composition of each of the UPS base cases without batteries. Note that all values are in grams

EcoReport Material Codes	Below 1.5 kVA [g]	1.5 to 5 kVA [g]	5.1 to 10 kVA [g]	10.1 to 200 kVA [g]
1-LDPE				80.0
2-HDPE				1333.3
8-PVC	85.0	261.6	241.8	6000.0
11-ABS	1216.0	547.7	662.5	5197.3
12-PA6		19.9	57.5	73.3
13-PC		74.3	5.5	41.0
14-PMMA				10.0
15-Epoxy	10.0	19.4	44.5	66.7
18-Talcum filler		0.7		
19-E glass fibre		13.9	17.3	3.3
20-Aramid fibre				1666.7
22-St sheet galv		5089.8		157083.3
23-St tube/profile		7.5	15106.0	
24-Cast iron	1123.0	1277.8	125.7	32000.0
25-Ferrite	91.0	303.2	955.5	18790.0
26-Stainless 18/8 coil	25.0			
27-Al sheet/extrusion	117.0	657.1	1712.0	21526.7
28-Cu winding wire	480.0	482.5		21768.3

[797] https://carrier.huawei.com/~/media/CNBGV2/download/products/network-energy/5G-Telecom-Energy-Target-Network-White-Paper.pdf
[798] Ibid.

EcoReport Material Codes	Below 1.5 kVA [g]	1.5 to 5 kVA [g]	5.1 to 10 kVA [g]	10.1 to 200 kVA [g]
30-Cu wire	232.0	428.3	1022.6	24650.0
31-Cu tube/sheet		4.5		19733.3
32-CuZn38 cast		103.9	183.4	2916.7
40-powder coating		20.7	12.5	1500.3
43-lcd per m2 scrn		11.3		0.3
45-big caps & coils	15.0	259.7	933.5	17340.0
46-slots . Ext. Ports	250.0		275.0	650.0
47-Ics avg 5% Si, Au	3.0	2.4	10.3	6.7
48-IC's avg 1% Si	7.0	29.1	89.0	16.7
49-SMD/LEDs avg	39.5	237.8	561.0	383.3
50-PWB 1/2 lay 3.75kg/m2	108.0	538.3	1302.1	1993.3
51-PWB 6 lay 4.5 kg/m2		87.5		
53-Solder SnAg4Cu0.5	70.0	158.2	66.8	140.0
Total	**3871.5**	**10637.0**	**23384.4**	**334970.7**

Table 279: The average material composition of the batteries in each of the UPS base cases and the combined weight. Note that all values are in grams

EcoReport Material Codes	Below 1.5kVA [g]	1.5 to 5 kVA [g]	5.1 to 10 kVA [g]	10.1 to 200 kVA [g]
Primary lead (40% of lead content)	807	8581	18687	282552
Secondary lead (60% of lead content)	1211	12872	28031	423828
Polypropylene	336	3576	7786	117730
Sulphuric acid	336	3576	7786	117730
Water	538	5721	12458	188368
Glass	67	715	1557	23546
Antimony	34	358	779	11773
Total	**3330**	**35397**	**77085**	**1165527**

22.5 Energy, Emissions and Costs

Energy, GHG emissions and monetary costs are given in the tables below. Data are covering all four base cases for the period 1990 to 2050.

Table 280 presents the total electricity consumption for EU calculated as losses in the UPSs. For 2020 it has been estimated to about 12 TWh and it is expected to double by 2050. Base case 2 (UPS 1.5 to 5 kVA) accounts for almost half of the electricity consumption followed by base case 4 (UPS 10 to 200 kVA) at a third. Base case 1 (UPS below 1.5 KVA) and 3 (UPS 5 to 10 kVA) accounts for less than 20 % combined. Note that UPSs in hyperscale data centres are not included in the numbers due to lack of data because they typically use highly specialised UPS solutions.

Table 280: Electricity consumption - EU total for UPS [799]

TWh	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
UPS BELOW 1.5 KVA	0.7	1.5	1.5	1.1	1.3	1.5	1.7	1.8	2.0	2.1
UPS 1.5 TO 5 KVA	2.7	5.8	6.3	3.9	4.7	5.4	6.2	6.9	7.5	7.9
UPS 5 TO 10 KVA	0.3	0.7	0.8	0.7	0.9	1.0	1.2	1.3	1.4	1.5
UPS 10 TO 200 KVA	1.9	4.2	4.6	6.1	7.1	8.3	9.6	10.8	11.8	12.6
TOTAL	**5.6**	**12.2**	**13.2**	**11.8**	**13.9**	**16.3**	**18.6**	**20.8**	**22.6**	**24.1**

Table 281 presents the primary energy consumption calculated with a PEF factor of 2.1. The total EU primary energy consumption is estimated to 90 PJ in 2020 for all four base cases.

Table 281: Primary energy consumption from use phase in PJ - EU total for UPS. PEF of 2.1

PJ	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
UPS BELOW 1.5 KVA	5.3	11.3	11.3	8.2	9.7	11.2	12.7	14.0	15.0	15.7
UPS 1.5 TO 5 KVA	20.4	43.8	47.6	29.6	35.3	41.2	46.9	52.1	56.5	59.9
UPS 5 TO 10 KVA	2.3	5.3	6.0	5.5	6.5	7.6	8.7	9.7	10.6	11.3
UPS 10 TO 200 KVA	14.4	31.8	34.8	46.0	53.5	63.0	72.4	81.4	88.9	95.1
TOTAL	**42.3**	**92.2**	**99.8**	**89.3**	**105.0**	**123.0**	**140.7**	**157.2**	**171.1**	**182.0**

Table 282 presents the GHG emissions related to the electricity consumption. It shows estimated GHG emissions at 4.5 MT CO2eq in 2020. The increase is smaller towards 2050 compared to the electricity consumption due to the expected decarbonisation of the electricity supply.

Table 282: GHG emissions from use phase - EU total for UPS

MT CO2eq	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
UPS BELOW 1.5 KVA	0.4	0.6	0.6	0.4	0.5	0.5	0.5	0.6	0.6	0.5
UPS 1.5 TO 5 KVA	1.4	2.4	2.5	1.5	1.7	1.9	2.0	2.1	2.1	2.1
UPS 5 TO 10 KVA	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
UPS 10 TO 200 KVA	1.0	1.7	1.8	2.3	2.5	2.8	3.1	3.2	3.3	3.3
TOTAL	**2.8**	**5.0**	**5.2**	**4.5**	**5.0**	**5.5**	**6.0**	**6.2**	**6.3**	**6.3**

Figure *91* gives the material composition of a small (<1.5kVA) UPS with a lead-acid battery from a Product Environmental Profile (PEP) provided by Schneider Electric. The representative product used for the analysis is the SUA1500I: 980 Watts / 1500 VA, Input 230V /

[799] VHK, Ecodesign Impact Accounting 2018, for the European Commission

Output 230V, Interface Port DB-9 RS-232, SmartSlot, USB, 27 kg. This model uses 2 batteries of 12V, 17 Ah.

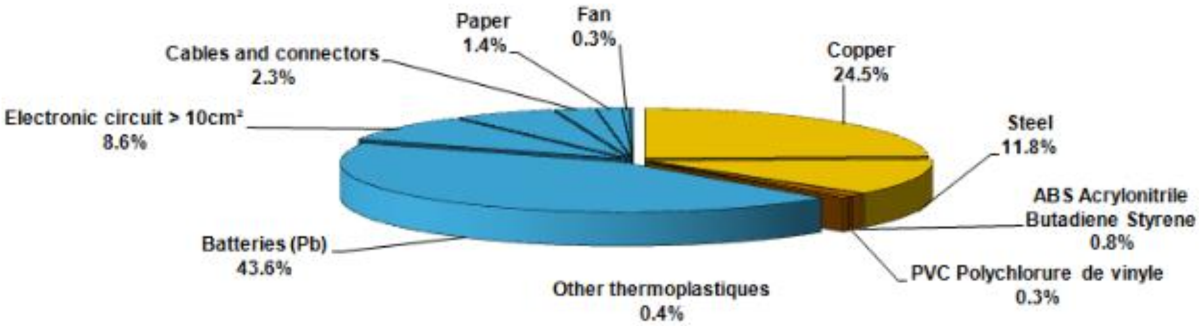


Figure 91: UPS <1.5 kVA Constituent Materials (source: Schneider[800])

The largest materials fraction, even for this small UPS, are lead-acid batteries (44%), followed by copper (25%), steel (12%) and electronics (9%). For larger UPSs the battery fraction will be larger (up to 70%). Given that the li-ion batteries are almost half as small and thereby use less materials, there is a considerable saving potential.

Table 283 shows the embedded energy consumption from material extraction, production, distribution and end-of-life. The total embedded energy consumption is estimated to 2.8 PJ in 2020, which is only about 2% of the total life cycle primary energy consumption.

Table 283: Total energy consumption from production, distribution and EoL - EU total for UPS

PJ	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
UPS BELOW 1.5 KVA	0.36	0.71	0.74	0.90	1.06	1.21	1.36	1.49	1.59	1.65
UPS 1.5 TO 5 KVA	0.43	0.85	0.88	1.07	1.26	1.45	1.62	1.77	1.89	1.97
UPS 5 TO 10 KVA	0.06	0.13	0.13	0.16	0.19	0.22	0.24	0.27	0.28	0.30
UPS 10 TO 200 KVA	0.28	0.52	0.56	0.69	0.81	0.93	1.01	1.13	1.21	1.25
TOTAL	**1.13**	**2.21**	**2.32**	**2.81**	**3.31**	**3.81**	**4.23**	**4.66**	**4.97**	**5.17**

Table 284 shows the embedded GHG emissions from material extraction, production, distribution and end-of-life. The total embedded GHG emissions are estimated to 0.16 MT CO2eq in 2020, which is, similar to the embedded energy consumption, only constitutes a small share of the total life cycle GHG emissions.

[800] https://download.schneider-electric.com/files?p_enDocType=Product+environmental&p_File_Name=GWOG-8WPL63_R0_EN.pdf&p_Doc_Ref=SPD_GWOG-8WPL63_EN

Table 284: GHG emissions from production, distribution and EoL – EU total for UPS

MT CO2eq	1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
UPS BELOW 1.5 KVA	0.02	0.04	0.04	0.05	0.06	0.07	0.08	0.08	0.09	0.09
UPS 1.5 TO 5 KVA	0.02	0.05	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.11
UPS 5 TO 10 KVA	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
UPS 10 TO 200 KVA	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.08	0.08
TOTAL	**0.07**	**0.13**	**0.14**	**0.16**	**0.19**	**0.22**	**0.25**	**0.27**	**0.29**	**0.30**

The end-user expenditure in the following table is calculated with the inputs from Table 3. The data represents the costs of the stock in 2020.

Table 285: End-user expenditure of stock in 2020 – UPS[801]

MILL. EUR	PURCHASE	INSTALLA-TION	REPAIR AND MAINTENANCE	ELECTRICITY	TOTAL
UPS BELOW 1.5 KVA	862	0	0	106	**974**
UPS 1.5 TO 5 KVA	2,314	1,108	108	383	**3,981**
UPS 5 TO 10 KVA	984	141	32	71	**1,243**
UPS 10 TO 200 KVA	4,896	207	651	594	**6,407**
TOTAL COST	**9,056**	**1,457**	**791**	**1,153**	**12,605**

Each year the end-users are spending 1.3 billion EUR on electricity costs and 0.8 billion EUR on repair and maintenance. The total value of the stock including the installation costs is 10.5 billion Euro. When taking into account the different lifetimes of the products, the end-users are annually spending 1.4 billion EUR purchasing and installing new equipment.

22.6 Saving potential

This section presents the savings potentials for BAT for each base case for energy consumption, GHG emissions and end-user expenditure. The estimates are based on the preparatory study, where BAT has been identified. The preparatory study further indicates that improving efficiencies beyond BAT is very costly for relatively small gains. Saving potentials for BNAT has therefore not been estimated. Also included in the saving potentials is an increase in product lifetime of 20% by applying resource efficiency requirements.

Regarding the saving potential in the preparatory study, industry stakeholders have commented on the current state on the implementation of the different options identified in Section 22.4.1. In Table 286 the improvement options are presented together with the inputs received by the industry.

[801] ErP Lot 27 – Uninterruptible Power Supplies, Preparatory Study, 2014

Table 286: UPS improvement options (BAT/BNAT) from the preparatory study[802] and comments received from industry stakeholders during the study regarding the current implementations (2020)

Component	Improvement	BAT/BNAT	Comments from the industry (2020)
Intelligent multi-mode operation	Up to +2% increase in efficiency	BAT	Function already implemented on most of the VFI UPS (above 10kW)
Improved Lead-acid batteries	Better performance and lifetime	BAT	No measurable impact on energy savings
Lead-carbon batteries	Increased cycle life	BNAT	No measurable impact on energy savings
Lithium-ion batteries	+20% of efficiency	BNAT	For products above 100kW the lithium ion is becoming a BAT and 20 to 30% of the UPS on the market are sold with that technology. For smaller power ratings the cost penalty is still unaffordable by the customers
Supercapacitors	Better performance and lifetime	BNAT	Super capacitors are not competitive in size and weight for UPS with runtime <2 minutes. Super capacitors are only compatible with DVR application (Dynamic Voltage Restorer) < 2 to 10 seconds but not for UPS.
Fuel cells	Better performance	BNAT	
Transformer-less UPS	+3% of efficiency and 25% less weight	BAT	All UPS on the market are now using the so-called transformer-less technology. The only exceptions are the UPS dedicated to market with specific requirements (e.g. oil & gas, hospitals …) but which are excluded from EE compliance by the IEC 62040-3 new Ed3
High-frequency transformer	Alternative to the transformer-less topology	BAT	Technology already adopted for most of the VFD products for battery mode. BAT High-frequency transformer is not providing savings for VI or VFI products compared to transformer-less technologies
Three-level converter	Reduction of 35% on the semiconductor losses	BAT	All UPS on the market today are transformer-less and are using three-level, four-level or five-level topologies.
Transformer-less + three-level converter + elimination of active components	+3% of efficiency and 46-60% less weight	BNAT	(See above)
Delta-conversion line-interactive UPSs	Better performance	BAT	Delta conversion technology due to the serial transformer and the same number of converters as a double conversion UPS is not anymore showing better performance than last generation of transformerless multi-level converters. All product ranges using delta-conversion techno have been replaced by new double conversion with better performance in EE and density.

However, based on the efficiencies provided in a draft proposal for an updated CoC for UPS systems and on the comments received from the industry, it seems that the current efficiency has reached the “intermediate level” from the preparatory study (see Table 273 to Table 276 for current efficiencies). The BAT scenario from the preparatory study is still used as an indicator for the possible savings.

Comments were received by CEMEP UPS on the final draft version of this report, see next section. One main comment was that a new version of the Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems (UPS) will be uploaded on the JRC website around mid-May 2021 and a notable addition to the minimum requirements is introduction of an Elite level. This Elite level will be mandatory if a data centre wants to be compliant with the Code of Conduct for Data Centres.

[802] Lot 27 preparatory Ecodesign study

The study team has compared the Elite UPS requirements with the draft CoC received during the study. The efficiencies in the table for Elite requirements are about 1-2 percent-points above the efficiencies in the draft CoC informed previously by CEMEP UPS, however, they were not at an Elite level, but at a level necessary to comply with under the CoC for UPS within a certain time limit as it was understood by the study team.

The study team believes that an Elite level for UPS required for complying with the CoC for data centres will help pushing the market towards more efficient UPS systems, however, the data centres in the CoC and candidates to it, typically already have much focus on the energy efficiency. Furthermore, the size and timing of such market transformation is unknown. Therefore, no changes made in the report, however, it is advisable to look into this when the updated version of the CoC for UPS is publicly available.

Table 287 presents the saving potentials for electricity and primary energy consumption as well as embedded energy consumption for 2030 (accounting for a complete change of stock to efficient UPS with efficiencies around 95%). The total saving potential for electricity consumption amounts to 7.2 TWh in 2030. Savings in embedded energy by increasing product lifetime by 20% is marginal compared to the use phase savings and is estimated to 0.8 PJ.

Note that these projections are all based on lead-acid (VRLA) batteries and did not take into account the technology switch from VRLA to lithium-ion batteries. It also did not take into account improved 'smart grid' control options.

Table 287: Assumed obtainable energy saving in 2030

	ELECTRICITY CONSUMPTION	**PRIMARY ENERGY**	**EMBEDDED ENERGY**
2030	TWh	PJ	PJ
UPS BELOW 1.5 KVA	1.2	9.4	0.2
UPS 1.5 TO 5 KVA	4.2	31.8	0.3
UPS 5 TO 10 KVA	0.2	1.5	0.0
UPS 10 TO 200 KVA	1.6	12.1	0.2
TOTAL	**7.2**	**54.8**	**0.8**

Table 288 shows the saving potentials in GHG emissions in 2030. The saving potential for GHG emissions related to electricity consumption amounts to 2.5 MT CO2eq in 2030. The savings in embedded GHG emissions are marginal in comparison at 44 kt CO2eq.

Table 288: Assumed obtainable GHG emissions saving in 2030

2030	ELECTRICITY CONSUMPTION kt CO2eq	EMBEDDED kt CO2eq
UPS BELOW 1.5 KVA	423	14
UPS 1.5 TO 5 KVA	1,429	17
UPS 5 TO 10 KVA	66	3
UPS 10 TO 200 KVA	545	12
TOTAL	**2,463**	**44**

Table 289 presents the saving potentials in end-user expenditure in 2030. The reduced electricity consumption amounts to a cost saving of 724 million Euro. An increased lifetime gives a saving in purchase and installation costs of 365 million Euro.

Table 289: Assumed obtainable savings in end-user expenditure in 2030

2030	ELECTRICITY CONSUMPTION mill. EUR	PURCHASE AND INSTALLATION COSTS mill. EUR	TOTAL mill. EUR
UPS BELOW 1.5 KVA	124	61	195
UPS 1.5 TO 5 KVA	420	131	646
UPS 5 TO 10 KVA	19	35	75
UPS 10 TO 200 KVA	160	138	381
TOTAL	**724**	**365**	**1,297**

It should be noted that the potential savings are based on the preparatory study (BAT), and the expected BAT efficiencies may be difficult to obtain. However, the saving potential is high if the BAT levels from the preparatory study can be reached. The expected change in the market towards larger UPS means that more energy is used by UPS, but it is assumed that UPS used at hyper-scale data centres are energy efficient.

While it is important to take into account the energy consumption and related GHG emissions, several social and local environmental effects are imperative to take into consideration in the case of battery production. UPS, and in particular batteries, pose a significant fire risk. UPS are often operating without surveillance, and close to flammable equipment (IT equipment, cables etc.). Accidental fire can have tragic social impacts, as well as significant environmental impacts (smoke pollution, material loss).

Social impacts are especially linked to the raw material extraction and processing in the battery supply chains, with some specific metals giving rise to especially severe concerns such as child and forced labour, or generally detrimental working conditions[803]. Furthermore, some of the materials originate from conflict areas, where armed conflict is present, or the risk of armed conflict breaking out is severe. Local environmental impacts from the mining and refining of raw materials cover a wide range from leaching of toxic chemicals into waterways and ecosystems to local air pollution from dust and toxic gasses. Furthermore, mining areas are also frequently subject to removal of vegetation and topsoil with large impacts on local ecosystems. Hence, it is important to focus on proper resource management of batteries at End-of-life to minimise some of these impacts.

Table 290: Total Cost of Ownership (TCO) of 1 MW UPS over 10 years with VRLA and Li-ion batteries

Capital expenditure	**VRLA**	**Li-ion**
UPS material costs	$ 60 000	$ 120 000
Installation costs	$ 12 000	$ 12 000
Transportation costs	$ 549	$ 366
Subtotal CAPEX	**$ 72 549**	**$ 132 366**
Operating expenditure over 10 years	**VRLA**	**Li-ion**
UPS maintenance	$ 46 330	$ 13 899
Space lease costs	$ 54 597	$ 28 368
Energy costs	$ 26 989	$ 13 495
Battery refresh	$ 108 790	$ -
Subtotal OPEX	**$ 236 706**	**$ 55 762**
CAPEX	$ 72 549	$ 132 366
OPEX	$ 236 706	$ 55 762
Total TCO	**$ 309 255**	**$ 188 128**

22.7 Stakeholder comments

Netherlands Enterprise Agency commented that the savings might be overestimated since they are based on old data and the efficiency has further improved since then and that the Code of Conduct for this product group has not been updated since years and is not effective.[804] The study team agrees and based on industry stakeholder input the saving potential has been re-assessed and is now smaller.

The Japan Electrical Manufacturers' Association (JEMA) commented that US DoE has introducing new mandatory (minimum) Energy Conservation Standards for UPS through the (amended) Energy Policy and Conservation Act 1975 (minimum energy efficiency standards were published on the 10th of January 2020, with compliance starting January 10, 2022). JEMA furthermore commented that the UPS defined by EN IEC standard 62040 series should be clearly in focus and that the study should be conforming to international standards especially, EN IEC 62040-3. The study team agrees and both the US DoE Energy Conservation Standard and the EN IEC 62040 are already mentioned in the report.

ZVEI e.V. - German Electrical and Electronic commented that regulation is not appropriate for customer-specific/ tailored / bespoken UPS systems and that due to the limited number

[803] Follow-up feasibility study on sustainable batteries under FWC ENER/C3/2015-619-Lot 1

[804] https://e3p.jrc.ec.europa.eu//communities/ict-code-conduct-ac-uninterruptible-power-systems

of tailor-made UPS systems and the overriding specific requirements (hospital, railway signal control, emergency call centre, etc.), the ecological impact will be neglectable. The study team informs that these tailor-made systems have not been included in the assessments.

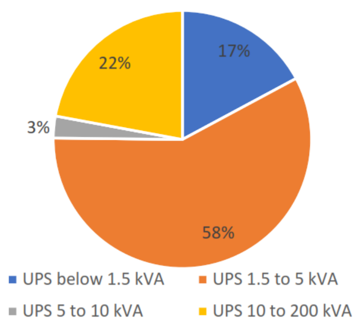
ZVEI also commented that UPSs were the subject of an ecodesign preparatory study by Ricardo-AEA Ltd in 2014 concluding there was a large energy and CO2 saving potential for standard UPS and no existing measures addressing that potential and that besides energy and CO2 savings, uninterruptible power supplies consist of different types of valuable and scarce resources in the printed circuit boards and the batteries. The study team agrees and have slightly updated the text regarding these aspects.

BAM and UBA agree to include UPS in the working plan with the following comments on the necessary revision of the 2014 study:

- The market for UPS systems, which could be affected by an ecodesign regulation, is on the move. Digitalization and thus the spread of UPS systems is progressing. The UK has left the EU with a large market share (2014: 17%).
- The structure and detailed analysis (e.g. the comparison of variants of different improvement options) of the 2014 study was very good and should essentially be retained.
- However, it should be investigated whether the base cases assumed in 2014 (1 to 4) are still representative for the market. Standard components are also increasingly used today for systems larger than 200kVA.
- The number of use cases and types of use of UPS systems has increased. For example, a trend can be observed that large UPS systems are also used for grid services (so-called UPS + systems).
- A fundamental new investigation into the best not yet available technologies (BNAT) is necessary. Lithium-ion accumulators are standard products and supercapacitors are available on the market.
- There has also been a further development of battery management systems in recent years. As a result, the number of charging cycles, lifetime and efficiency have increased, despite high charge/discharge currents and charge density.

CEMEP UPS provided the following comments:

- Regarding the savings potential, you estimate that the potential lies in the 1.5 to 5 kVA. We tend to think that the potential is actually in categories above 10 kVA (yellow part of the graph in the presentation at the second stakeholder meeting).



- We want to insist that the projections made today are based on data from the impact study whom robustness and reliability can be questioned.

- A new version of the Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems (UPS) will be uploaded on the JRC website within a month (from mid-April). A notable addition to the minimum requirements is an elite level (see hereafter) has been introduced. It will be mandatory if a data centre wants to be compliant with the Code of Conduct for Data Centres.

Elite weighted UPS efficiency requirements (%) or "CoC for UPS elite requirements"

Power Range (kW)	Performance Classification		
	VFD	VI	VFI
≥ 0.05 to ≤ 0.3	91.0%	90.0%	85.5%
> 0.3 to ≤ 3.5	94.0%	93.0%	87.5%
> 3.5 to ≤ 10	95.7%	94.4%	90.0%
> 10 to ≤ 200	97.0%	95.0%	91.5%
> 200	98.0%	96.0%	93.5%

- UPS are in the middle of several European processes either directly (Ecodesign, PEFCR) or indirectly (data centres, batteries). Therefore, the European Commission needs to be careful and must provide clarity and consistency if it does not want to harm our industry.

The study team has compared the Elite UPS requirements with the draft CoC received during the study. The efficiencies in the table for Elite requirements are about 1-2 percent-points above the efficiencies in the draft CoC informed previously by CEMEP UPS, however, they were not at an Elite level, but at a level necessary to comply with under the CoC for UPS within a certain time limit as it was understood by the study team. The study team believes that an Elite level for UPS required for complying with the CoC for data centres will help pushing the market towards more efficient UPS systems, however, the data centres in the CoC and candidates to it, typically already have much focus on the energy efficiency. Furthermore, the size and timing of such market transformation is unknown. Therefore, no changes made in the report, however, it is advisable to look into this when the updated version of the CoC for UPS is publicly available. Therefore, no changes made in the report.

Regarding the saving potential, our calculations show the largest potential for the smaller UPSs (1.5 to 5 kVA), which is due to high sales volume and high percentage saving potentials.

23 ELECTRIC VEHICLE CHARGERS

23.1 Scope, policy measures and test standards

Charging technologies for electric cars (electric vehicle (EV) chargers), is of particular interest due to the expected increase in sales of electric cars in the future and it seems relevant to consider the electricity consumption from wallbox chargers and the public charging points.

When the cars are charged, there will be a conversion loss in the charger from the mains to the voltage level required for the batteries and the charger also contains additional control systems consuming energy, even when it is not actively charging. The cars will have the option of being charged at public charging stations or via a home charger (wallbox charger). There are various methods to charge the electric cars, but it is expected that most electric cars today and in the future will be charged with a wallbox charger at home. These wallbox chargers are becoming more and more advanced with display, internet connection and smart functionalities, which can lead to increased energy consumption compared to a simple charger, which only has an LED charging indicator. The smart functionalities may however also provide energy system savings via demand flexibility. See an example in Figure 92.

When using electric cars for longer trips, it will often be necessary to charge the car at a public charging station. These chargers can charge at significantly higher power levels, resulting in reduced charging time.

Note that the public chargers larger than 22 kW (high speed chargers) include the AC to DC conversion and the potential energy losses. When using a wallbox charger, these chargers typically only supply the AC power at mains voltage as the conversion happens in the onboard charger[805].

Figure 92: Illustration of the on-board charger

Hence, it makes sense to consider the following types of chargers:

[805] According to a stakeholder this might change in the future

- Simple AC wallbox connector for installation at home (not including the on-board charger)
- Smart AC wallbox connector for installation at home (not including the on-board charger)
- Public "low" speed AC charger (less than 22 kW)
- Public "high" speed DC charger (22 kW or more)

The trend is clear and it is assumed that in coming years, there will be significantly more electric cars and that more public and private charging stations will be installed in the near future. Therefore it is relevant to consider any savings potentials for this product group.

Of regulations, standards and other initiatives, the following is considered relevant for the products in scope and related to the assessments in this study:

p) Other initiatives

1. ENERGY STAR[806] Energy Star has a specification for wall-box chargers from 2017, mainly covering modes other than on-mode. Converting the expected savings in USA to the EU, the amount would be 180 GWh/year.

It has to be noted that before further studies will be launched it should be verified if electric vehicle chargers are in scope of the Ecodesign Directive, because the directive does not apply to means of transport for persons or goods. It has been preliminarily verified by the Commission that electric vehicle charges are considered to be in scope.

23.2 Market

Table 291 shows estimated stock of AC wallbox connectors and of public DC chargers. The calculation of the stock is based on the sales of both types of chargers.

The sale figures of AC wallbox connectors are based on the expected increase in electric cars in the Preparatory Study on Ecodesign and Energy Labelling of rechargeable electrochemical batteries with internal storage[807]. The penetration rate of private wallbox chargers is assumed to be 100% of owners with an electric car or a plugin hybrid car meaning that all owners of electric cars and plugin hybrid cars are assumed to have a wallbox charger. This may be an overestimation, but due to the uncertainty in the expected sales of electric cars, it provides an estimation of the potential numbers of wallbox chargers for further calculations.

The sale figures of DC chargers are based on the average number of "slow" and "fast" chargers available over the last five years in Europe[808] assuming 7.7 EVs per slow charger and 82 EVs per fast charger in EU. Based on the above assumptions the stock is calculated and presented in Table 291.

[806] https://www.energystar.gov/products/spec?term_node_tid_depth_1%5B%5D=1089&field_status_value%5B%5D=Historical&field_status_value%5B%5D=Sunsetted&field_effective_start_date_value%5Bvalue%5D%5Bdate%5D=&field_effective_start_date_value2%5Bvalue%5D%5Bdate%5D=

[807] https://ecodesignbatteries.eu/documents

[808] https://www.eafo.eu/alternative-fuels/electricity/charging-infra-stats

Table 291: Stock of AC connectors and public DC chargers

Stock [millions]	2020	2030	2040	2050
Simple AC wallbox connector	1.74	23.79	54.56	57.59
Smart AC wallbox connector	0.31	23.79	127.30	230.35
Public "low" speed AC charger	0.27	1.59	6.19	14.48
Public "high" speed DC charger	0.02	0.15	0.58	1.36
Total	**2.34**	**49.31**	**188.63**	**303.78**

23.3 Usage

Today the normal procedure for refuelling a car is to fuel at a gas station after the car have driven 500-1000 km on a full tank of gasoline. The actual time it takes to refuel a car depend on the size of the tank and the speed of the pump. A modern pump can deliver 30-50 litres gasoline per minute meaning that the typical tank size between 45 and 65 litres can be refuelled in a few minutes on average.

In future with a high share of electric cars the "refuelling habits" will change dramatically and the majority of the "refuelling of energy" will occur at home during the night. In a study performed by Transport and Environment[809] the charging habits are described:

"Whilst there has been considerable focus on and investment in public recharging infrastructure evidence from studies shows that it is a very minor part of the way electric cars are charged and just 5% of vehicle charging happens at public charging locations including on-street city charging, car parks and fast charging along road corridors.4 95% of EV charging happens home and at work. Evidence from Norway, the most developed EV market in Europe, shows that as the EV market matures, public urban charging is used less rather than more. A comparison of surveys from 2014 to today elaborated by IEA5 on evolution of charging habits indicates that relatively fewer people use publicly accessible slow chargers and that fast charging along corridors is the only charging type that has increased in use in Norway. This could be explained by improved coverage and power of fast charging networks and increasing driving ranges. As a consequence, in Norway, the share of drivers relying on public slow charging on a daily basis dropped from almost 10% in 2014 to just 2% in 2017 (about 15% of drives used it on a weekly basis).

Cities are both the destination for many long trips and location of most off-street parking and will therefore be the location of most public recharging infrastructure. However, as the range of EVs improves to reach real-world ranges of 400 km, the average urban driver only needs to typically charge once a week, far less than at present. Charging solutions in cities will be composed of a mix of slow, fast and ultra-fast chargers. Slow/regular chargers are the solution with the most limited grid impact since powers are lower and demand can easily be directed to off-peak hours since the car is usually parked at these timers. In cities slow charger may be found at: 1. On-street charging for drivers that leave their car during the day or the night parked in the street; 2. 'Park & Ride' chargers in parking lots with public transport connections that allow commuters to enter the city center without their car. In densely populated areas, a demand-driven approach using slow rechargers, as piloted in Amsterdam, ensures chargers are appropriately located and used from day one

[809] https://www.transportenvironment.org/sites/te/files/Charging%20Infrastructure%20Report_September%202018_FINAL.pdf

and also addresses the issue of uncertain usage forecasting that makes constructing a robust business case difficult. 50 kW fast chargers typically charge an EV in about one hour. They are therefore most suited for facilities and amenities where people typically stay 30 minutes to 2 hours. For example, these locations would be parking lots of stores, supermarket or commercial zone. There is a strong incentive for owners of such properties to install chargers to encourage customers to their facilities. Ultra-fast charging sites near cities are ideal for tackling range anxiety and recharging for those users without off-street parking or access to a slow charging site. They are particularly appropriate for shared electric cars enabling these to be operative most of the time. Studies have shown how the provision of fast charging infrastructure is a strong driver for EV uptake. For example a first study has shown that providing charging solutions above 50 kW close to urban areas increases the annual EV kilometers traveled by about 25% (even in cases where it was used for less than 5% of total charging events). A second study has shown that fast charging is a stronger driver than standard charging and confirms that access to fast chargers increases daily electric distance travelled. There are indications users prefer to use ultra-fast chargers for both inter- and intra-urban travel. A network of fast chargers may therefore prove to be more popular and cheaper than installing a large number of slow chargers in cities. Fast chargers do however incur greater impact on the electricity grid and less readily balance renewables and cannot be so smart. The optimum balance of slow and fast charging in urban areas may therefore depend to some extent on the capacity of the local electricity grid to accommodate fast charging and possibly differential charges. In China, there are several examples of charging hubs serving many types of vehicles. For example, the Qian Hai charging station can charge 60 vehicles simultaneously (maximum capacity of 3 200 kW) and is used by taxis (50%), vans (30%), passenger cars (10%) and buses (10%). The project Mega-e, also aims to bring multimodal charging hubs including ultra-fast chargers to metropolitan areas. Providing a mixture of services can potentially help to balance demand throughout the day and night but may require considerable space to park vehicles before and after charging overnight."

Hence, only 5% of the charging is assumed to be performed at public charging stations, meaning that 95% of the time the car is charged by the onboard charger and a wallbox connector at home[810].

Regarding the use of both AC and DC chargers different operational modes exists. Below are the different modes described (based on Energy Star[811]), see Table 292:

1. *Disconnected: Condition of the equipment during which all connections to power sources supplying the equipment are removed or galvanically isolated and no functions depending on those power sources are provided. The term power source includes power sources external and internal to the equipment.*
2. *No Vehicle Mode: Condition during which the equipment is connected to external power and the product is physically disconnected from vehicle (mode can only be entered or exited through manual intervention). No Vehicle Mode is intended to be the lowest-power mode of the EVSE. Note: The vehicle-EVSE interface is in State A of SAE J1772, where the vehicle is not connected.* [812]

[810] https://www.transportenvironment.org/press/only-5-percent-ev-charging-happens-public-charging-points

[811] https://www.energystar.gov/sites/default/files/Version%201.0%20EVSE%20Program%20Requirements%20%28Rev.%20Apr-2017%29_0.pdf

[812] This mode is intended to be associated with a vehicle/EVSE interface state (e.g., A, B, or C) as defined in SAE J1772.

3. *On Mode: Condition during which the equipment provides the primary function or can promptly provide the primary function.*
    a. *Operation Mode: Condition during which the equipment is performing the primary function. Note: The vehicle-EVSE interface is in State C, where the vehicle is connected and accepting energy.*[812]
    b. *Idle Mode: Condition during which the equipment can promptly provide the primary function but is not doing so. Note: Idle Mode is the condition within On Mode where the EVSE is connected to the vehicle or vehicle simulator but is not actively providing current. The vehicle-EVSE interface is in State C, where the vehicle is connected and ready to accept energy.* [812]
4. *Partial On Mode: Condition during which the equipment provides at least one secondary function but no primary function. Note: The vehicle-EVSE interface is in State B1 or B2, where the vehicle is connected but not ready to accept energy and the EVSE is or is not ready to supply energy.*[812]

Table 292: Operational Modes and Power States as defined in Energy Star

OPERATIONAL MODES	MOST CLOSELY RELATED INTERFACE STATE AS DEFINED IN SAE J1772	FURTHER DESCRIPTION
NO VEHICLE MODE	State A	No Vehicle Mode is associated with State A, or where the EVSE is not connected to the EV. The EVSE is connected to external power.
PARTIAL ON MODE	State B1 or State B2	Partial On Mode is associated with State B1 or State B2 where the vehicle is connected but is not ready to accept energy. Sub-state B1 is where the EVSE is not ready to supply energy and substate B2 is where the EVSE is ready to supply energy.
ON MODE		
IDLE MODE	State C	Idle Mode is associated with State C, where the vehicle is connected and ready to accept energy and the EVSE is capable of promptly providing current to the EV but is not doing so.
OPERATION MODE	State C	Operation Mode is associated with State C, where the EVSE is providing the primary function, or providing current to a connected load (i.e., the relay is closed and the vehicle is drawing current).

Regarding time in the different modes, the estimations for further calculations are presented in Table 293.

Table 293: Use time in the different modes

	No Vehicle Mode	Partial On Mode	Idle Mode	Operation Mode
Simple AC wallbox connector	40%	1%	39%	20%
Smart AC wallbox connector	40%	1%	39%	20%
Public "low" speed AC charger	35%	5%	15%	45%
Public "high" speed DC charger	40%	5%	5%	50%

23.4 Technologies

Different charging standards exist and different plugs for charging are available on the different markets. Regarding AC charging, all electric cars are equipped with a Type 2 socket in Europe (see Figure 94). However, different types of wallbox connectors exist. Tesla has made some simple chargers with only a LED indication, but more advanced chargers exist with displays and built in Wi-Fi. The ID.Chargers from Volkswagen somehow represents some of the different types of chargers on the market presented in Figure 93.

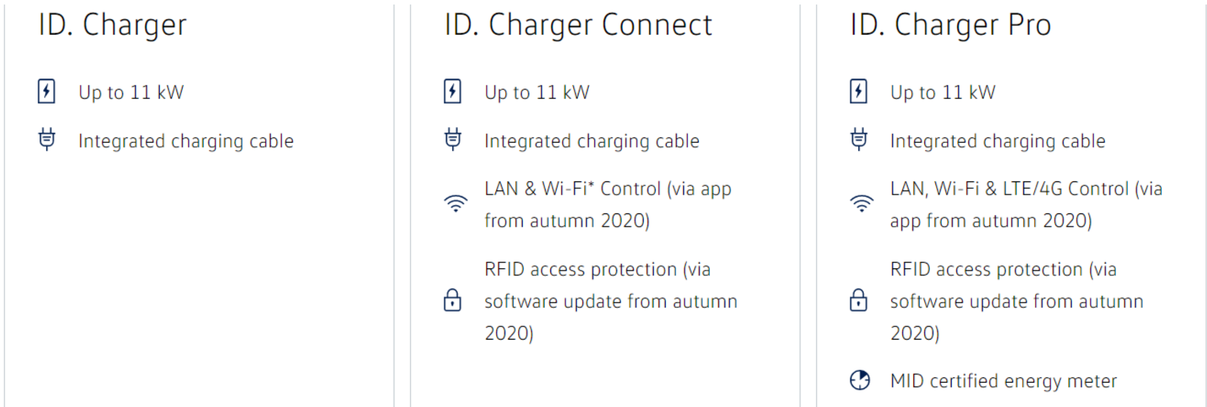


Figure 93: Types of different AC chargers illustrated by VW ID chargers[813]

The number of functions in the charger can affect the energy consumption of the charger. Even with the extensive number of extra functionalities, most chargers cannot be categorised as genuine smart chargers. Today most "smart chargers" can provide information regarding the expenses related to charging, but so far, only few chargers can react to external stimuli and provide bidirectional charging[814].

For DC charging several different plugs exist. In Europe, all DC charging occurs through a type 2 plug and the DC charging plug can be through CHAdeMO or CCS2. The CHAdeMO plug requires two separate sockets in the car, while the CCS2 socket includes the Type 2 socket, which saves space compared to CHAdeMO socket. The different plugs and socket types are presented in Figure 94 below.

[813] https://charging-energy.elli.eco/ie-en/IDcharger

[814] Note that only CHAdeMO chargers provides bidirectional charging

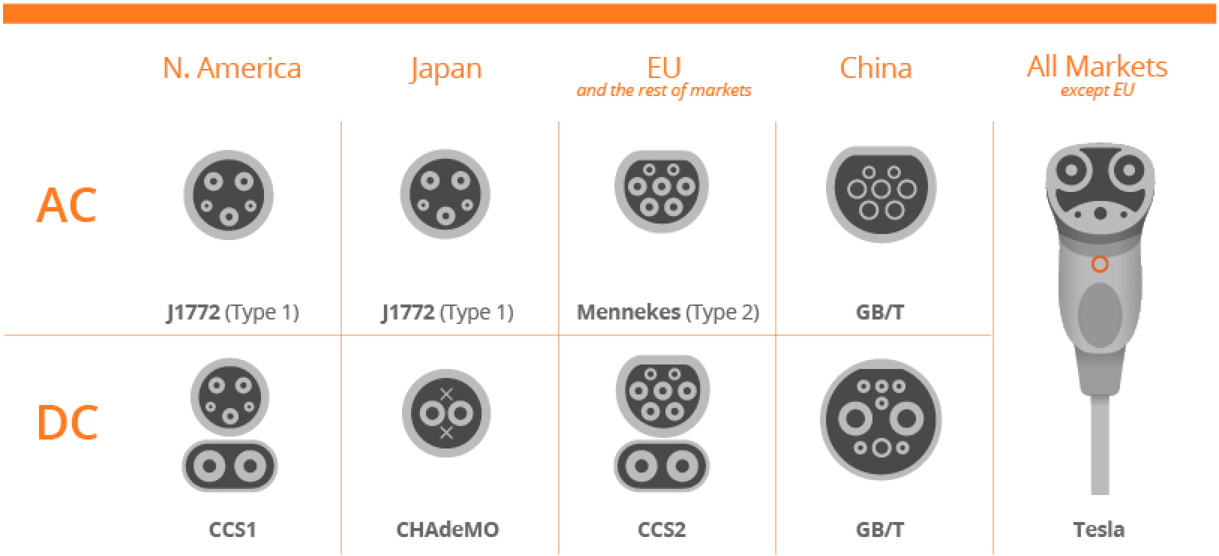


Figure 94: Illustration of the different plugs/sockets[815]

In connection with the different plugs, the different standards on charging can have an impact on the charging time of public chargers. The only two available charging standards in cars on the European market are:

- The CHAdeMO standard was introduced by Japanese automotive manufacturers Nissan and Mitsubishi in 2005 and then, in 2011, adopted in Europe. It is expected to be a legacy standard in Europe after Nissan decided to change to CCS[816]. However, the standard still exists and are popular in Asia. The CHAdeMO standards have some benefits regarding bidirectional charging which makes smart ready. However, the CCS will include bidirectional charging in the future[817].

- The combined charging system (CCS) plug was initially developed in 2009 and then adopted by Audi, BMW, Daimler, Ford, General Motors, Porsche, Volvo, and Volkswagen in mid-2012, with specific plug forms for the US and the rest of the global markets. Each of these standards operates at different DC voltages with different maximum power levels.

The technical data for CHAdeMO and CCS2 are presented in Table 294 and Table 295.

Table 294: CHAdeMO Technical Data, Hybrid (PHEV)-14 kWh, Electric Vehicle (EV)-24 kWh[818]

		Level 1		
Voltage (V)	**Current (A)**	**Power (kW)**	**SoC (%)**	**Time (min)**
200–450	<125	<62.5	PHEV 0–80	15
			EV 20–80	50
		Level 2		
500	<200	<100	PHEV 0–80	<10

[815] https://evcharging.enelx.com/eu/about/news/blog/552-ev-charging-connector-types
[816] https://www.greencarreports.com/news/1128891_nissan-s-move-to-ccs-fast-charging-makes-chademo-a-legacy-standard
[817] https://theenergyst.com/evs-v2g-vehicle-to-grid-battery-storage-smartgrid/
[818] https://www.mdpi.com/1996-1073/11/8/1937

			EV 20–80	<30

Table 295: CCS Technical Data, Hybrid (PHEV)-14 kWh, Electric Vehicle (EV)-24 kWh[819]

Voltage (V)	Current (A)	Power (kW)	SoC (%)	Time (min)
		DC Level 1		
200–450	<80	Up to 36	PHEV 0–80	22
			EV 20–80	80
		DC Level 2		
200–450	Up to 200	Up to 90	PHEV 0–80	10
			EV 20–80	20
		DC Level 3		
200–600	Up to 400	Up to 240	EV 0–80	<10

The data presented in Table 294 and Table 295 are from 2018, and the development goes towards even higher charging speeds. Soon it can be expected that charging can be performed with ultra-fast chargers with 350 kW[820]. Also, the voltage can change from the typical 400 V to 800 V as this change reduce the heat generated during charging and allow for even greater charging speeds[821].

The efficiency of the DC charging is typically around 90% but can be greatly influenced by the weather conditions. The impact of cold climates has been investigated in the study "Evaluation of Fast Charging Efficiency under Extreme Temperatures" and found that efficiency can go below 50% under cold temperature conditions. The results from the study are presented in Figure 95.

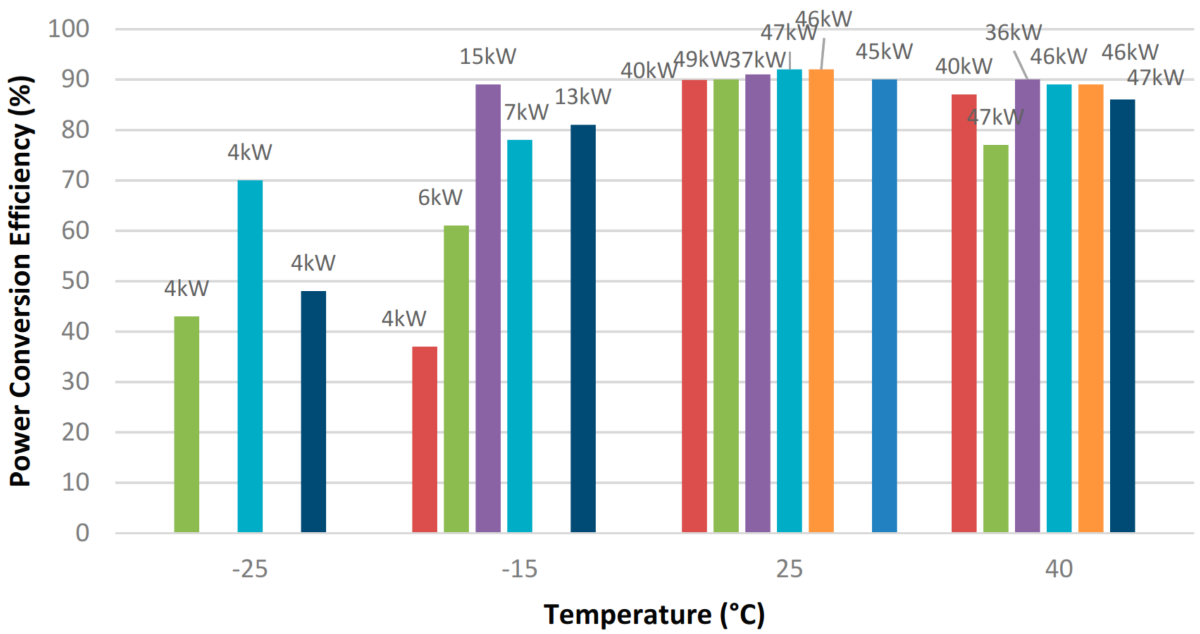


Figure 95: Power conversion efficiency results as a function of the temperature.

[819] https://www.mdpi.com/1996-1073/11/8/1937
[820] https://insideevs.com/news/347476/350-kw-12-mw-fast-charging-ess-norway/
[821] https://chargedevs.com/newswire/why-did-porsche-go-to-the-trouble-of-designing-an-800-v-taycan-ev/

Besides the impact of the temperature, another study[822] on the energy efficiency of quick DC vehicle battery charging[823] states that the charging speed (kW) and SOC (State Of Charge) also could influence the efficiency of the charging. Some of the results from this study are presented in Table 296.

Table 296: Charger efficiency vs power and initial SOC[824]

P [kW]		3	16	22	43	50
SOC	23	85.0	84.6	91.1	91.7	91.4
	43	85.0	88.1	90.5	90.6	89.7
	60	85.0	83.2	83.7	87.5	83.2

Based on these studies it can be concluded that several factors can have an impact on the chargers.

23.5 Energy, Emissions and Costs

The calculated energy consumption and GHG emissions are based on the following assumptions:

1. Simple AC wallbox connector for installation at home (not including the on-board charger)
   - Average energy consumption in standby of roughly 2.5 W[825] in standby
   - The "standby" energy consumption is assumed to be representative for the energy consumption in all states meaning a constant power draw of 2.5 W.
   - The energy loss in the onboard charger is not included in the calculations

2. Smart AC wallbox connector for installation at home (not including the on-board charger)
   - The energy consumption is based on data from Energy Star with the highest consumption in idle mode. The connector has the following energy consumption in the different modes: 4.17 W in no vehicle mode, 4.17 W in partial on mode and 5.58 W in idle mode.
   - The partial on mode is also assumed to occur during charging.
   - The energy loss in the onboard charger is not included in the calculations

3. Public "low" AC and "high" speed DC chargers
   - The energy consumption is based on data from Energy Star with the highest consumption in idle mode. The connector has the following energy consumption in the different modes: 4.8 W in no vehicle mode, 4.8 W in partial on mode and 17.9 W in idle mode.
   - The partial on mode is also assumed to occur during charging.
   - The AC/DC conversion efficiency is assumed to 85 % on average

[822] Test with a Nissan Leaf and a CHAdeMO charger
[823] https://www.mdpi.com/2032-6653/7/4/570
[824] https://www.mdpi.com/2032-6653/7/4/570
[825] https://teslamotorsclub.com/tmc/threads/wall-charger-idle-240v-consumption.143381/

Based on the above assumptions and the assumptions regarding the use time in Section 23.3, the energy consumption, emission and a simple LCC (life cycle costs) (only energy) is calculated and presented in Table 297, Table 298 and Table 299.

Table 297: Energy consumption of AC connectors and DC chargers

TWh/year	2020	2030	2040	2050
Simple AC wallbox connector	0.04	0.52	1.20	1.26
Smart AC wallbox connector	0.01	0.93	4.97	8.99
Public "low" speed AC charger	0.03	0.76	2.90	4.60
Public "high" speed DC charger	0.02	0.42	1.60	2.54
Total	**0.10**	**2.63**	**10.67**	**17.39**

Table 298: GHG emissions related to the use of AC connectors and DC chargers

MT CO2eq/year	2020	2030	2040	2050
Simple AC wallbox connector	0.01	0.18	0.36	0.33
Smart AC wallbox connector	0.00	0.32	1.49	2.34
Public "low" speed AC charger	0.01	0.26	0.87	1.19
Public "high" speed DC charger	0.01	0.14	0.48	0.66
Total	**0.04**	**0.89**	**3.20**	**4.52**

Table 299: Consumer costs related to the use of AC connectors and DC chargers

mln. EUR/year	2020	2030	2040	2050
Simple AC wallbox connector	7.8	110.7	257.3	263.7
Smart AC wallbox connector	2.4	197.0	1069.2	1878.2
Public "low" speed AC charger	6.6	161.2	624.7	960.1
Public "high" speed DC charger	3.7	89.1	345.4	530.9
Total	**20.5**	**558.0**	**2296.6**	**3632.9**

23.6 Saving potential

No updated data on obtainable energy saving potentials were identified. The saving potential is difficult to estimate due to the number of uncertainties including future development of this emerging market. Chargers will most likely be more advanced, and maybe include different network functions (including bidirectional charging).

To indicate a saving potential the following assumptions are made:

- A 50% reduction of the current energy consumption of the AC wallbox chargers (see Section 23.5) are assumed to be obtainable.
- The average efficiency of DC public chargers is expected to increase from 85% to 95%.

One industry stakeholder commented that these assumptions are too ambitious and with today's technology, it is not possible to reach these efficiency improvements. Due to lack of more data and information, the assumptions are maintained.

The above savings are estimated in order to provide an overview of potential savings in the EU. In Table 300, Table 301 and Table 302, the potentials are presented. Note that monetary and GHG emission savings are related to the potential energy savings. The savings in the long term i.e. until 2050 have also been estimated due to the expected high increase in EVs and their chargers over the coming years.

Table 300: Potential electricity savings (TWh/year) and total primary energy savings (PJ/year, CC: 2.1) EU-27 based on the stock in the particular years[826]

TWh/year	2020	2030	2040	2050
Simple AC wallbox connector	0.02	0.26	0.60	0.63
Smart AC wallbox connector	0.01	0.46	2.48	4.49
Public "low" speed AC charger	0.02	0.44	1.70	2.69
Public "high" speed DC charger	0.01	0.28	1.05	1.67
Total electricity savings, TWh/year	**0.06**	**1.44**	**5.84**	**9.49**
Primary energy savings, PJ/year	**0.4**	**11**	**44**	**72**

Table 301: Potential GHG savings EU-27 based on the stock in the particular years[826]

MT CO2eq/year	2020	2030	2040	2050
Simple AC wallbox connector	0.01	0.09	0.18	0.16
Smart AC wallbox connector	0.00	0.16	0.75	1.17
Public "low" speed AC charger	0.01	0.15	0.51	0.70
Public "high" speed DC charger	0.00	0.09	0.32	0.43
Total	**0.02**	**0.49**	**1.75**	**2.47**

Table 302: Monetary saving EU-27 based on the stock in the particular years[826]

Million EUR/year	2020	2030	2040	2050
Simple AC wallbox connector	3.88	55.33	128.66	131.84
Smart AC wallbox connector	1.22	98.52	534.62	939.11
Public "low" speed AC charger	3.89	94.45	366.10	562.70
Public "high" speed DC charger	2.41	58.42	226.45	348.06
Total	**11.39**	**306.73**	**1255.83**	**1981.71**

No data were available for analysing circular economy and material efficiency aspects.

With the assumptions established, within the next 10 years, the energy saving potential is limited.

However, after 2030 the potential savings are expected to increase dramatically and in 2050 the savings may be almost 10 TWh annually. The estimates are related to a high degree of uncertainty but based on future projection special attention should be put on this product group to ensure that the "losses" related to charging are kept at a low level.

Also, the batteries in the cars can be a keystone in a sustainable future with a high degree of renewable energy and it may become necessary to include requirements of bi-directional

[826] The only dynamic factor in the calculations are the stock of BEVs and PHEVs. Meaning that the stock and thereby the saving potential will increase rapidly between 2020 and 2030

charging and genuine smart functionalities such as demand side flexibility in a smart grid e.g. where charging takes in periods with excess of green electricity though still securing a charged car when it is needed. This potential is not considered in the above numbers, but it is assumed to potentially lead to substantial additional savings in GHG emissions.

23.7 Stakeholder comments

Comments were received from the following stakeholders:

- BAM and UBA
- Danish Energy Agency
- European Copper Institute
- Schneider Electric
- Swedish Energy Agency
- Volta
- ANEC and BEUC

The following comments were provided; the study team's answers are provided for each of them:

- There are many indications that the development in sales of electric and hybrid cars in the EU has been significantly faster than expected in the above-mentioned preparatory study. Preliminary new assessments of sales of electric and hybrid cars in the EU indicate that sales have been around 1.395 million cars in 2020 or almost 90% higher than expected in the EELWP study. Therefore we recommend the saving potential for this product group to be updated and the relevancy to be get on the working plan to be reconsidered. In addition, it is considered to be significantly more relevant to look at the savings potential in 2040 than 2030, as a possible regulation will only have achieved a small part of its total effect by 2030.
  We would like to question the conclusion that it is too early to set requirements. Requirements should be set early to help shape the development. Other technologies such as LEDs and displays have been regulated while undergoing a major development and LEDs at a time when technology was in its infancy. Taking into consideration the timing of regulation, due to the long and thorough preparatory study process, the ecodesign requirements might earliest come into force after 2027. This might likely be too late.
  We recommend that losses due to conversion and savings opportunities related to this, are included in the analyses of savings potentials. Additionally the future revision of the Ecodesign Directive (cf. SPI), there is a possibility that the scope can be expanded with means of transport and thus requirements can also be set for converters in electric cars, which would increase the savings potential even more.

  Study team answer: The sales were very high in 2020, which means that our stock numbers were low in 2020. The stock in 2020 reached our predicted stock in 2021, meaning that our numbers are off by one year currently. However, the sales are very difficult to predict, because the sales are heavily dependent on subsidies or other beneficial schemes in the Member States. Without subsidies etc., the sales might flatten in a period of time afterwards. The most crucial factor to consider is the number of vehicles needed before the saving potential becomes significant, which not are likely to happen in the near future. The calculated saving potential, which one industry stakeholder believes is based on not-realistic assumptions, is not sufficiently large. We agree that it is important to consider the current rollout of public chargers, which are occurring now, and follow the development.

- “Electric vehicle chargers”, i.e. public chargers and charging points ("wallbox connectors") should be included in the short list of the working plan for 2020-2024 for the following reasons:
  - The development of electric vehicles (Battery and Plug-in Hybrid) may occur faster than foreseen in the report. (The share of EV in the EU was in 3% in 2019, 11% in 2020, and 23% in December 2020. According to ICCCT, Market Monitor European Passenger Car Registrations: January–December 2020, January 2021)
  - Chargers will also be needed for the growing number of other types of electric vehicles then light vehicles. Ecodesign requirements for these chargers should also be addreesed.
  - The number of "wallbox connectors" will increase at the same pace as the vehicles (penetration of 100% according to task 3 report), and the public chargers will also increase proportionally. It is probably the product group within ecodesign where the fastest penetration growth is expected.
  - Public chargers (and their AC-DC conversion) are in many cases using the same technology than the one used in onboard chargers. These chargers tend to have low energy efficiency. There is therefore a large energy efficiency improvement potential, for example by using wide band gap based power electronic devices.
  - Fast chargers and "wallbox connectors" have a large potential for allowing demand-side flexibility. These products, and fast chargers in particular, may imply significant investments in the electricity network and consequently have a relevant impact in terms of use of material, land-use and other resources.
  - The ecodesign requirements for these products will have an impact beyond the European Union.
  - This product group scores well in the criteria from Task 4: resource efficiency, other environmental impacts, cost effectiveness, route to market, regulatory coverage and industrial competitiveness.
  - We cannot wait for the next working plan. If chargers and charging points are included in the current working plan, ecodesign requirements will come into force at the earliest in 2026 but most probably later. The roll-out of chargers is already happening at a high pace, being promoted through legislation and through public funding.
  - If we wait for the next working plan, ecodesign requirements will come into force ca 2031. By then, the first generation of products will have been installed and we will have lost the opportunity of regulating them.

  Stiudy team answer: The technical analyses show that the saving potential in the near future is limited compared to other products in the working plan study (even if other vehicles are included). However, the development is very much depending on Member States policies regarding possible schemes for supporting an increase in the amount of electric vehicles and of public chargers.

- The product scope is welcomed as it comprises public chargers as well as residential (“at home” chargers), both being relevant for the charging habits of consumers, while being run by different parties. We think the impact of chargers used for other type of e-mobility products (such as electric scooters, electric bikes, etc.) could also be addressed in this or a separate study. E-products used for micro-mobility are increasingly gaining popularity among consumers and their environmental and social impact is highly underestimated. (https://www.vzbv.de/pressemitteilung/e-bikes-teuerund-kurzlebig).

Study team answer: The scope for the analyses focused on the public and home chargers, but if a preparatory study should be initiated, it could be considered to extend the scope.

- Only 1/3 of the cars are parked overnight at off-street lots. It seems contradictory stating "7.7 electric cars per slow charger". Source: JRC (2012). Driving and parking patterns of European car drivers – a mobility survey. http://dx.doi.org/10.2790/7028.

  Study team answer: The JRC study is rather old and a lot have changed since 2012. More recent studies suggest that only 5% of EV charging happens at public charging points. For simplicity we assume that 100 of PHEV and BEV owners has a charger at home. However, this may change in the future with changed infrastructure and more BEVs on the market. The assumption regarding "7.7 electric cars per slow charger" is based on data from www.eafo.eu.

- The German "Masterplan Ladeinfrastruktur der Bundesregierung" assumes 15% to 40% of the chargings are public charging. This might strongly depend on the population density, share of people living in rented appartments etc.

  Study team answer: When more BEVs and PHEVs in future are put on the market the need for public overnight charging is increasing for e.g. people living in appartments.

- Public charging seems underestimated. As 2/3 of EU cars park on the street (or public car parks) it's clear that the mix is going to move to a higher public share. Our benchmark here is around 80% AC and 20% DC (city and roads).

  Study team answer: The JRC study is rather old and a lot have changed since 2012. More recent studies suggest that only 5% of EV charging happens at public charging points. A reference is added in the document.

- The assumptions in the potential energy savings are not supported by any sources or explanation. Please clarify assumptions to ensure validity of the saving potential.

  Study team answer: As stated in the report, the saving potential is difficult to estimate. Hence, we had to set up some clear boundary conditions based on assumptions as provided in the report. Many uncertainties exists within these calculations, but the study team did not find any actual data on obtainable saving potentials. However, the overall conclusion must be that the stock of electric cars needs to increase significantly before the saving potential becomes significant.

- The report does not describe circular economy and environmental aspects.

  Study team answer: No data were available for analysing circular economy and material efficiency aspects. However, if a preparatory study should be launched, it could look further into this area.

- To indicate the saving potential assumptions have been made, which require some technology breakthrough.

  Study team answer: These saving potentials are only used to illustrate the saving potential. It may be difficult to reach these efficiencies in 2025, but in 2040 it may be obtainable meaning that we might overestimate the saving potential between 2020 and 2030 but underestimate the potential saving in 2050. However, recent data has shown that the sales of BEVs and PHEVs has increased more than expected. Meaning that the indicative saving potential may be of right size. Overall data shows that the most important factor is the penetration rate of BEVs and PHEVs

- Policy recommendations and conclusions are missing in the study. We ask the study team to consider adding separate paragraphs clearly identifying possible policy actions addressing both energy efficiency and material efficiency aspects (durability, repairability), as well as an evaluation on the impact of potential energy labelling rules. Our key recommendations for this product group are:
  - Consumers should be given information on conversion loss due to the length of the cable,
    the display of information on the meter/charging stations or the charging environment (ambient temperature and temperature of the battery, etc.).
  - Requirements should be introduced to reduce and enable easy comparison of these conversion losses.
  - Requirements should be introduced to tackle upgradability (in terms of potential power delivered) of fast-charging cables/charging stations.
  - Durability and repairability requirements for cables should be introduced as these items represent a considerable investment for consumers when buying an EV. Public charging stations already suffer from maintenance issuesdue to hardware deterioration and software failures.

  Study team answer: Task 3 is assessing the technical topics including energy consumption and savings etc., while assessment of regulatory feasibility etc. is carried out in Task 4 for the selected products. However, the scope of the study is focused on recommendations for inclusion in the working plan.

Additionally, factual comments were provided, which resulted in minor updates of text and figures in the report.

24 Base Stations

24.1 Scope, policy measures and test standards

Base stations (BTS) were studied in Task 3 and 4 of in the last working plan study and recommended for regulation. The Commission did not include them in the actual working plan but included the product group in a separate ICT impact study together with datacentres and other ICT equipment. Network switching subsystems were also screened in the last working plan study, but eventually not selected.

The ICT impact study[827] reported that the total consumption of the base stations and subsystems in the radio access network (RAN) is about 11 TWh/year. The 5G development will increase the number of base stations. Hence it becomes increasingly important to consider the saving potential by applying Ecodesign requirements. Relevant results from the ICT study are presented in the following sections together with further assessments based on literature reviews and stakeholder input.

The previous working plan study defined base stations as follows: "A base station is a network element in radio access network responsible for radio transmission and reception in one or more cells to or from the user equipment".

To this extent, base stations are a key element in network architecture for mobile communication. They are one of the links in the chain between the public network and the private mobile phones or smartphones (user equipment) – they allow voice and data to be transmitted along these two poles. The technical description of base stations is further explained in Section 24.4.

For introduction, a short explanation of Radio Access Network (RAN), the types of base stations, and typical equipment connected with base stations are briefly described below[828]:

"A Radio Access Network (RAN) is the part of a telecommunications system that connects individual devices to other parts of a network through radio connections. A RAN resides between user equipment, such as a mobile phone, a computer or any remotely controlled machine, and provides the connection with its core network. The RAN is a major component of wireless telecommunications and has evolved through the generations of mobile networking leading up to 5G.

A RAN provides access and coordinates the management of resources across the radio sites. A handset or other device is wirelessly connected to a backbone, or core network, and the RAN sends its signal to various wireless end points, so it can travel with other networks' traffic. A single handset/phone could be connected at the same time to multiple RANs, which is sometimes called dual-mode handsets.

[827] https://circabc.europa.eu/ui/group/1582d77c-d930-4c0d-b163-4f67e1d42f5b/library/b6884364-4e14-44a1-9e23-03a7fed002af

[828] Explanations are from CableFree.net, available at https://www.cablefree.net/wirelesstechnology/4glte/lte-4g-5g-radio-access-network-ran/

The term radio access network (RAN) has been in use since the beginning of cellular technology and has evolved through the generations of mobile communications (from 1G up to 5G today). Components of the RAN include a base station and antennas that cover a given region depending on their capacity, plus required core network items.

In modern 4G networks the Base Station is termed eNodeB (Evolved NodeB). For 5G networks, the term gNodeB (Next Generation NodeB) is used. The base station takes digital packets from the network core (typically the EPC) and synthesises the radio signals for transmission. Modern eNodeB and gNodeB base stations typically use Software Defined Radio (SDR) for this purpose.

The Base Station may comprise of 1 sector (an example being a Small Cell) up to 3 sectors or more (typically a Macro Site) for longer range and higher capacity. A modern multi-band LTE Base station may transmit on more than one carrier, with the ability of Carrier Aggregation across multiple bands to provide higher user throughput.

The Base Station may be split into a Baseband Unit (BBU) plus one or more Remote Radio Heads (RRH) which is a typical design for 4G LTE, or may be combined into a single unit for a Small Cell featuring 1 or 2 sectors only. The Radio Heads are typically mounted up on the tower next to the Sector Antenna(s) with short RF jumper cables for low signal loss to ensure maximal coverage.

The Remote Radio Heads typically feature MIMO connections to the antennas with 2×2, 4×4, 8×8 or even higher count for Massive MIMO. Generally, high order MIMO only works effectively at shorter distances in urban environments. However, 8×8 configurations can also feature beamsteering to enhance range and capacity at the cell edge, making 8×8 MIMO potentially useful for long range & rural broadband applications."

Regarding the mobile network protocols (and fitting technologies), these are given in Figure 96. Note the timing of 1G, 2G, 3G, 4G and 5G showing that it is reasonable to expect 6G in 2030. Hence 6G is not part of this assessment, however, further improvements are expected with the introduction of 6G.

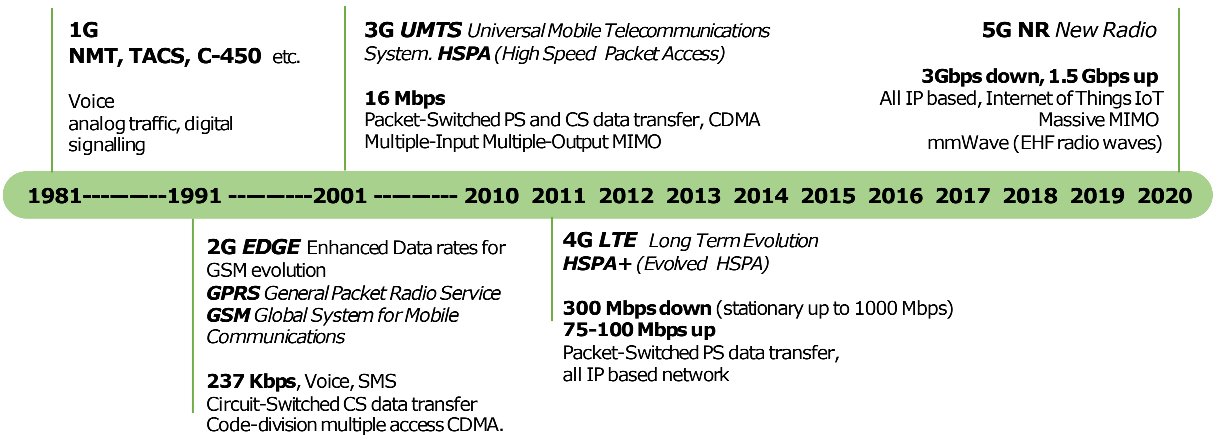


Figure 96: Mobile network protocol milestones and maximum bandwidths (source: VHK 2020[827,829])

[829] Picture by VHK, based on miscellaneous sources.

24.2 Market

It has not been possible to collect data on the actual sales and install base of base stations. However, industry stakeholders have provided input on the estimated energy consumption of all the installed base stations in Europe, see Section 24.5.

24.3 Usage

The use of base stations is very dependent on future development, but overall, it is expected that the data traffic will increase. More products (speakers, televisions, printers, bulbs etc.) will be connected to the internet and emerging services like Netflix, Disney+, Stadia, xCloud, Spotify, Tidal etc. will increase the data traffic through networks. Also, with new iterations of the mobile network protocols, more consumers might choose the flexibility of the mobile network instead of e.g. a fibre connection.

24.4 Technologies

The complexity of the telecom network including RAN networks is presented in Figure 97.

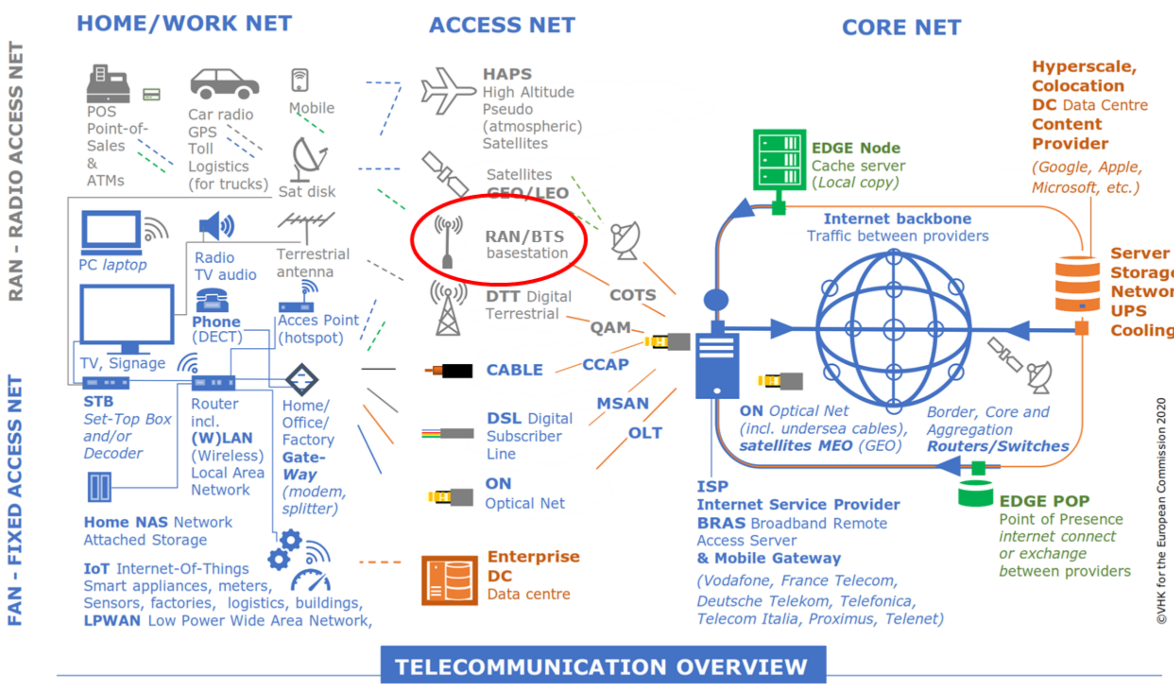


Figure 97: Illustrative overview of telecom network. RAN/BTS: Radio Access Network / base stations (marked with red circle) (source: VHK 2020)

Regarding the base stations, they can nowadays be connected to the ISP servers at the core network with optical fibre cables.

Base stations consist of the following main components:

- Antennas (corresponding to the relevant frequencies)
- Radio units (RRU – Remote Radio Units, processes, amplify and convert the signals (Radio Frequency, RF) to/from the radio antennae)
- Transmission network (microwave antennas and radio units or fibre connection)
- Baseband units (BBU, processes the voice and data signals, to and from the RRUs)
- Remote management units
- Battery backup systems
- Power distribution unit, rectifier
- Power supply (typically from the grid; in remote areas solar, diesel or hybrid systems)

Base stations can be tower mounted, or roof-top or ground mounted.

The technology development in the mobile network protocol presented in Figure 96 somehow also present the development of base stations and the energy consumption in connection with sending and receiving data. Below are different aspects related to energy consumption and efficiency listed:

- The performance metric for telecommunication technology is bandwidth and for time-critical operations, the latency, i.e. the time elapsed between sending and receiving and/or a round-trip, expressed in milliseconds. The relevant bandwidth at end-user level is Megabits per second (Mbps) or Gigabits per second (Gbps). Aggregated units can be GB (1 GigaByte=8 Gigabit) per month or per year at end-user level. At the level of energy policy, globally or regionally (EU27 in our case), this can be aggregated to EB (Exabytes 10^{18} Bytes) or ZB (Zettabytes=10^{21}Bytes) per year (1 year ≈ 31.54 million seconds).
- The bandwidth is typically used for the peak capacity in data communication. However, the energy consumption should relate to the actual use and the actual Gbytes delivered. This is usually a small fraction of peak capacity.
- The time-critical operations for which low latency is relevant are human reaction times. These are in the order of 100 milliseconds and applications that involve or replace human actions are typically one order of magnitude faster, like Augmented Reality (AR), Remote Motion Control, Autonomous Driving and more.[830]
- The electricity consumption of RAN/BTS is typically measured in GWh electricity per year by RAN operators.
- The energy efficiency metric is by definition energy consumption per unit of performance, so in principle kWh/GB. Many authors use the reciprocal GB/kWh, i.e. how many GB one can achieve with a kWh. At global or regional level, the measure would be TWh/EB or EB/TWh.
- The energy efficiency can relate to peak performance and an average for a typical duty cycle.

A recent IEA report "Data Centres and Data Transmission Networks"[831] stresses that projections for electricity consumption of mobile networks have a considerable degree of uncertainty regarding 5G introduction. The IEA references an STL Partners study on 5G for

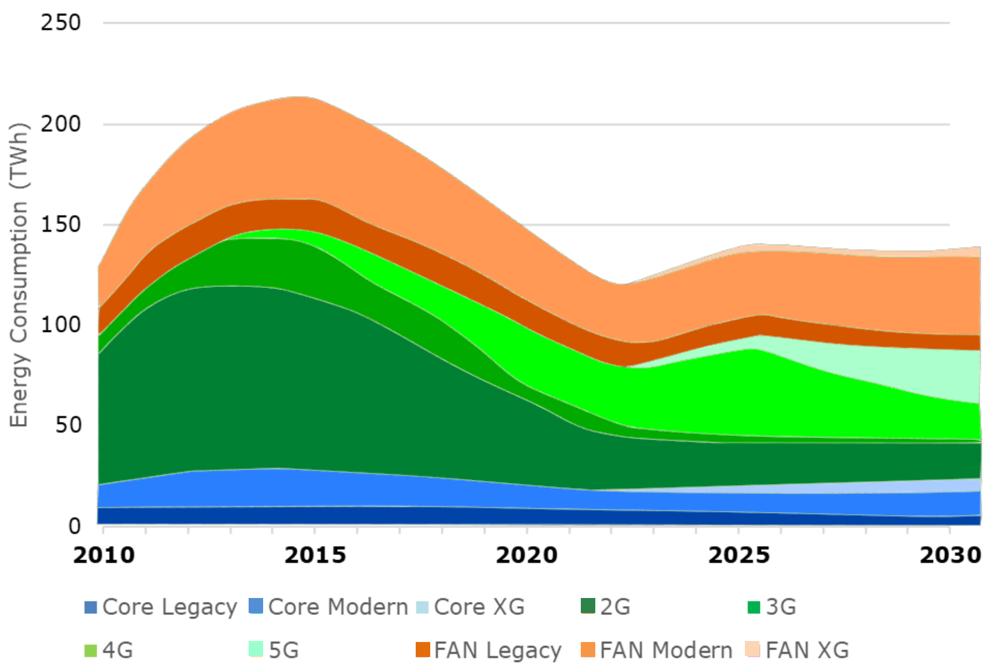
[830] Design Aspects of Low Latency Services with Time-Sensitive Networking. Available from: https://www.researchgate.net/publication/323696804_Design_Aspects_of_Low_Latency_Services_with_Time-Sensitive_Networking [accessed Mar 29 2020].Energy Efficiency Improvement Options

[831] https://www.iea.org/reports/data-centres-and-data-transmission-networks

Huawei[832], which sketches four different global energy and carbon emission scenarios for mobile networks: no, slow, medium-speed and fast roll-out of 5G in the period 2020-2030. The medium-speed scenario is presented as the default and is similar to what is projected in Figure 98 showing for RAN (2G-5G) a small increase in energy consumption until 2025 and a decrease 2025-2030 despite a large increase in data traffic. The fast 5G roll-out saves 30% more and the slow roll-out scenarios saves 15% less than the medium speed 5G roll-out. The no 5G roll-out has double carbon emissions compared to the medium-speed roll-out scenario.

The IEA mentions that while a 5G antenna currently consumes around three times more electricity[6], than a 4G antenna, power-saving features such as sleep mode could narrow the gap to 25% by 2022. However, network infrastructure providers and operators are projecting that 5G could be up to 10 to 20 times more energy efficient than 4G by 2025-30.[831]

Figure 98 shows that total global electricity consumption of RAN (2G-5G) is about 78 TWh in 2020 and 63 TWh in 2030, a reduction of about 20% during this period. The EU27 is responsible for approximately 11% of global energy use[833], though the share of the RAN electricity consumption is assumed to be higher due to higher RAN coverage. Using 15% as a rough share of the EU RAN energy consumption, the resulting electricity consumption is 12 and 9 TWh/year for 2020 and 2025, respectively. In Section 24.5, the energy consumption data is further assessed.



[832] https://carrier.huawei.com/~/media/CNBGV2/download/program/Industries-5G/Curtailing-Carbon-Emissions-Can-5G-Help.pdf
[833] https://ec.europa.eu/eurostat/statistics-explained/index.php/The_EU_in_the_world_-_energy

Figure 98: Global electricity consumption access and core network 2010-2030. 2G-5G are the Radio Access Network relevant for this study (source: IEA-4E 2019[834,835] medium-speed scenario)

Figure 4 shows how the energy efficiency (lines and right Y-axis in TWh/EB) of the RAN networks increases more than the data traffic (surfaces and left Y-axis in EB).

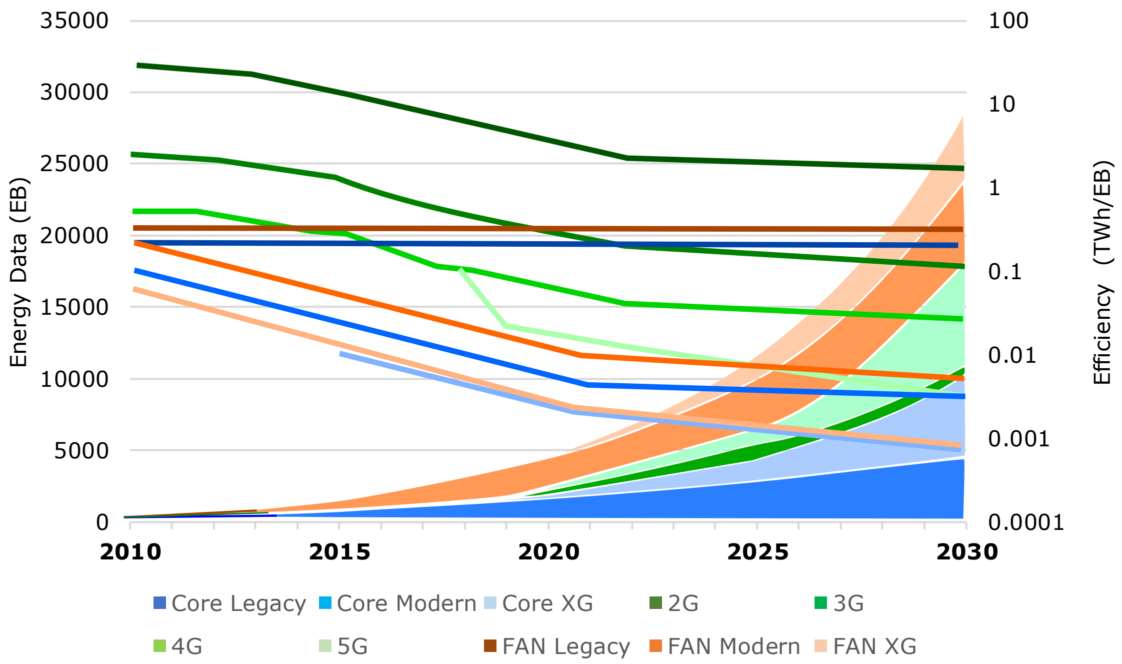


Figure 99: Telecommunication network data traffic and efficiency 2010-2030. 2G-5G are the Radio Access Networks relevant for this study (source: IEA 4E 2019[834])
Left y-axes and the stacked curves depict (real and projected) data traffic in EB (10^{18} Bytes). Right y-axis and the solid/dashed curves depict the (reverse) energy efficiency in TWh (10^{12} Wh) per EB. Note that 'XG' stands for Next Generation.

The IEA 4E 2019 report[834] states that the projected RAN traffic (mostly 5G network) is growing very fast, over 40% a year, partly because network traffic is growing more for RAN than FAN, while the efficiency improves with 20% a year. The report however also states that data traffic may also be reduced and optimized via routing schemes, good design of the software and service, new network protocols, etc.

24.5 Energy and Emissions

Based on data from the ICT impact study combined with inputs from industry stakeholders, the total energy consumption of base stations today is estimated at about 15-20 TWh annually, which is slightly higher than calculated based on the data in Figure 98.[836] The

[834] Intelligent Efficiency forData Centres & Wide Area Networks. Report Prepared for IEA-4E EDNA. May 2019.

[835] Image VHK 2020

[836] One stakeholder provided this information: If EU's share of global RAN/BTS electricity use (range 130 TWh to 152 TWh) is proportional to EU's share of global primary energy use (14%), 14% of 130 TWh would be EU RAN/BTS electricity use in 2015. Approximately 18 TWh.

higher end of the above-mentioned interval, 20 TWh/year, is considered as the consumption in 2030.

These 15-20 TWh corresponds to approximately 6-8 Mt CO_2-eq.

Due to expected data traffic increasing more than the efficiency of the RAN, the energy consumption is expected to increase, however, as mentioned above, traffic optimisation may also keep the energy consumption stable.

24.6 Saving potential

24.6.1 Energy efficiency

The RAN industry is aimed at driving energy efficiency because it facilitates reduction of size and weight of the base stations, which is important when locations for the base stations are to be found. E.g. using only fans for cooling and not active cooling systems reduces both size and weight and energy consumption. This also takes place due to a push on the manufacturers from the operators.

As mentioned previously, network infrastructure providers and operators are projecting that 5G base stations could be up to 10 to 20 times more energy-efficient than 4G by 2025-30. However, regulative interventions may still push a further development of energy efficiency.

Below are examples of energy efficiency improvements that 5G is expected to bring relative to 4G based on the ICT impact study[827], literature review and stakeholder input:

- **Optimise power management e.g. via:**
  - Reduce idle power by variable-control packet switching. This means making a split between the energy-efficient control layer and the fast user/data transport layer (C/U decoupling).[837]
  - Increase the time in energy-saving sleep/'off'-mode by targeting a smaller group of users (e.g. smaller distance range of base stations).
  - Use Artificial Intelligence (AI) to automatically power down parts of the network when unused considering the complex dependencies between overlapping coverage areas ensuring there is no negative impact on data speeds or customer experience.
- **Increase hardware efficiency[838] e.g. via:**
  - Use the ultimate small improvements at the level of rectifiers (99% instead of 98%) and power supplies

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Global electricity use: The "L.1470" method (trajectories in Table A.1 in https://www.itu.int/rec/T-REC-L.1470-202001-I/en) and the "EASL" method "extreme positive scenario" (https://pisrt.org/psr-press/journals/easl-vol-3-issue-2-2020/new-perspectives-on-internet-electricity-use-in-2030/) show very similar trajectories for global RAN including BTS (RAN/BTS) electricity use between 2015 and 2030.

[837] Yan and Fang, Reliability evaluation of 5G C/U-plane decoupled architecture for high-speed railway, EURASIP Journal on Wireless Communications and Networking 2014,2014:127 https://jwcn-eurasipjournals.springeropen.com/articles/10.1186/1687-1499-2014-127

[838] https://sciencebusiness.net/network-updates/huawei-predicts-10-emerging-trends-telecom-energy-next-5-years

    - Replace base station lead-acid battery back-up (UPS) with li-ion batteries that are more efficient, live longer, etc.[839]
- **Use solar energy powered** mobile base stations where there is enough space for the photo-voltaic panels. E.g. LPWAN base stations used for IoT devices are more compact.[840]

Power management features such as powering down parts of the network, may not be used by some network operators due to a concern about customer experience being impacted negatively. However, improvement of the power management functionality may reduce this concern and secure a higher degree of implementation across the operators.

A real-life example, which may show lack of power scaling with data traffic intensity is that during the COVID-19 lockdown periods, where mobile data traffic in some areas grew by 50% or more, the energy consumption of the equipment remained stable[841]. A well-functioning power management would up- and downscale power draws with up- and downscaling of data traffic.

The saving potential additional to what the industry already is and will be implementing is difficult to estimate. The study team has estimated based on sources used for this study and stakeholder information that regulative measures may bring additional savings by 2030 of about 20% of the energy consumption of base stations (about 20 TWh/year 2030) corresponding to about 4 TWh/year of electricity (30 PJ/year primary energy consumption) and to 1.5 Mt CO_2-eq. /year.

24.6.2 Material efficiency

According to the industry stakeholders, size and weight of the base stations and therefore also the material content have been reduced since the introduction of 1G mobile networks aiming at primarily reducing costs and making it easier to find suitable locations and the space required for the base stations.

Lifetime is about 10-20 years. Network operators may move the base stations around in the network balancing performance with long operational lifetimes of the base stations. Lifetime extensions may take place via software updates as long as the units are working in same frequencies and via replacement of parts of the components.

A material efficiency potential is expected to relate mainly to improved recycling of components and materials at end-of-life. It has not been possible within the scope of this study to quantify a potential.

24.7 Stakeholder comments

Comments were received from the following stakeholders:

- BAM and UBA
- Danish Energy Agency
- DIGITALEUROPE

[839]

[840] Compare LoRaWAN protocol. Note that these compact base stations can only be used for Low Power WAN.

[841] https://www.gsma.com/gsmaeurope/latest-news-2/covid-19-network-traffic-surge-isnt-impacting-environment-confirm-telecom-operators/

- ECOS-EEB-Coolproducts-CLASP
- Huawei Technologies Sweden AB

Based on comments supplemented with further literature review, the text is been revised, corrected and more focused on the base stations.

Several stakeholders have commented that the energy saving potential is larger and especially expected to grow more than indicated, however, with no further data sources behind it. Other stakeholders confirm the approximate size of energy consumption and the saving potential.

A few stakeholder have requested more details and analyses of circular economy, environmental and material efficiency aspects. An brief section has been added on material efficiency, however, without quantification due to lack of data.

25 INDUSTRIAL SMART SENSORS

Industrial smart sensors measure, process, store and communicate data on electric loads, temperatures, pressure, vibration, and other performance parameters that can be relevant for energy optimisation during use of the products and systems they are connected or related to and for lifetime extension of these products. The optimisation for energy savings takes mainly place for the products in a system perspective e.g. an electric motor connected to a ventilation system or a pump system. Use of sensors in an Ecodesign perspective should therefore be considered as energy-related rather than energy using products. Furthermore, it is important to recognise that products with sensors or sensor functionality will not automatically save energy; only when sensor data will actively be used for optimisation, maintenance, repairs etc., the saving potential will be achieved.

The lifetime extension of the product provides material savings. The sensor system can notify technical staff on sub-optimal performance in order to take measures to increase product life, reduce down-time of the processes in which the motors are engaged, reduce energy use, perform optimal 'condition-based maintenance' (CBM), etc. Industrial smart sensors can be used to detect abnormalities in the environment and production, e.g. if there is a gas leakage or an increase in temperature due to breakage of insulation. This enables the operator to act on abnormalities in good time.

Sensors can react and send a notification when specific parameters suddenly are deviating from a design situation e.g. when there are wrong temperatures in a heat exchanger showing that it is operating as it should. Sensors can also collect and analyse operative data over a period of time e.g. for filters in a ventilation system and notify the operator the filter should be replaced.

One main area of interest for this study is sensors connected to industrial electric motors placed on the market individually or integrated with fans, pumps, compressors, and other industrial equipment. Approximately 75% of the electric motors are used for ventilation fans, pumps and compressors.[842]

"Sensors" may not only be physical sensors attached to the motors; the sensor functionality may also be an integrated part of the motor or an VSD (Variable Speed Drive). When using the term "industrial smart sensor" in this study, it should be understood as the functionality provided by sensors or other electronic system i.e. to send measure, process, store and communicate data for various relevant parameters in order to be technology neutral.

Separate sensors typically use very little energy and may be battery-driven, especially if they are installed on existing motors or other devices. They may also be supplied via the product they are connected to or other source.

Industrial smart sensors were included in a recent study on ICT equipment (ICT impact study[843], prepared by VHK and Viegand Maagøe), which was included in Ecodesign Working

[842] Stakeholder information.

[843] ICT Impact study July 2020. Prepared by VHK and Viegand Maagøe for the European Commission

Plan 2016-2019. Much of the assessments in the current study are based on this ICT impact study including the defined scope, market data, technology descriptions, usage, energy consumption and saving potentials. The final version of the report has been updated based on stakeholder comments, see Section 25.7, and additional information collected by the study team.

25.1 Scope, policy measures and test standards

The scope for this study is wired and wireless industrial smart sensors or sensor functionality connected to or built into products such as electrical motors, fans, pumps and compressors and connected drives and control systems to lower running costs (energy, auxiliaries), optimise maintenance (lower costs and down-time), increase product life and integrate systems across platforms.[partly based on: 844,845]

Sensors and sensor systems consist typically of the following five components; see an illustrative example in Figure 100:

- analogue transducers (the actual sensor) that convert physical analogue input (temperature, vibrations, acceleration, acoustics, etc. [846]) into electrical digital output signals;
- a computing unit that processes the electrical signals into intelligible information. It can have expanded capabilities, such as data filtering, combining output from multiple (types of) transducers, self-calibration, data pre-processing to reduce data load on gateways, etc.
- a memory module for temporary storage of data until they are transmitted.
- a communication interface that sends the information via wired or wireless networks (e.g. Wi-Fi, Bluetooth, ZigBee, LoRaWAN, EnOcean[847], mobile network or other network) to local or distant (cloud) storage for analysis by an operator.
- a power supply (wired, built-in battery or energy harvester).

[844] Tyler Wojciechowicz, Smart Sensor vs Base Sensor - What's the Difference? Semiconductorstore, Sep 18, 2018. https://www.semiconductorstore.com/blog/2018/Smart-Sensor-vs-Base-Sensor-Whats-the-Difference-Symmetry-Blog/3538/

[845] Gary W. Hunter, Joseph R. Stetter, Peter J. Hesketh, Chung-Chiun Liu - Smart sensor systems, Article in NATO Science for Peace and Security Series B: Physics and Biophysics · January 2012 https://www.researchgate.net/publication/258734399_Smart_Sensor_Systems

[846] The IEEE 1451 family of standards (with the most recent addition of 1451.7 in 2010) provides a digital communication interface standard for transducers and network-capable processors.

[847] https://www.pressac.com/insights/making-sense-of-smart-sensor-technology/#whichwirelessprotocolisbest

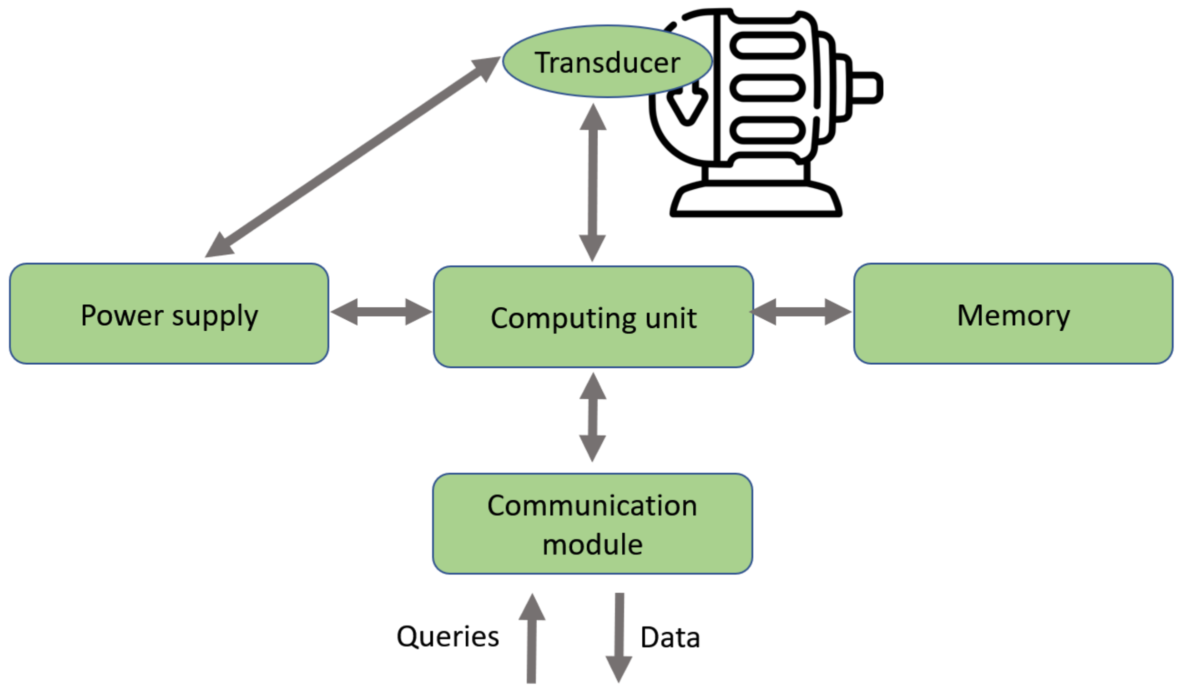

Figure 100: Illustrative example of an industrial smart sensor connected to an electric motor.

Figure 2 shows how industrial smart sensors can be attached to electric motors.

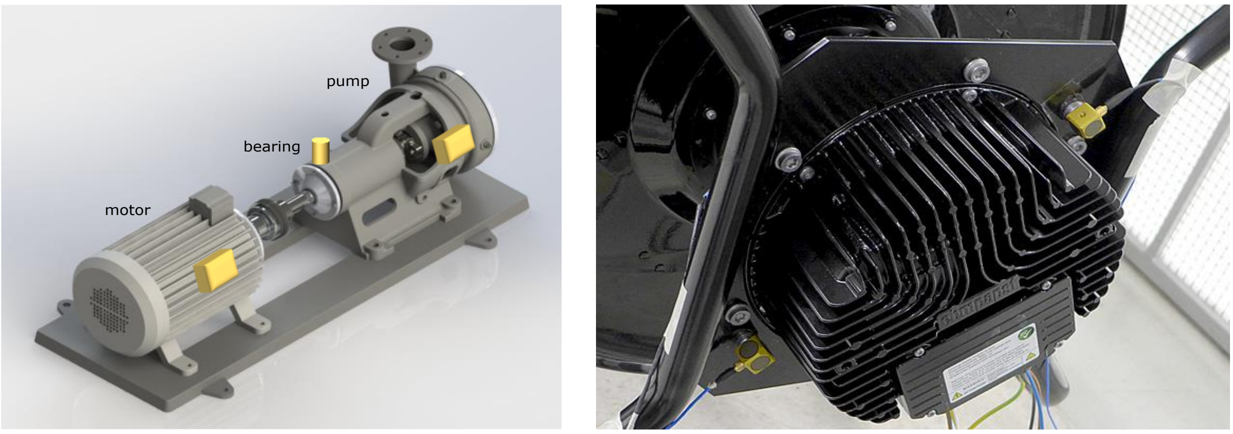

Figure 101: Examples of industrial smart sensors (yellow) attached to electric motors.[843]

The communication protocol for transmitting information to external devices is wired_(usually Modbus or LAN protocols) or wireless (e.g. Bluetooth Low Energy (BLE), IEEE 802.11gn, Zigbee (IEEE 802.15.4)). Besides transmitting information, the sensors may also receive information for remote updating, change logging frequency, settings etc.

Energy consumption for smart industrial sensors is often very low and a button- or coin-cell battery for an add-on sensor may last 5 to 10 years. Energy harvesters, i.e. taking the power from the ambient (sunlight, vibrations, etc.) are starting to be used in some industrial sensors. However, the energy consumption is very much dependent on the frequency and length (decided by the amount of data) of the data transmission and the battery lifetime can be much reduced e.g. if data is transmitted more often than originally planned.

In terms of potential inclusion in the Ecodesign and Energy Labelling Working Plan, sensors are interesting for energy optimisation during use of the products and system they are connected to, and for lifetime extension of the products. One main product group for application of smart sensors is electric motors including the ones in fans, pumps and compressors.

The technology of industrial smart sensors is sometimes referred to as IIoT (Industrial Internet of Things) because it enables devices (things) to be online e.g. it is possible to track the vibrations of a motor equipped with a smart sensor. IoT (Internet of Things) is already a well-known technology in most homes today, where speakers, thermostats and light bulbs can be accessed and controlled through apps on a smartphone through the internet and a local network.

Data and information security and privacy is an important topic, which needs to be taken into account.

Of relevant regulations, standards and other initiatives, the following are considered relevant for the products in scope:

q) Regulations

1. Commission Regulation (EU) No 4/2014 of 6 January 2014 amending Regulation (EC) No 640/2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors. Industrial sensors are not included in the standard, but the standard is relevant, because many motors use input from sensors to control the motor speed. A new regulation (EU) 2019/1781, which include VSD (Variable Speed Drives), will entry into force from 1 July 2021.
2. Commission Regulation (EU) No 327/2011 of 30 March 2011 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for fans driven by motors with an electric input power between 125 W and 500 kW. Industrial sensors are not included, but the regulation is considered relevant, because many fans use sensors to control output.
3. Commission Regulation (EU) No 547/2012 of 25 June 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for water pumps. Industrial sensors are not included, but the regulation is considered relevant, because many water pumps use sensors to control output.
4. Commission Regulation (EU) No 622/2012 of 11 July 2012 amending Regulation (EC) No 641/2009 with regard to Ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products. Industrial sensors are not included, but the regulation is considered relevant, because many circulators use sensors to control output.

r) Standards

1. IEC standard 60529 – Degrees of protection provided by enclosures (IP Code). Applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72.5kV.
2. IEC 61000 - Electromagnetic compatibility (EMC). A series of standards dealing with basic EMC publications, including terminology, description of electromagnetic phenomena and the EM environment, measurement and testing techniques, and guidelines on installation and mitigation.
3. IEC 60068-2-64:2008 - Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance. Used to demonstrate the adequacy of specimens to resist dynamic loads without unacceptable degradation of its functional and/or structural integrity when subjected to the specified random vibration test requirements. Broadband random vibration may be used to identify accumulated stress effects and the resulting mechanical weakness and degradation in the specified performance. This information, in conjunction with the relevant specification, may be used to assess the acceptability of specimens. This standard is applicable to specimens which may be subjected to vibration of a stochastic nature resulting from transportation or operational environments, for example in aircraft, space vehicles and land vehicles.
4. IEC 60068-2-6:2007 - Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal). Gives a method of test which provides a standard procedure to determine the ability of components, equipment and other articles, hereinafter referred to as specimens, to withstand specified severities of sinusoidal vibration.
5. IEEE 1451.4-2004 - IEEE Standard for A Smart Transducer Interface for Sensors and Actuators--Mixed-Mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats. This standard defines the protocol and interface that allows analogue transducers to communicate digital information with an IEEE 1451 object. It also defines the format of the Transducer TEDS. The Transducer TEDS is based on the IEEE 1451.2(TM) TEDS. The standard does not specify the transducer design, signal conditioning, or the specific use of the TEDS. The standard ensures that human-read and computation errors are not made when the engineer configures the sensor.

25.2 Market

Table 239 shows estimated unit sales and stock of industrial sensors based on the ICT impact study from July 2020. The sales are expected to increase rapidly during the next years and forecasted to reach a stock on 120.8 million units in 2025. No forecast was available for 2030.

The actual product life is unknown but considering that the battery is non-replaceable for some products, it is fair to assume an average product life of 5-10 years.

Table 303. Sales and stock based on lifetime of 5 years[843]

Sales [mln. units]			Stock [mln. units]		
2015	2020	2025	2015	2020	2025
4	8.7	19.4	26	53.4	120.8

25.3 Usage

Smart sensors are available for motors in sizes from 0.12 to over 1,000 kW (IEC framesizes 56 to 450), i.e. the full range of the Ecodesign motor regulation. They can also be applied to or used in bearings, fans, pumps and compressors or for monitoring environments.

Smart sensors are typically used to achieve:

- Energy savings: Detect if, how much and how long the motor/fan/pump/compressor is operating at suboptimal conditions (stall conditions, frequent on/off switching, vibrations etc.) and suggest – at the analysis phase – suitable remedies through system optimisation (adjusting process control, motor cooling, etc.), install variable speed drive, substitute worn parts causing the vibrations, proper lubrication, etc.

- Optimal Condition-Based Maintenance (CBM): Unlike time-based maintenance (TBM) or run-to-failure maintenance (RTF), CBM is based on the actual measured condition of the equipment as indicated by the industrial sensors. This leads to savings in maintenance costs, because actions are only performed when necessary, and significantly less down-time, because parts are performing in optimal conditions and they are replaced/repaired in time, i.e. before the process that they are part of breaks down.

- Enhanced product life: Smart sensors can extend the life of the motor by up to 30% by detecting faults and poor system design resulting in temperatures exceeding the rated operating temperature of the windings; vibrations from misalignment; wear of bearings; cavitation, etc. which all can cause mechanical damage.

- System integration: Smart sensors can integrate systems throughout plants, allowing multiple pieces of machinery to be networked together. This empowers operators to monitor the system as a whole.

A critical factor for smart sensors is the software application used to analyse asset health from the measured variables by the sensors and to provide timely, meaningful information. The functionality and quality of the software application are therefore central for capturing the full energy and resource saving potentials.

Machine Learning (ML) and Artificial Intelligence (AI) may play an important part in that. CBM uses continuous (real-time) measurements on the assets, statistical models and historic failure data to predict failures before they happen, to reduce the risks of unexpected breakdowns, reduce maintenance costs (only when needed), improve product-life, enhance energy-efficiency and performance.

25.4 Technologies

The ICT impact study provides a very detailed description of the technologies behind industrials sensors. The description of technologies from the ICT impact study is therefore the basis for this section.

25.4.1 Transducers

More and more, MEMS (Micro Electro Mechanical Systems) and NEMS (Nano Electro Mechanical Systems) are becoming the basis for the new generation of industrials sensors. They are small embedded systems combining electrical, mechanical and/or chemical components, varying in size from micro- or nanometres to a few millimetres.

A particular system may contain a few or millions of MEMS. Production techniques are often similar to those used in computer chip production: CVD (Chemical Vapour Deposition), PVD (Physical Vapour Deposition), optical lithography, etching and micro-machining of silicon wafers, etc. Currently, they are used in pressure sensors, acceleration meters, acoustic sensors, magnetic sensors, gyroscopes, etc. MEMS sensors also find their applications in whole classes of new devices like fitness trackers, smart watches and virtual reality glasses.

25.4.2 Power supply

Smart sensors that are a part of a Wireless Sensor Network – (WSNs) must have their own power supply to operate. Several developments are described here that are aimed at improving a WSN's reliability and lifecycle.

Lowering power consumption

The US DARPA has a programme aimed at extending battery life on IoT devices (for military purposes)[848]. The goal is to consume less than 10 nW during sleep, a 1000-fold improvement over current state-of-the-art sensors (10 µW). The 10 nW threshold was chosen since the battery passively loses 10 nW of power on its own, also known as passive self-discharge. DARPA intends to make this technology available for commercial use, e.g. in detecting damage to critical infrastructure, automobiles, industrial control systems, medical devices, and climate monitoring systems.

The latest generation commercial energy harvesting wireless sensors requires standby currents of only 100 nanoamperes (nA) or less which results in a very low energy consumption, due to the typical low voltage of the batteries that power the sensors.[849]

Energy harvesters

While energy harvesters are intended to make wireless sensor networks maintenance-free with regards to energy supply, the source (vibrations, light, etc.) for generating the energy may not always be available or reliable. Systems using energy harvesters therefore almost always include a rechargeable battery or (super) capacitor for storing the harvested energy to bridge periods when the energy source is not available.

Most consumer electronics devices today have a standby current of a few milliamperes (mA), whereas power-optimised embedded designs typically achieve standby currents of a few microamperes (µA), an improvement of factor 1,000. The latest generation of energy harvesting wireless sensors requires even lower standby currents of 100 nanoamperes (nA) or less, an improvement of more than factor 10,000.[850]

[848] https://www.iotforall.com/darpas-take-iot-battery-problem-n-zero/

[849] https://www.enocean.com/en/technology/energy-harvesting-wireless/

[850]https://www.enocean.com/fileadmin/redaktion/pdf/white_paper/White_Paper_Internet_of_Things_EnOcean.pdf

MEMS are one of the most promising solutions for use in energy harvesters (EH)[851]. They transform energy from vibrations using a piezoelectric material placed onto a mechanical resonator[852]. A forecast on energy harvesting efficiency improvements is shown in the table below. It shows thermoelectric, photovoltaic (PV) and vibration sources. Among PV technologies, dye-sensitized solar cells (DSC) are relatively new and have made the most progress in recent years[853]. In 2020 commercial DSC have reached efficiencies of up to 19%.[854]

Table 304: Energy harvesting efficiency forecast[855]

Energy Harvesting type	2020	2024
Thermoelectric	1 mW/K² MEM technologies: material-modulation doping, devices-surface micromachining, polymer substrate, heat path optimization, BITe film technology	4.5 mW/K² MEM technologies: TEG enhancement by nanostructured materials (superlattice or high-density nanowires), advanced radiator materials & designs, hybridization with PV cells
Photovoltaic	PCE > 15% PV technologies: Hight quality organic molecules, NW, QD, multi-junctions, junctions with low interface recombination, integration in 3D flexible electronic chip	Indoor: > 20% Outdoor: > 40% PV technologies: Breakthrough in DSSC/NW/QD based cells, tandem, hybrid & integrated solar cell
Vibration	1.5 mW/cm² MEM technologies: Hybrid generators, non-linear characteristics, new piezo materials	10 mW/cm² MEM technologies: Heterostructured piezo nanostructures, near-field characterization, integrates nano-magnets, increased NW density into devices, new integration techniques

Source: https://www.slideshare.net/Funk98/energy-harvesting-for-iot (2015)

Batteries

Lithium-ion (li-ion) batteries is one of the best performing battery technologies and today industrial grade lithium-ion batteries can operate for up to 20 years and 5,000 full recharge cycles, with a temperature range of -40°C to 85°C, and the ability to deliver high pulses for two-way wireless communications.

As an alternative for long lasting low-power operation, often non-rechargeable lithium batteries with very low self-discharge rates are chosen. Most notably, lithium thionyl chloride ($LiSOCl_2$) is able to deliver a 40-year service, because of its high specific energy, high

[851] https://www.electronicdesign.com/power-management/article/21796369/energy-harvesting-and-wireless-sensor-networks-drive-industrial-applications (2013)

[852] Optimization Method for Designing Multimodal Piezoelectric MEMS Energy Harvesters, Conference: SPIE 9517, Smart Sensors, Actuators, and MEMS VII; and Cyber Physical Systems, Barcelona, Spain, Volume: 9517 (https://www.researchgate.net/publication/277138101_Optimization_Method_for_Designing_Multimodal_Piezoelectric_MEMS_Energy_Harvesters)

[853] https://www.nrel.gov/pv/cell-efficiency.html

[854] https://www.3gsolar.com/technology

[855] A stakeholder has provided this information: Beyond the performance enhancement of the energy harvester, the robustness and lifetime are also a key element to consider when dealing with smart sensors that have to run over 10 to 15 years on the field. DSSC based cells technology are promising but have so far limited lifetime. Enhancement in robustness will have to be achieves as well.

energy density, wide temperature range (–80°C to 125°C), and very low self-discharge rate (<1% per year)[856].

Solid-state batteries are an upcoming type of battery that compared to lithium-based batteries, are potentially safer with a higher energy density[857]. Due to these qualities much research is done to develop solid-state batteries for electric vehicles, focused on extending battery lifetime and lowering production cost. They are also being used in pacemakers, RFID and wearable devices, at high cost.

When energy harvesters are used, the harvested energy needs to be stored in rechargeable batteries or supercapacitors. The latter is often cheaper, but not preferable due to its bulky size and high self-discharge rate and thus li-ion batteries are usually employed.

25.4.3 Computing

All smart sensor measurement information needs to be interpreted to become usable knowledge about the monitored asset. Data science is often of key importance for successfully determining problems and predictions, to improve operations, energy efficiency, and minimize maintenance disruption and costs.

With the rise of data centres and cloud computing in the past years, there has been considerable development in collecting and handling massive quantities of continuous data. Almost every major technology company and a number of product manufacturers (in scope) are developing artificial intelligence (AI) technologies to automate tasks of turning information to knowledge. As this knowledge is valuable for purposes of CBM prognostics and process optimisation, these technologies are being offered as services by such companies to clients.

Machine learning (ML) is an application of AI to discover information from large datasets, and automatically learn from experience. Whereas ML requires large datasets to learn, research is lately also being done on learning models that are able to learn from scratch[858] or only few training samples ("few-shot learning")[859]. In the future these developments could lead to less dependence on massive amounts of measurements for deriving usable knowledge, less dependence on large scale computing resources (data centres) making CBM cheaper and easier to implement, and improved CBM prognostics.

25.4.4 Configurations

One way of introducing smart sensor technology to products is to integrate or embed it into the product as a default feature.

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[856] https://www.embedded-computing.com/guest-blogs/low-battery-self-discharge-the-key-to-long-life-remote-wireless-sensors

[857] https://en.wikipedia.org/wiki/Solid-state_battery

[858] https://deepmind.com/blog/article/alphago-zero-starting-scratch

[859] https://towardsdatascience.com/advances-in-few-shot-learning-a-guided-tour-36bc10a68b77?gi=616c6c1779dc; https://arxiv.org/abs/1904.05046

The company Ebm-papst outfits all of their electronic controlled (EC) fans and blowers with a communication interface for remote monitoring and control[860,861,862]. Thus, making their products smart sensing devices from the beginning.

Another way is providing universal add-on smart sensors for products that need to be managed, which has the considerable advantage of using them with existing equipment. Several global manufacturers (e.g. ABB, Bosch, Schaeffler) have taken on this strategy.

Advancements in miniaturisation already make complete coin-sized energy harvesting wireless sensor nodes (EH WSNs) possible, that include sensors, solar cells, energy harvesting unit, power storage, a wireless communication transceiver and a micro-processing unit. Lower costs of smart sensors can make them more ubiquitous in use (commoditisation), further improving asset management.

EH WSNs are now primarily used in locations that are difficult to reach that would make battery replacements very costly. However, they can also be a viable alternative to battery driven WSNs.

25.4.5 Using smart sensors with products in scope

As mentioned, the main reason why smart industrial sensors might be eligible for Ecodesign or Energy Label measures is in its saving potential for industrial motors, pumps, fans and compressors.

Below is a summary of the most commonly occurring problems these products may experience, and which smart sensors may be used for monitoring and how they can save on operational costs.

Smart sensors may also be used to improve or optimise production or logistics process-related aspects only, and not monitor the asset specifically. E.g. monitor a specific gas mixture or humidity in a space. However, as this usage is highly dependent on specific processes, it is not possible to assemble general cost-benefit figures.

Motors
The best way to measure the temperature of motor windings is through embedded temperature sensors in the motor.

Vibration in motors can be caused by e.g. imbalance, misaligned couplings, failing foundation or metal frame. Vibration directly affects the bearings and leads to damage to the motor and/or connected parts.

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[860] https://www.ebmpapst.com/media/content/info-center/downloads_10/brochures/ebm-papst_GreenTech-EC-Technology_en.pdf

[861] https://hte.ebmpapst.com/content/dam/ebm-papst/corporate/downloads/catalogues/products/en/Brennwerttechnik_2017-03_EN.pdf

[862] https://global.ebmpapst.com/jp/en/global/company/industry4point0.html

Vibration specifically originating from the bearings is usually caused by electric discharge machining (EDM) [863], which causes bearing noise and grease degradation. As most mechanical forces come together at the bearings, mechanical vibrations are usually measured on the motor bearings.

Power parameters like current and harmonic distortion can reveal how the motor (or machine) is performing, however, with a VFD (Variable Frequency Drive) this may be more complicated.

If the electrical condition of motors specifically needs to be monitored, then e.g. high potential sensors and power signal analysis may be employed to identify changes in the system properties (such as resistance, conductivity, dielectric strength and potential) caused by electrical insulation deterioration, broken motor rotor bars and shorted motor, stator lamination etc.

Various field studies have often found vibration and temperature measurement to be sufficient in providing very reliable indications of motor condition.

Since motors form the basis for the other products in scope, the same sensors can be used for the other products to monitor or predict the problems mentioned for motors.

Pumps
As with motors, pump vibration can be caused by imbalance, a failing foundation or metal frame, shaft misalignment, but also by impeller damage, pump bearing wear, and/or coupling wear and cavitation. Besides equipment failure, vibration also causes a loss of energy efficiency.

Cavitation[864] in the impeller may develop during operation of a pump or be caused by e.g. poor piping design, wrong sizing of the pump and NPSH (Net Positive Suction Head) misalignment. Often, cavitation is not discovered until acoustic or vibration anomalies are noticed. By that time, substantial damage has occurred to the pump and often also to connected equipment such as the motor driving the pump and piping. Pump cavitation is therefore a prime reason that warrants early warning.

Vibration sensors may be used to detect imminent cavitation but will need to rely on machine-learned knowledge of the pump (offered as a service by some pump manufacturers). Alternatively, high-sensitivity differential pressure sensors can be specifically used to measure minute pressure fluctuations which are often a precursor of cavitation.

Power sensors can determine how often a submersible or hydraulic pump is cycling on/off to maintain flow or pressures, which contribute to knowledge about the pump’s performance.

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[863] When voltage accumulates on a motor shaft, it often finds the path of least resistance to ground via the motor bearings. This causes pitting on the bearing surfaces and ultimately leads to a grooved pattern (fluting) in the bearing raceways. When noise occurs, the damage is usually already substantial enough that failure is imminent.

[864] Pump cavitation is the result of a drop in the liquid pressure below its vapour pressure at the pump suction. This causes bubbles to form, which collapse at the impeller and other interior surfaces. The hydraulic impacts caused by the collapsing bubbles are strong enough to cause areas of fatigue on the metal impeller surfaces.

Pumps account for an estimated 7% of maintenance costs of a plant or refinery, and pump failures are responsible for 0.2% of lost production [865].

Fans
Besides the potential problems with motors, fans can additionally experience stall[866], surge and instability issues.

Stall or rotating stall[867] can cause mechanical damage for fans, as it generates (usually random) vibrations, and vibration-related noise (hammering). Continuously operating in stall can cause structural metal fatigue. However, even without damage, fans operating in stall have a suboptimal efficiency.

Surges are violent instabilities of the complete fan and ducting system during which the airflow may reverse and recover at an oscillating frequency (a few Hz). In a system surges can alternate the velocity in the duct compressing the air in the plenum[868].

Fan instability[869] occurs where the fan has more than one working conditions (i.e. having more than one fan curve), on which the fan can operate due to external causes (temperature, pressure, etc.), leading to a flow fluctuation between its fan curves. This should not be confused with "instability", as the resulting duty, although unexpected and unacceptable for many reasons, may well be perfectly stable.

In all cases the volume flowrate and thus the efficiency decreases. These problems can be measured through vibration, flow, pressure (e.g. using a Petermann probe) and also acoustic frequency sensors. The measurements will need to rely on algorithms to determine the probable cause(s).

Compressors
Rotating stall is the most prevalent type of stall phenomenon[870] with compressors, and it can cause vibration stress which can result in blade failure[871]. Modern compressors are carefully designed and controlled to avoid or limit stall within an engine's operating range[872].

Compressor fouling are defined as particulate fouling and/or corrosion fouling. Particulate fouling mostly reduces the efficiency due to distorted airflow. In corrosion fouling deposits cause pitting corrosion on the blades, which may ultimately (partially) break. The resulting

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865 Niki Bishop, Improve reliability with essential asset monitoring, InTech, 2012

866 Stall is a reduction in the lift generated by a foil as the angle of attack increases. In stall the air no longer follows the foil surface uniformly.

867 Rotating stall occurs when a disturbance causes the fl ow to separate from one of the blades, which results in blocking of the fl ow through the corresponding blade cell. This in turn affects the fl ow angles in the blade cells either side to change, so that the following blade then tends to stall whilst the preceding blade becomes more stable. The stall cell eventually moves to the next passage and then the one after that, rotating around the impeller in the opposite direction to that of the rotation. (Eurovent 1-11, FANS and SYSTEM STALL: PROBLEMS and SOLUTIONS, Eurovent WG 1, 2007)

868 Engineering Data 600, Twin City Fan Companies, Ltd., 1999

869 It is most commonly found where the fan delivers into a large plenum chamber, or an extensive duct system having a large cubic capacity. (Eurovent 1-11, FANS and SYSTEM STALL: PROBLEMS and SOLUTIONS, Eurovent WG 1, 2007)

870 M.P. Boyce, in Combined Cycle Systems for Near-Zero Emission Power Generation, 2012

871 Flow-Induced Vibrations, editors Shigehiko Kaneko, Tomomichi Nakamura, Fumio Inada et al., 2014 (https://www.sciencedirect.com/book/9780080983479/flow-induced-vibrations)

872 https://en.wikipedia.org/wiki/Compressor_stall

imbalance in the impeller causes vibration and fatigue damage, and finally compressor failure[873].

For compressors, mainly vibration can be measured. Usually, conductivity resistance sensors are used to determine particulate fouling.

25.4.6 Material composition

The material composition is estimated for an ability Smart Sensor from the company ABB, which is presented in Table 241.

Table 305: Material composition of an industrial smart sensor[874]

Description of materials	%	Material group	Material
Stainless steel	12%	3-Ferro	26 -Stainless 18/8 coil
Plastic	68%	1-BlkPlastics	11 -ABS
Circuit board	12%	6-Electronics	98 -controller board
Battery	3%		Lithium
Sensing device	4%	6-Electronics	98 -controller board

25.5 Energy, Emissions and Costs

25.5.1 Self-consumption of smart sensors

Power for smart sensors is typically delivered by a button- or coin-cell (battery), with voltages from 1 to 3.3V and capacities from 120 mAh to 1 Ah. This means it can deliver 3.3 Wh over its lifetime. The (usually) non-replaceable battery is dimensioned to last the lifetime of the smart sensor, i.e. at least 5 to 10 years in worst conditions[875]. So, in the worst case, not considering transmission to the cloud or remote storage (cell phone, tablet or PC), the annual energy use is typically no more than 0.6 Wh/yr (0.0006 kWh/yr) per sensor. Wired power sources for smart sensors include DC such as power over USB, or Power over Ethernet (PoE), usually also at 3.3 V or 5 V.

[873] https://www.turbomachinerymag.com/compressor-rotor-failure-due-to-fouling/

[874] The material composition is based on an ABB Ability Smart Sensor. The weight is informed to be 260g and the case materials consist of stainless steel and thermoplastic. It is assumed that the sensor is equipped with a controller board with similar properties to an Arduino MKR WIFI 1010 (32g). It is assumed that the sensing device in the smart sensor is consisting of electronics similar to those in a controller board and the weight of the sensing device is assumed to be 10g.

[875] A stakeholder has provided this information: Extended lifetime of smart sensor is relying on Hw/Fw optimization. Today, a smart sensor can run over 15 years with a single 1 Ah battery capacity when transmitting the data every 2 min. It depends also on the level of computation done at the sensor level, the wireless communication technology and how often the sensor is making measurement and transmitting the data.

Table 306: Comparison of wireless technologies[876]

Time, current	BLE	ZigBee	ANT
Time of one connection ±SD*	1150 ms ±260ms	250 ms ±9.1 ms	930 ms ±230 ms
Sleep current	0.78 µA	4.18 µA	3.1 µA
Awake current	4.5 mA	9.3 mA	2.9 mA

*SD: standard deviation

Source: Artem Dementyev, Steve Hodges, Stuart Taylor, Joshua R. Smith - Power consumption analysis of Bluetooth Low Energy, ZigBee and ANT sensor nodes in a cyclic sleep scenario, Wireless Symposium (IWS), 2013 IEEE International, April 2013, DOI: 10.1109/IEEE-IWS.2013.6616827[877] [878]

There is a large difference in energy use between sleep mode and active mode. Taking the BLE (Bluetooth Low Energy) as a reference, the power use during the 1150 ms (~1s) transmission is 14.85 mW and the energy is thus 0.005 mWh per hour or 0.043 Wh per year (1 yr =8760 hours). Then, assuming that 1 data transmission (1 sample) per hour is enough[879], the other 3599 seconds/hour the sensor is using 2.57 µW of power, in energy this is 0.00256 mWh of energy per hour or 0.022 Wh per year. In total, the sensor is using 0.065 Wh/year. The coin-type battery in the smart sensor has a capacity of 3 Wh (3V*1Ah), so more than enough for the declared product-life of 5 years even at the state-of-the-art 2013. This does not take into account possible extra computing power but on the other hand it also does not take into account that the state-of-the art 2020 is over 7 times more energy efficient than that of 2013, which is the source used in the calculation.

Note that Wi-Fi takes up much more energy than BLE and the annual energy consumption is then much closer to the 5-year battery capacity.

For storage on a remote location, messages from the sensors are usually less than a few hundred bytes. Assuming that the sensor sends 8,760 messages per year (i.e. one per hour) this comes down to 8,760 write actions. This results in an energy consumption of 0.0007 Wh (SSD drive) up to 0.08 Wh (HDD), i.e. on average 0.0042 Wh. Note that this is not the energy use of the sensor but of the storage device.

Subsequently, the data is analysed by software on a computer that alerts an operator when maintenance action is required. The annual energy use for the data analysis and interface of the computer is estimated at (less than) 1 Wh/yr.

The total energy use per smart sensor would then be 0.36 Wh/yr (sensor and electronics) + 0.006 Wh/yr (sensor communication) + 0.24 Wh/yr (gateway communication to remote

[876] A stakeholder has provided this information: Today, both BLE and ZigBee Green Power (Ultra Low Power mode of ZigBee 3.0) can run on the same monochip meaning that sleep current of BLE and ZigBee Green Power are the same. Typical value of sleep current can be lower than 0,3 µA for both BLE and ZigBee Green Power. Looking at the peak current, it varies from transceivers selection but are for both BLE and ZigBee in the range of 5 to 10 mA for transmission in term of peak current. What makes the difference is the time of transmission that need to be optimized by the design.

[877] https://semiwiki.com/wp-content/uploads/2016/08/IWS20201320wireless20power20consumption.pdf

[878] Data are from 2013. Current state-of-the-art energy consumption for Bluetooth in active mode (4.5mA*3.3V»14.8 mW) is over a factor 7 less (2 mW).

[879] [https://journals.sagepub.com/doi/full/10.1155/2014/782710]

storage) + 0.042 Wh/yr (writing data on remote storage) + 1 Wh/yr (data analysis and interface)[880] = 1.65 Wh/yr. This is illustrated below.

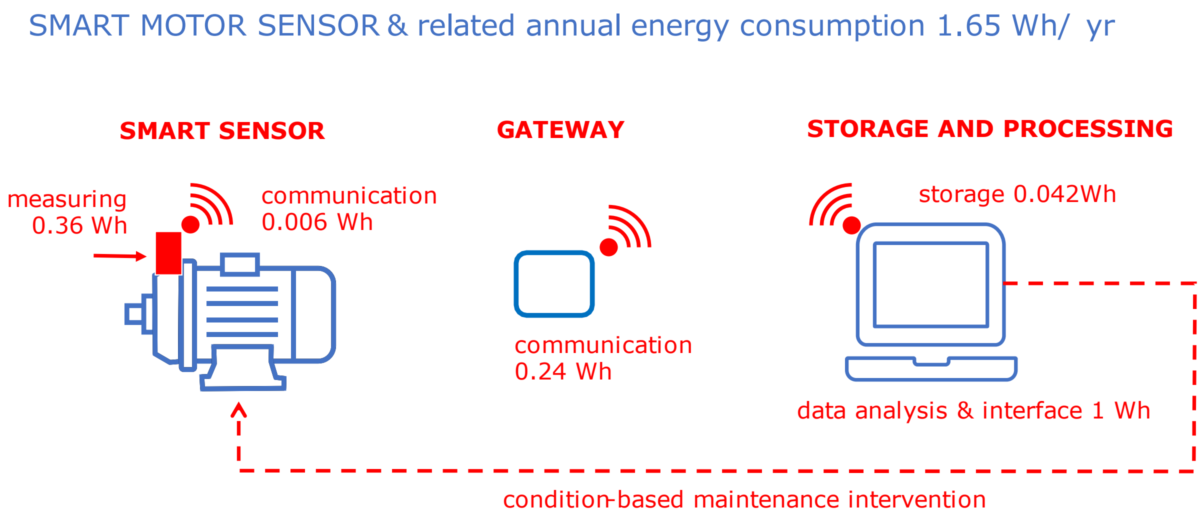

Figure 102: Energy consumption components in smart monitoring[881]
Source: ICT Impact Study 2020

In addition, if a back-end system for the smart sensors needs to be established, this system would also consume energy. This is outside the scope of this assessment and not looked into any further.

Comparison with an example case

The above annual energy consumption of 1.65 Wh/year for an industrial sensor has been compared with a specific example: Wzzard™ mesh wireless sensor[882] can be used with external industry-standard sensors. The wireless sensor communicates with wireless 802.15.43 SmartMeshIP network to a SmartSwarm Gateway. The wireless sensor is equipped with a 3.6V 2400mAH lithium battery. The company estimates a lifetime of 5

[880] The analysis is done once per hour (8760 times/year) and involves setting up reference values for 'normal behaviour' especially in the beginning and then a relatively simple floating point operations in a stochastics context. This should be possible within 1 Wh/year (approx.. 0.4 Ws per operation).Probably the most energy-intensive part, which the study team does not consider part of the strict sensor functionality, is the graphics user interface (GUI) for managing a few hundred sensors.

[881] A stakeholder has provided this information: The balanced between smart sensor, gateway, storage and data process at system level depends on architecture selected and level of intelligence that is compute at smart sensor level. One trend is to process the information at the smart sensor level to reduce the amount of data to be transmitted to the system resulting in extending battery lifetime and reducing energy consumption at the system level (less data storage and less computing at system level).

[882] http://advdownload.advantech.com/productfile/PIS/BB-WSD2C21150/Product%20-%20Datasheet/BB-WSDx_WzzardMeshWirelessSensor-IndApps_0318ds20180321231634.pdf

years, based on 1 min. sensor sampling and reporting. This corresponds to an annual energy consumption of 1.73 Wh/year.

Figure 103: Wzzard™ Mesh Wireless Sensor for Industrial Applications used for comparison of the annual energy consumption.

Total energy consumption smart sensors

The EU stock in 2020 of around 53.4 million units will then use around 88 MWh/yr when one sensor consumes 1.65 Wh/year.

In Table 244 it can be seen that the primary energy used to produce materials for the industrial smart sensors is almost 6 times higher.

Table 307: Energy and material input of industrial sensors 2020

Annual input EU-27 2020	**ENERGY INPUT (stock)**		**MATERIAL INPUT (stock)**	
	Annual electricity	Annual primary energy[883]	Combined weight[884]	Primary energy
	TWh	PJ	Kt	PJ
Industrial smart sensors	0.09	0.67	14	4

Table 245 shows the CO_2 emissions related to electricity consumption and materials.

Table 308 - GHG emissions related to electricity and materials

Annual emissions EU-27 2020	**GHG emissions**	
	From the electricity consumption [kt CO2-eq/year]	From the materials [kt CO2-eq/year]
Industrial smart sensors	33.4	363.7

[883] CC factor 2.1

[884] It is assumed that the average weight of an industrial smart sensor is equal to the weight of ABB Anility Smart Sensor https://search.abb.com/library/Download.aspx?DocumentID=9AKK106930A9867&LanguageCode=en&DocumentPartId=&Action=Launch

25.6 Saving potential

Due to the insignificant in-use energy consumption of industrials smart sensors, no energy consumption saving option has been considered for the use phase energy consumption of the sensor itself. The focus has instead been on material saving potentials and saving potential in energy consuming products equipped with sensors, such as motors, pumps, fans and compressors.

25.6.1 Ressource efficiency requirements related to the sensors

The ICT Impact Study found that the lifetime of industrial smart sensors is only about 5 years for some products. This is far less than the products they are used on. Industrial motors and pumps[885] often has a lifetime of 10 years or more. The industrial smart sensor, which is performing a relatively simple task (collecting and transmitting data), that is attached to the operating machine (motor, pump, fan or compressor) should therefore have a lifetime that corresponds to the lifetime of the operating machine.

In the technology section it is described how the lifetime of some industrials sensors are depended on battery capacity. The following are therefore seen as potential initiatives to ensure that the lifetime of the industrial smart sensor is not depended on the battery capacity and thus saving 50% of the primary energy related to materials:

- Replaceable batteries.
- Wired power supply to the sensors, where possible.
- Upscale the battery capacity, ensuring that the industrial smart sensor has enough battery capacity to transmit data for the lifetime of the product it is used on, however, balancing with the resource use for battery production.
- Supply the smart sensor with an energy harvester that is powerful enough to ensure the power through out the lifetime of the product it is used on.
- Build smart sensor technology in the device.

Based on the assumption that the above mentioned initiatives are able to double the lifetime of the industrial sensor, the saving potential of setting ressource efficiency requirements to industrial smart sensors is up to 411 kt CO_2-eq in 2025. See Table 247.

Table 309: Assumed obtainable energy savings related to materials

EU-27 based on stock	Material saving	
	Primary energy saving	CO2 saving
	PJ	kt CO2-eq.
Industrial Smart Sensors 2020	2.2	181.8
Industrial Smart Sensors 2025	5.0	411.3

[885] Impact Assessment Circulators 2020

25.6.2 Related energy savings in connected products

As mentioned previously, the reason why industrial sensors could be eligible for Ecodesign measures lies mainly in their energy and resources saving potential in connected products and mainly motors (>0.12 kW) and motor applications. The table below gives an overview of the installed stock of motors as well as their annual electricity use in 2020 and 2030. The differences between 2020 and 2030 are not large, as this is a mature market.

In total, there are 420-444 million electric motors installed in the EU. Assuming that industrial sensors will not be placed on small (below 0.75 kW) and on special motors, around 100 million electric motors in the EU would be suitable for industrial smart motors. Assuming that for fans, water pumps and standard air compressors, around 25% of the installed stock would be suitable for sensors, some 70 million units would be added to the potential. For bearing-sensors we might add an extra 30 million and the total EU market for sensors would be about 200 million units.

As calculated, the current stock with sensors is at the most 50 million sensors and thus there is still a potential of placing sensors for 150 million motors and motor systems.

The energy use of the industrial motor stock, without small and special types, is 1,294 TWh/year in 2030. Even at a conservative estimate of 5-10% saving from sensors, this comes down to a potential of 65-130 TWh/year electricity saving.

Even if already 25% of this is realised, this still leaves a potential electricity saving of 50-100 TWh/year corresponding to primary energy savings of 380-760 PJ/year. The potential is however only achieved, when sensor functionality is established on the motor-driven systems and when the capabilities of the functionalities are exploited. If this is the case for 20% of the new installations, which in average save 5-10%, the total saving potential in 2030 (total stock replacement assumed) is 76-152 PJ.

An advantage is that the measure could be applied to all motors, new and existing, however, the Ecodesign Directive can only regulate products when placed on the market and not already installed products. The average lifetime of electric motors is approximately around 10 years, i.e. over a period of 10 years, all motors and motor-driven products can have sensor functionality built-in.

Table 310: Motors, fans, pumps, and air compressors installed and their electricity use in EU (source: VHK, EIA 2018 update)

	Life (years)	Installed (000 units)		Electricity use (TWh/year)	
		2020	2030	2020	2030
Small & special*	8-16	322,540	339,582	183	187
Medium (S) 0.75-7.5 kW (3 ph)	9	81,829	87,369	160	157
Medium (M) 7.5-75 kW (3 ph)	11	13,635	14,656	265	262
Medium (L) 75-375 kW (3 ph)	16	1,593	1,751	574	574
Large LV 375-1000 kW (3 ph)	18	176	194	286	301
Total electric motors		**419,773**	**443,551**	**1,468**	**1,481**
Total excl. small & special motors		**97,233**	**103,970**	**1,286**	**1,294**
Industrial fans >125W	15	241,065	272,904	153	159
Water pumps	11	19,830	22,884	134	153
Standard air compressors	9-12	1,141	1,229	56	58
Total other industry products with electric motors		**262,036**	**297,017**	**343**	**371**

*=<0.75kW, 1-phase>0.75 kW, Brake, Explosion, 8-pole

25.6.3 Related material savings in connected products

The sensors installed on electric motors and motor systems may also provide material savings for the motors and motor systems due to opportunities for improved maintenance and for immediate reactions due to e.g. overload, too high temperatures, vibrations etc.

It has however not been possible to identify suitable data sources to be able to quantify this potential and therefore no data for material savings could be reported. The is also only implemented, when sensor functionality is established on the motor-driven systems and when the capabilities of the functionalities are exploited.

25.6.4 Monetary savings

Apart from the monetary saving on electricity costs as indicated above, additionally a saving potential exists for maintenance costs and from less process down-time.

A source using internal studies estimates that a properly functioning CBM programme can provide savings of 8-12% over the traditional PM schemes[886].

Furthermore, CBM programmes can deliver the following benefits [887,888,889]:

- Maintenance costs: 14-30% reduction
- Downtime: 20-45% reduction[890]
- Breakdowns: 70-75% reduction
- Production: 15-25% improvement

[886] Gopalakrishna Palem, Condition-Based Maintenance using Sensor Arrays and Telematics, International Journal of Mobile Network Communications & Telematics (IJMNCT) Vol. 3, No.3, June 2013. DOI: 10.5121/ijmnct.2013.3303

[887] Gulati, Ramesh (2012-08-17). Maintenance Best Practices. Industrial Press, Inc.

[888] Niki Bishop, Improve reliability with essential asset monitoring, InTech, 2012

[889] Intel IoT Industrial Automation – Solution Brief – Improving Downtime and Energy Efficicency with IoT-Connected Air Compressors (https://cdrdv2.intel.com/v1/dl/getcontent/333853)

[890] For motors, ABB estimates a 70% reduction in unplanned downtime using smart sensors.

On average, repair cost for a failed asset is typically 50% higher than if the problem had been addressed prior to failure.

Additionally, for compressors, Fusheng reports the following improvements:

- Mean time to repair (MTTR[891]): up to 15% less due to timely repairs.
- First-time fix rate: up to 20% more repairs adequately fixing a problem (consequently less repairs were needed to solve a specific problem).

A plant-wide benchmark[892] for maintenance costs is: maintenance costs / estimated plant replacement costs.

Maintenance costs include direct labour, materials, labour by contractors, salaries and overhead. Estimated plant replacement costs are the total indexed value of plant and equipment. As a reference, a world-class performing company on reliability has typical maintenance costs between 1 - 2.5% of estimated plant replacement asset value.

25.6.5 Realisation of the saving potential

The saving potential is extensive, but the realisation of the potential needs detailed analyses and considerations because the sensors and sensor functionalities will mainly provide savings in connected products and systems and only when the capabilities of the functionalities are exploited. I.e. a requirement on sensors as itself would not provide savings, only when the sensor functionalities are used for optimisation of operation, maintenance, repairs etc. Sensor requirements may also be in the form of rewards and incentives in an Ecodesign implementing measure and use of the sensors for energy efficiency could be promoted through other regulation e.g. the Energy Efficiency Directive.[893] A preparatory study or a screening study should among others clarify this subject.

Several product groups could be relevant for requirements on sensor functionality, however, due to larger differences between suitable sensors and functionality for different product groups, product-specific implementation is seen as the best way of for a potential regulation.

An advantage is that many of the products that will benefit from the industrial smarts sensors are already regulated under Ecodesign (motors, fans, pumps, compressors), where sensor requirements can be established via amendments to the existing regulation.

However, product-specific requirements may be based on a horizontal study of basic principles regarding among others type of implementing measures, protocols to ensure interoperability; type of measurement parameters, minimum level of data quality; data security and privacy, etc.

[891] MTTR is the total corrective maintenance time for failures divided by the total number of corrective maintenance actions for failures during a given period of time.

[892] https://www.efficientplantmag.com/2000/09/comparing-maintenance-costs/;
Reducing operations and maintenance costs, Emerson Process Management, 2003 (https://www.emerson.com/documents/automation/product-data-sheet-reducing-operations-maintenance-costs-en-41038.pdf)

[893] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02012L0027-20210101

25.7 Stakeholder comments

Comments were received from the following stakeholders:

- BAM and UBA
- CEMEP
- Danfoss
- Danish Energy Agency
- Europump
- EVIA – European Ventilation Industry Association
- Japan Business Council in Europe (JBCE) & The Japan Electrical Manufacturers' Association (JEMA)
- Schneider Electric

Regarding the main conclusions on the potentials, a number of stakeholders support that the saving potential by using sensor data for optimizing motor-driven systems is very large. Stakeholders also agree that there is a large material saving potential through sensors helping in assessing whether a product needs to be repaired, re-used, refurbished etc.

Other stakeholders believe that there are overlaps with energy savings achieved via existing regulation such as for extended product approach for pumps, where the variable frequency drive secures that the pump delivers the head and flow as required by the application. The study team does not see an overlap because sensor-based solutions provide other optimisations such as adapting requirements by motor-driven systems to the actual needs and provide material savings by reaching a longer lifetime of the systems the sensors are connected to.

A number of other comments resulted in adjustment and additions to the text, such as:

- The large energy saving potential is realised through the use of the data from the sensors and not from the sensors themselves and mainly at the system level and not necessarily for the products that host the sensors.
- The initiative should be based on relevant product groups and not broadly for sensors.
- The measure should be technology neutral and also cover e.g. speed drives with sensor functionality built-in and open or standardized protocols should be used to secure interoperability.
- Data and information security, cybersecurity and ownership of the data need to be taken into account.
- Sensors can be wired or wireless, integrated in products or separate add-ons or as for the VSD, one of the already existing components, and this should be reflected in any coming regulatory initiative.
- Vibration sensors as described in your report will not help to run the pump at its optimal duty point required by the system because pumps only vibrate if something goes wrong in the application or if the wrong pump was selected.
- Other minor comments.

A few stakeholders have requested a more detailed study especially regarding material efficiency, other environmental emissions, etc. However, within the resources available, it has not been possible to quantify the potentials more than what is in this report. If this product group will be included in the working plan, a following preparatory study would naturally cover all relevant aspects in sufficient depth.

26 LIGHTWEIGHT DESIGN

26.1 Scope, policy measures and test standards

26.1.1 Introduction

Light-weighting of products, i.e. effecting the same functionality with less material, is undoubtedly the most effective design strategy for material efficiency. It is the first '*R*' in the waste Framework Directive[894]: the '*R*' of *Reduce*. Unlike the other '*R*'s —*Re-use, Recycle, Recover, Remove* - it has instant impact, there is 100% certainty that the design effort pays off in terms of materials efficiency, one of the key parameters *product weight* is easy to measure and often has beneficial side-effects in terms of extra functionality, e.g. easier transportation of mobile devices for the user and/or lower manufacturing & distribution costs.

Yet, it is the most neglected material efficiency strategy. There are no incentives like regulations, subsidies, labels, information campaigns, etc. to reinforce this concept. It is not even a topic deemed worth investigating in the Mandate M/543[895], which is preparing standards for material efficiency. Probably because of the beneficial side-effects mentioned above, policy makers seem to think that there is no need for promotion: if light-weighting were possible for a certain product, the designers will do it; if not, there must be a technical/economic reason for it. However, the same argument can be used for the implementing measures and delegated acts adopted under the ecodesign and energy labelling regulations and in reality, the market is not self-regulating these areas.

Green NGOs perspective seem not very enthusiastic about the subject, often pointing at the exceptions where lightweighting is not beneficial. And of course, it matters which material is being substituted: substituting 10 kg of cement by 100 grams of gold in a product is unlikely to have a positive effect on source-to-sink material efficiency. There are also instances, although less than one may think, when saving material may shorten product life.

By highlighting these theoretical issues, it is often overlooked that the functionality of products when using light-weight designs often demands a similarity in materials selection and thus the risk of substituting e.g. cement by gold in any product is close to zero. Also a relatively simple additional analysis of the energy content, i.e. the energy required to produce the materials, could identify such cases, following several authors as far back as the late 1970ies[896].

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[894] Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste OJ L 150, 14.6.2018, p. 109–140

[895] Commission's Standardisation Request M/543 on Material Efficiency Aspects of ErP

[896] Gregory, S.A. and Commander, M.W., New materials adoption study:…, Design Studies 1, nr. 2, Oct. 1979, 107-112. Cited in https://www.vhk.nl/downloads/Reports/1981/Energy_conscious_design1981.pdf

As regards lighter products having a shorter product-life, there is not much evidence that this would apply to energy-related products (ErP). Recent German research [897]shows that most disposed ErP are in good working order, or would be with a small repair. If there is a fatal technical breakdown it is usually a specific component failure, planned or accidental, but not because of overall light-weighting.

As regards the boundaries of 'light-weighting' it is important to stress that in the topic for this working plan we do not include 'dematerialisation', i.e. replacing physical products by services (e.g. laundrette, lease versus buy, etc., where the same amount of material is shared by many buyers of the service), shared usage of products (e.g. carpooling, shared laundry rooms, etc.) or extended lifetime where the material content can be distributed over more years. These are all valid strategies –in addition or instead of lightweighting-- under certain circumstances and for certain products, but e.g. 'dematerialisation', for instancehas a large social component and there are safety and legal issues involved. Here we would like to focus on the technical possibilities for light-weighting.

The next paragraphs aim to show the environmental and economic significance as well as untapped saving potential of horizontal measures in this area.

26.1.2 Scope

Lightweighting is relevant—in principle- for all products in the scope of Ecodesign and beyond. Naturally, it is more relevant for products where the environmental impact of materials is more significant (heavier and/or more critical materials), where the economics are more pronounced (e.g. improved functionality, lower production costs, etc.), where there is a larger disparity in material efficiency (larger differences in design solutions with a product group, suggest more saving potentail) and where the market failure is more evident. These aspects will be elaborated in the next sections.

26.1.3 Policy measures

Lightweighting has a very long tradition in mechanical and electrotechnical engineering of ErP (as in most other fields of engineering), but has virtually no tradition in policy making.

To start such a new direction it is usually prudent to start with "capacity building", i.e. design horizontal measures that make the impact visible, e.g. information requirements for the product weight (and its packaging) and possibly an simple energy content analysis to uncover unforeseen extremes in the Bill-of-Materials. Then, if there is enough experience and confidence for relevant product groups, the data could be given more visibility to influence consumer behaviour, e.g. on an energy label. Lastly, if there are heavyweight solutions for products and/or their components that could easily be avoided, these could be phased out –in an appropriate time span-- through Ecodesign.

Another way in which lightweighting can play a role in policy making is in making a balanced decision vis-à-vis other design aspects, e.g. recycled or re-use. For instance, as is

[897] Prakash, S. et al., Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz", Study for the German Federal Environmental Ministry (UBA), 2015. https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_11_2016_einfluss_der_nutzungsdauer_von_produkten_obsoleszenz.pdf

illustrated in figure 54, the full policy focus with ink cartridges is now on (suitability for) re-use, whereas possibly for material efficiency light-weighting could be a better strategy.

26.1.4 Test standards

The weight (or volume) of the product –and all its components-- is the basis and starting point for every Life Cycle Analysis and other form of material efficiency analysis. Yet, it seems that it is usually seen as a given, i.e. not put into question by the environmental analysts unless it is somehow linked with re-use or recycling. For instance, there are studies for plastic cups versus ceramic mugs, plastic versus cardboard, etc..

The result is, that there are virtually no test standards that specifically deal with light-weighting. In principle, for the product- or component weight, there is no need for a general standard. Only when the measures are introduced for specific products, it might be useful to introduce such as standard.

26.2 Market

26.2.1 Data sources

Following discussions on 'Circular Economy'[898] and the important role of Ecodesign and Energy Labelling in the 2015 Commission's proposal[899] on the first Circular Economy Action Plan as well as meetings of the Competitiveness Council of 29 February 2016[900] and the Environmental Council of 4 March 2016[901], VHK prepared a comprehensive analysis of materials consumption in Energy-related Products (ErP). The analysis was part of its Ecodesign Impact Accounting (EIA) for the Commission in 2016 and it still constitutes the most comprehensive assessment to date.[902]

The basis for the analysis of the material content is the EcoReport tool, which is part of the MEErP 2011[903] methodology for the over 40 preparatory Ecodesign studies available in 2016. On average there are about 5 reference products ('base cases') per study/product group and thus 200 EcoReports, each with a specification of the product content ('Bills-of-Materials') of up to 60 types of materials, clustered in 8 material groups (bulk and technical plastics, ferro and non-ferro metals, coatings and electronics, packaging and miscellaneous). The analysis is a harmonised compilation of Bills of Materials (BoMs) over a 10-year time period (2005-2015, reference 2010) carried out by different contractors as part of preparatory or review studies and with varying level of quality. VHK has tried to use the most reliable and recent BoMs especially for dynamic sectors such as electronics. Nonetheless, there is a considerable margin of uncertainty especially for those sectors.

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[898] 7th Environmental Action Plan (EAP), Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet',OJ L 354, 28.12.2013, p. 171–200

[899] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Closing the loop - An EU action plan for the Circular Economy, COM/2015/0614 final, Brussels 2.12.2015.

[900] Flynn, V., Circular economy needs impact analysis – ministers, ENDS Daily, 1 Mar 2016.

[901] Flynn, V., Strong support for circular economy ecodesign at Council, ENDS Daily, 7 Mar 2016. See also http://www.consilium.europa.eu/en/meetings/env/2016/03/04/#

[902] VHK, EIA II - Special Report Materials 2016, for the European Commission, 2016

[903] Kemna, R., Methodology for Ecodesign of Energy-related Products (MEErP), VHK fort he Commission, 2011.

The sales and stock figures were taken from EIA for the year 2010.

26.2.2 Sales

Figure 104 shows that some product groups have a more significant impact in terms of total weight than others. The total weight of all product groups was calculated as 14.6 Mton. The most heavy product group is 'Tyres' with a total weight of 3.1 Mton (equal to 21% of the overall weight), followed by 'Domestic Refrigerators' (RF, Lot 13) with 1.2 Mton (8%) and the 'Washing Machines' (WM, Lot 14) with 0.9 Mton (7%).

Figure 46 summarizes the data per material cluster. Ferrous materials represent the majority of the material consumption (45%), followed by the Miscellaneous group with a share of 26%, mostly due to the synthetic and natural rubber consumed in the 'Tyres'. Bulk Plastics cover 10% of the material inputs, Non-Ferrous metals (8%), TEC Plastics (4%), Electronics (2%) and Coatings (0.3%). The Packaging (5%) was treated separately, since this could be a specific target for improvements.

Table 100 gives the numbers and abbreviations behind the two figures.

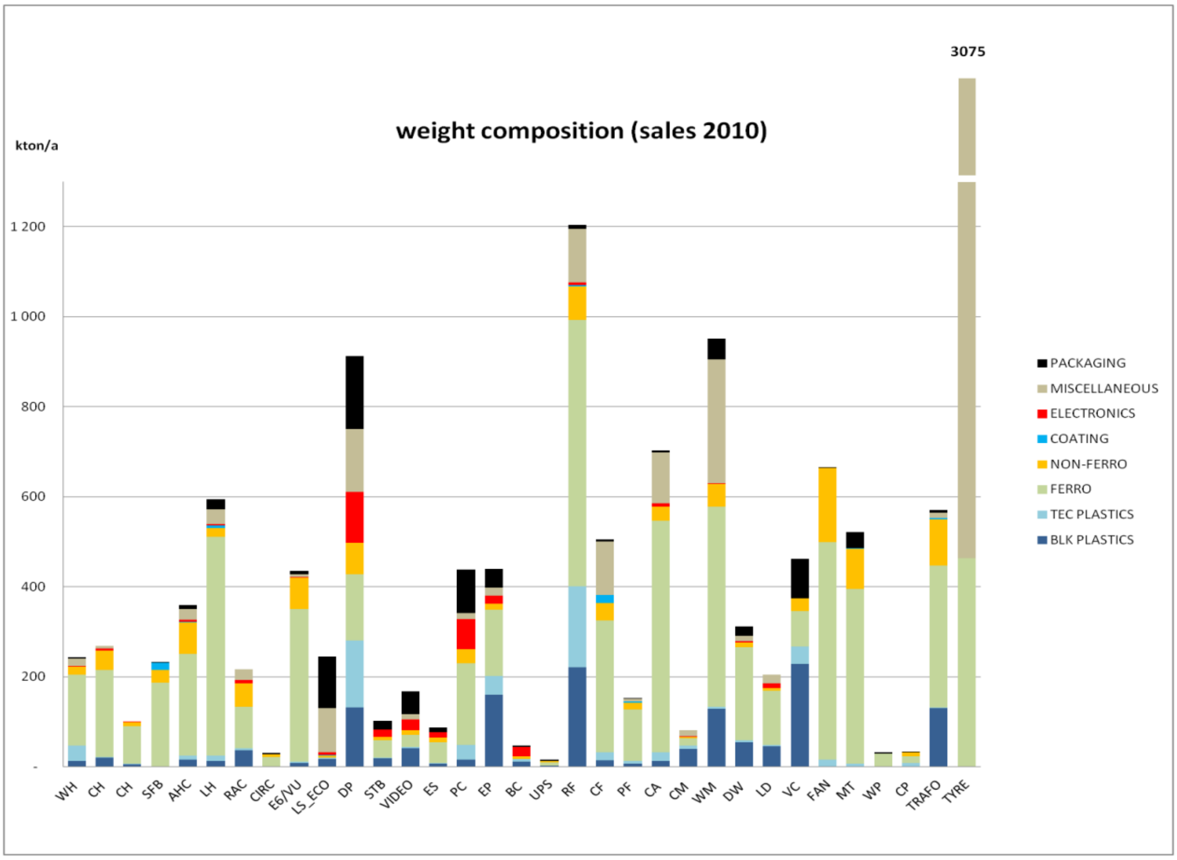


Figure 104. Total weight of the products sold in 2010, in kton/a[904]

[904] Abbreviations are given in Tables 1 and 2 as well as the acronym list

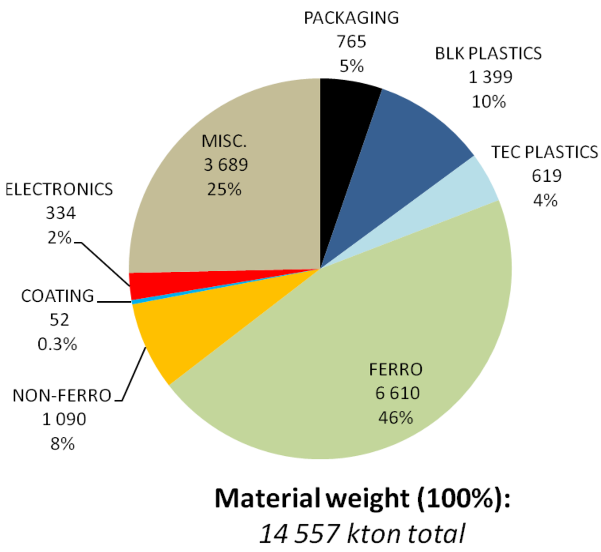


Figure 105. Material consumption per category in products sold in 2010, in kton[904]

Table 311. Material inputs for products sold in the reference year 2010, in kton/a (data underlying Figure 104).

	BULK PLASTIC	TEC PLASTIC	FERRO	NON-FERRO	COATING	ELEC.	MISC.	PACK>	TOTAL
WH dedicated Water Heater	12	34	159	17	0	2	16	3	**243**
CHC Central Heating boiler	6	1	69	12	0	1	1	0	**89**
CH Central Heating	25	6	357	41	0	4	0	0	**434**
SFB Solid Fuel Boilers	0	0	187	28	16	1	0	0	**232**
AHC total Heating & Cooling	16	9	226	70	1	4	25	8	**359**
LH Local Heaters	12	12	486	19	6	4	32	23	**594**
RAC Room Air Conditioner	36	4	93	51	0	7	24	0	**216**
CIRC Circulator pumps <2.5 kW	1	0	21	5	0	0	0	2	**30**
VU Ventilation Units (res & nonres)	8	2	340	71	0	1	6	7	**435**
LS Light Sources, mln units ECO	17	2	0	5	0	7	98	114	**244**
DP electronic DisPlays	131	150	147	70	0	113	140	163	**913**
STB Set Top Boxes	18	2	39	6	0	16	1	19	**102**
VIDEO	41	2	27	11	0	24	12	50	**167**
ES Enterprise Servers	7	1	47	9	0	12	0	10	**86**
PC Personal Computers	15	33	181	32	0	67	13	97	**438**
EP & IJ imaging equipment	160	42	146	14	0	16	19	41	**440**
BC Battery Charged devices	11	6	0	6	0	20	0	4	**47**
UPS Total	2	0	7	3	0	1	0	2	**15**
RF Household Refrigeration	221	180	592	74	3	6	119	9	**1204**
CF Commercial Refrigeration	13	19	293	39	17	1	118	5	**505**
PF Professional Refrigeration	6	6	114	15	3	0	6	1	**152**
CA Cooking Appliances	12	19	516	30	0	8	114	4	**703**
CM household Coffee Makers	40	7	17	3	0	2	13	0	**81**
WM household Wash Machine	129	4	446	50	0	2	275	46	**952**
DW Household Dishwashers	55	4	207	10	0	4	11	22	**312**
LD household Laundry Drier	45	3	121	6	0	10	20	0	**205**
VC Vacuum Cleaners	228	39	79	28	0	0	0	88	**461**
FAN Industrial Fans >125W	0	15	484	165	0	0	0	2	**666**
MT Motors 0.75-375 kW	0	7	389	88	2	0	0	37	**522**
WP Water pumps	0	0	29	0	0	0	0	4	**33**
CP Standard Air Compressors	0	8	16	8	0	0	0	1	**32**
TRAFO Utility Transformers	131	1	315	104	2	0	13	5	**570**
TYRE	0	0	463	0	0	0	2612	0	**3075**
TOTAL	**1399**	**619**	**6610**	**1090**	**52**	**334**	**3689**	**765**	**14557**

26.2.3 Stock

The total weight of materials 'in stock' (in use) is 161 Mton. This is 11 times more than the weight of products sold in the year 2010. Roughly this signifies a materials-weighted average lifetime of 11 years. Figure 106 provides the distribution over the product groups, showing that products with a short life, like Tyres (4 years life) become less dominant, and products with a long life like 'Utility Transformers' (TRAFO, 32.3 years life) become more dominant, compared to their relative position in materials sales.

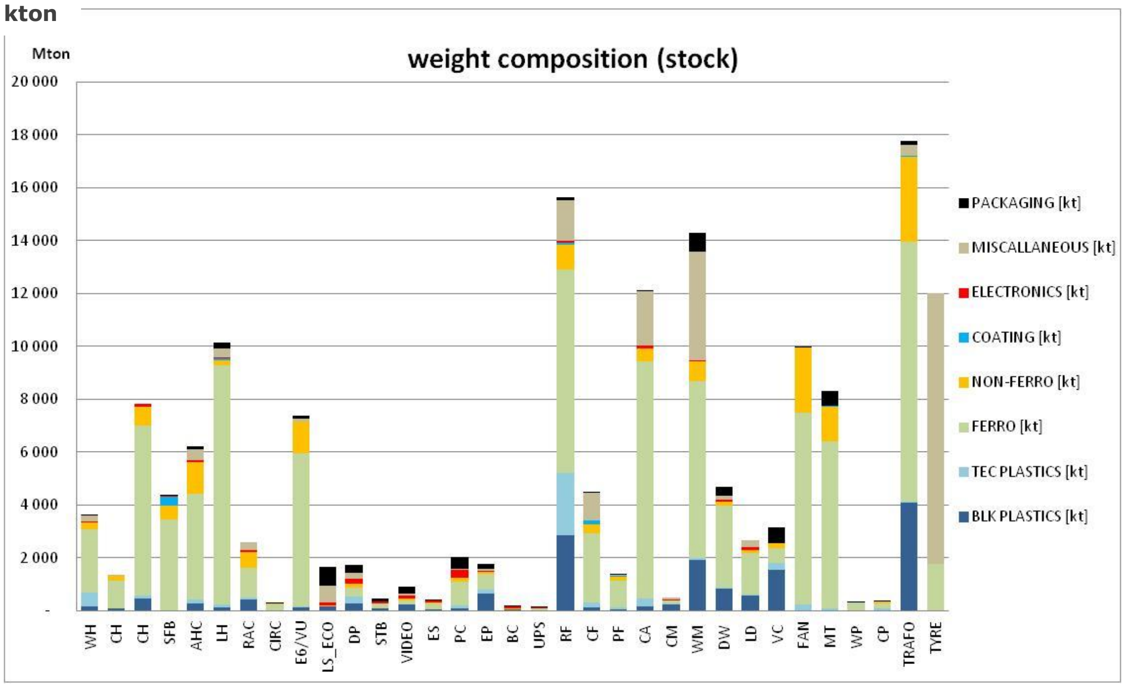


Figure 106. Total weight of products in the stock (sales 2010 x lifetime), in kton[904]

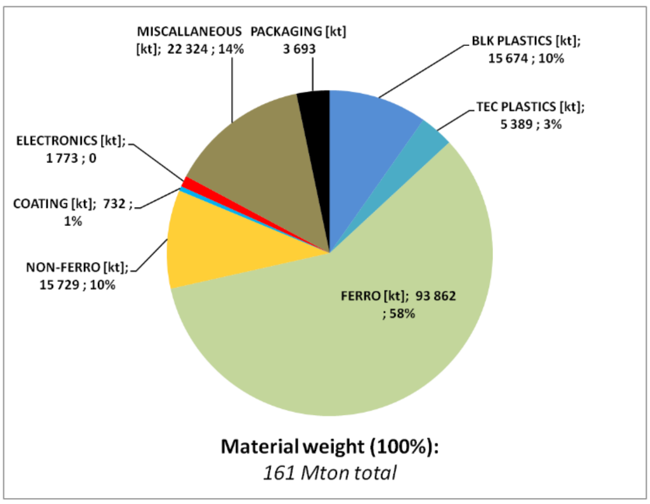


Figure 107. Consumption for the main categories

The Top 5 most used materials in stock are galvanized steel sheet (47 Gton), cast iron (23 Gton), stainless steel 18/8 (13 Gton), steel tube/profile (13 Gton) and PolyPropylene (PP, 10 Gton).

26.3 Usage

The typical applications of materials for each group are given hereafter.

26.3.1 Bulk Plastics

The total quantity of Bulk Plastics in products sold in 2010 is 1399 kton/a. More than half of the Bulk Plastics (62%) is consumed by only five product groups (Figure 108). The highest shares can be found in 'vacuum cleaners' (VC) and 'household refrigeration' (RF), both with a share of 16%. Other large consumers are 'printers and copiers' (EP), 'displays' (DP) and 'utility transformers' (TRAFO). Bulk plastics are mainly used for the housings of these products (except for TRAFO[905], where it is a proxy for mineral oil use for insulation and cooling purposes).

The most used material types are *polypropylene (PP: 43%), ABS (17%)* and *polystyrene (PS: 16%).* The plastics LDPE and EPS (combined covering 8% of the Bulk Plastics) are mostly used for packaging purposes only (see Figure 112 in paragraph 26.3.8).

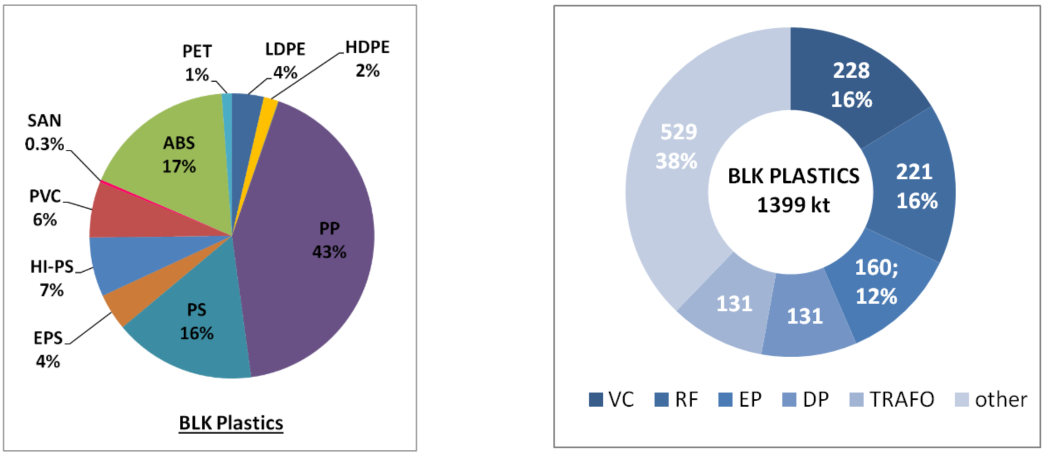


Figure 108. Consumption of Bulk Plastics in products sold in 2010[904]

26.3.2 TEC Plastics

The main consumers of technical ('TEC') plastics (total 619 kton/a) are 'household refrigeration' (180 kton/a; 29%) and 'displays' (150 kton/a; 24%), that together account for more than half of the amount of TEC plastics. Other product groups with high consumption levels are similar to those of the bulk plastics: 'printers & copiers' (42 kton/a) and 'vacuum cleaners' (39 kton/a).

Rigid PUR (39%) is the most widely used TEC plastic (thermal insulation in refrigerators). Other common TEC Plastics are *polycarbonate (PC, 28%)*, *PMMA (e.g. Plexiglas, 14%)* and *PA6 (e.g. Nylon, 12%)*.

26.3.3 Ferro

The Ferro group – 6610 kton in total (Figure 109) - does not have a dominant consuming product group, but multiple consumers of similar size. Again 'household refrigeration' (592

[905] The high share of transformers in the Bulk Plastics is the introduction of 'mineral oil' and not actually a plastic.· It is assumed that 'mineral oil' was modelled as PP since it was the best available equivalent in the EcoReports

kton; 9%) has the highest share. In addition, there is high consumption of ‘cooking appliances’, ‘local heaters’, ‘industrial fans’ and ‘tyres’; groups which, in general, are heavy. The main conclusion here is that the ferrous materials are more equally spread over the product groups than other material categories.

More than half of the Ferro material use consists of *galvanised steel sheet (52%),* followed by *cast iron (21%)*, *steel tubes and profiles (12%), stainless 18/8 coil (12%)* and a small amount of *ferrite (1%).*

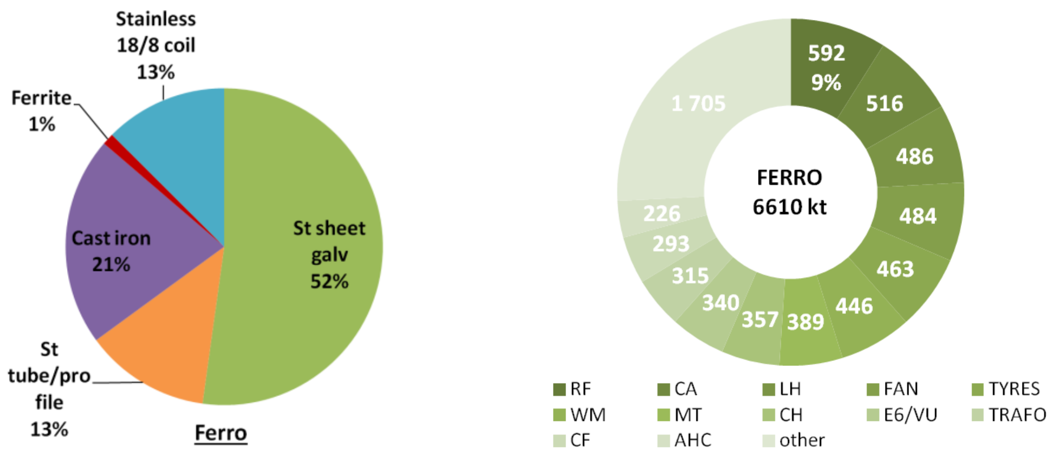
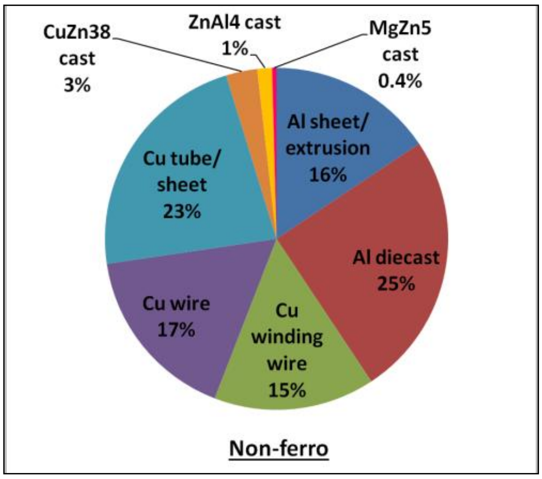


Figure 109 Consumption of Ferro materials in products sold in 2010904

26.3.4 Non-Ferro

In the Non-Ferro group (Figure 110), copper (Cu) is the main consumer, though in different forms. Copper in total covers 55% of the Non-Ferro materials and can be split up in *Cu tube/sheet, Cu wire* and *Cu winding wire*. Another 41% of the group consists of aluminium: *aluminium die cast* and *aluminium sheet/extrusion.*

Non-Ferro materials (1090 kton) can mainly be found in industrial products such as ‘industrial fans’ (165 kton; 15%), ‘utility transformers’ (104 kton; 10%) and motors (88 kton; 8%). Analogous to the share of product groups of the Ferro category, the weight of the Non-Ferro groups is more equally divided over multiple product groups.



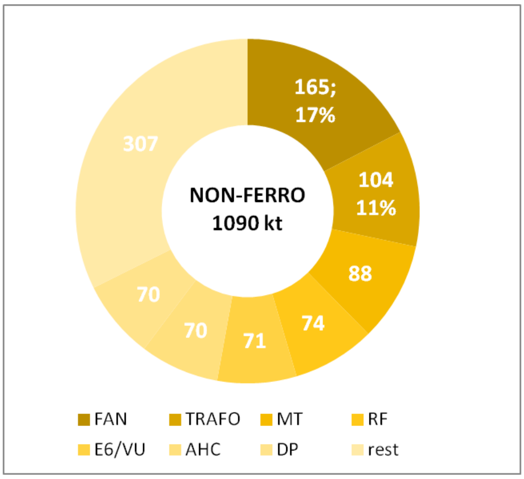


Figure 110. Consumption of Non-Ferro materials in products sold in 2010[904]

26.3.5 Coating

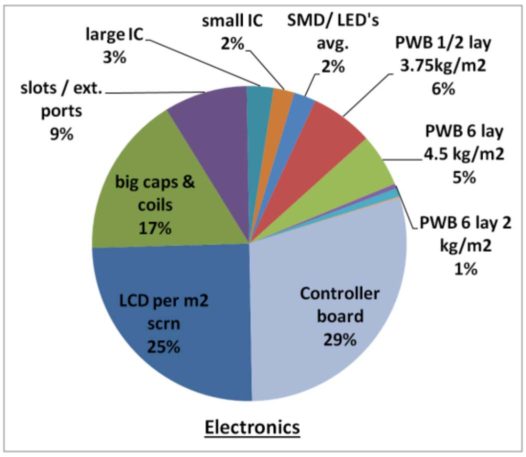
Coatings represent a (small) total of 52 kton/a in products sold in 2010. The main share in this group (65%) is defined as *powder coating* without further specifications.

Precoating and/or plating (52 kton) is applied in few product groups. The main shares can be found in 'commercial refrigeration' (17 kton; 33%) and solid fuel boilers (16 kton; 31%).

26.3.6 Electronics

The major share in Electronics (total 334 kton/a) can be traced back to 'displays' (113 kton) (Figure 111), which is related to the large sales numbers in this group. Together with 'computers' (67kton) they cover more than half of the weight of electronics.

In the Electronics group, the most apparent components are the *controller boards (30%), LCD electronics (25%)* and *big caps & coils (16%).* Note that 80-90 weight % of certain components are not made up of semiconductor materials (ICs, diodes, resistors, etc.) but support-materials such as resin-boards (for PWBs, controller boards), glass (for LCD screens), conductor material (copper/aluminium) and plastics (e.g. for slots, ports, enclosures).



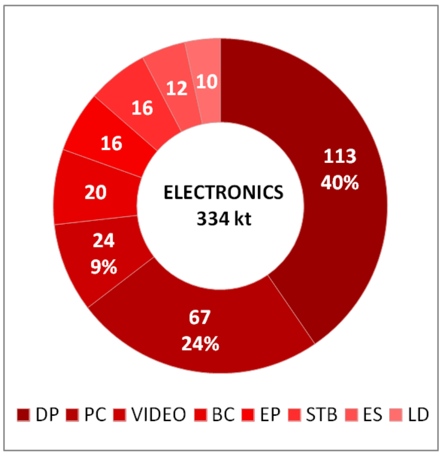


Figure 111. Consumption of Electronics in products sold in 2010[904]

26.3.7 Miscellaneous

The category "Miscellaneous", groups materials that are found in only a few specific products, e.g. *rubbers*, both *natural (46%)* and *synthetic (29%)*. As explained earlier, these are not original materials used in EcoReports. However, since rubber became so significant due to the large sales numbers of 'Tyres', it was decided to treat them as a separate material instead of placing them in the 'other' group. From the graphs, it can also be seen that 'tyres' account for 71% of the weight in this category.
Another material in this category is '*glass for lamps' (15%)*, with the notion that this most likely represents *all* sorts of glass and not only inputs for light sources (Lot 8/9/19) [906]. Glass is also found in 'displays' (140 kton in total), 'refrigeration' (shelves, Lot 12/13/E1), ovens (doors, Lot 22/23), copiers (glass plate for scanning, Lot 4).

The share of 'washing machines' is derived from the concrete included in their bases.

26.3.8 Packaging

Product packaging and manuals are included in the 'Packaging' category, of which the main consumer is *cardboard (67%)*, followed by *office paper (18%, in the manuals)* and smaller shares of *EPS (8%)* and *LDPE (7%).*

Most of the packaging (and manuals) is linked to 'displays' (163 kton; 37%), while 'light sources' (19%), 'computers' (16%) and 'vacuum cleaners' (15%) also have significant shares.

[906] In the EcoReports the material 'glass' is not available, only 'glass for lamps' is defined. Consequently, many preparatory studies used the characteristics of the latter material to approximate the impacts of the glass material in their products.

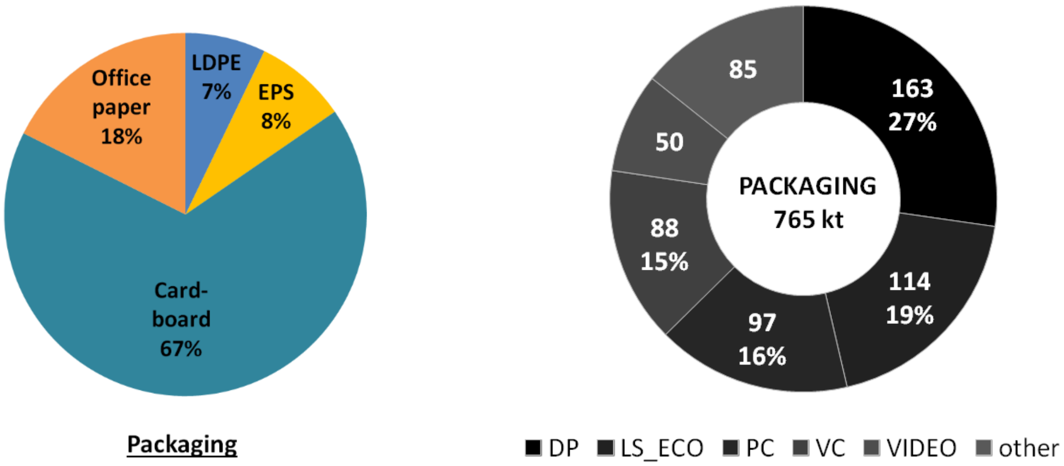


Figure 112. Consumption of packaging in products sold in 2010[904]

To find the proportion of materials consumption in ErP products relative to total consumption in the EU, is an important issue when trying to establish the relative importance of material efficiency measures in general and lightweighting measures specifically for the Energy-related products. Table 101 gives a comparison at the most detailed level for those materials where data are available. ErP materials that make up more than 10% of EU-total consumption are marked within a box.

For bulk-plastics, relative peak users are PS (e.g. for fridge inner lining, 12.2% of EU total) and ABS (typically used for housing of consumer products, 29% of EU total). PP use is relatively high at 7%.

The technical plastics PC (for housing) and PMMA (for optical functionality) are popular for ErP with around 30% of total EU-consumption. PUR (fridge insulation) is also relatively high at 7%.

Galvanised steel sheet is popular in the ferro-metals group. Stainless steel sheet is used e.g. in washing machines (drum) and dishwashers (inner lining).

For non-ferro metals none of the specific materials makes up more than 10% of the total.

In the miscellaneous group, apart from rubber, the use of technical glass e.g. for light sources, washing machines and displays is significant with two-thirds of ErP share in the EU-total. Nonetheless, technical glass is a relatively small segment of the total glass market.

Overall, the material input in ErP is 13.1 Mton/a (excl. packaging and electronics) or 7.45% of the EU-total for the selected materials.

Table 312. Selected materials consumption total EU versus regulated ErP (2010)

Materials	EU *kton/a*	ErP *kton/a*	ErP/EU %
PLASTICS			
LDPE (1,3) Low-density polyethylene	8222	56	0.7%
HDPE (2) High-density polyethylene	5784	25	0.4%
PP (4) Prolypropylene	9178	645	7.0%
PS, EPS (5,6,7) (Exapanded) Polystyrene	3346	409	12.2%
PVC (8) Poly-vinylchloride	4923	96	1.9%
ABS (9,10) Acronityl-Butadien-Styrene	908	269	29.6%
PET Polyvinyl therephtalate	3346	17	0.5%
BULK Plastics	**35707**	**1518**	**4.3%**
PA (11) Polyamid	860	76	8.8%
PC (12) Polycarbonate	621	173	27.8%
PMMA (13) Polyethyl methacrylate	287	88	30.7%
Tec-pl (14+) Technical thermoplasts misc.	956	12	1.3%
PUR (15,16) Polyurethane	3585	255	7.1%
Other Fillers, carbon/aramid fibres, etc.	5784	3	0.1%
E-glass fibre Glass fibres	1004	11	1.1%
TEC plastics	**13097**	**607**	**4.6%**
FERRO (St=Steel, Fe=iron)			
St sheet galvanised (21)	24867	3450	13.9%
Plastic coated (38)	4231	15	0.4%
Other flat products (incl. 24, ferrite)	5978	78	1.3%
St tube/profile (22)	12341	843	6.8%
Fe castings (23)	11511	1411	12.3%
Stainless coil/sheet (25)	3670	828	22.5%
FERRO TOTAL	**62598**	**6625**	**10.6%**
NON-FERRO (Al=aluminium, Cu=copper)			
Al sheet/extrusions (26)	7500	170	2.3%
Al-Castings (27, 32)	3200	288	9.0%
Cu-Winding wire (28)	375	166	7.4%
Cu-wire (29)	1854	183	9.9%
Cu-tube/sheet(30)	833	246	9.2%
Cu-alloy castings (31)	*403*	32	8.0%
MgZn5 cast (33) MagnesiumZinc alloy	62	5	7.3%
NON-FERRO total	**14227**	**1090**	**7.7%**
MISCELLANEOUS			
Special glass (54) used in light bulbs	662	437	66.0%
Other graphic papers (57)	22402	135	0.6%
Cardboard box material (56)	24077	512	2.1%
Natural rubber (93)	1150	854	74.2%
Synthetic rubber (94)	2350	1349	57.4%
MISC. total	**50641**	**3287**	**6.49%**
TOTAL OVERALL (for above materials)	**176270**	**13127**	**7.45%**

26.4 Technologies

There are a number of ways to realize light-weighting:

1. Advanced design and modelling: general CAD/FEM tools[907] (NX[908], SolidWorks, On-Shape), Computational Fluid Dynamics CFD (ANSYS, NX NASTRAN), topological optimisation strategy,
2. Advanced prototyping and analysis: 3D plastic and metal printing[909], numerical CAM milling, X-ray microscopy (XRM), scanning electron microscopy (SEM), etc.[910]
3. New innovative materials/manufacturing: MEMS and NEMS (micro and nano electromechanical systems), nano tubes and fibres, electrospinning, multi-K injection moulding, injection blow moulding, carbon/aramid/e-glass filament winding and laminates, 3D-printed bespoke series production, advanced honeycomb/sandwich/dome/etc. constructions, textile or flex solutions of traditionally rigid products, wearables, printable electronics, membrane and truss structures, foldables (including knitted structures) and blow-ups, etc..
4. Step-change in the technology: e.g. LED lamps instead of fluorescents, Solid State Disks instead of Hard Disk Drives, vacuum insulation instead of PUR, Li-ion instead of traditional lead-acid, Permanent Magnet ('brushless DC') variable speed motors instead of fixed speed AC and universal motors, stationary inkjet versus laserjet imaging technology, micro-/nano LEDs instead of LCD, optical fibre versus copper, enhanced human powered technology (speedelec versus electric bike), energy harvesters and other low-power technology, hydrogen producing solar panels.
5. Miniaturisation & integration: laptop instead of desktop, tablet instead of laptop, laptop→smartphone, Video/AR[911] glasses & smartphone, keyboard→ voice & gesture.
6. Multi-function instead of single function: washer-drier, oven-microwave, sofa-bed, smartphone-camera, combi-boiler, circulator & 3-way valve subassembly.
7. Tailor-made instead of one-size-fits-all. Avoid physical over-dimensioning for the sake of standardisation, artificial intelligence (AI) and machine learning (ML) instead of universal problem solvers.

There is an abundance of options, but none will apply to every product and a balanced approach, 'smart light-weighting' is needed to avoid or at least balance potential negative side-effects. Many lightweight strategies tend to require higher investment costs than traditional solutions. Possibly – for initial lack of mass production volumes – there might be a cost-surplus and/or long payback periods, especially for products where low weight has no functional benefits.

[907] Computer Aided Design (CAD) and Finite Element Modelling and Simulation (FEM) tool examples only show the more common tools for typically large industries (NX), SMEs and educational (SolidWorks SW) and cloud-computing (OnShape). NASTRAN is a common solver for NX; ANSYS is an all-round top-range FE modeller. 'topological optimisation is more a light-weighting design strategy (material only where there is load) that is only possible with FE-modelling.

[908] https://www.youtube.com/watch?v=maWOh4SdXV4

[909] Including:

Stereolithography, Laser Sintering, Fused Deposition Modeling (FDM), Metal 3D Printing, Multi Jet Fusion, PolyJet, Vacuum Casting, TetraShell. Explanation from a service provider: https://www.materialise.com/en/manufacturing/3d-printing-technology/metal-3d-printing

[910] More examples and explanations in e-book: https://www.zeiss.com/microscopy/int/cmp/mat/20/energy-materials/ebook/thank-you.html

[911] Augmented Reality

There might be negative material-efficiency side-effects, such as higher energy content and/or diminished recyclability, where a proper balance needs to be found with the positive impact of light weighting ('smart light-weighting').

Table 313. Selected examples comparing design strategies

Design for Lightweighting	Design for Recycling
• Best materials for the load *combine specific properties of different materials in one component* • Best shape for the load *optimal geometry for the expected force* • Technical function integration *reduce the number of components (more complexity, less weight)* • Minimize mechanical joints *minimize peak loads* • Miniaturize & be compact *especially but not exclusively in electronics* • Optimize for life *'re-use' and 'reparability' are emergency measures to deal with (partially) oversized products. The right product life should be guaranteed, but not more.*	• Mono-materials per component *higher quality scrap (less contamination) after pre-disassembly* • Easy (pre-) disassembly *Joints (screws, knock-outs, etc.)* *Easy accessibility and removal of parts* • Prioritize the above for special parts *printed circuit boards, LCDs, batteries, refrigerants, REM, etc.* • Plan for smart shredding for the rest optimize for different shredder routes

For aviation, cars, windmills, mobile electronics, hand-tools, etc. saving potentials up to 40-50% are mentioned for lightweight materials.[912] For products with a step-change in technology, like the switch from CRT to LCD electronic displays, weight reduction --for the same screen size and better resolution—savings potential went up by a factor of 10 (from 60 to 6 kg for 32"display). Similar weight saving impacts come from replacing Solid State Drives instead of Hard Disk Drives. Multi-functional products, like laundry washer-driers, save 40% on materials with respect to the single washing machine and single laundry drier. The latest stationary ('pagewide') inkjet cartridges are 10 times lighter than the laserjet powder cartridges at the same performance. Less spectacular, but still valid and usually with fewer side-effects, is the weight-saving of up to 20% by using advanced modelling and prototyping.

Without pre-empting the outcome of a systematic and comprehensive study on the subject, the study team estimates that targeted Ecodesign and/or Energy Label measures could lead to ErP material savings in ErP of at least 20%.

[912] ttps://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/automotive%20and%20assembly/pdfs/lightweight_heavy_impact.ashx

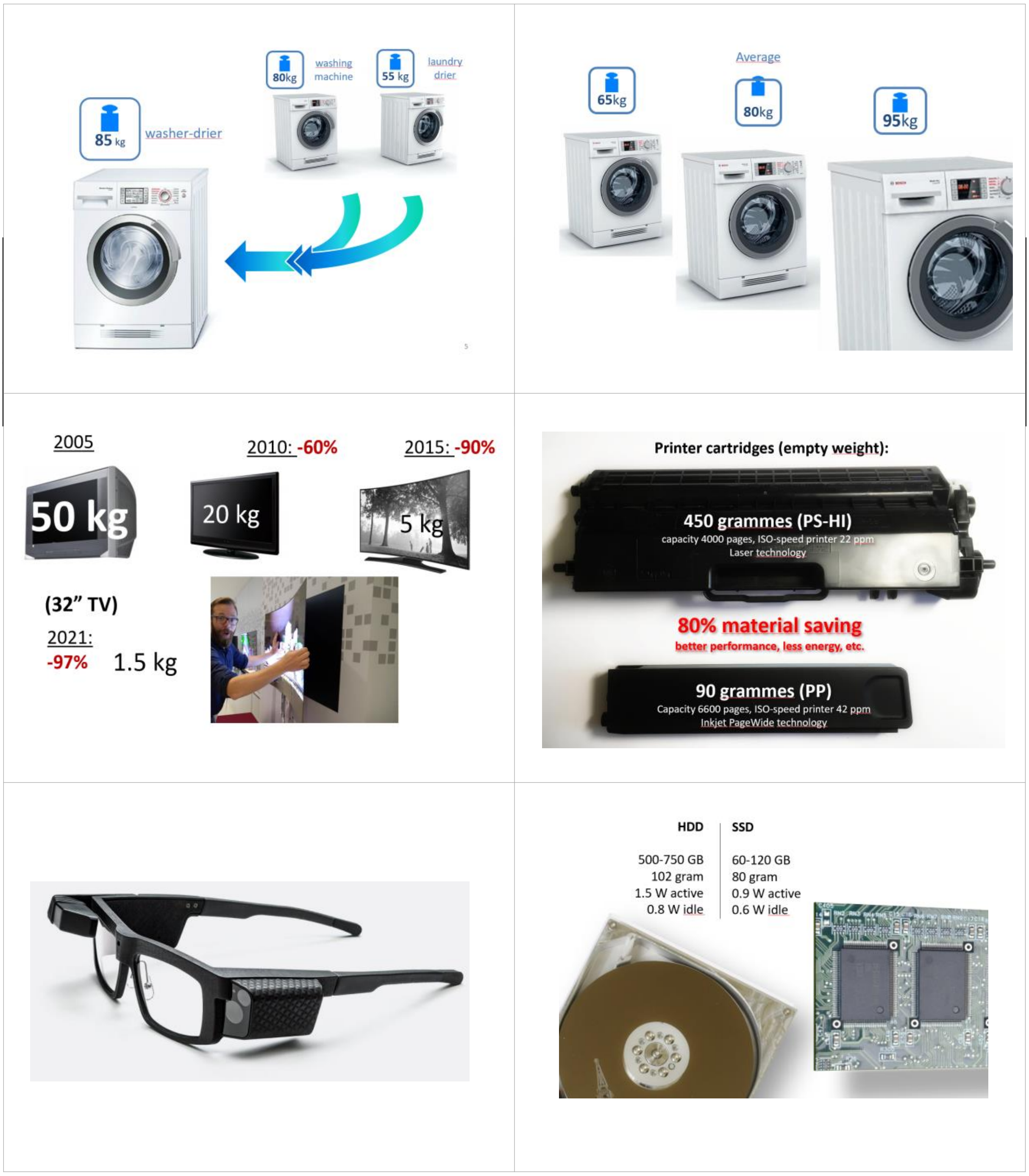


Figure 113. Some examples: (top-left): washer-drier replacing washer + drier. (top-right): different product weights in the market. (mid-left): light-weighting of TVs over the past 20 years. (mid-right). Printer cartridges with 80% weight saving. (bottom-left): Iristick glasses with display, camera, audio (bottom-right) Solid State Drive versus Hard Disk Drive.

26.5 Energy, Emissions and Costs

In the previous sections, the annual material input for regulated ErPs was established at about 14 Mton. Multiplying the weight of the various fractions with their energy content as applied in the EcoReport, a total energy content – i.e. the Gross Energy Requirement in primary energy – was estimated at around 1349 PJ or 375 TWh/a.

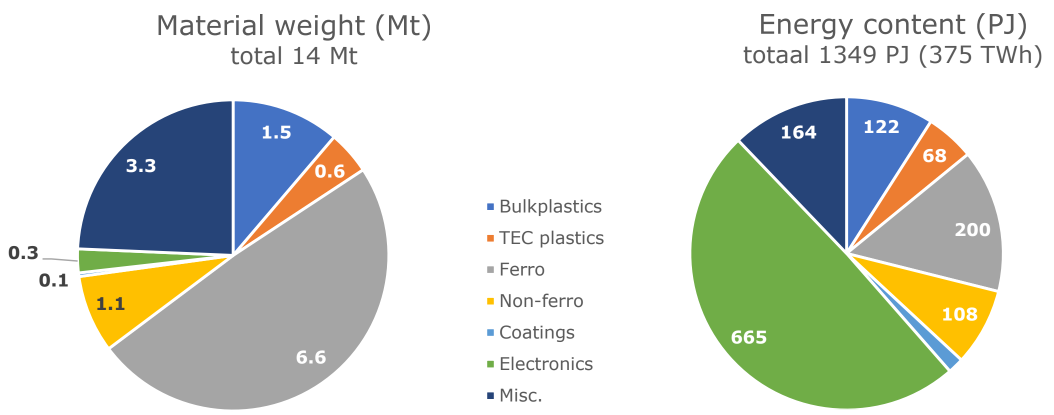


Figure 114. Material consumption and energy content of production materials for ErP (reference EU 2010).

It is difficult to establish the monetary costs of materials, because it is also linked to manufacturing techniques and typical markets. The total acquisition cost of all the ErPs is a little over €500 bn/a in end-consumer prices. At a factor of 2.5 between manufacturer selling price (MSP) and end-consumer price, including VAT, the total MSP will be €200 bn. If we then assume a materials price – at the level of half-products – to be 40% of the MSP, it results in €80bn in material costs.

Naturally, these are only rough estimates that will need to be firmed up in a comprehensive study.

26.6 Saving potential

Light-weighting is part of the MEErP accounting, notably the EcoReport, which also includes societal costs, but in terms of environmental impacts it usually very small compared to other environmental impacts during the use phase and has not led to proposals for Ecodesign or Energy Label policy measures. For horizontal measures in this field new priorities need to be set.

Bringing together the findings from the previous chapter, we estimate that through light-weighting, a long term 20% saving potential in 2030-40 may be possible for ErPs in the EU. This comes down to a saving of:

- 2.5-3 Mt/a in material inputs
- 55-75 TWh/a primary energy saving in materials production
- 15-20% reduction in carbon and other emissions from materials production.

We anticipate that there will be no significant monetary savings for industry and end-users, but the overall financial picture can be cost-neutral over a period of time.

As regards the practical implementation, the most likely format is a product-specific approach and preferably in Energy Labelling where the product weight could be given a prominent role and possibly even a rating. The aim would be to empower the R&D department to spend more budget on the matter, to be recuperated through higher commercial appeal. A mandatory measure e.g. through Ecodesign is not self-evident on the short run.

The light-weighting strategy would involve all market actors, from materials-industry[913] to suppliers[914], various end-product industries[915], distributors[916], consumers[917], recyclers[918], etc.

26.7 Stakeholder comments

Stakeholder comments on the issue of light-weighting basically repeat every warning that has been mentioned in this Task 3 report, but use it to say that nothing should be done out of fear that Ecodesign measures will set a mandatory maximum weight limit per product, i.e. similar to the minimum recycling quota under the Waste Directive. However, what is propose here is quite the opposite. The stress on minimum recycling rates can lead to suboptimal material efficiency choices, e.g. heavy TV-pedestals, glass shelves, etc.. The idea is to move long-term towards a more balanced approach, where e.g. demands on recycling rates can be more relaxed when products/components with the same functionality and durability are less heavy.

Despite the explicit focus of the study team on incorporating light-weighting in a holistic circular economy approach, many industrial stakeholders voice a fear of a one-dimensional implementation of light-weighting as a single design-criterion. To clarify what a holistic approach could entail, the example of a holistic approach formula for the product resources impact calculated in the current Ecodesign methodology MEErP can be mentioned:

$$\frac{Produce + Distribute + Use + Discard - RecycleBalance\ (impact)}{Product\ Life\ (years)\ \times Users\ (number)}$$

where the impact in the numerator is typically split in a quantity (e.g. kg) and a specific impact, e.g. energy content, CO2-emissions or another environmental impact per kg. The RecycleBalance depends both on the actual net recycled content input in production and the (predicted) actual net recycled material from the discarded product. The above formula is complemented by taking into account peak impacts (hazardous emissions, critical material use, etc.) and boundaries for product life depending on whether the product has a significant future efficiency improvement potential in the use phase or not.

[913] Eurofer, Plastics Europe, Copper Institute, European Aluminium, etc.
[914] E.g. Orgalime
[915] APPLiA, EHI, Digital Europe, etc.
[916] E.g. EuroCommerce.
[917] ANEC-BEUC
[918] EERA and many others

27 Post-consumer recycled content

27.1 Scope, policy measures and test standards

Recycled content is the amount of recycled material that goes into the manufacturing of a new product, expressed either as a fraction of the total material input (in %) or in absolute numbers (kg per unit, million tonnes Mt in aggregates). Recycled content is the demand side of recycling and just as important for the circular economy as the effort to recycle the product at its disposal. In line with recommendations in MEErP only post-consumer recycled material will be considered[919] [920]. The focus of this chapter will be on recycled content of plastics in ErP, i.e. as this is much more problematic than with the well-established practice for other materials.[921]

In its drive towards a Circular Economy[922], the Commission has committed itself to a series of packages to bolster the uptake of secondary raw materials into the production of new products.

It has launched an EU-wide pledging campaign to ensure that by 2025, ten million tonnes of recycled plastics find their way into new products on the EU market -each year - a figure that has also been endorsed by "The Circular Plastics Alliance" from – reportedly - an EU market of 4 million tonnes for recycled plastics in 2019 helping to deliver the circular economy with a life cycle approach.

Currently in the EU27 +UK+ Norway + Switzerland, 51.2 Mt of plastic are consumed. Should this 10 million tonnes figure be attained, then the EU will have attained an almost 20 % success rate of recycled plastics uptake into new products for all applications. A figure that will bolster ambitious objectives to achieve "zero plastics to landfill" and therefore 100% recovery of plastic waste by organisations such as Plastics Europe.

Recognising the existing difficulties in plastic recycling uptake, the Commission contributed an addition EUR 100 million under the Horizon 2020 programme, "to drive investment towards resource-efficient and circular solutions…" [923]

Under standardisation request M/543, standards to ensure that materials from end of life products – in particular plastics - can be recycled are being developed by entities such as CEN and the Commission.with together with industries, also to develop quality standards for sorted plastic waste and recycled plastics[924]. See Table 314.

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[919] Kemna, R. , Methodology for Ecodesign of Energy-related Products (MEErP), Part 2, VHK for the Commission 2011. Note that several test standards also consider pre-consumer pl

[920] Unlike several test standards like ISO ISO 14021, also referenced in prEN 45557:2019, that consider recycling of pre-consumer waste –i.e. waste during production—also as part of 'recycled content'.

[921] With metals both the supply side (at end-of-life) as the demand-side in production are relatively unproblematic, with typical recycled content 80% in foundry products, 10-20% in extrusion/profiles, 0-10% in sheet. For electronics there is mandatory disassembly under the WEEE-directive and the components go into specialised directories to recuperate precious and rare materials for which there is ample demand. For cardboard and paper in respectively packaging and manuals a high recycled content is now obvious.

[922] https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy.pdf

[923] 'A European Strategy for Plastics in a Circular Economy' (COM(2018)0028)

[924] Ibid. 32

Table 314. Test standards relevant for recycled plastics content

Standard	Year	Title	Comment
prEN 45557	2019	General method for assessing the proportion of recycled materials content in energy related products	Issued by CEN-CLC J/TC 10 in a series of (pre-)standards following the Commission's Standardisation Request M/543 on Material Efficiency Aspects of ErP. This pre-standard on recycled content prescribes its accounting and reporting
ISO 15270	2008	Plastics — Guidelines for the recovery and recycling of plastics waste	Provides guidance for the development of standards and specifications covering plastics waste recovery, including recycling.
EN 15342	2007	Plastics. Recycled plastics. Characterization of polystyrene (PS) recyclates	Defines a method of specifying delivery condition characteristics for polystyrene (PS) recyclates.
EN 15343	2007	Plastics - Recycled Plastics - Plastics recycling traceability and assessment of conformity and recycled content	Control of input material; control of the recyclate production process; plastics recyclate characterisation; traceability; quality assurance
EN 15344 (PE) EN 15345 (PP) EN 15346 (PVC) EN 15348 (PET)	2007 2007 2014 2014	Plastics. Recycled plastics. Characterization of polyethylene (PE) recyclates	Quality Assurance; method for the determination of contaminants; test method for the determination of bulk density. Defines a method of specifying delivery conditions for respectively polyethylene (PE) recyclates, Polypropylene (PP) recyclates. poly(vinyl chloride) (PVC) recyclates, poly(ethylene terephthalate) (PET) recyclates.
EN 15347	2007	Plastics. Recycled Plastics. Characterization of plastics waste	Scheme for the characterisation of plastic wastic; supplying informationon properties of waste to customers; identifying test methods.
CEN/TR 15353	2007	Plastics - Recycled plastics - Guidelines for the development of standards for recycled plastics	Provides standards for recycled plastics.
EN 45556	2019	General method for assessing the proportion of reused components in energy-related products	Deals with the assessment of the proportion of reused components in energy-related products on a generic level, which can be applied at any point in the life of the product.
CEN/CLC/JTC 10	2019	Energy-related products - Material Efficiency Aspects for Ecodesign	Assessment of the proportion of re-used components in energy-related products on a generic level. All energy-related products are in the scope of this standard.
CEN/TC 249/WG 11	Under approval	Plastics - Recycled plastics - Determination of solid contaminants content	Specifies a method for determination by melt filtration of solid contaminants content in a sample of recycled thermoplastic material, evaluating their number and, optionally, their size and substance (material).
CEN/TS 16010	2013	Plastics - Recycled plastics - Sampling procedures for testing plastics waste and recyclates	Defines a system for sampling procedures for testing plastics waste and recyclates which take into account the specifics of the plastics waste and recyclates
CEN/TS 16011	2013	Plastics - Recycled plastics - Sample preparation	Specifies the preparation of samples of recycled plastics prior to testing and takes account of the specifics of the material.

27.2 Market

According to Plastics Europe, the EU 2018 plastics production is almost 62 Mt. There is a trade surplus of almost 9 Mt, so 51.2 Mt of is the consumption by the plastics converters in the EU27+UK/N/CH. This is a 14% (6.2 Mt) increase with respect to 9 years before, as shown in Figure 1. The figure also shows the subsequent plastic flows, with 6% (~3 Mt) going to Electric and Electronic Equipment EEE. The total plastic waste in 2018 is 29.3 Mt, of which almost 25% (7.3Mt) went to landfill and 75% (21.8 Mt) was recovered. This is a considerable improvement over 2009 where 46% (11.2 Mt) went to disposal, of which 5.5 Mt (22.5% of waste) went to recycling.

In 2018 as much as 9.4 Mt (32.5%) went to recycling. Of this, not shown in the diagram, 1.8 Mt (19%) is trade-surplus going to extra-EU countries[925] and 7.6 Mt is processed in the EU. The yield of the process of producing recycled plastics is estimated to be around 65%[926], so about 5 Mt of recycled plastics will be produced for the European market (without UK, N, CH; close to 4 Mt for the EU27 alone)[927].

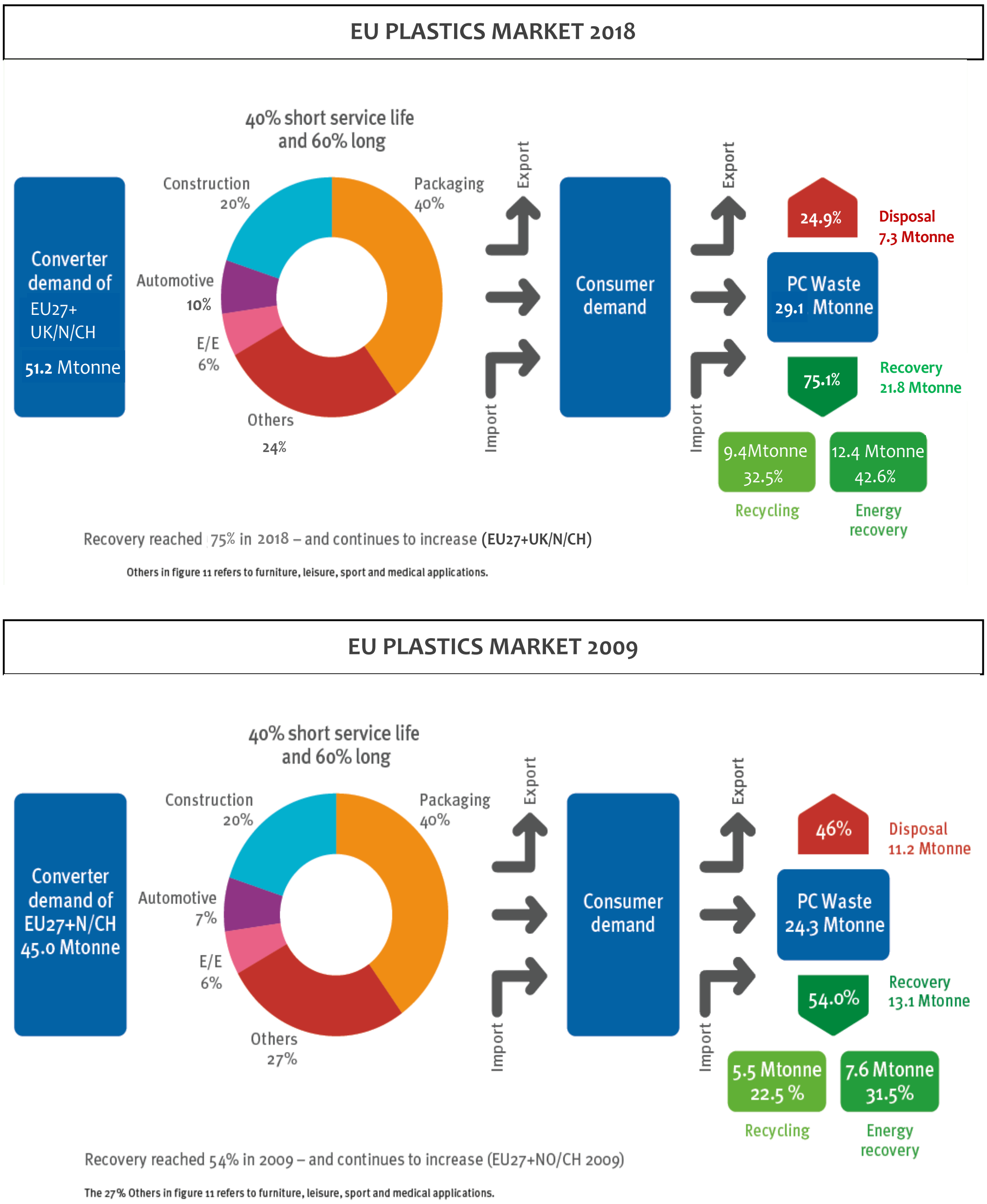

Figure 115. European Plastics Market 2009 and 2018 (source: Plastics Europe 2010, 2019)

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[925] Until Jan. 2018 most went to China and Malaysia. China then blocked plastic waste imports, which led first to a drop in total EU's plastic waste exports and other countries, notably Turkey and Malaysia, taking over the role of China. See: https://www.eea.europa.eu/highlights/reuse-and-recycling-are-key

[926] http://www.container-recycling.org/index.php/estimated-yield-rates-from-collected-plastic#:~:text=Plastics%20recyclers%20report%20that%20in,yield%20rate%20of%20about%2085%25.

[927] Note that a part of recycled plastic granulate may also be exported but that information is not available.

27.3 Usage

The typical applications of plastics, per product group, are given hereafter. The source is a comprehensive analysis of materials consumption in Energy-related Products (ErP) that VHK prepared for the European Commission in 2016. The analysis was part of its Ecodesign Impact Accounting (EIA) for the Commission in 2016 and still constitutes the most comprehensive assessment to date.[928] (see also Chapter on Light-weighting)

According to this source, the sales of plastics in the Energy-related Product (ErP) group in the EU27+UK amounted to 2.1 million tonnes, i.e. 4.7% of EU converter demand in 2010. Taking into account converter production loss (10%) and underestimation of the packaging fraction (PE shrink-wrap and pallets, see figure 2), this is coherent with the 6% for E/E products given by Plastics Europe in the previous paragraph.

Figure 116. Wholesale packaging, examples

The table below shows that the largest fractions are PP (30%), ABS and PUR (each 13%), PS (12%) and PC (8%). The table does not show the PE-fraction of wholesale packaging, which will be similar in size as the PP.

The largest plastic-using product group is Electronics (31%), Food Appliances and Cleaning (each 25%). All the other products make up less than 19%.

The Top 5 single products with the largest plastics consumption are household refrigerators (405 kton, 19%) and electronic displays (294 kton, 14%), vacuum cleaners (267 kton, 13%), imaging equipment (210 kton, 10%) and household washing machines (155 kton, 7%). These 5 product groups make up 63% of the total ErP plastics consumption and could be prime candidates for recycled plastics.

[928] VHK, EIA II - Special Report Materials 2016, for the European Commission, 2016

Table 315. Amount and type of plastics consumed annually in ErP sold in EU27+UK 2010 (source: VHK, EIA Special materials report, 2016)

	ErP product group	BLK Plastics [kt]							TEC plastics [kt]				
		PE [1]	PP	PS	EPS	HI-PS	PVC	ABS [2]	PA6	PC	PMMA	PUR [3]	TOTAL
Hot Water	WH dedicated Water Heater	0.1	1.7	4.9	0.5		0.3	4.9	7.0	0.0		27.4	46.9
	CHC Central Heating Combi	-	2.8	0.2				2.8				0.7	6.7
	(2.5%)												***54***
Heating, Ventilation, AirCo	CH Central Heating	-	23.2	1.9				-				6.4	31.5
	SFB Solid Fuel Boilers	0.1						-				-	0.1
	AHC total Heating & Cooling	-					6.7	9.3		8.9		-	24.9
	LH Local Heaters	-						12.3		12.3		-	24.7
	RAC Room Air Conditioner	-	36.1					-	4.4			-	40.5
	CIRC Circulator pumps	0.5	1.4					-				-	1.9
	VU Ventilation Units	11.0					3.9	0.5		1.6		0.8	17.7
	(6.7%)												***141***
Light	LS Light Sources	-						-		0.1		2.1	***2***
	(0.1%)												
Electronics	DP electronic DisPlays	-		0.3	13.5	34.3	35.0	61.3	8.6	49.6	85.9	5.7	294
	STB Set Top Boxes	0.2	0.0	0.6		0.6	2.1	15.0	0.4	0.4		0.9	20.4
	VIDEO game consoles, DVD	0.3	0.3	2.5			9.3	29.1	0.2	1.1		0.7	43.6
	ES Enterprise Servers	1.0	0.0	3.4			0.6	1.5	0.0	0.8		0.1	7.5
	PC Personal Computers	7.4	0.1	0.1	1.8		0.8	14.2	13.5	16.0	1.3	2.5	57.7
	EP & IJ imaging equipment	8.2	4.1	40.4	3.0	62.5	2.0	47.5	9.8	25.3	0.6	6.4	210
	BC Battery Charged devices	0.8	0.0				6.0	3.9	0.1	6.1		-	16.9
	UPS Uninterruptible	0.3	0.0		0.1		0.3	1.5	0.0	0.0	0.0	0.0	2.4
	(30.8%)												***653***
Food appliances	RF household Refrigeration	5.6	28.8	159.4	0.5		12.1	17.9	0.7	0.3		179.5	405
	CF Commercial Refrigeration	0.5	0.5	0.9	3.9	1.0	6.2	4.5	0.2	0.8	0.0	18.0	36.4
	PF Professional Refrigeration	0.4	0.7		0.7	3.6	1.3	0.4	1.2	0.0		5.2	13.4
	CA Cooking Appliances	11.7	0.2		2.1		1.9	0.6	6.9	7.2		5.0	35.6
	CM household Coffee Makers	-	28.3	0.5			0.6	10.2	2.1	0.2		4.2	46.2
	(25.3%)												***536***
Cleaning	WM hh.Washing Machine	23.8	109.3				3.0	15.8	1.3	2.6		-	155
	DW Household Dishwashers	7.2	39.0	3.9	0.4		3.0	5.8	2.9		0.0	1.0	63.2
	LD household Laundry Drier	-	9.9	25.1			0.6	9.4	0.8	0.4	0.2	1.5	47.9
	VC Vacuum Cleaners	-	227.8					-		38.8		-	267
	(25.2%)												***533***
Industrial	FAN Industrial Fans >125W	-						-	14.8			-	14.8
	MT Motors 0.75-375 kW	-			36.6			-				6.6	43.2
	WP Water pumps	1.3						-				0.0	1.4
	CP Standard Air Compressors	-	0.2				0.1	-	0.7	0.0		7.0	8.0
	(3.2%)												***67***
Misc	TRAFO Utility Transformers	0.5	130.3					-				1.3	***132***
	(6.2%)												
		3.8%	*30.4%*	*11.5%*	*3.0%*	*4.8%*	*4.5%*	*12.7%*	*3.6%*	*8.1%*	*4.2%*	*13.4%*	*100%*
	TOTAL (kton)	**81**	**645**	**244**	**63**	**102**	**96**	**268**	**76**	**173**	**88**	**283**	**2119**

[1]=includes LDPE, HDPE, LLDPE; [2]=includes SAN (2% of values); [3]=includes all thermosets & fillers/fibres,70% is rigid PUR

There are no statistics for the actual recycled plastics market in the EU. Hereafter some anecdotal examples are given from efforts by individual companies.

- The first of Electrolux vacuum cleaners to be made with recycled plastics were made in 2008 and these contained 55 % of recycled content. The current models in the Green Collection contain up to 70 percent recycled and recyclable plastic, saving water and energy compared to virgin material. Electrolux developed CarboRec, a blend based on recycled polypropylene and calcium carbonate. Coming from using 7.4 kton in 2016 they aim for 20 kton in 2020.[929]

- Philips has developed an EcoDesign process with six key Green Focal Areas, including increasing the use of recycled materials. A target is to use only recycled plastics in inner parts of consumer electronic products by 2025. Along with more colour options and visual quality, the amount of recycled plastics can be increased to external parts. Philips has introduced a number of consumer lifestyle products made of recycled plastics, such as vacuum cleaners (25-47% recycled content r.c.), coffee machines (13% r.c. uptake) and steam irons (30% r.c.).[930]

- In 2018, Dell used 6.2 kton of e-plastics (electronic plastics waste). The closed-loop e-plastics are blended with virgin resin at an average recycled content level of 30-35%. On top of that, the company used 3.5 kton post-consumer plastics sourced from packaging such as water bottles and CD cases. Also in 2018, Dell used 287 metric tonnes of reclaimed carbon fibre from the aerospace industry, which is incorporated into the company’s laptop bases and backs.

- Sony recently developed a recycled plastic for audio products that it claims improves sound quality while retaining a high percentage of recycled content. This recycled plastic was used in soundbars and home theatre systems. Sony uses its own type of recycled plastic which is a mix of 58% pre-production (primary) and 42% post-consumer (secondary) recycled plastic. In fiscal 2018, the Sony Group used some 11 kton of recycled plastic in its products.[931]

- By 2030, Samsung aims to use 500 thousand tons of recycled plastics and collect 7.5 million tons of discarded products (both cumulative from 2009).[932]

- For iPhone 11 Pro and iPhone SE, Apple uses 35 percent or more recycled plastic in multiple components.[933]

[929] https://www.electroluxgroup.com/sustainabilityreports/2019/key-priorities-and-progress-2019/our-nine-promises/make-better-use-of-resources/

[930] https://www.philips.com/a-w/about/sustainability/sustainable-planet/circular-economy/recycle.html

[931] https://www.sony.net/SonyInfo/csr_report/environment/products/plastics.html

[932] https://news.samsung.com/global/samsung-electronics-to-replace-plastic-packaging-with-sustainable-materials

[933] https://www.waste360.com/e-waste/apple-adds-more-recycled-materials-new-iphones

27.4 Technologies

For the manufacturers of Energy-related Products the main barrier to increasing their input of recycled plastics is the

- availability of (waste) material
- at the correct quality and
- competitive costs.

For policy makers the main challenge in actively promoting the use of recycled plastics in ErP, through Ecodesign, Energy Label and/or financial incentives, is

- effective market surveillance without prohibitive administrative burden

for both the industry and market surveillance authorities (MSAs).

27.4.1 Availability of material

As shown previously, there is a 22 Mt gap between the EU-demand for plastics (51 Mt) and the registered EU plastic waste (29 Mt). Generally speaking, there may be various reasons for that, e.g. a negative trade balance of plastic-containing products, illegal dumping, plastic dispersed in the ambient and ultimately the oceans. But for plastics in ErP and other products with a long service life, e.g. in construction (windows, tubes, etc.), probably the main reason is the fact that there is a considerable time gap between the moment that the products are bought and the moment they are discarded.

In that timeframe of on average 14 years[934], most ErP markets tend to grow in unit sales and often also in the average size/capacity of the product (e.g. televisions, refrigerators, etc.). Even at a moderate compound average growth rate of 4% per year, the material that went into the production 14 years ago is 40% less than the material that goes into production today. In other words, even in a hypothetical ideal lossless case where all discarded plastics are collected and recycled, it will not be possible to realise a closed-loop recycling with a recycled content of 100% for ErP. At best, an average recycled content of 60% is the maximum that theoretically can be achieved for the average product in a closed-loop.

[934] Outcome of the EIA 2016 study is an average product-life over all regulated ErP of 13.9 years.

27.4.2 Quality

Plastics in ErP have to meet technical (surface quality, chemical/physical properties, mechanical properties, etc.) but also technological specifications, i.e. components have to be mass-produced at competitive costs. (see text box for examples)

Examples of plastics specifications

- For instance, plastic (PS) for the inner-liner of a refrigerator has to be food-safe (no migration of toxins, e.g.), scratch- and cleaner resistant, mechanically fit to realize a sturdy cabinet through a sandwich with the insulation-foam (PUR) and the outer steel sheet, but also it has to withstand the thermal and mechanical stress of a competitive mass-production technology like blow-moulding, currently the technology of choice. The heaviest demand for this possible application of recycled plastics is probably the food-safety requirement and –as is done today in recycled plastic milk bottles—use an extra thin film of virgin material.
- For vacuum cleaners, where the use of recycled plastics (PP) is already a reality today for e.g. lower part of the casing, the heaviest (mechanical) requirement is that the product needs to survive a drop-test at product-temperature 0°C (e.g. emulating a worst case where the vacuum cleaner is stored on a balcony). To survive such a test, a certain amount of virgin material and filler/fibre (up to 50-70%) is required.

There are various ways for ErP-manufacturers to ensure the quality of recycled plastics.

Recycling plastics from same products

One way, which is unique for ErP which have their own (mandatory) collection system under the WEEE[935], is for an ErP-manufacturer not to take just any recycled plastic granulate but get the plastics from its own –or similar—products. Although not in quantity but in quality, it can be called a 'closed loop'. This is for instance the current practice with Philips, through its recycler Veolia, that uses recycled plastics from its own vacuum cleaners. The advantages are, that you get the right plastic-blends that have already been used for that same functionality and that the 'paper-trail' to prove to 3rd parties that a plastic is really recycled is limited.

Recycling from generic source

A second way is to use generic recycled plastic granulate from specialist suppliers/recyclers. Section 1 has shown that there are already several test standards, generic and polymer-specific, to verify the properties of recycled plastics meet specifications. These are relevant for acceptance tests e.g. between recycler and end-product manufacturer. Apart from that, the ErP-manufacturer will make its own quality spot checks in the production. For the recycler, the sorting process of the plastic waste is the way to guarantee a certain quality. Apart from magnetics, sifting and floating there are now also sophisticated processes for colour separation. The next step could be digital watermarking, instead of the legacy letter-identification of plastic parts, to increase efficiency of sorting. Digital watermarking is a process of printing QR- or barcodes on plastic products/components with

[935] As opposed to e.g. food packaging that is mostly a fraction in the mixed household garbage.

invisible, but machine-readable ink to help automatic high-speed sorting of (shredded) plastics.

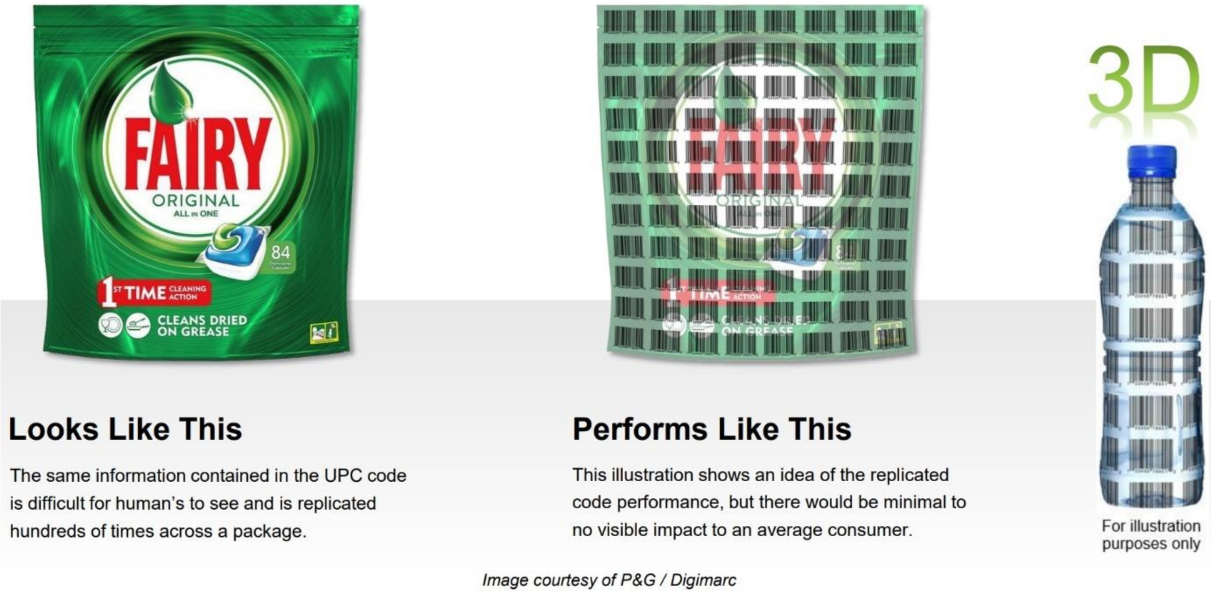

Figure 117. Digital watermarking (source: Gian de Belder, HolyGrail 2.0, 2019[936])

Chemical recycling

The two above methods relate to mechanical recycling, where plasticizers, reinforcement fibres, flame retardants and other additives set boundaries to maximum recyclability. For that reason, several (petro-) chemical companies like BASF[937], Shell[938] and others are now developing full-scale chemical recycling plants to convert these difficult-to-recycle plastics into pure feedstock, which could be used to make virgin-like quality recycled plastics.

27.4.3 Costs

As mentioned in the Vacuum Cleaner Ecodesign Review study[939] the strict material cost (€/kg) of recycled plastic pellets is about half of that of virgin plastics in the case of ABS and PP (situation 2018). Also Philips confirmed that the use of recycled plastics for their vacuum cleaners, even with extra costs for quality control, is lower than for virgin plastics.

Table 316. Prices of plastic injection moulding grades

Material	Recycled EUR/kg	Virgin EUR/kg	Difference
ABS pellets 2018	1.46	2.6	-78%
PP pellets 2018	0.89	1.77	-99%
PP pellets 2015 plastic recyclers Europe	0.9-0.95	1.43-1.50	-73%
source 2018: www.plasticsnews.com; conversion 1 lbs=0.4535 kg, 1 US $= 0.86 EUR			
prices at annual volumes of 2 to 5 million lbs.			
injection moulding grade pellets, typically colour black			
source 2015: Plastics Recyclers Europe, Increased EU Plastic recycling targets:			

[936] Gian de Belder (P&G), HolyGrail 2.0 presentation, 2019.

[937] https://www.basf.com/be/en/who-we-are/sustainability/whats-new/sustainability-news/2019/BASF-signs-dutch-green-deal.html

[938] https://www.shell.com/business-customers/chemicals/media-releases/2019-media-releases/shell-uses-plastic-waste-to-produce-chemicals.html

[939] Viegand Maagoe A/S, VHK, Review study of Vacuum Cleaners, Ecodesign study for the European Commssion, Final Report, June 2019.

27.4.4 Market surveillance

Apart from voluntary targets and subsidies for relevant research, there have been no mandatory policy actions in promoting post-consumer recycled content in ErP –or any other group of plastics-containing product for that matter. The main reason is reportedly that the recycled content of a plastic component cannot be verified. However, there are a few methods that claim to assess recycled content:
Accounting, auditing and certification of the production/recycling chain, according to prEN45557[940]. Within Europe and realising keeping the recycling group within the same ErP this 'paper trail' seems to be feasible at reasonable administrative burden for industry and MSA. The problem is the reliability of recycled content declarations for products imported from countries where it is difficult and certainly costly to set up an auditing practice. This might prompt 3rd party verification, a service that is already being offered by several large test houses like UL, Intertek, SGS, etc..

One method that is suggested could reduce the administrative burden of the above procedure is the use of tracers, e.g. minute quantities of fluorescents that are added to the recycled plastics for identification. The amount of tracers would then help assess the fraction of recycled plastics in a blend.

A different route from the paper trail to avoid *'greenwashing'* is that of laboratory tests. At the moment, the same test houses mentioned above offer various technologies to assess the number and type of impurities in recycled plastics. Test houses like Intertek propose (combinations of) *Nuclear magnetic resonance (NMR), Gel Permeation Chromatography (GPC), Inductively Coupled Plasma mass spectrometry (ICP) and X-Ray Fluorescence (XRF)* for the analysis of impurities in recycled plastics.[941] German equipment manufacturer Netzsch proposes *Differential Scanning Calorimetry (DSC)* in combination with their proprietary *Proteus* database/software as well as additional insight from *Thermal Gravimetric Analysis (TGA)* for the analysis of number and typology of impurities in recycled materials.[942]

Further research is needed, but it seems technically possible to assess recycled plastics content within appropriate verification tolerances.

27.5 Energy, Emissions and Costs

The EcoReport tool developed for Ecodesign analysis gives key environmental impacts of virgin versus recycled material for 3 plastics: HDPE, PVC and PET (see Table below).

940 https://www.eera-recyclers.com/files/cen-clc-tc10sec132dc-secr-enquiry-pren45557-recycled-material-content.pdf
941 https://www.intertek.com/analytical-laboratories/recycled-plastics/
942 https://ta-netzsch.com/how-to-control-the-quality-of-recycled-plastic-materials

Table 317. Ecoreport environmental impacts virgin versus recycled plastics (examples)

Source: VHK for virgin plastics, Fraunhofer IZM for recycled plastics[943]

Key impact per kg plastic	unit	HDPE	HDPEr	credit	PVC	PVCr	credit	PET	PETr	credit
Primary Energy	MJ	76.56	9.44	67.12	56.61	26.00	30.61	78.80	11.92	66.88
Electr energy	MJ	9.83	1.76	8.07	11.11		11.11	13.37	1.66	11.71
Feedstock fd	MJ	54.10		54.10	22.93		22.93	38.83		38.83
Water process	ltr	3.40	3.91	-0.51	11.00	69.20	-58.20	7.30	4.80	2.50
Water cooling	ltr	31.00		31.00	62.00		62.00	36.00		36.00
Waste hazardous	g	5.44		5.44	5.00		5.00	1.60	0.00	1.60
Waste non-hazardous	g	38.34	0.08	38.26	67.09		67.09	92.15	0.22	91.93
GWP Global Warming	kg CO2 eq.	1.81	0.67	1.14	2.16	2.06	0.10	3.11	0.80	2.31
AD Acidification	g SO2 eq.	6.09		6.09	14.99	1.67	13.32	34.37	0.00	34.37
VOC Volatile Organics	g	0.16		0.16	0.00		0.00	1.30	0.04	1.26
POP Persistent Organic	ng i-Teq									
Hma Heavy Metals air	mg Ni eq.							2.27	0.03	2.24
PAH Polyclic Aromatics	mg Ni eq.	0.34		0.34	0.03		0.03	1.45	0.00	1.45
PM Particulates	g	0.86	0.05	0.81	2.90		2.90	5.00	0.04	4.96
HMw Heavy Metals water	mg Hg/20	0.00		0.00	2.81		2.81	0.00	0.00	0.00
EP Eutrophication	g PO4	29.82	0.06	29.75	313.99	1.84	312.15	380.26	2.06	378.20

Recycled instead of virgin plastics saves 100% on feedstock, waste, cooling water and PAHs. Almost complete (97%-99%) savings on acidification, VOC, POP, particulates, eutrophication and heavy metals emissions. There is on average a 78% saving on primary energy (67 MJ/kg on average) and 50% saving on Global Warming Potential (2.31 kg CO2 eq.). Only for process water, recycling uses more than producing the virgin material.

Especially as regards the energy and global warming potential, there is the alternative route of energy recovery, i.e. incineration with waste heat recovery usually where the plastics are a fraction in incinerated municipal solid waste (MSW). An American study assessed the lower heating value of HDPE in MSW to be ~37 MJ/kg. So, instead of saving 67 MJ/kg of primary energy (virgin minus recycling), one could also compare this 67 MJ/kg with the 37 MJ/kg from energy recovery and come to a saving of 30 MJ/kg from recycling.

As regards the monetary costs, assuming an average virgin plastics cost of €2/kg and a recycled plastic costs of €1/kg, replacing virgin by recycled plastics will save 50% on strict materials cost. Having said that, due to the procurement and quality aspects being more critical, additional costs for recycled plastics can be expected. Still, a 25% monetary saving (€0.25/kg) seems a fair assumption.

Naturally, these are only rough estimates that will need to be investigated in a comprehensive study.

943 https://ec.europa.eu/growth/industry/sustainability/ecodesign_en (EcoReport)

27.6 Saving potential

Recycled content of plastics is part of the MEErP-accounting but in terms of environmental impacts usually dwarfed by impacts during the use phase and --with one exception[944]-- has not led to proposals for policy measures. For horizontal measures in this field new priorities need to be set.

The target of 10 Mt of recycled plastics in 2025 means that 20% of the 51 Mt EU plastics input would come from recycled plastics. For ErP and in 2030 an extra ~0.5 Mt of recycled plastics would seem realistic. For ErP in 2040 an extra 1 Mt recycled plastics would be inline with the commitment from the European Plastics industry.

Following the previous paragraph, using 0.5 Mt of recycled plastics instead of 0.5 Mt of virgin plastics gives 33.5 PJ primary energy saving, equivalent to 9.3 TWh primary energy saving annually. Using 0.5 Mt of recycled plastics instead of incinerating with heat recovery 0.5 Mt non-recycled plastics gives 15 PJ primary energy saving, equivalent to 4.2 TWh primary energy saving annually. In 2040, at 1 Mt recycled plastics for ErP, the primary energy savings are double, i.e. 18.6 TWh or 8.4 TWh primary energy.

In monetary terms, at a saving of €0.25/kg, the annual saving for the EU would amount to €125 million in 2030 and €250 million in 2040.

The recycled plastics promotion would involve all market actors, from materials-industry[945] to suppliers[946], various end-product industries[947], distributors[948], consumers[949], recyclers[950], etc.

Table 318. European Plastics Industry facts & figures

European Plastics Industry	# Employees	€ bn Turnover	#Companies
Plastics Manufacturers	140,000	100	2,000
Plastics Converters	1,600,000	260	50,000
Plastics Recyclers	30,000	2	1,000

source: circularplastics.org

27.7 Stakeholder comments

Stakeholder comments focus on the problems of enforcing the difficult-to-measure recycled content and there is always the fear that the legislator will set unrealistic mandatory

[944] In the recent Review study on Vacuum Cleaners (ibid. 1) specific Ecodesign measures were proposed on recycled content of plastics, but the proposal was rejected in the 2nd stakeholder meeting on the grounds on insufficient confidence in the effectiveness of market surveillance. Consequently it was not followed up.

[945] Plastics Europe, CEFIC

[946] EU Plastics Converters (EUPC), Polyolefin Circular Economy Platform (PCEP), European Carpet and Rug Association (ECRA), PETcore Europe, Vinyl Plus

[947] APPLiA, EHI, Digital Europe, etc.

[948] E.g. EuroCommerce.

[949] ANEC-BEUC

[950] Plastics Recyclers Europe, EERA and others

minimum limits. However, as with light-weighting, the (long term) goal is to have a balanced approach. Recycled content and recycling are two segments of the same circle and some extra effort in one can compensate the other. With China no longer importing recycled plastics and low oil prices bringing the price of virgin plastics down, just focussing on recycling without looking at recycled content is not sustainable.

Industry associations like CEMEP and DIGITALEUROPE welcome the focus on recycled content as a study subject in the Working Plan to face the many challenges to further uptake of especially recycled plastic, but stress it is as yet too early for mandatory measures.

APPLIA and others confirm the study team's assessment of the current surveillance problem, i.e. verifying the claims for use of recycled content in physical terms rather than through a paper trail.

28 ECOLOGICAL PROFILE

28.1 Background

Annex I of the Ecodesign Directive 2009/125/EC describes the method for setting generic ecodesign requirements aiming at improving the environmental performance of products, and focusing on significant environmental aspects thereof without setting limit values.

Each phase of the life cycle of products (raw material selection and use; manufacturing; packaging, transport, and distribution; installation and maintenance; use; and end-of-life) shall be taken into account in the analysis of significant environmental aspects related to product design.

Annex I part 1 of Ecodesign Directive 2009/125/EC: Ecodesign parameters for products

Certain environmental aspects are listed in part 1 of Annex I of the Directive to be analysed for each of the life cycle phases:

- predicted consumption of materials, of energy and of other resources such as fresh water;
- anticipated emissions to air, water or soil;
- anticipated pollution through physical effects such as noise, vibration, radiation, electromagnetic fields;
- expected generation of waste material; and
- possibilities for reuse, recycling and recovery of materials and/or of energy

These aspects are further specified for evaluating the potential for improving the environmental aspects:

- weight and volume of the product;
- use of materials issued from recycling activities;
- consumption of energy, water and other resources throughout the life cycle;
- use of substances classified as hazardous to health and/or the environment;
- quantity and nature of consumables needed for proper use and maintenance;
- ease for reuse and recycling as expressed through: number of materials and components used, use of standard components, time necessary for disassembly, complexity of tools necessary for disassembly, use of component and material coding standards for the identification of components and materials suitable for reuse and recycling (including marking of plastic parts in accordance with ISO standards), use of easily recyclable materials, easy access to valuable and other recyclable components and materials; easy access to components and materials containing hazardous substances;
- incorporation of used components;
- avoidance of technical solutions detrimental to reuse and recycling of components and whole appliances;
- extension of lifetime as expressed through: minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability, reparability
- amounts of waste generated and amounts of hazardous waste generated;
- emissions to air, water and soil.

Although for some of these Ecodesign parameters, such as reparability or minimum time for availability of spare parts, specific ecodesign requirements have been recently included in the Ecodesign regulations adopted in the end of 2019, for other parameters such as incorporation of used components or the use of hazardous substances, the application of generic mandatory minimum requirements under the Ecodesign Directive could be far more complex.

Therefore, part 3 of Annex I of the Directive generally foresees a different approach for these generic Ecodesign requirements, described as follows.

Annex I part 3 of Ecodesign Directive 2009/125/EC: Requirements for the manufacturer
Manufacturers of products must perform a product assessment throughout its lifecycle based upon realistic assumptions about normal conditions and purposes of use, addressing those environmental aspects identified in the implementing measure as relevant. On the basis of this assessment, manufacturers must establish the product's "ecological profile" which must be based on environmentally relevant product characteristics and inputs/outputs throughout the product life cycle expressed in physical quantities that can be measured.

The Commission has to identify benchmarks in the implementing measure on the basis of information gathered during the preparation of the measure.

Manufacturers must then make use of their assessment to evaluate alternative design solutions and the achieved environmental performance of the product against these benchmarks. The choice of a specific design solution must achieve a reasonable balance between the various environmental aspects and between environmental aspects and other relevant considerations, such as safety and health, technical requirements for functionality, quality, and performance, and economic aspects, including manufacturing costs and marketability, while complying with all relevant legislation.

To date, the setting of generic Ecodesign requirements based on the ecological profile as a whole of a product without setting limit values for particular environmental aspects has not yet been applied in any of the product-specific regulations under EU Ecodesign.

Related to this approach, however, back in 2017 a study was published on the assessment of the feasibility and usefulness of introducing Ecodesign requirements especially for complex products or product systems via using a "points system" method, exemplified for two case studies on data storage systems and machine tools. The general approach and conclusions of that study[951] are summarized below.

28.2 Development and analysis of a points-systems methodology under EU Ecodesign

The "points-system study" aimed at providing the European Commission with technical assistance in the evaluation and derivation of a points-systems methodology that could be applied to the development of generic Ecodesign implementing measures especially for

[951] See https://points-system.eu

complex products or product systems such as for example machine tools, data storage devices or professional washing machines and driers. These are complex in a sense that they may have more than one functional unit due to the variety of functions the product is capable of performing, can be modular, are often customised products adapted to a specific application, i.e. lack of a stable usage profile, and can be finally installed at the user's site, i.e. they have varying degrees of heterogeneity that complicate their assessment against common metrics and measurement methods.

The study started with a review of state-of-the-art methods and assessed a variety of multi-criteria environmental impact assessment methods and points-systems based decision making models to examine their characteristics and assess their potential applicability for adaptation and use in the appraisal of Ecodesign requirements for complex products as well as their compatibility with the MEErP and Ecoreport tool approaches under EU Ecodesign (Waide et al. 2017). The analysed methods included inter alia the international standards on Life cycle assessment, principles and framework (ISO 14040) and requirements and guidelines (ISO 14044), the Product Environmental Footprint (PEF) methodology, multi-criteria environmental impact assessment approaches of buildings (BREEAM, LEED and DGNB), or the points systems used for eco-labelling and green public procurement. Also, three different weighting techniques, i.e. approaches to combine different environmental effect indicators based on their relative importance to derive an overall assessment score, were described and evaluated to consider their relative strengths and weaknesses for potential application in an Ecodesign related points scheme.

- Delphi-or panel methods, where a group of experts representing different stakeholders are asked to provide their weighting factors;
- Distance-to-target methods, where the weighting factors for each environmental impact or theme depend on the difference between the current performance and a target level;
- Monetisation or external costing methods, where the weighting factors are expressed in monetary values (external environmental costs) according to the estimated economic damage incurred in an impact category or to what is necessary to prevent the damage itself.

The overall analysis concluded that most of the existing methodologies are more suited to the setting of specific thresholds as to be used in Annex II (Method for setting specific ecodesign requirements), whereas only some of the methods also contain elements that would be suited to setting generic Ecodesign requirements i.e. such as would be used in Annex I of the Ecodesign Directive, however none of the being directly applicable.

Based on these findings, the study developed a proposal for an Ecodesign points system designed to complement the existing MEErP methodology and the overall Ecodesign regulatory process. The approach consists of 9 assessment steps used for the determination of whether a points system approach is justified and feasible in principle and, if this is confirmed to be the case, for awarding points:

1. Step 1: Assessment of key lifecycle stages
2. Step 2: Assessment of product scope boundaries and associated impacts at the wider (extended product or product-system) level
3. Step 3: Selection of environmental impact criteria
4. Step 4: Determination of the phases at which product design may influence lifecycle impacts

5. Step 5: Assessment of whether a points system approach is potentially merited or not. The methodology approach provides three questions to ask and if the answer is Yes to any of those, then a points approach may be appropriate:
    a. Are there a mix of quantifiable (cardinal) and more qualitative product ecodesign features, ANDis it appropriate to also ascribe some value to the qualitative features because these are expected to bring eco-design benefits?
    b. Although the presence of specific ecodesign features are known to bring ecodesign benefits, is the relative importance of the benefit to a given ecodesign performance parameter difficult to determine in a reliable manner, and at the level at which the scope of a prospective regulation would be expected to apply?
    c. Is it too complex to apply a rigorous performance assessment method in practice, but could a points-based approach (which awards points depending on the eco-design features used) provide an acceptable compromise that allows requirements to be set that encourage progress in a positive direction without being overly constraining?
6. Step 6: Assessment of the implications of product modularity
7. Step 7: Assessment of the implications of product performance sensitivity to the final application
8. Step 8: Determination of environmental impact budgets
9. Step 9: Normalisation and awarding of points (NB on a product-specific basis)

In two case studies, the points system approach was applied to data storage systems and machine tools. The case study on machine tools concluded that the method enables complexity to be addressed; recognises and rewards good eco-design practices; is designed to award points for design options in proportion to their expected effect on the impact parameter in question; is capable of working for unique customised machine tool designs; is adapted to address product modularity; fits within the MEErP methodology, although it does not require some of the steps, and does require the input of detailed information on expected savings from using specific design options at the module level; is capable of working with the Ecodesign and energy labelling regulatory process; and is technically feasible from a conformity assessment perspective, but will require a more elaborate procedure than is the case for simpler products (Rohde et al. 2017)

28.3 Similar points system approaches in EU product policy

28.3.1 Application of a points system in the EU Ecolabel for hard floor coverings

The criteria for awarding the EU Ecolabel for hard covering products (draft legal text of 2020) are based on a combination of mandatory requirements and optional requirements where points are awarded either for going beyond the minimum mandatory requirements or for complying with optional criteria. For the EU Ecolabel to be awarded, applicants must comply with all mandatory requirements and attain the minimum required number of points set for each specific product. The criteria are consequently more flexible than before and maximise the steerability for applicants and license holders. Such an approach is seen as encouraging continuous improvement towards the maximum score possible. (Donatello et al. 2020)

The scoring system and the minimum number of points necessary are presented in the table below exemplified for the EU Ecolabel for natural stone products. (DG JRC 2020).

Table 319: Scoring system for the EU Ecolabel for natural stone products.

Criteria where points can be awarded	Intermediate blocks or slabs of dimension or ornamental stone	Final transformed natural stone products
1.3. VOC emissions	n/a	0 or 5 points
1.7. Environmental Management System (of quarry)	0, 3 or 5 points	n/a
1.7. Environmental Management System (of transformation plant)	n/a	0, 3 or 5 points
2.1. Energy consumption at the quarry	Up to 20 points	Up to 20 points
2.2. Material efficiency at the quarry	Up to 25 points	Up to 25 points
2.6. Quarry landscape impact ratios	Up to 10 points	Up to 10 points
2.7. Energy consumption at the transformation plant	n/a	Up to 20 points
2.8. Water and waste water management at the transformation plant	n/a	Up to 10 points
2.10. Process waste reuse at the transformation plant	n/a	Up to 10 points
2.11. Regionally integrated production at the transformation plant	n/a	Up to 5 points
Total maximum points	**60**	**100+5**
Minimum points required for EU Ecolabel	**30**	**50**

28.3.2 Proposal of a scoring system for repair and upgrade of products

Currently, the Commission is studying the possibility of a scoring system on the reparability of products, in the context of the contribution of the Ecodesign and Energy Labelling framework to the objectives of the Circular Economy. In 2019, the Joint Research Centre (JRC) completed a report on the analysis and development of a scoring system for the repair and upgrade of products. (Cordella et al. 2019)

Twelve technical parameters were identified that can be potentially taken into consideration to assess the reparability and upgradability of products. They shall be applied to each of the priority parts identified at product group level, i.e. components that are functionally important and at the same time likely to fail or to be upgraded.

1. Disassembly depth / sequence
2. Fasteners
3. Tools
4. Disassembly time
5. Diagnosis support and interfaces
6. Type and availability of information
7. Spare parts
8. Software and firmware

9. Safety, skills, and working environment
10. Data transfer and deletion
11. Password reset and restoration of factory settings
12. Commercial guarantee

The scoring system requires the definition of classification/rating criteria, to evaluate single parameters in relation to a set of priority parts of the products to be analysed; appropriate assessment and verification procedures; as well as an aggregation mechanism, to combine the scores achieved for each parameter and priority parts.

A hybrid system (see table below) is proposed by (Cordella et al. 2019):

a) Pass/fail criteria that products have to fulfil in order to be eligible for the repair/upgrade rating; these are the "minimum" entry level for the scoring system: a product that does not fulfil pass/fail criteria would score 0 in the assessment of reparability and upgradability even if scoring higher for other parameters.
b) A scoring framework based on scoring criteria, indicating to what extent/ how much a product is reparable or upgradable. Points ranging from 0 to 1 have been modulated proportionally to different rating classes for each parameter assessed at priority part/product level. 0 corresponds to the case in which repair/upgrade is not considered possible. Points above 0 have been set to conditions facilitating the repair/upgrade of products, with 1 being the ideal condition. Since the fulfilment of pass/fail criteria is by definition considered to enable main repair/upgrade operations, a score higher than 0 is in general assigned in the corresponding rating/classification criteria

Table 320: Hybrid system for scoring.

Parameter	Pass/fail criteria	Rating classes [a]	Support to assessment (A) and verification (V)
1) Disassembly depth/sequence	For each priority part, information about the disassembly sequence has to be available to the target group of repairers (see #6) Note(s): 1) target group of repairers to be defined for each priority part at product specific level 2) The disassembly sequence is defined as the order of steps needed to remove a part from a product (which might include getting access to fasteners). A step consists of an operation that finishes with the removal of a part, and/or with a change of tool[35]. 3) In general, it is considered that the removal of one or additional fasteners in a consecutive way and with the same tool has similar impact on the ease of disassembly. Therefore, the consequent removal of a group of fasteners with the same tool is considered a step.	A score is assigned for each priority part based on their disassembly depths (DD_i). A continuous rating can be calculated as: $S_{1,i} = 1 - (DD_i - 1) / (DD_{ref} - 1)$ where: DD_i is the depth for the priority part i; DD_{ref} is the reference depth for the priority part i. The score is set to 0 if (DD_i – 1) is greater than (DD_{ref} – 1). Alternatively, a discrete rating could be considered: I) DD_i < X steps = 1 pt. II) X < DD_i < Y steps = 0.75 pt. III) Y < DD_i < Z steps = 0.5 pt. IV) DD1 > Z steps = 0.25 pt. Where: X, Y and Z have to be defined for each priority part of the product group under assessment. Note(s): 1) The disassembly depth is the number of steps required to remove a part from a product. 2) Threshold values to be defined based on the analysis of representative products on the market.	A: A description supported by illustrations of the steps needed to disassemble priority parts is needed. The description has to show that the disassembly is reversible by including the steps needed for the reassembly of priority parts. V: physical disassembly and recording of the operation are needed. Note(s): This is considered sufficient to address the reversible disassembly of priority parts, as also done in the prEN 45554 (November 2018). The inclusion of the reassembly of parts in the rating could be considered as well in future applications.

When the generic scoring framework is applied to specific products, it is necessary to evaluate the relevance of each pass/fail and rating criterion and to tailor the criteria in order to reflect the specificities of the product(s) and of the related priority part(s). The study applied the generic scoring system exemplary to the product categories laptops, washing machines and vacuum cleaners.

At a Consultation Forum Meeting in July 2019, the Commission services discussed with stakeholders the state of the play considering the potential implementation of such a reparability scoring system within the Ecodesign and Energy labelling frameworks, as they allow the possibility to set minimum requirements on repair aspects (as recently done for a number of products under Ecodesign) and provide information to consumers through both instruments. In this context, the Commission has also contracted a study to assess how reparability information can be presented to consumers so that they understand it and it has the most effective influence on their purchasing behaviour. Depending on the results, the Commission services will develop a proposal for an implementation approach.

28.4 Possible routes of establishing an "ecological profile" under the EU Ecodesign and Energy Labelling Working Plan

So far, in all Ecodesign regulations adopted under Ecodesign Directive 2009/125/EC, mainly Annex II - the method for setting specific minimum ecodesign requirements - has been applied besides some generic ecodesign requirements relating to the supply of information. According to the Directive, when it is not appropriate to set limit values for the product group under examination, then the method referred to in Annex I must be applied, establishing an ecological profile to be assessed and provided by the manufacturer to evaluate alternative design solutions and the achieved environmental performance of the products against benchmarks.

Annex I, however, has not yet been used at all, although additional improvement potential would be possible compared to what is achieved by Annex II only. Annex I would be incentivising improvement potentials for products on the European market related to certain benchmarks, whereas Annex II sets restrictive minimum levels to be achieved by all products to be placed on the European market to demonstrate their compliance.

28.4.1 Annex I (generic ecodesign requirements) instead of Annex II (specific ecodesign requirements)

The idea of using Annex I instead of Annex II would be applicable and favourable in following cases where the setting of specific ecodesign requirements being applicable to all products placed on the market is most challenging:

1. Improving the environmental performance of **rather complex products and product systems**
    - Limitations of Annex II so far: Difficulty in setting specific ecodesign requirements due to variety of functions and impacts/improvement potentials being highly application-dependent; difficulty in identifying average or characteristic usage profiles (duty cycles); partly no implementing measures adopted at all after preparatory study process, or only voluntary agreement

- Idea of application of Annex I: possibility of taking into account customized approaches; more flexibility for manufacturers to use a mix of measures to reach a specified level of performance improvement instead of adopting no requirements at all due to methodological constraints in setting specific minimum requirements; exploiting the high improvement potential of these product groups which would else not be covered by Ecodesign measures
- Product examples where Annex I might be applicable: customized professional laundry and dishwashing appliances, solar photovoltaic systems, data storage systems, professional machine tools, medical equipment, Building Automation and Control Systems, etc.

2. Improving the environmental performance of products with comparably lower environmental impacts and improvement potential / energy savings during use phase but **high impacts / improvement potential of raw material extraction, manufacturing and End-of-life phases**.
    - Limitations of Annex II so far: Rather generic assessment approaches within MEErP / EcoReport tool for the life cycle phases regarding raw materials extraction, reuse/lifetime extension and recycling, thus not benefitting and incentivising enough product specific design options
    - Idea of Application of Annex I: Improvement potential could be better addressed by dedicated design options as listed in Annex I: Extension of lifetime, incorporation of used or post-consumer recycled components, design to facilitate reuse, design to facilitate recycling
    - Product examples where Annex I might be applicable: Smartphones, games consoles, printers, battery operated appliances (handheld power tools, etc.)

3. Improving the overall environmental performance of products with **environmentally relevant use of consumables**
    - Limitations of Annex II so far: Rather generic assessment approaches within MEErP / EcoReport tool for consumables not benefitting enough specific product design options; often no implementing measures regarding product specific design options on reducing the impacts of related consumables
    - Idea of Application of Annex I: Improvement potential could be better addressed by taking into account design options as listed in Annex I: quantity and nature of consumables needed for proper use and maintenance
    - Product examples where Annex I might be applicable: Printers (e.g. product design facilitating the use of reused/recycled cartridges), washing machines / dishwashers (product design leading to reduced consumption of detergents).

4. Improving the overall environmental performance of products with mainly **indirect environmental impacts**, e.g. by shifting impacts of the use phase into the cloud
    - Limitations of Annex II so far: No assessment approaches within MEErP / EcoReport tool for indirect environmental impacts caused by large data streams / high network utilization
    - Idea of Application of Annex I: benefitting specific design options on data sufficiency, reducing software related obsolescence, etc.

- Product examples where Annex I might be applicable: Smart appliances, smartphones, interconnected home audio, video & voice service equipment interoperable IT solutions, networking equipment.

Specific requirements as addressed by Annex II of the Directive are likely to have the most certain effectiveness and hence are the most powerful regulatory tool; however, as they remove products with low performances from the market they also require the greatest certainty of net benefit prior to their introduction. In cases where this is challenged by methodological constraints, major environmental improvement potential of the Ecodesign regulatory framework will not be exploited if this leads to potentially weak implementing measures, only voluntary agreements, or, at the worst, to no regulatory measures for certain product categories at all. On the other hand, applying Annex I, i.e. setting generic ecodesign requirements based on ecological profiles in those fields of constraints as illustrated above, gives the possibility of a more flexible treatment with the ability to capture, value and encourage also (future) product specific innovations.

According to feedback of a stakeholder, the following approach for implementation of Annex I Part 3, the requirements for the manufacturer, is proposed:

The basic idea would be that the Ecological profile is available to end-users and that a general improvement of the Ecological profiles can be observed over the course of time, e.g. due to improved product lifetime, reduced impact from manufacturing, light weighting, substituting materials, etc. The approach could be implemented via pure product information requirements:

- Establishing the Ecological profile of the respective model (and providing the information to the end-user).
- The Ecological profile should (not shall) be more favourable than the benchmark.
- If it is less favourable an explanation shall (not should) be provided.

If the Ecological profile is established correctly and an explanation is given (public summary document, where relevant), the model complies.
The benchmark could be defined flexible and should be dynamic:

- as performance of a preceding/older model in the product line of a manufacturer.
- as the average performance of all models of the previous year.
- as a generic, improving benchmark projected in the future (and set in the Implementing Measure).

According to the stakeholders feedback, the Ecological profile approach could be 'tested' on for example on insulation materials due to the following reasons:

- Insulation materials are relatively simple products.
- The construction sector has experience with Ecological profiles (called EPDs; available in several Member States).
- Product Environmental Footprint Category Rules (PEFCRs) for thermal insulation[952].
- There is a 2013 Ecodesign/Energy Labelling study which could be revised.

Especially for construction products, Ecological profiles could be used in a relevant way to assess buildings. An example is TOTEM ("Tool to Optimise the Total Environmental impact

[952] https://ec.europa.eu/environment/eussd/smgp/pdf/Thermal%20Insulation%20final-Oct2019.pdf; last accessed on 16 Oct 2020

of Materials")[953], a web-based calculation tool that enables environmental impact calculations at the building (element) level. The tool is targeted at building designers, and enables them to handle (and communicate) environmental trade-off and synergies for highly variable projects in an objective, transparent and scientifically grounded way. Manufacturers of construction products can upload their Ecological profiles (i.e. EPDs) in a database, linked to such a tool. The building designer can compare and choose the most appropriate solution.

28.4.2 Hybrid approach, combining Annex I and II implementing measures

Annex I and Annex II might also be applied in a hybrid approach where a product still has to meet certain specific minimum requirements but has to demonstrate in parallel a design optimisation process with regard to the environmental aspects listed under Annex I. A points system with a minimum points score specified for mandatory requirements and additional points awarding the implementation of broader Ecodesign principles might be a possibility to establish both generic and specific Ecodesign requirements. Also, in principle, Annex II is deemed as equally applicable for regulatory or voluntary implementing measures.

28.4.3 Combining Annex I and II implementing measures in different product policy instruments

Finally, applying Annex I (generic requirements) and Annex II (specific requriements) could be used by combining different sustainable product policy instruments (Ecodesign, Energy Labelling, Ecolabel, or Green Public Procurement) to achieve synergies. For example, starting from Ecodesign and Energy labelling resulting in specific mandatory minimum requirements, more advanced generic ecodesign criteria, e.g. based on a points system, might be developed and applied within the EU Ecolabel and GPP policy instruments.

This approach was first used in the preparatory study on Solar Photovoltaic modules, inverters and systems commissioned by DG GROW and carried out by the Joint Research Centre, Seville[954]. The aim of this project was to develop an integrated preparatory study on sustainable product policy instruments to assess the feasibility of applying in parallel Ecodesign, Energy Label, Ecolabel and Green Public Procurement instruments to solar photovoltaic modules, inverters and systems. The preparatory study takes into account the different stringency, scopes, targeted life cycle stages as well as verification schemes of these policy instruments, as outlined in the following table taken from Task 7 of the preparatory study.

[953] See https://www.totem-building.be; last accessed on 16 Oct 2020

[954] See https://susproc.jrc.ec.europa.eu/solar_photovoltaics

Table 321: Example of combining Annex I and Annex II in the preparatory study on Solar Photovoltaic modules.

Policy Instrument	Stringency	Scope	Life cycle stage	Verification
Ecodesign	Mandatory	Products, packages of products	Requirements can be set on tested use stage product performance, although material efficiency requirements relating to other life cycle stages have been implemented as both requirements and information requirements. Annex V of the Directive also allows for a management system for design through manufacturing to be used for conformity assessment.	Market surveillance is carried out at member state level.
Energy label	Mandatory	Products, packages of products	The chosen Energy Efficiency Index (EEI) shall address performance in the use stage. It is not clear if the EEI can be applied to other life cycle stages.	Market surveillance is carried out at member state level.
EU Ecolabel	Voluntary	Can be products or services	Criteria can be set on any life cycle stage and can include manufacturing sites as well as tested product performance.	Member State Competent Bodies verify compliance evidence and award the label.
Green Public Procurement (GPP)	Voluntary	Can be products or services	Criteria can be set on any life cycle stage and can include manufacturing sites as well as tested product performance. The criteria must always link to the subject matter.	Verification is through evidence from tenderers provided during the procurement process.

In combining different policy instruments through setting specific minimum requirements based on Annex II of Directive 2009/125/EC in the context of Ecodesign and Energy labelling regulations, and in parallel awarding product design optimisation with regard to the environmental aspects listed under Annex I in the context of EU Ecolabelling or Green Public Procurement, the environmental improvement potential of products and systems could be utilized in the most effective way.

28.5 Stakeholder comments

The following advantages of the development of an ecological profile and/or a points system under the Ecodesign framework are seen by some stakeholders:

- The establishment of "ecological profiles" for certain categories of products could facilitate manufacturers to evaluate alternative design solutions and the achieved environmental performance of the products against benchmarks.
- Assessing the ecological profile of appliances could be an instrument to evaluate the overall environmental impact of appliances, and in particular with regard to material efficiency aspects. A multi-dimensional view is better alignable to the different design strategies of manufacturers for sustainability and can better take

into account possible trade-offs e.g. with regard to durability and reparability; durability and recyclability; light-weighting and use of recycled material etc.

- The points-system approach could encourage further firms to take action towards more sustainable products and also have a positive impact on consumption by empowering citizens being able to choose their products with greater transparency.
- If properly adapted, the ecological profile could be used for industrial products.

On the other hand, the following limitations of an ecological profile according to Annex I of the Ecodesign Directive 2009/125/EC were mentioned by some stakeholders:

- By establishing an ecological profile, not all products will fulfil the same minimum requirements anymore which would be against the principle of developing a level playing field using the Ecodesign regulation.
- The fact that product manufacturers are in charge of assessing their own products represents a risk.
- Regarding the methodology, the setting of benchmarks by the Commission is deemed as not being an easy task; on the other hand, if it would be possible to set benchmarks it is questioned why these would not be used for setting specific requirements. Also, evaluating alternative design solutions seems to be a relatively broad term, which might be satisfied by minor (not relevant) changes in the design. Finally, the reasonable balance criterium does not likely allow for a negative verification, i.e. it will be very difficult to argue that a manufacturer has not struck a reasonable balance (and thereby does not comply), even in case a design is used with a relatively high environmental impact because this will be argued as necessary for functionality/quality/performance/economic aspects. Also here: if such balance could be quantified, then also specific requirements could be set.
- An ecological profile requirement will add costs which should be considered in terms of impacts to reflect the market dynamics and growth trends.
- With an ecological profile according to Annex I, the evaluation of environmental impacts and potential for improvement cannot be common criteria and minimum requirements due to the nature of the methodology and its qualification/quantification. It would rather be appropriate to handle this information as referential values evaluated based on the settings of various conditions. Annex I and Annex II are different processes and approaches; the idea of "combining Annex I and II implementing measures" is seem as applicable to limited cases only.

Limitations were also seen by some stakeholders with specific regard to a points system:

- Especially with regard to extension of product lifetime through repair, an additional scoring system e.g. on the energy label is questioned as for some products minimum ecodesign requirements have just been agreed so that it is recommended that the impact of these new requirements should be assessed first.
- A scoring system risks to be designed with elements that could be considered subjective, leading to market distortions. Within each type of product, the models can vary greatly in their function, performance and complexity. Aggregating results into one overall score has the potential to be misrepresentative, depending on how the score is calculated.
- The proposal to share the reparability/upgradability scoring index with consumers on the label of the products could represent a competitive disadvantage for products requiring professional repair services, not intended to be upgraded (hardware

perspective) or be repaired by end-users, such as for example complex set-top boxes or small network equipment.

- Also, a reparability scoring does not give any information about the likelihood that a product will be effectively repaired.
- A point system would complicate the task of market surveillance authorities who would have to check all features for which "points" are provided and then evaluate if the product has sufficient points to be considered as compliant. This will increase the workload in developing requirements and standards to verify compliance with the criteria.

Against these limitations, the following prerequisites are necessary according to stakeholders' feedback for the implementation of an ecological profile or a points system:

- One stakeholder recommends that the two topics of a points system methodology and a scoring system for repair and upgrade should not be mixed up with the ecological profile since they have a broader application (the points system) or have little to do with an ecological profile as such (scoring system for repair and upgrade).
- For measuring reparability, the need for a single, EU-wide methodology is seen rather instead of various different and/or national initiatives. Also, any scoring should be based on product-specific EU standardisation work.
- Point- or scoring-systems for different eco-design aspects (e.g. reparability) need to be specifically defined for each product category
- A scoring system shall truly reflect real environmental impacts of products. Each impact shall be weighted in a proportional manner versus others.
- It is recommended that the proposed scoring system for repair and upgrade of products should be applied differently to industrial products due to the different design and life requirements in comparison to consumer products (e.g. some industrial products cannot be disassembled).
- If a label is required, it is recommended to make an integrated durability & repairability label as for some product groups, reliability could have higher importance than reparability and upgradeability. No repair label should incentivise putting low-quality products that easily break, but are repairable, on the market. Also a European Commission study[955] has shown that the effect of such information is "strongest when durability and reparability information was presented together". It showed that durability is more important for consumer decisions, whereas "reparability only marginally led participants to choose products with overall better credentials to Circular Economy".
- One stakeholder points out that there is a proliferation of different methods to assess the environmental impacts and green claims of products; the introduction of possible ecological profile requirements shall support the EU single market.
- The ecological profile according to Annex I of the Ecodesign Directive 2009/125/EC should not be used in a way that it weakens attempts to set limit values, and should not be used by some stakeholders as a way to delay or circumvent hard regulation.
- Setting an ecological profile should be prioritised for those product categories with a lower focus on possible efficiency improvements.
- According to one stakeholder, the environmental aspects of Annex I Part 1 and the information requirements in Annex I Part 3 could be agreed as long as the information can be acquired from secondary data.

[955] https://ec.europa.eu/info/sites/info/files/ec_circular_economy_executive_summary_0.pdf

- As an alternative, it could be investigated how Annex I, Part 2 can be used to improve the situation regarding (public) information on materials in products, i.e. by requiring a material passport for each product.
- It is recommended by a stakeholder that the methodology for the ecological profile should be consistent and reproducible with other product policies. This would imply a revision of the MEErP methodology to take into account developments such as the Product Environmental Footprint, PEF, and integrate aspects that consider recycled content and recyclability e.g. through the PEF circular footprint formula.
- Also another stakeholder encourages the Commission to avoid establishing disparate approaches across product legislation, to avoid consumer confusion and to ensure consistency and fairness across sectors. In this respect, Annex I of the Ecodesign Directive could be revised to outline the Methodology for Establishing a Product Environmental Footprint Category Rule (PEFCR) for products in the scope of the Ecodesign Directive. This could be integrated into the Methodology for the Ecodesign of Energy related Products (MEErP), currently under revision. Subsequent revision of the implementing legislation would see PEFCR's developed, initially for information requirements, as a potential basis for future minimum requirements under Annex II.
- One stakeholder suggested as part of the ecological profile information requirements to be disclosed on specific dimensions, notably on material and chemical contents (= Bill of Materials, BOM); on chemicals, starting with substances of very high concern (SVHC) as planned by the SCIP[956] database of the European Chemicals Agency ECHA, but not limited to those, and to be documented per model of product; and specific dimensions of an ecological profile, such as Carbon Footprint and Abiotic Resources depletion in line with the Commission's rules on life cycle assessments (= Product Environmental Footprint, PEF).
- Another stakeholder recommends that economic aspects of each design option should be weighted in the methodology so that the environmental performance of products is improved without entailing significant negative impact on consumers, in particular as regards the affordability of products.
- Also, as product manufacturers are in charge of assessing their own products, the use of a unified survey or control mechanism by notified bodies should be encouraged and incentivised to ensure that environmental aspects are properly and substantially taken into account in the balance between environmental aspects and other relevant considerations and fraud is prevented. The efficiency of such a measure heavily relies on the system transparency, its reliability and a complete equality in the notation system.
- It is critical to ensure that MSAs are able to carry out compliance assessments in order to avoid distortions of the market and to protect consumers. It is therefore essential to make sure that potential requirements based on a point systems methodology are enforceable. The proposed methodology would require procedural checks (e.g. how the product design) rather than checks on the outputs via testing (e.g. minimum energy performance requirements, noise requirements, etc.). These procedural checks imply an in-depth technical knowledge to assess the application of design option on products that MSAs do not necessarily have.

[956] **S**ubstances of **C**oncern **I**n articles as such or in complex objects (**P**roducts), see https://echa.europa.eu/scip

29 DURABILITY[957]

29.1 Scope, policy measures and test standards

29.1.1 Scope

Taking as its starting point the application of the material efficiency and Circular Economy measures of the most recent Ecodesign and Energy Labelling regulations (published in the Official Journal in 2019), this study analyses the further improvement potential of policy options on the "durability" of energy-related products in the Ecodesign and Energy Labelling Working Plan 2020-2024.

According to the recently published European standard EN 45552:2020 *General method for the assessment of the durability of energy-related products*, "durability" (of a part or a product) is defined as *ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached. The degree to which maintenance and repair are within the scope of durability will vary by product or product-group*.

It should be noted that for the purpose of this study, measures to facilitate maintenance, repair[958], upgrade and reuse of products are included in the term "durability".

Enhancing the durability of products, i.e. increasing the reliability and technical lifetime by reducing failures and early breakdowns reflecting the state of a fully functioning product until the first failure occurs without any measures for repair being necessary, delaying ageing processes, or by repairing defective products for a "useful life prolongation", including measures to facilitate re-use (2nd life for a 2nd owner, i.e., second-hand sales) is an important part of a Circular Economy. Although it is not a new phenomenon, the topic of durability and reparability has in recent years become partly more political, thus demanding more societal attention – especially with regard to combatting premature obsolescence. In previous years, it could already be observed e.g. in consumer testing magazines like Which? (UK), Test Achats (BE) or Stiftung Warentest (DE), or in scientific studies like Prakash et al. (2020)[959] that the lifetime of many products was subject to some decreases. On the other hand, design approaches emphasising more durable products were not "mainstream", but were rather targeted to specific purpose applications (e.g. rugged appliances for heavy outdoor usage) and niche markets. Design for durability is not *a priori* a targeted product strategy of designers and manufacturers; rather, there must be technical, reputational (now increasingly associated with environmental "pedigree") or economic reasons for it.

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[957] Contribution by Kathrin Graulich (Oeko-Institute)

[958] According to stakeholder feedback, the concept of "durability" of products should not be understood as including repair activities; durability is rather about making products of better quality and less prone to wear and tear of single components that artificially shorten the lifetime. Therefore, it is recommended that the concept of "reliability" of products should also be introduced in the study, to refer to the actual length of a product's life.

[959] Prakash, S.; Dehoust, G.; Gsell, M.; Schleicher, T.; Stamminger, R. (2020): Influence of the service life of products in terms of their environmental impact: Establishing an information base and developing strategies against "obsolescence", 2020. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020-01-16_texte_09-2020_obsolescense_en_0.pdf, last accessed on 13 Jul 2020.

Durability tackles the first two '*R*'s in the Waste Framework Directive[960]: not only the '*R*' of *Reduce* but also *Re-use*. In a strict sense, second hand sales of products as well as refurbished products are outside the scope of the Ecodesign Directive. Nevertheless, the Ecodesign Directive can set design requirements to *facilitate* reuse and refurbishment[961].

As regards the further boundaries of 'durability' it is important to stress that in the topic for the Ecodesign and Energy Labelling Working Plan 2020-2024 we focus on product *design* options and do not include usage or business models of products to prolong their lifetimes (e.g. sharing concepts like shared laundry rooms instead of household washing machines, or rental or leasing business models like 'Device as a Service' (DaaS) for computers or printing devices). The reason for this narrower scope of application is because both the Ecodesign 2009 directive and the 2017 Energy Labelling regulation have a focus on the design of products per se, and much less on the "product-as-service" aspects, also owing to the replicability and market surveillance inspection/ testing difficulties that might come with "service" rather than "product" claims.

And although 'durability' has also a large economic and social component and there are safety and legal issues involved, here we would like to focus on the technical possibilities for durability (also since the other aspects mentioned above are dealt with primarily in other legislation measures).

Unlike the other '*R*'s — *Recycle, Recover,* and *Reuse*, focusing on the end-of-life, durability, i.e. the extension of the lifetime or products is mostly related to the use phase. With regard to environmental impacts, however, durability and reparability measures rather affect the manufacturing phase. Using products longer reduces the overall need for manufacturing new products and placing them on the market. On the other hand, trade-offs also have to be carefully assessed when analysing the environmental impacts of design approaches or other measures for extending products' lifetimes. Additional or different material effort to create durable products, additional material and spare parts effort due to repair cycles need to be accounted for, as well as potentially foregone energy savings and other resources savings, if the technology state of the original product being used for longer would be significantly lower compared to that of the new products on the market.

Under the policy framework of Ecodesign, the initial *analysis* of impacts due to decreasing lifetimes and benefits by potential durability requirements should generally apply as a horizontal approach to all product categories within the scope of the Ecodesign Directive. However, not all product categories might generally face problems with shorter lifetimes or benefit from durability measures. Therefore, the focus or prioritisation of setting related *implementing measures* on durability in forthcoming Ecodesign product groups, preparatory studies and resulting possible regulations could be placed particularly on the following types of product categories:

- Product categories with short, decreasing, or wide ranges of lifetime(s) and innovation cycles (identified e.g., according to available time series of data from consumer testing associations, market innovation reports or other sources);

[960] Directive 2008/98/EC on waste (Waste Framework Directive), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN, last accessed on 13 July 2020

[961] According to stakeholder feedback, this should be taking into account the limitations of approaches limited to design aspects; for example, reuse is also tied to substantial transaction cost (offering, transport, etc.) in particular for bulky and heavy-weight products.

- Product categories with high failure rates (identified e.g., through consumer testing associations, reparability networks or other sources);
- Product categories with comparably higher impacts in the manufacturing phase compared to the use phase throughout the lifecycle (identified e.g., through published full or streamlined life cycle assessments);
- Product categories with key functions with a relatively high dependence on software, and in turn, regular software updates (identified e.g., through the technical analyses in the Ecodesign preparatory studies).

Design approaches, and therefore also possible implementing measures and requirements related to durability, are rather vertical (i.e., product-specific, or related to a defined "family" of products), depending on product specific materials, key components and design approaches. Aspects to be analysed with regard to durability could be for example:

- Ageing and respective improving durability of materials;
- Robustness & reliability of key components, with a horizontal focus also on quality and lifetime of batteries in battery-operated products;
- "Durability" of software (i.e. support and updates throughout product lifetime)[962]; and
- Design for repairability including replaceability of key components through spare parts, with additionally a horizontal focus also on replaceability and accessibility of batteries in battery-operated products.

According to one stakeholder's feedback, the horizontal and vertical approach could be combined by introducing two tiers to addressing durability. The first tier could address overarching horizontal minimum requirements on durability (defining which ErP would be the exceptions to the application of specific aspects, for example by excluding product categories with long lifetimes, low failure rates, low manufacturing stage impacts, etc.). The second could address priority product groups where beyond these horizontal minimum requirements more stringent durability performance requirements could apply.

29.1.2 Durability-related policy measures in present and draft EU Ecodesign regulations under review

So far, only a few regulations stipulate Ecodesign requirements with a specific focus on durability per se, as listed below. However, with the package of regulations adopted in winter 2019, consolidated requirements have been introduced on reparability and upgradeability, such as spare parts replaceability and availability, and on maximum delivery time of spare parts as well as access to repair and maintenance information.

Ecodesign requirements with a specific focus on durability per se
Ecodesign requirements with a specific focus on durability have included:

- Draft revised Ecodesign Regulation on vacuum cleaners[963]:
    - operational motor lifetime for household and commercial vacuum cleaners shall be greater than or equal to 550 hours with an empty receptacle,

[962] See also detailed analysis of "software" issues in section ## of this Task 3 report.

[963] Online available at https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/Vacuum%20cleaners%20ENER%20Lot%2017/forslag-ekodesign-dammsugare_190930.pdf, last accessed on 1 Jun 2020.

- the hose, if any, shall be durable so that it is still useable after 40 000 oscillations under strain
- battery lifetime for cordless vacuum cleaners shall be at least 600 cycles while maintaining 70% capacity.

The requirements on hose durability and operational motor lifetime were already included in Regulation (EU) 666/2013[964] on vacuum cleaners (500 hours at that time); owing to a lack of harmonized standards at that time, specific measurement methods for testing the durability of the hose and operational motor lifetime were included. Meanwhile, these methods have now been specified in the harmonized standard EN 60312-1:2017.

- Ecodesign regulation (EU) 2019/2020 on light sources and separate control gears[965]:
  - Models of LED and OLED light sources shall undergo endurance testing to verify their lumen maintenance and survival factor. The specific measurement methods are directly described in Ecodesign regulation (EU) 2019/2020.

- Ecodesign regulation (EU) 617/2013 on computers and computer servers[966]:
  - Information to be provided by manufacturers: the minimum number of loading cycles that the batteries can withstand (applies only to notebook computers), including the measurement methodology used to determine information.

- Ecodesign regulation (EU) 2019/424 for servers and data storage products[967] includes information requirements related to the tested functionality of the products under declared operation condition classes which indirectly addresses the durability:
  - Information to be provided by manufacturers: declared operating condition class; it shall also be indicated that 'This product has been tested in order to verify that it will function within the boundaries (such as temperature and humidity) of the declared operating condition class'.

Ecodesign requirements with regard to reparability and upgradeability (both contributing to durability through extending overall product lifetime)
In most of the regulations adopted in winter 2019 (welding equipment, refrigerating appliances, electronic displays, household dishwashers, household washing machines and washer-dryers, refrigerating appliances with direct sales function as well as servers and data storage products)[968], consolidated requirements aiming at reparability and upgradeability of key components have been introduced:

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[964] Commission Regulation (EU) No 666/2013 of 8 July 2013 with regard to ecodesign requirements for vacuum cleaners, Version of 8 Jul 2013. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0666&from=EN, last accessed on 6 Jun 2020.

[965] Commission Regulation (EU) 2019/2020 of 1 October 2019 laying down ecodesign requirements for light sources and separate control gears. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2020&from=EN, last accessed on 24 May 2020.

[966] Commission regulation (EU) No 617/2013 of 26 June 2013 with regard to ecodesign requirements for computers and computer servers. Online available at https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:175:0013:0033:EN:PDF, last accessed on 7 Jun 2020.

[967] Commission regulation (EU) No 2019/424 of 15 March 2019 laying down ecodesign requirements for servers and data storage products. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0424&from=EN, last accessed on 30 Aug 2020.

[968] Commission Regulations (EU) 2019/1784; (EU) 2019/2019; (EU) 2019/2021; (EU) 2019/2022; (EU) 2019/2023; (EU) 2019/2024; (EU) 2019/424

- **Availability of spare parts** for a (product-specific) minimum period after placing the last unit of the model on the market; note that the definition of which spare part units should be made available is defined at the product-specific level in each of the individual product-related regulations from winter 2019, as referred to above;
- **Availability of software and/or firmware** as specific kinds of spare parts for a (product-specific) minimum period of years after placing the last unit of the model on the market, as required in the regulations on servers and data storage products, welding equipment, household dishwashers, household washing machines and household washer-dryers, as well as in refrigerating appliances with a direct sales function and electronic displays.
- **Maximum delivery time of spare parts**: within 15 working days after having received the order;
- **Access to repair and maintenance information** - including a registration process for professional repairers;
- **Replaceability**: spare parts shall be replaceable with the use of commonly available tools and without permanent damage to the product (different to "removability", i.e. dismantling for material recovery and recycling purposes).

Ecodesign regulations (EU) 2019/2019 for refrigerating appliances[969] and (EU) 2019/2024 for refrigerating appliances with a direct sales function[970] include information requirements related to a guarantee which might facilitate repairs, where defects occur:

- Information requirements: Instruction manuals for installers and end-users, and free access website of manufacturers, importers or authorised representatives shall include the following information: the **minimum duration of the guarantee** of the refrigerating appliance / refrigerating appliance with a direct sales function offered by the manufacturer, importer or authorised representative; 'guarantee' means any undertaking by the retailer or a manufacturer, importer or authorised representative to the consumer, to: (a) reimburse the price paid; or (b) replace, repair or handle refrigerating appliances with a direct sales function in any way if they do not meet the specifications set out in the guarantee statement or in the relevant advertising.

Ecodesign regulations (EU) 2019/424 for servers and data storage products[967] include material efficiency and information requirements related to a **functionality for secure data deletion** which might facilitate repairs, but also the reuse (2nd life) of products:

- Material efficiency requirements: From 1 March 2020, a functionality for secure data deletion shall be made available for the deletion of data contained in all data storage devices of the product.
- Information requirements: information on the data deletions tool(s) referred to, including instructions on how to use the functionality, the techniques used and the supported secure data deletion standard(s), if any.

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[969] Commission Regulation (EU) 2019/2019 of 1 October 2019 laying down ecodesign requirements for refrigerating appliances. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2019&from=EN, last accessed on 24 May 2020.

[970] Commission Regulation (EU) 2019/2024 of 1 October 2019 laying down ecodesign requirements for refrigerating appliances with a direct sales function. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2024&from=EN, last accessed on 24 May 2020.

29.1.3 Existing test standards

To support Ecodesign requirements related to material efficiency aspects in support of the implementation of Directive 2009/125/EC, European Standards have been developed under the standardisation mandate M/543. The following standards are related to durability as well as reparability, reusability and upgradeability – these are horizontal standards which might have to be complemented by product-specific vertical standards, as needed[971]:

- **EN 45552:2020: General method for the assessment of the durability of energy-related products.** This standard inter alia describes the differences between durability (i.e. the ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached) and reliability (i.e. the probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event) and provides examples for their assessment methods including details on accelerated tests to reduce the testing time.

- **EN 45554:2020: General methods for the assessment of the ability to repair, reuse and upgrade energy-related products**. This standard describes the approach and process to assess the ability of a product to be repaired, reused or upgraded (establishing a list of priority parts; assessment of the relevance of parts or repair, reuse or upgradeability; ranking of parts in a priority parts list to focus on the parts most likely to require repair, reuse or upgrade; assessment methods for the ability of a product to be repaired, reused and/or upgraded as well as documenting requirements). For establishing an assessment method through aggregation of criteria scores, the standard defines each different levels e.g. for the disassembly depth, fasteners and connectors, tools, working environment, skill levels, diagnostic support and interfaces, availability of spare parts (duration, target group, interfaces), types and availability of information, return options, data management as well as password and factory reset for reuse. The possible application of such assessment method and scoring system is described in more detail and exemplified for the product categories laptops, vacuum cleaners and washing machines in the study "Analysis and development of a scoring system for repair and upgrade of products" by JRC (Cordella et al. 2019)[972].

In other European product policy instruments, such as Ecolabel or Green Public Procurement, requirements on durability and robustness are based for example on following international standards (see for example revised proposal on GPP Criteria for Computers and Monitors and extension to Smartphones (Alfieri et al. 2020)[973]):

[971] According to stakeholder feedback, the general assessment methods based on these standards requires time and cost-extensive testing for reliability, which seems to limit the applicability to product groups.

[972] Cordella, M.; Alfieri, F.; Sanfelix, J. (2019): Analysis and development of a scoring system for repair and upgrade of products, Final report. European Commission, Joint Research Centre. Seville, Spain, 2019. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC114337/jrc114337_report_repair_scoring_system_final_report_v3.2_pubsy_clean.pdf, last accessed on 24 May 2020.

[973] Alfieri, F.; Sanfelix, J.; Bernad, D.; Graulich, K.; Moch, K.; Quack, D. (2020): Revision of the EU Green Public Procurement (GPP) Criteria for Computers and Monitors (and extension to Smartphones), Technical Report v2.0: Second draft criteria proposals, 2020. Online available at https://susproc.jrc.ec.europa.eu/computers/docs/200616_Technical_Report_GPP_Computers_v2.pdf, last accessed on 12 Jul 2020.

- **IEC/EN 60529:2013 'Degrees of protection provided by enclosures (IP Code)'** for electrical equipment. It applies to the classification of degrees of protection against dust (first digit) and against water (second digit). Protection against solid foreign objects indicated by the *first* characteristic numeral, such as IP5x (ingress of dust is not totally prevented, but dust must not penetrate in a quantity to interfere with a satisfactory operation of the apparatus or to impair safety), or IP6x (no ingress of dust; complete protection against contact), as well as to the degree of protection against water indicated by the *second* characteristic numeral, such as IPx4 (water splashed against the enclosure from any directions must have no harmful effect) up to IPx8 (ingress of water in quantities causing harmful effects must not be possible when the enclosure is continuously immersed in water under conditions which must be agreed between the manufacturer and user but which are more severe than for numeral 7). This means, e.g., a product can be classified IP68 (completely dust and water proof).

- **IEC 60068 'Environmental testing of electronic equipment'** providing a collection of methods for environmental testing of electronic equipment, components and electromechanical products to assess their ability to perform and survive under conditions such as transportation, storage, operational environments, extreme cold and heat[974].
    - Temperature stress: IEC 60068-2-1 (aimed to determine the ability of equipment or components to be used, stored or transported at low temperature) and IEC 60068-2-2 (aimed to determine the ability of equipment or products to perform when being used, transported or stored at high temperatures).
    - Accidental drop: IEC 60068-2-31 is a test procedure for simulating the effects of rough handling shocks, knocks, jolts and falls which may occur during repair work or rough handling in operational use.
    - Resistance to shock: IEC 60068-2-27 (intended for equipment or products that could be subjected to infrequent or repetitive shocks during storage, use or transportation; designed to uncover mechanical weaknesses and/or degradation caused by those shocks)
    - Resistance to vibration: IEC 60068-2-6 (applying to components/equipment which may be subjected to vibrations of a harmonic pattern – due to rotating, pulsating or oscillating forces – during transportation or service. The test is aimed at determining mechanical weaknesses or degradation.)

- **MIL STD-810 'Environmental engineering considerations and laboratory tests'**. The standard emphasizes tailoring equipment's environmental design and test limits to the conditions that it will experience throughout its service life, and establishing chamber test methods that replicate the effects of environments on the equipment rather than imitating the environments themselves. Although prepared specifically for military applications, the standard is often used for commercial products as well. The standard's guidance and test methods are intended to define environmental stress sequences, durations, and levels of equipment life cycles; to develop analysis and test criteria tailored to the equipment and its environmental life cycle; valuate equipment's performance when exposed to a life cycle of environmental stresses; to identify deficiencies, shortcomings, and defects in equipment

[974] Cf. https://www.desolutions.com/testing-services/test-standards/iec-60068-2/

design, materials, manufacturing processes, packaging techniques, and maintenance methods; and to demonstrate compliance with contractual requirements.[975] MIL-STD-810G, Change Notice 1, issued in 2014 was superseded by MIL-STD-810H as of 2019[976]. Methods referred to in the revised proposal on GPP Criteria for Computers and Monitors and extension to Smartphones as durability tests for mobile equipment are (US Department of Defense 2019)[977]:

- Accidental drop: Method 516.8 - Shock
- Temperature stress: Method 501.7 - High temperature; Method 502.7 -Low temperature
- Dust ingress protection: MIL-STD-810G Method 510.7, Sand and dust
- Water ingress protection: MIL-STD-810G, Method 506.6 Rain

- **EC EN 61960-3:2017 'Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications - Part 3: Prismatic and cylindrical lithium secondary cells and batteries made from them'**. IEC 61960-3:2017 specifies performance tests, designations, markings, dimensions and other requirements for secondary lithium single cells and batteries for portable applications. The objective is to provide the purchasers and users of secondary lithium cells and batteries with a set of criteria with which they can judge the performance of secondary lithium cells and batteries offered by various manufacturers. Portable applications comprise hand-held equipment, transportable equipment and movable equipment[978]. The standard is referred to in the revised proposal on GPP Criteria for Computers and Monitors and extension to Smartphones for setting requirements on rechargeable battery endurance and minimum requirements on the electrical performance of batteries in mobile devices (notebooks / tablets and smartphones), with the following parameters included (Alfieri et al. 2020)[979]:
    - Discharge performance at 20 °C and -20 °C (Rated Capacity); these tests verify the rated capacity of the battery and determine the capacity of the battery at standard and at low temperatures.
    - High rate discharge performance at 20 °C; this test determines the capacity of the battery when discharged at high rate.
    - Charge (capacity) retention and recovery; this test determines firstly the capacity which a battery retains after storage for an extended period of time (28 days), and secondly the capacity that can be recovered by a subsequent recharge.
    - Charge (capacity) retention after long term storage; this test determines the capacity of a battery after extended storage (90 days) at 50% state of charge, followed by a subsequent charge.

[975] https://en.wikipedia.org/wiki/MIL-STD-810

[976] https://quicksearch.dla.mil/Transient/E54E8102FE9A402197B11CD48C20599A.pdf

[977] US Department of Defense (ed.) (2019): MIL-STD-810H of 31 January 2019 superseding MIL-STD-810G w/Change 1 of 15 April 2014, Environmental engineering considerations and laboratory tests, 2019. Online available at https://www.iest.org/Standards-RPs/MIL-STD-810H, last accessed on 12 Jul 2020.

[978] https://www.en-standard.eu/iec-61960-3-2017-secondary-cells-and-batteries-containing-alkaline-or-other-non-acid-electrolytes-secondary-lithium-cells-and-batteries-for-portable-applications-part-3-prismatic-and-cylindrical-lithium-secondary-cells-and-batteries-made-from-them/

[979] Alfieri, F.; Sanfelix, J.; Bernad, D.; Graulich, K.; Moch, K.; Quack, D. (2020): Revision of the EU Green Public Procurement (GPP) Criteria for Computers and Monitors (and extension to Smartphones), Technical Report v2.0: Second draft criteria proposals, 2020. Online available at https://susproc.jrc.ec.europa.eu/computers/docs/200616_Technical_Report_GPP_Computers_v2.pdf, last accessed on 12 Jul 2020.

- Endurance in cycles; this test determines the number of charge/discharge cycles which a battery can endure before its capacity has been significantly depleted.
- Electrostatic discharge; this test is to evaluate the ability of a battery to with stand electrostatic discharge

In the product-specific preparatory and revision studies, the effectiveness of current standards and the availability and applicability of further reliability or durability standards for products and/or their key components should be analysed in more detail.

29.2 Market – Sales

Assuming that durability is initially relevant horizontally for all ErP that are currently regulated under EU Ecodesign, the following sales figures for product-specific regulations are expected for the years 2020, 2030, and 2050 according to the Environmental Impact Accounting (EIA) study (VHK 2019)[980], with the largest share of sales numbers for lighting, electronics and cleaning products:

Table 322. Annual sales data estimates for 2020, 2030 and 2050 of currently regulated ErP[981] (source: Ecodesign Impact Accounting study by VHK, 2019)

Expected sales (in 000s of units)	2020	2030	2050
Water heating	**18344**	**19704**	**22426**
Dedicated Water Heaters	11398	11878	12839
Central Heating combi, water heating	6946	7826	9587
Space heating	**43327**	**48092**	**52419**
Central Heating boiler, space heating	7951	9508	12624
Solid Fuel Boilers	362	365	696
Central Air Heating	486	507	511
Local Heaters	26492	28534	28740
Room Air Conditioners (Heating)	8036	9178	9848
Space cooling	**9786**	**11128**	**11997**
Central Air Cooling	697	769	917
Room Air Conditioners (Cooling)	9089	10359	11080
Ventilation	**3360**	**4492**	**6155**
Ventilation Units	3660	4492	6155
Lighting	**1737000**	**650000**	**662000**
Electronics	**905477**	**1008180**	**1132888**
Electronic Displays (incl. TVs)	70000	86000	87000
Set Top Boxes	44117	43501	58549
Video[982]	16225	13622	13622
Enterprise servers & data storage	4227	5698	5698
Personal computers	130650	183413	213563

980 Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, SALESBAU data besides for lighting (SALESECO data); VHK (2019): Ecodesign Impact Accounting, Status Report 2018. Prepared by VHK for the European Commission December 2018 (rev. Jan. 2019). Online available at https://ec.europa.eu/energy/sites/ener/files/documents/eia_status_report_2017_-_v20171222.pdf, last accessed on 12 Jul 2020.

981 The Ecodesign impact accounting study (VHK 2019) separately lists market data for product categories for which no separate regulation is foreseen so far, however, being covered by the networked standby regulation (EU) 801/2013, i.e. household coffee makers, home gateways (modem, router, stand-alone or combined), networked storage (NAS) and DECT phones. As these appliances are probably interesting for durability measures as well, they were taken into account in the following analyses for the purpose of this study.

982 This category covers products of the voluntary agreement on "games consoles", i.e. video recorders, video players, games consoles

Expected sales (in 000s of units)	2020	2030	2050
Imaging equipment	36876	40765	49697
Gateways, Network Attached Storage, Phones	97703	121048	167737
External power supplies	503856	511670	533672
Uninterruptible power supplies	1823	2463	3350
Food preservation	**22718**	**23599**	**25437**
Household refrigeration	19799	20402	21608
Commercial refrigeration	1785	1908	2171
Professional refrigeration	1134	1289	1658
Cooking	**67491**	**71147**	**78462**
Cooking appliances (ovens, hobs, hoods)	40126	42102	46086
Household coffee makers	27365	29045	32376
Cleaning	**121432**	**142295**	**184946**
Household washing machines	14151	13585	13585
Household dishwashers	9280	11524	16011
Household tumble driers	5932	6103	6239
Vacuum cleaners	92069	111083	149111
Total expected sales (in 000s of units per year)	**2929235**	**1978637**	**2176730**

Industrial product categories analysed in the Ecodesign Impact Accounting study (i.e. industrial fans, electric motors, water pumps, air compressors, and transformers) are not included in the above overview data. Other than improvement potential for energy efficiency and resource consumption, our assumption is that the improvement potential with regard to "durability" measures is rather low for product categories in the industrial sector. It is expected that industrial products in B2B settings, often complemented by service and maintenance agreements, already include measures like for example error diagnostics, spare part availability of key components, maintenance and reparability information etc.

According to stakeholder feedback, however, there may still be substantial untapped opportunities for repair and reuse of industrial products that may actually be prevented due to current business models (e.g. tie-ins to service contracts that incentivise early product replacement without reuse). Within the preparatory studies for industrial products, there seems to be no systematic consideration across the different products. The assessment is not comprehensive enough in most of the cases and does not necessarily lead to clear conclusions. For instance, for circulators the preparatory study includes statements such as "repair is labour intensive so it is only done in countries where labour costs are lower", "failure of bearings leads to replacing the entire circulator"; on water pumps the preparatory report says "sometimes it will be more economical to replace pumps rather than repair them"; and in the case of motors, the review preparatory study states that "small motors and VSDs are normally not repaired but replaced upon failure".

The above sales data include each certain shares of product applications in the residential, tertiary and industry sectors. It can be assumed that decreasing lifetimes of appliances might mostly occur in the residential, and possibly partly in the tertiary sector, but again, with regard to industrial product categories, the appliances used in various industry sectors are assumed to be mostly rather optimised with regard to durability (e.g. leasing or service contracts ("device as a service") with maintenance and reparability included). Data on the application shares in the EIA study are only at the level of sub-product categories[983]; however, the data suggest that as average over all product categories the residential and tertiary application shares might roughly sum up to about 90% of the above sales data.

It has to be noted that besides the above product categories, durability measures might also be applied to further ongoing product preparatory studies like electric kettles as well as mobile phones, smartphones and tablets as well as new product categories under the next Ecodesign and Energy Labelling Working Plan 2020-2024 (see also section 29.7.3, saving potential).

Products specifically designed to be more durable, or 'rugged' seem to be a niche market; rugged notebooks are designed to withstand harsh environmental factors, such as dust, rain, cold, and high temperatures for outdoor working sectors such as military, police, oil and gas extraction rigs or construction works. Relevant contemporary market data[984] are mostly not publicly available, generally requiring such evidence to be purchased from specialist market data entities[985].

29.3 Usage

In general, the distinction has to be made between technical product lifetime, i.e. until replacement due to a non-reparable defect, and the time or duration of first use when also products being still functional or having reparable defects might be replaced. The overall technical product lifetime might cover usage by different users due to 2nd hand markets.

Prakash et al. 2020[986] distinguish between the following types of obsolescence as reasons for the ageing (natural or artificial) of a product, such that it no longer satisfactorily meets the intended need:

- **Material obsolescence**, depending e.g. on deficient mechanical and electronic robustness, built-in lower quality materials or resulting in insufficient performance or defects of materials and components;

983 Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, CLASSES; VHK (2019): Ecodesign Impact Accounting, Status Report 2018. Prepared by VHK for the European Commission December 2018 (rev. Jan. 2019). Online available at https://ec.europa.eu/energy/sites/ener/files/documents/eia_status_report_2017_-_v20171222.pdf, last accessed on 12 Jul 2020.

984 One commercial market data report example is "Rugged Devices Market by End-user, Product, Type, and Geography - Forecast and Analysis 2020-2024" https://www.technavio.com/report/rugged-devices-market-industry-analysis

985 According to stakeholder feedback, it is recommended to buy the relevant data if these market data would be necessary for the assessment of the market share and the importance of "rugged" products; also another stakeholder pointed out that the rugged products market is very relevant to this study asking for an analysis of the market size and trends for these products being included.
The study team recommends to include these more detailed analyses within preparatory or review studies at product-specific level.

986 Prakash, S.; Dehoust, G.; Gsell, M.; Schleicher, T.; Stamminger, R. (2020): Influence of the service life of products in terms of their environmental impact: Establishing an information base and developing strategies against "obsolescence", 2020. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020-01-16_texte_09-2020_obsolescense_en_0.pdf, last accessed on 13 Jul 2020.

- **Functional obsolescence**, mainly due to software-related reasons, e.g. new product functionalities resulting in greater requirements on both software and hardware, different transmission standards or limited updates of the operation systems;[987]
- **Economic obsolescence**, i.e. high cost of repairs compared to the prices of new products, e.g. due to repair-unfriendly design, high costs for spare parts, the need for special tools etc.; and
- **Psychological obsolescence**, based on new product innovations, technological trends and fashion (partly enhanced energy-efficient), the desire for new functionalities, and changing consumption patterns resulting in a premature ageing and discarding of a still functioning product.

Although all four types of obsolescence might also be induced by usage behaviour (e.g. by extensive usage, not undertaking required/ recommended maintenance, discarding instead of repairing defect products, or discarding of still functional products), product design focusing on durability can reduce these effects (see section 29.4).

Public available market research on product-specific average technical lifetimes are rare, as are consumer behaviour studies on product-specific usage times in households. Therefore, most life cycle assessments, as well as Ecodesign preparatory studies, often operate with average data on product lifetimes; thus, it has to be carefully checked if these data relate to the technical lifetime, the duration of first use or replacement cycle, or also include a 2nd or even 3rd life due to a second-hand market. Scenarios or estimations in Ecodesign preparatory studies and other scientific research on decreasing lifetimes are based e.g. on test reports or articles in consumer magazines reporting typical defects. Accelerated durability tests are rarely performed, as running them is costly for test laboratories. Market trend reports, consumer organisations' findings incl. even selling websites[988] and fast technological innovation cycles (e.g. for TVs, lighting, or smartphones) might provide indications on changing lifetimes.

For example, the average replacement cycle of flat panel televisions had apparently decreased on a global scale to around 7 years, compared to the previous 10-15 year average, when the previous main replacement was from like-for-like 'CRT-to-CRT' technology. The most important reasons for the newer, lower 7-year replacement cycle compared to the past trend were assumed to be owing to declining prices for the newer technologies, a wider variety of sizes, and the desire to experience the advantages of the latest technologies, such as improved picture quality or internet connectivity at that time (Osmani et al. 2013)[989], (Sanfelix et al. 2019)[990]. Thus, it supposed that the reduction from typically 10-15 years to c. 7 years was basically a decrease driven by psychological obsolescence due to this particular case of technological and functional innovations in TVs.

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[987] According to EEA, functional obsolescence is not only related to software reasons. Functional lifetime / functional obsolescence is determined by the conditions that are created around the product. Source: EEA Report No 6/2017 - Circular by design Products in the circular economy

[988] For example MaGarantie5ans.fr

[989] Osmani, D.; Wolf, O.; Graulich, K.; Groß, R.; Liu, R.; Manhart, A.; Prakash, S. (2013): Development of European Ecolabel and Green Public Procurement Criteria for Televisions, Technical Report, Task 4. 2013. Online available at https://susproc.jrc.ec.europa.eu/televisions/docs/Draft_Task4-report_Ecolabel-GPP_TV_September_12.pdf, last accessed on 13 Jul 2020.

[990] Sanfelix, J.; Cordella, M.; Alfieri, F. (2019): Methods for the Assessment of the Reparability and Upgradability of Energy-related Products: Application to TVs, Final Report, 2019. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC116105/jrc116105_e4c_task_4_reparability_tv_final_v2.2_id.pdf, last accessed on 18 Jun 2020.

For smartphones, on the other hand, the average global smartphone replacement cycle was reported to be 21 months in 2016 by global consumer surveys, indicating that the average 'time of first use' of smartphones increased from 18.3 months in 2013 to 21.6 months in 2016 in the five most populated countries of Europe. From these data one might conclude that consumers of developed countries are holding on to their phones longer than in previous (but recent) years, which might be partly explained by a decrease in the innovation speed of mobile phones' technologies/ software. By contrast, the average time before a mobile phone reaches the end-of-life, i.e. the technical lifetime, was reported to be around 6 years instead (Cordella et al. 2020).[991] At least for higher-value smartphone brands, however, there is a well-developed market of 2nd hand products.

For large household appliances in Germany, Prakash et al. 2020[986] report that the average first useful service-life (i.e. product used by the first user; not to be confused with technical product lifetime) has declined slightly between 2004 and 2012/2013 from 14.1 to 13.0 years. The average lifespan of equipment which has been replaced due to a defect decreased from the year 2004 (13.5 years) to 2012/2013 by one year, i.e., to 12.5 years. On the other hand, it is important to realize that almost one-third of the replaced large household appliances were still functional. It was also noticeable that there was an increase in the proportion of large household appliances replaced within less than 5 years due to a defect.

Further, there are some interesting consumer research results regarding users' expectance and acceptance related to more durable design.

For example, in England and Wales, WRAP (WRAP 2013)[992] undertook research on some general aspects related to product lifetimes based on desk research, six focus groups and a nationally representative survey of 1,104 consumers of household appliances (refrigerators, washing machines and vacuum cleaners) and consumer electronics (televisions and laptops):

- Key barriers to the uptake of products with longer lifetimes were the secondary attention given in general to this issue by consumers, the lack of information and advertising on product lifetimes, and consumers' lack of trust of manufacturers/ manufacturers' claims.
- However, contrary to the above information, product lifetime was claimed as important to consumers in the survey, particularly for 'workhorse' products such as washing machines, fridges and vacuum cleaners. Consumers saw a long lifetime as a core requirement of these products and there was a clear interest from consumers participating in the survey in longer lasting products.
- Consumers were not knowledgeable about how long refrigerators, washing machines and vacuum cleaners can last, and were not aware of the availability of information on how long these products may last. Some consumers also had doubts about whether the lifetime of products can be accurately measured.

[991] Cordella, M.; Alfieri, F.; Sanfelix, J. (2020): Guidance for the Assessment of Material Efficiency: Application to Smartphones. 2020. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC116106/jrc116106_jrc_e4c_task2_smartphones_final_publ_id.pdf, last accessed on 13 Jul 2020.

[992] WRAP (2013): Electrical and electronic product design: product lifetime. In collaboration with Knight, T.; King, G.; Herren, S. and Cox, J., 2013. Online available at http://www.wrap.org.uk/sites/files/wrap/WRAP%20longer%20product%20lifetimes.pdf, last accessed on 13 Jul 2020.

- Consumers' valuations of the lifetimes of products was based on a combination of 'general knowledge', sources of knowledge available during the purchase process, and proxies to make assessments about the lifetimes of comparative products. The main sources of information which consumers thought they could access during the purchase process to evaluate and compare the lifetimes of different products were online reviews made by other consumers. However, consumers primarily relied on brand knowledge and to a lesser extent on price as proxies for the anticipated lifetime, expecting that well-known brands and more expensive products would last longer.
- Around half of consumers indicated they would be willing to pay more for products that were advertised to last longer, backed by a longer standard guarantee or warranty. (NB This is being currently investigated [status: Sept 2020] by DG JUST in its "Consumer Empowerment" consultations and Impact Assessment studies[993])

Further, an extensive empirical investigation by Wieser and Tröger 2015[994] among 1,009 Austrian residents collected data on the use-times of 21 durable goods (including small and large household appliances and consumer electronics). The main results comprised:

- Consumers want products to last considerably longer than the period for which they are currently used. Depending on the product category, the desired lifetime is 1.73 to 3.62 times higher than the contemporary use-lifetime.
- Consumers generally assume that products will last only for relatively short periods. This can be partially explained by the widespread concern among consumers that planned obsolescence is ubiquitous. These low expectations make high-priced quality products and second-hand products less attractive to consumers.
- Consumers' trust in premium brands and the lifespan of products is very low (partly contradicting the findings of the above-cited WRAP study). 18 out of 25 people interviewed believe that the phenomenon of "planned obsolescence" is widespread. This prevalent scepticism should be particularly alarming for manufacturers of high quality products.
- For mobile phones, 9% of the respondents to the survey listed durability as one of the three most important aspects, while 7% mentioned robustness.
- Decisions on whether to repair or replace a defective product critically depend on two factors: repair costs and consumers' expectations regarding product lifetimes. Consumers with low expectations regarding product lifetimes are more likely to prefer replacements to repairs because the latter are not expected to pay off.

Another consumer survey was conducted in Germany on behalf of the Federal Environment Agency (Prakash et al. 2016)[995]. In total, 2000 people were questioned on the four product groups studied: washing machines, TV sets, notebooks and hand mixers. Main results:

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[993] See https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12464-A-New-Consumer-Agenda/public-consultation

[994] Wieser, H.; Tröger, N. (2015): The use-time and obsolescence of durable goods in the age of acceleration, An Empirical Investigation among Austrian Households. Summary, 2015. Online available at https://www.beuc.eu/documents/files/FC/durablegoods/articles/0515_AK_Austria.pdf, last accessed on 13 Jul 2020.

[995] Prakash, S.; Dehoust, G.; Gsell, M.; Schleicher, T.; Gensch, C.-O.; Graulich, K.; Antony, F.; Köhler, A.; Hilbert, I.; Stamminger, R. (2016): Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz" – Verbraucherbefragung, Anlage zum Abschlussbericht, 2016. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/texte_11_2016_anlage_verbraucherbefragung.pdf, last accessed on 13 Jul 2020.

- Consumers would opt for higher quality technical equipment if they were provided with simple and easily understandable information on the quality, durability and reparability of the products. This would include information on how long the equipment will last, how it can be repaired, the availability of spare parts and other information related to the lifetime of the equipment. Consumers would then be prepared to accept a higher price for the higher-quality goods that are more durable and easier to repair.
- On the other hand, if there was no life cycle-related product information available at all, the majority of people chose amongst the models with comparable functionalities the cheapest model available for a washing machine, TV, laptop and blender.
- In all four product groups, price was one of the most important decision criteria when making a new purchase - in the case of televisions, notebooks and hand mixers it was even the most important.
- Nevertheless, consumers clearly included life cycle-related information in their decision. They rated any information on product quality - such as manufacturer warranties or information on service life - as positive and thus weighed up the purchase in terms of the price-performance ratio. Within this framework, they were also prepared to spend more money on higher-quality appliances.
- In contrast, it could be seen that the willingness to pay a higher price did not increase linearly with the improvement in product quality. The proportion of consumers who chose appliances with the most demanding life cycle-related features remained in the single-digit percentage range - irrespective of comprehensive life cycle-related product information.

Further, in a consumer survey study commissioned by the European Economic and Social Committee (EESC 2016)[996] a sample of 2 917 participants across four different European regions (France, Spain, Czech Republic and Benelux) was used to analyse whether lifespan labelling on products might influence consumers' purchasing decisions. Several different ways of displaying this information were tested. Differentiated analyses were performed on nine categories of product (inter alia, coffee machines, printers, vacuum cleaners, smartphones, washing machines and televisions), four label formats, ranges of purchase prices, and according to each participant's country of residence. An experiment was based on simulated online shopping and involved designing a dummy retail website. Main results:

- Lifespan labelling has an influence on purchasing decisions in favour of products with longer lifespans. On average, sales of products increased by 13.8% where a label was included showing a longer lifespan, compared to competing products (with no longer lifespan label).
- A significant influence on purchasing decisions was noted for printers (+ 20.1%), coffee machines (+ 14.4%), washing machines (+ 12.9%), vacuum cleaners (+ 12.3%), and smartphones (+ 11.4%). Only the simulated purchases of televisions were not significantly affected by environmental labelling.
- Four label designs that were tested proved to be effective. Each label was seen to have an influence on purchasing decisions. However, two labels appeared to be particularly effective in exerting a changing influence on purchase decisions. Labels with a scale from A (long lifetime) to G (short lifetime) (+ 20.4%) and displaying useful lifetime (+ 14.1%) achieved better results than the other two labels (+

[996] EESC (2016): The influence of lifespan labelling on consumers, 2016. Online available at https://op.europa.eu/en/publication-detail/-/publication/13cac894-fc83-11e5-b713-01aa75ed71a1/language-en/format-PDF, last accessed on 13 Jul 2020.

11.4% for a label displaying the cost per year and + 9% for a label displaying the lifespan in years). However, the A-G scale may potentially have been confused with the EU Energy Label. 68% of all participants fully understood that this label contained information about the lifespan of the product.
- The label with a lifespan given as a time period (months, years) was the best understood, with 82% of participants associating it with lifespan. This suggests that useful lifespan should be displayed, in a similar format. In terms of format, however, the study has some reservations regarding the use of large numbers. More specifically, individuals find it difficult to mentally picture – and therefore take on board – large quantities (e.g. 10 000 hours, 500 wash cycles). In the end, however, the label with a lifespan given as a time period, although being best understood, turned out to be less effective in terms of purchase decisions.

In 2018, the European Commission published a behavioural study on consumers' engagement in the Circular Economy (CE)[997], with special focus regarding the purchase of goods which were more, or less, durable and the potential for increasing the repair of goods. The study focussed on vacuum cleaners, televisions, dishwashers, smartphones and clothes. The study also included a behavioural experiment with regard to purchasing and repair behaviour[998].

The "purchasing experiment" tested different forms of durability and reparability information and their effects on consumers' product choices ('manufacturer warranties' and 'expected lifetime' claims; durability commitments and reparability ratings included in the EU Energy and Ecolabels using novel icons; claims such as 'Products that last longer may save you money over time' and 'A majority of people choose products that last longer and are easier to repair').

The "repair experiment" confronted respondents with a broken product for which they could decide whether to have it repaired, or to replace it with either a brand new or second-hand product. The main results comprised the following:
- While a majority of consumers report that they habitually repair products (64%), a substantial share have not repaired products in the past (36%). A reason for this low engagement could be that consumers lack information regarding product durability and reparability.
- Interest in product durability and reparability was generally higher for large and expensive products (e.g. white goods), and slightly lower for fashion items (e.g. smartphones)
- Consumers most associate durability with product quality; reparability, on the other hand, was most associated with availability of spare parts. Reparability was

[997] https://ec.europa.eu/info/live-work-travel-eu/consumers/sustainable-consumption_en#behaviouralstudyonconsumersengagementinthecirculareconomy

[998] A systematic literature review was carried out across all 28 EU Member States, Norway, Iceland, Switzerland, Japan, Canada, and the USA. This review was complemented by insights collected through 50 interviews with stakeholders from e.g. business and consumer associations, NGOs, public authorities and academia, and consumer focus groups with the general public and potentially vulnerable consumer groups in 4 countries. These activities contributed towards the results of the study and informed the design of an online consumer survey and behavioural experiment conducted in respectively 12 and 6 countries with 12,064 and 6,042 respondents who were representative of the general population for each country in terms of age, gender and geographic region.

throughout the study found to be less important to consumers than durability. According to the survey this is because consumers trust manufacturer warranties and would not expect durable products to break.

- Consumers who have received durability information via manufacturer warranties, or durability promises at the point of sale in a purchasing exercise were significantly more likely to expect free replacement or free repairs of faulty products. Instead, those who had not seen such information were significantly less likely to expect free repairs or replacements and instead expected to pay for these services.
- The price-quality ratio was found to be the most important driver, and simultaneously also a barrier for consumer engagement in the CE, followed by convenience: Many consumers were willing to pay more for products with better durability and reparability, but could be persuaded by low prices to disregard CE credentials. Similarly, when replacement is more convenient than repairing, consumers are easily led to purchase new products.
- The study uncovered that information on durability and reparability of products was in fact difficult to find and consumers wanted to receive better information.
- Improved information provision at the point of purchase (e.g. on EU labels, or provided by manufacturers) was effective at promoting CE behaviour amongst consumers. When, respectively, durability or reparability information was provided in the experiment consumers were almost three times more likely to choose products with the highest durability on offer, and more than two times more likely to choose products with the highest reparability ratings. Preferences were strongest when durability and reparability information was presented together.
- Depending on how durability/reparability information was presented, willingness-to-pay for an additional year of durability ranged between €20-36 for vacuum cleaners and dishwashers, €92-148 for TVs, and €148-217 for smartphones. Willingness-to-pay for an improved reparability rating was around €29-54 for vacuum cleaners, €83-105 for dishwashers, €77-171 for TVs, and €48-98 for smartphones.
- ‘Nudges’ informing consumers of the benefits and social norms of buying durable/repairable products increased the saliency of CE characteristics and triggered shifts in preferences towards more durable/repairable products.

The study recommended, inter alia:

- Making repairs easier, for example by:
    - Making essential product components replaceable by consumers;
    - Including repair instructions for minor defects in user manuals;
    - Ensuring the availability of spare parts in the longer run, for example, by requiring manufacturers to provide spare parts for a defined time period (and also after a product has been discontinued);
    - Encouraging manufacturers to offer a commitment to repair. Commitments could function in a similar way as manufacturer guarantees. The study found that consumers have a high trust in these guarantees and that they are more likely to seek repair of a product if it is covered by guarantee.
- Making durability and reparability information available at the point of sale, for example by:
    - Integrating durability and reparability information into existing (EU) labels;
    - Examining the development of a scoring system for reparability of products
    - Providing information to consumers on the availability of spare parts and repair services.

In 2019, a French study[999] analysed the perceptions and practices of the French in terms of product repair, and more precisely the knowledge and perceptions that the French have of repair (actors, approaches, environmental, social, economic impacts, etc.) as well as their reparation practices (types of practices, frequency of these practices, motivations/reasons associated with these actions and their implementation). According to the summary of that study, the results of this product repair survey show that the French share a generally positive image of repair (81% of the French have a good image of the repair sector). 87% of French people believe that repair contributes to the preservation of the environment and 78% believe it contributes to the dynamism of the local economy. However, in terms of practices, repair is not systematic: 36% of French people repair a product when it breaks down, while 54% replace it. Moreover, certain categories of products are less repaired than others (small household appliances). In 2019, repair still needs to gain in visibility and image, especially among the youngest, where efforts need to be made to raise their awareness of this practice.
The study highlights three main types of action:

- Increasing the "repair reflex" among consumers and the visibility of repairers, but also enhancing the value of the repair profession and repair activities. In the case of products for which the French do not think about repairs, it is also a question of making the latter more relevant.
- To counter the pervasive image of products that are irreparable or subject to programmed obsolescence (particularly in certain categories).
- In this context, the repairability and durability indices tested at some French retailers are very well received and appear credible (83% of French people say that the repairability index would influence them in their purchases, and 88% for the durability index). Any action by manufacturers and retailers allowing greater transparency both on the product (information on its manufacture, its hidden side: presenting an exploded view of the product would encourage 85% of French people to repair more) and on spare parts is welcome (transparency on the product's spare parts (availability, price and delivery time) would encourage 86% of French people to repair more). Repairs should also be able to benefit from the increasingly positive image of the second-hand market.

The following measures were analysed for encouraging the practice of repair by reducing persistent challenges:

- Reduce the cost of repair and provide information on prices (the cost of repair is the 1st challenge on repair for 68% of French people),
- Make access and the reparation process simpler (40% of the French fear that the reparation process is too complex or too cumbersome),
- Reassure on the quality of information, but also on the quality of services, especially on emerging or specific products (the lack of information is a hindrance for 25% of the French). The introduction of a guarantee on repairs can also have a beneficial effect (this would encourage 82% of French people to repair more).

Finally, the European Commission’s DG Environment is currently undertaking a consumer survey study to test consumer understanding, and to try to determine the best layout for presenting a scoring system for repair and upgrade of products. The methodological approach was presented in a study by (Cordella et al. 2019).[1000]

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[999] ADEME (2020): Français et la reparation. Perceptions et pratiques - Édition 2019. Online available at https://www.ademe.fr/francais-reparation, last accessed 24 Nov 2020

[1000] https://susproc.jrc.ec.europa.eu/ScoringSystemOnReparability/documents.html

As lessons learnt for addressing the "durability" topic under the Ecodesign and Energy Labelling Working Plan 2020-2024, the above consumer survey studies provide strong arguments to further follow up and analyse the possibilities for setting Ecodesign and Energy (or possibly other, separate) labelling requirements, especially regarding the following aspects:

- Reliable information on labelling of the durability or expected lifetime of products[1001],[1002];
- Information on the product's "quality" (to be defined), backed e.g. by commercial warranties (incl. for example manufacturer's commitment to repair);
- Information on the product's reparability (e.g. reparability rating);
- Consumer information regarding how and/or where the product can be repaired (e.g. instructions for easy self-repair of minor defects to address the "how"); information on the period of service / availability of spare parts;
- Facilitating repairs and provisions with the aim of keeping repairs costs for consumers at a reasonable level (e.g. repair-friendly product design including essential product components being replaceable by consumers; reparability information for professional repairers and/or consumers; availability of spare parts for professional repair services and/or consumers; etc.)[1003];
- Design options reducing the material, functional or psychological obsolescence (see also next section).

29.4 Technologies

There are different technological design approaches to implementing increased durability in energy-related products. Table 2 below gives a non-exhaustive list of examples (own

[1001] According to stakeholder feedback, the reliability of information concerning the lifetime of different products is important in the context that several studies have shown that fake online reviews are influencing consumers' behaviours. For example, the UK consumers organisation Which? found that fake reviews make consumers twice as likely to choose poor-quality products. The standard ISO 20488:2018 "Online consumer reviews — Principles and requirements for their collection, moderation and publication" could be referred to as providing good practices but remains a voluntary tool and thus limited in its application.

[1002] Another stakeholder points out that whilst there has been much activity on a scoring approach for reparability, definitions and methodologies to facilitate the provision of information on lifetime aspects have been rather neglected, e.g. there is a gap in studies where definitions and methodologies to facilitate the provision of information on expected lifetime are analysed. It is recommended that further work to close these gaps or a standardisation request from the Commission to address this aspect at a horizontal level could ensure that this work is appropriately tackled.

[1003] According to stakeholder feedback, the number of skilled technicians that will be required may not be met by current supply as training technicians to the required level takes several years and considerable resource.

compilation based on Alfieri et al. 2018[1004]; Cordella et al. 2019[1005]; Sanfelix et al. 2019[1006]; Cordella et al. 2020[1007]):

Table 323: Different product design approaches to implementing increased durability of energy-related products (source: own compilation)

Approaches to increase the durability of ErP	Examples of more durable design options
Durability (reliability & resistance) of materials; robust / rugged construction and design to withstand accidental drops or other mechanical stresses (e.g. shocks, vibrations, exposure to dust and water), i.e. adressing material obsolescence	• Robust and more durable materials and construction • Robust, i.e. water and dust proofing as well as corrosion-resistant housings, screen protectors and protective cases • Damping to reduce the effects of vibrations during operation • Ensuring internal components are well-secured against shock and vibrations • Sensors / electronic controls to reduce vibrations and wear • Parts protection against potential internal leaks • Design that protects key components from overheating • Wiring held in place by clips • Slip-resistant design of mobile / handheld products • Provision of additional protection accessories with the product (as observing opposite design trends that might reduce the resistance to accidental drops such as bezel free displays, or glass back covers in smartphones)[1008] • etc.
Durability (reliability & resistance) of key components in ErP, i.e. adressing material obsolescence	• Quality and durability of batteries; battery management systems incl. user adjustable maximum charging levels[1009] to protect the battery and optimise the battery endurance in cycles • Symmetric ports reducing the risk of breaking the slot while forcing cables into the wrong side • Low-maintenance, brushless motors • Solid State Disks (SSD) instead of Hard Disc Drives (HDD) • etc.
Alternative product design solutions	• Wireless charging as an alternative design solution for physical ports[1010] • LED instead of incandescent light bulbs, also for lighting as integrated components in other products • etc.

[1004] Alfieri, F.; Cordella, M.; Stamminger, R.; Blues, A. (2018): Durability assessment of products: analysis and testing of washing machines, Final report, 2018. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC114329/jrc114329_task_3_durability_final_v3.0.pdf, last accessed on 18 Jun 2020.

[1005] Cordella, M.; Alfieri, F.; Sanfelix, J. (2019): Analysis and development of a scoring system for repair and upgrade of products, Final report. European Commission, Joint Research Centre. Seville, Spain, 2019. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC114337/jrc114337_report_repair_scoring_system_final_report_v3.2_pubsy_clean.pdf, last accessed on 24 May 2020.

[1006] Sanfelix, J.; Cordella, M.; Alfieri, F. (2019): Methods for the Assessment of the Reparability and Upgradability of Energy-related Products: Application to TVs, Final Report, 2019. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC116105/jrc116105_e4c_task_4_reparability_tv_final_v2.2_id.pdf, last accessed on 18 Jun 2020.

[1007] Cordella, M.; Alfieri, F.; Sanfelix, J. (2020): Guidance for the Assessment of Material Efficiency: Application to Smartphones. EUR 30068 EN (doi:10.2760/037522, JRC11610), 2020. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC116106/jrc116106_jrc_e4c_task2_smartphones_final_publ_id.pdf, last accessed on 13 Jul 2020.

[1008] According to stakeholder feedback, this option should be carefully discussed; it is deemed useful to offer the possibility to get such accessories on demand, but on the other hand it should be avoided that these are produced but not used by anyone. Additionally, a design trend that might reduce the resistance of products as mentioned in the example should not be greenwashed by accompanying the product with an additional protection cover which might then not be used.

[1009] According to stakeholder feedback, however, it seems questionable if user adjustable maximum charging levels would make batteries more durable as good knowledge of the characteristics of the present battery chemistry is required to adjust these levels properly.

[1010] According to stakeholder feedback, however, it should be carefully assessed if this alternative to physical ports really helps to enhance the durability of a product.

Approaches to increase the durability of ErP	Examples of more durable design options
Modular design / design for reparability including replaceability of key components as spare parts, indirectly addressing also economic obsolescence	• Embedded fault diagnostics and prevention systems • Embedded use meters and consumer feedback mechanisms regarding optimized use and maintenance • Easy access and replaceability (for upgrades and repairs) of key components, e.g. batteries • Provision of and access to spare parts by repairers and/or consumers • Access to information facilitating fault diagnostics and repairs by repairers and/or consumers • etc.
Timeless exterior design / fashion to reduce psychological obsolescence (i.e. desire for always latest design)	• Manufacturers'/ importers' renunciation of purely visual changes when launching new products on the market, extending the period of new 'fashion cycles'[1011] • etc.
"Durability" of software (i.e. software updates and overall supporting period), i.e. addressing functional obsolescence	• Availability of software/firmware updates and extended software support provision for functionality and safety (Operating System, security updates etc.) • etc.
Design for reuse	• Provision of data transfer and safe deletion options (e.g. in the case of privacy of personal data on smartphones, computers etc.) • Password reset and restoration of factory settings • etc.

There is an abundance of options, but not all of them will apply to every product[1012] and a balanced approach for implementing durability measures is needed to avoid or at least balance also potential negative side-effects and trade-offs (see also section 29.6, saving potential); such a balanced approach can be addressed and assessed in detail during each product-specific Ecodesign and Energy Labelling preparatory study for those product groups under investigation.

29.5 Energy, Emissions and Costs

This section provides an overview of the energy, emissions and costs of the products in scope, building the basis for the estimation of the overall untapped saving potential of durability measures as calculated in section 0.

With regard to sales data, it is assumed that durability is initially by default relevant horizontally for all ErP currently regulated under EU Ecodesign. However, this "default relevance" may not so automatically apply to industrial product categories (i.e. industrial fans, electric motors, water pumps, air compressors, and transformers) where it might be expected that product categories in the industrial sector are already optimised to quite a

[1011] According to stakeholder feedback, this should be carefully assessed as it would be a very strong regulatory intervention. Also, one stakeholder points out that facelifts of products are legitimate measures to encounter a low market uptake of products which did not meet the consumer expectations, impossible to predict the market response to a specific design.

[1012] According to one stakeholder's feedback, it is proposed that horizontal measures can address common components in products (when present) with generic requirements. For example, easy user removal and replacement of batteries without the need for tools; public availability of spare parts for a set number of years; maximum delivery time for spare parts; availability of repair and maintenance instructions to non-professional repairers; availability of software and firmware updates; presence of inbuilt data deletion tools; presence of integrated password and factory reset for reuse; provision of information on minimum commercial guarantee duration. Further, implementing horizontal durability measures and applying exemptions to specific aspects of horizontal measures, assessed in further detail during each product-specific Ecodesign and Energy Labelling preparatory study for those product groups under investigation are proposed.

degree with regard to durability (i.e., by optimising overall life cycle costs via service agreements including in purchase contracts, etc). Moreover, the calculations for the appliance categories cited below are solely performed for their application in the residential and tertiary/services sector. As such, products may be optimised with regard to durability when used in industry sectors (where maintenance and reparability are most often included, via leasing or service contracts) but further analysis is necessary to assess to what extent the durability is improved for each product group in these sectors.[1013]

The underlying basis of this overview appraisal is the 'ECO scenario' of the Ecodesign Impact Accounting (EIA) study by VHK (2019)[1014], which includes the impact of known implementing measures under Ecodesign and Energy Labelling regulations, as well as Voluntary Agreements (VAs). The 2019 VHK study was written with the associated status for products and legislation/ VAs as of October 2018, with the basis for data referred to pre-dating Oct 2019. Therefore, these EIA data do not yet include the effects of implementing measures on durability and reparability, as adopted in several regulations of the 2019 'Winter package' of Ecodesign regulations.

Table 3 shows the following predicted **total electricity use** per year that is expected for the years 2020, 2030, and 2050, according to the Environmental Impact Accounting (EIA) study (VHK 2019)[1015].

Table 324. Total electricity use per year in 2020, 2030 and 2050 of currently regulated ErP for ECO scenario for the sectors 'residential' and 'tertiary/services' (source: Ecodesign Impact Accounting study by VHK, 2019)

Total final electricity consumption per year (ECO scenario) for the sectors Residential and Tertiary/Services	2020	2030	2050
Water heating	197	163	185
Space heating	317	309	298
Space cooling	137	136	140
Ventilation	75	68	80
Lighting	308	243	276
Electronics	220	205	210
Food preservation	157	123	120
Cooking	79	82	92
Cleaning	88	84	82
Total (TWh/a)	**1578**	**1413**	**1483**
Total (PJ/a)	**5681**	**5087**	**5339**

Table 4 shows that the following **total primary energy use** per year, i.e. primary electricity and input fuel for the full lifecycle, is expected for the years 2020, 2030, and 2050 according to the Environmental Impact Accounting (EIA) study (VHK 2019)[1016].

Table 325. Total primary energy use per year in 2020, 2030 and 2050 of currently regulated ErP for ECO scenario for the sectors 'residential' and 'tertiary/services' (source: Ecodesign Impact Accounting study by VHK, 2019)

[1013] If these assumptions not apply, then the calculated energy, emissions and cost as well as the expected savings potential due to implementation of durability measures would even increase.

[1014] https://ec.europa.eu/energy/sites/ener/files/documents/eia_status_report_2017_-_v20171222.pdf

[1015] Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, ELECECO

[1016] Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, NRGECO; Primary Energy Factor (PEF) of 2.5 according to Energy Efficiency Directive (2012/27/EU) as basis

Total primary energy use per year (ECO scenario) for the sectors Residential and Tertiary/Services	2020	2030	2050
Water heating	985	834	934
Space heating	2150	1658	1281
Space cooling	342	341	350
Ventilation	188	170	199
Lighting	771	606	692
Electronics	551	512	524
Food preservation	393	306	300
Cooking	233	234	254
Cleaning	219	210	207
Total (TWh/a)	**5832**	**4871**	**4741**
Total (PJ/a)	**20995**	**17536**	**17068**

Table 5 show that the following **total greenhouse gas emissions** per year are expected for the years 2020, 2030, and 2050 according to the Environmental Impact Accounting (EIA) study (VHK 2019)[1017].

Table 326. Total emissions of greenhouse gases (GHG) per year in 2020, 2030 and 2050 of currently regulated ErP for ECO scenario for the sectors 'residential' and 'tertiary/services' (source: Ecodesign Impact Accounting study by VHK, 2019)

GHG emissions per year (ECO scenario) for the sectors Residential and Tertiary/Services	2020	2030	2050
Water heating	180	146	149
Space heating	364	253	151
Space cooling	65	63	60
Ventilation	28	23	21
Lighting	117	82	72
Electronics	85	71	56
Food preservation	81	65	58
Cooking	37	33	29
Cleaning	34	28	22
Total (Mt CO_{2eq}/a)	**991**	**764**	**618**

According to the Environmental Impact Accounting (EIA) study (VHK 2019)[1018], the total acquisition costs per year of currently regulated ErP for the ECO scenario for the sectors 'residential' and 'tertiary/services' is around €525 bn/a in end-consumer prices in 2020, as shown in Table 6 below. Using a ratio of 2.5 between the manufacturers' cost price and the end-consumer price, which includes the profits of the manufacturers, the retailers and VAT, manufacturers' total cost prices are estimated to be around €210 bn.
It is assumed that durability measures will mostly affect materials; therefore, if then the costs of materials are assumed to comprise ca. 40% of the manufacturers' total product cost price (i.e., prior to distribution costs and profit), this results in materials making up ca. €84bn of the total cost price post-production, for the above "basket of products".

Table 327. Total end-consumer acquisition costs per year in 2020, 2030 and 2050 of currently regulated ErP for ECO scenario for the sectors 'residential' and 'tertiary/services' (source: Ecodesign Impact Accounting study by VHK, 2019)

[1017] Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, EMISSECO
[1018] Taken from Ecodesign Impact Accounting study (VHK 2019); Annex A, ACQECO

Total acquisition costs per year (ECO scenario) for the sectors Residential and Tertiary/Services	2020	2030	2050
Water heating	27	31	35
Space heating	107	141	204
Space cooling	21	26	31
Ventilation	93	104	125
Lighting	17	12	16
Electronics	179	229	261
Food preservation	16	17	20
Cooking	22	23	24
Cleaning	42.6	46.9	56.5
Total (bn €/a incl. VAT & installation)	**524.6**	**629.9**	**772.5**

Naturally, these are only rough total *grosso modo* estimates that would need to be firmed up in a comprehensive study.

29.6 Possible actions and policy options in the Ecodesign and Energy Labelling Working Plan 2020-2024

Given the complexity and diversity of the durability topic, possible design options, saving potentials, trade-offs and implementing measures under the EU product policy framework should be assessed in more detail for each product specific preparatory and revision studies. As a minimum guideline, the reparability/ durability provisions contained in the "Winter 2019 Package" of Ecodesign new and revised product regulations will be taken as the baseline measures, upon which further more advanced measures may be superimposed, on a product-by-product basis.[1019],[1020]

The following measures are proposed to be considered for all product regulation revisions and new product regulations under the Ecodesign and Energy Labelling Working Plan 2020-2024:

Potential durability measures related to product design (i.e. measures specific to products, which should be systematically analysed and considered in preparatory and review studies)

- Extending requirements on reparability / upgradeability (e.g. availability[1021] and delivery time of spare parts)[1022] and reusability (e.g. tools for safe data deletion, presence of of integrated password and factory reset for facilitating reuse)

[1019] According to one stakeholder's feedback, it is proposed to introduce a horizontal level of durability measures in terms of overarching requirements and that these requirements may go further than the requirements contained in the 2019 package of measures. By assessing further details for each product specific preparatory and revision studies, product-specific exemptions to specific aspects of horizontal measures could be applied.

[1020] According to another stakeholder, durability requirements can be set out for those product categories where improvements in efficiency can no longer be delivered. However, setting durability requirements should not block the development of more energy-efficient products where this is still reasonably possible.

[1021] According to one stakeholder's feedback, manufacturers should ensure the availability of all needed spare parts for a time period which relates to the expected lifetime of the device/product (which should start counting when the model is fully retrieved from market and should be clearly stated to consumers). Further, it is requested the necessity to make spare parts available to all consumers, and not only to the manufacturer's official technical assistance.

[1022] According to stakeholder feedback, another measure would be "Economically attractive pricing of spare parts"

- Product-specific durability and reliability requirements for the product and/or key[1023] materials and components in further product categories
- Definition of certain operating condition classes which might include e.g. environmental aspects as temperature, humidity but also Ingress Protection Levels (IPxx).
- Battery durability/ replaceability as a cross-cutting issue for battery-operated products
- Requirements to combat software-related obsolescence as a cross-cutting issue
- Remote access to products for error diagnostics/ mandatory incorporation of use meters incl. consumer feedback mechanisms regarding optimized use and maintenance to assess future requirements on maintenance, guarantees, use patterns in standards, combatting premature obsolescence[1024].

Potential durability measures related to consumer information/ labelling (i.e. measures that could be taken for all or a major number of products covered by Ecodesign)[1025]

- Availability of repair and maintenance instructions to non-professional repairers and/or consumers
- Information about the minimum duration of commercial warranties
- Average statistical parameters on reliability/ failure rates (e.g. on the product-specific Energy Label, and/ or in the product information sheet)[1026],[1027]

1023 According to the study "Analysis and development of a scoring system for repair and upgrade of products" by Alfieri & Sanfelix (2019), products are generally made of a large number of parts. In order to reduce the complexity of the assessment, it may be relevant to focus only on those parts that are more important for repair and/or upgrade operations, which are referred to as "priority parts". Priority parts have to be identified at product group level to enable the comparative assessment of products belonging to the same product group. It has been considered that a priority part has to be functionally important and is likely to fail or to be upgraded.

1024 Normally requirements are based on accelerated tests which are complex and and expensive. Meters, loggers etc. might be used for collecting information from the users' use of the products, which can be used as an input for following preparatory studies, however, taking into account GDPR issues. Also, according to stakeholder feedback, it has to be taken into consideration that e.g. frugal products due to their characteristics will not incorporate modules which enable them to be remote accessed. Another stakeholder raised concern that with products getting more connected and smarter, consumers face higher cybersecurity risks and therefore requires that Ecodesign requirements should be aligned with the EU Cybersecurity strategy; it must be ensured that there is no trade-off between better remote access for diagnostics and other key consumer rights such as security and privacy.

1025 According to stakeholder feedback, consumer information measures should further include "Easily accessible consumer information on correct maintenance and its importance for a long service life" and "Information regarding access to repair services"

1026 Keimeyer et al. (2020) provide a detailed analysis of the suitability of technical parameters for determining the (minimum) lifetime of products; cf. Keimeyer, F.; Brönneke, T.; Gildeggen, R.; Gailhofer, P.; Gsell, M.; Graulich, K.; Prakash, S.; Scherf, C.-S.; Schmitt, R.; Schwarz, N. (2020): Weiterentwicklung von Strategien gegen Obsoleszenz einschließlich rechtlicher Instrumente, 2020. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_115-2020_weiterentwicklung_von_strategien_gegen_obsoleszenz_einschliesslich_rechtlicher_instrumente.pdf, last accessed on 23 Nov 2020. However, according to stakeholder feedback, as these requirements would apply as horizontal measures also to "new" products in their respective product group, it should be clarified how these requirements can be met for innovative products entering the market for the first time, e.g. through pre-tests on reliability of prototypes. According to another stakeholder's feedback, average statistical parameters on reliability/ failure rates should be visible directly at the point of sale (e.g., in the product's labels), and there should not be the possibility to include this type of information only in the product information sheet. To achieve a market pull regarding durable products via product information, this information should be accessed by consumers in the easiest possible way. One stakeholder points out that this kind of data requires standardised tests and reporting methods, which are not yet available.

1027 According to stakeholder feedback, product durability could also be increased by changing internal components during the model's life cycle. Hence, information should be provided not only on the product itself, but also online for delivery of the latest durability information.

- Introduction of a Reparability Scoring Index[1028],[1029] or Product Circularity Data Sheets (PCDS)[1030] to assist purchasing decisions.
- Product-specific labelling of minimum lifetime with civil law effect to be applied in the case of non-conformities[1031],[1032]
- Mandatory provision of the product's life cycle assessment information by manufacturers (e.g., inter alia, the use of the generic Ecodesign ("Ecoprofile") provisions of the 2009 Ecodesign Directive, Annex I – see below, in addition)[1033]

Product information requirements under the EELWP 2020-2024 should closely take into account the developments of a digital "Product Passport" under the so-called Sustainable Product Policy Initiative (SPPI) as envisaged in the Commission's European Green Deal[1034] and New Circular Economy Action Plan (CEAP)[1035] to provide information on a product's origin, composition[1036], repair and dismantling possibilities and end of life handling, as well as interlinkages to other product information systems such as the EPREL database[1037], and the concept of a "battery passport" (and database) introduced throughout the review of the existing Battery Directive or others.

[1028] For example, as of January 2020, France has made it mandatory to display a repairability index of electrical and electronic equipment. Furthermore, France plans to support an initiative to make the harmonisation of information on repairability a European Community obligation; European Environment Agency (2020b): Electronics and obsolescence in a circular economy, Eionet Report - ETC/WMGE 2020/3. Online available at https://www.eionet.europa.eu/etcs/etc-wmge/products/electronics-and-obsolescence-in-a-circular-economy/@@download/file/ETC-WMGE_Electronics%20and%20obsolescence%20in%20CE_final.pdf.

[1029] According to feedback of one stakeholder, it could be too premature to consider a repair scoring system based on legal requirements when new Ecodesign requirements related to provision of repair information and spare parts are already being established for products by ongoing policy work through product-specific Ecodesign requirements. Therefore, it is proposed rather to evaluate the introduction of an information system for consumers about the likelihood that a product can (and will) be repaired.

[1030] The concept of Product Circularity Data Sheets (PCDS) were recently published by the government of Luxembourg, cf. https://meco.gouvernement.lu/fr/le-ministere/domaines-activite/ecotechnologies/circularity-dataset-initiative.html. PCDS refers to the functional use period as the basis for product durability.

[1031] According to stakeholder feedback, the proposed requirement bears the risk that lifetimes are declared at the lower end, while the actual lifetime is longer because the manufacturer cannot bear the financial risk of taking the guarantee for more than a certain share of the life time. Further, it is pointed out that declaration of lifetime, even if described in a standard, cannot be immediately linked to non-conformities in real life, as real-life usage conditions can never be standardised. Another stakeholder requires that in the case of a legal regulation, the contents of the guarantee would have to be standardized to make them comparable.

Keimeyer et al. (2020) provide a detailed analysis of legal aspects related to lifetime labelling and its influence on buyers' rights (warranty for non-conformities). Keimeyer et al. (2020) also analysed the suitability of technical parameters for determining the (minimum) lifetime of products. They recommend to use the parameters B-1, B-10, B-50, etc. for establishing lifetime requirements; although they are of limited benefit to individual consumers they can be used for the verification by market surveillance authorities. These parameters represent a lifetime indication related to a predefined failure rate (1%, 10%, 50%, etc.) in a given time interval. The B-10 value is the statistically expected time by which 10% of the population of a product will have failed under defined conditions. Conversely, this is also the probability that 90% of the tested products will reach the specified lifetime B-10. If, for example, a smartphone has a B-10 value of 2 years, it means that 10% of the smartphones are expected to fail within 2 years. The time specification for B-10 could be based on the expected lifetime of products (e.g. 5 years for mobile phones, 10 years for washing machines). Internationally harmonised standards, such as the IEC TC 56 standards, already exist and provide methodological, statistical and technical support for the calculation and testing of lifetime information, such as B-10 or similar.

[1032] According to one stakeholder's feedback, in this context it should be taken into account that the EC is considering the introduction of new information requirements in the new proposal on empowering consumers in the green transition, including a requirement about a "guaranteed lifespan".

[1033] According to stakeholder comments, whilst it is useful to consider this possibility in exceptional cases, it is important that such an approach is only considered where fully justified, and that the preferred approach remains well defined regulatory requirements.

[1034] COM(2019) 640 final

[1035] COM(2020) 98 final

[1036] According to stakeholder feedback, this refers only to those substances which already have to be declared according to existing regulations (e.g. REACH).

[1037] https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/product-database_en

Methodological developments or conditions to be ensured to enable these approaches

- Further methodological analysis regarding the use and benefits of statistical parameters on reliability/ failure rates, Reparability Scoring Index or Product Circularity Data Sheets (PCDS), or minimum lifetimes for the purpose of setting information requirements[1038]
- Standardisation activity on definitions and methodologies to facilitate the provision of information on lifetime aspects of products such as expected and minimum lifetime and reliability scorings.
- Revision of the MEErP (and EcoReport tool, as needed), better facilitating systematic assessment of durability and trade-off analyses, as well as possible implementing measures, as key aspects to be handled in all preparatory studies
- Possibility of setting generic ecodesign requirements using an "ecological profile" according to Annex I of Ecodesign Directive 2009/125/EU, in cases where the setting of specific ecodesign requirements according to Annex II of the Directive is not possible
- Evaluating components' "reuse" value, and apportioning possible "bonus" points to such real, validated incorporation of such reused components in the new product placed on the market (remanufacturing strategy).[1039]

A durability strategy, or several durability-related strategies, has to involve all market actors along the value/ supply chain, i.e., from the various industries supporting the provision of materials to suppliers, various end-product industries, distributors, the repair and remanufacturing sectors, consumers, recyclers, etc. This is especially necessary due to the remaining methodological challenges, new data requirements, more complex/long/costly preparatory or revision studies, additional market surveillance aspects to ensure the full enforcement of the proposed measures, potential impact on human resources in the Commission etc.[1040] Also, the potential overlapping and interplay between proposed (new) measures on durability under the Ecodesign and Energy labelling Working Plan 2020-2024 and existing or upcoming measures on durability and reparability have to be assessed.

29.7 Savings potential

29.7.1 Savings potential for selected product categories

Saving potentials accruing from durability and reparability measures via Ecodesign and Energy Labelling regulations are highly dependent on the specific baseline situation for

[1038] According to stakeholder feedback, lifetime declarations without sound standardisation base bear the risk of distorting markets and disappoint consumers if there is no appropriate market surveillance, i.e. declaration of (minimum) lifetimes for the purpose of setting information requirements should be backed by harmonised standards and sufficient resources for market surveillance according to the feedback.

[1039] According to stakeholders' feedback, however, bonuses for reused parts in new products are challenging as it is a) hard to verify whether the parts are actually reused, thereby implying lack of transparency to consumers, b) difficult to handle for the manufacturer, c) causes uncertainty about overall product quality (potential early failures). Also, it is uncertain how to assess the impact of these re-used parts in the product's performance. EN4556 for instance describes a general methodology how to assess re-used parts in the product but it is not clear whether this standard could be applied, e.g., to home appliances directly or whether it would need modifications. Instead, it is proposed to offer remanufactured spare parts instead of reused components in new products placed on the market.

[1040] According to stakeholder feedback, restriction upon product design might also constitute a limiting factor of technological innovation; thus, if the EU is contemplating to introduce specific design requirements for durability, also possible negative implications of such requirements should be carefully taken into account.

each product (average and optimum lifetimes within the product category, technical improvement potentials, the relative environmental proportion of the manufacturing and use phases in the overall lifecycle assessment, annual sales, and basic energy, resource consumption and emissions of the product category etc.), as well as the product-specific implementing measures per se.

For example, Cordella et al. 2020[1041] calculated for **smartphones** a scenario with extended years of use (replacement cycle of devices extended from 2 years to 3 and 4 years) which resulted in significant reductions of greenhouse gas (GHG) emissions. Savings in GHG achieved by extending the average replacement cycle of devices from 2 years to 3 or 4 years were -29% and -44%, respectively. The reduction of impacts is associated with the lower amount of devices, and thus parts and materials, needed to cover the overall reference period of 4.5 years.

The above study also showed that longer replacement cycles of 3 or 4 years also achieved related LCC cost reductions of 10% and 15%, respectively. However, where the increased lifetime of the product is inherently associated with initially high-end products, economic benefits for consumers could be more moderate - or even offset - by the higher purchase price. Where the longer replacement cycles were dependent on changing the battery, there could be still economic benefits for consumers from a life cycle point of view. However, such savings would be lower when the product design necessitated that the battery change be made by a professional repairer compared to the replacement doable by the user.

Where the longer replacement cycles depended on the repair of the display, there could be less or zero economic benefits for consumers from a purely financial life cycle cost point of view, due to the associated higher repair costs (Cordella et al. 2020). For smartphones, it was estimated that the production phase accounts for between 35–92 per cent of the total greenhouse gas emissions. However, in a different study (Bachér et al. 2020)[1042], the mobile phone use phase - which generally includes the emissions linked to electricity consumption from charging the smartphones at the homes/ premises of end-consumers - was found to contribute around 10–49 per cent of the total lifetime greenhouse gas emissions. Thus, by prolonging the average replacement cycles, environmental impacts of the manufacturing of new products are decreased or avoided. Also, according to the EEB (EEB 2019)[1043], a 1-year lifetime extension of all smartphones in Europe would save an estimated 2.1 million tonnes of carbon dioxide per year by 2030, which would result in a 31 per cent reduction in smartphones' overall carbon footprint.

For **washing machines**, Prakash et al. 2020 shows that the environmental impact of washing machines with a short life is higher for all investigated environmental indicators

[1041] Cordella, M.; Alfieri, F.; Sanfelix, J. (2020): Guidance for the Assessment of Material Efficiency: Application to Smartphones. EUR 30068 EN (doi:10.2760/037522, JRC11610), 2020. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC116106/jrc116106_jrc_e4c_task2_smartphones_final_publ_id.pdf, last accessed on 13 Jul 2020.

[1042] Bachér, J.; Dams, Y.; Duhoux, T.; Deng, Y.; Teittinen, T.; Mortensen, L. (2020): Electronic products and obsolescence in a circular economy, Eionet Report - ETC/WMGE 2020/3. European Environment Agency (ed.), 2020. Online available at https://www.eionet.europa.eu/etcs/etc-wmge/products/electronics-and-obsolescence-in-a-circular-economy/@@download/file/ETC-WMGE_Electronics%20and%20obsolescence%20in%20CE_final.pdf, last accessed on 22 Jun 2020.

[1043] EEB (2019): Coolproducts don't cost the earth, Full report, 2019. Online available at https://mk0eeborgicuypctuf7e.kinstacdn.com/wp-content/uploads/2019/09/Coolproducts-report.pdf, last accessed on 13 Jul 2020.

compared to the environmental impacts resulting from the average and longer-life machines. Despite the energy efficiency increases for the up-to-date design of the latest new washing machines, and higher production costs of longer-life appliances, shorter-life appliances exhibit a poorer performance for all environmental indicators. The cumulative energy demand (CED)[1044] and the global warming potential emissions resulting from the manufacture and use of a short-life washing machine (5 years lifetime) are approx. 40% higher compared to those resulting from a long-life washing machine (with a lifetime of 20 years) as the manufacturing of four short-life machines would become necessary over a period of 20 years compared to only one machine that is lasting for the whole duration.

Over a period of 20 years, it was estimated that a longer-life washing machine caused around 1100 kg fewer CO_{2e} emissions than a short-life appliance. The production-related greenhouse gas emissions account for approx. 47% of the overall greenhouse gas emissions for the short-life washing machine over a period of 20 years. In another study, the EEB (EEB 2019) calculated that, to compensate for the greenhouse gas emissions from production, distribution and disposal, and taking into account normal energy-efficiency improvement rates, the minimum optimal lifetime of a washing machines should be years. Extending the lifetime of all washing machines in the EU by one year would save 0.25 million tonnes of carbon dioxide per year by 2030, since the impact of manufacturing, distribution and disposal would be spread over the longer lifetime of the revised machine. The EEB study calculated that a lifetime extension of 3 years for such a washing machine would save around 0.66 $MtCO_2$, and a 5-year extension would correspond to about 1 $MtCO_2$.[1043]

For **notebooks**, EEB also assessed (EEB 2019) the environmental impacts resulting from lifetime extension of all notebooks in the EU beyond the typical 5-year lifespan. The analysis shows that: a 1-year lifetime extension of all notebooks in the EU would save 1.6 Mt CO_2 per year by 2030; a longer lifetime extension of 3 years would save annually around 3.7 $MtCO_2$, and a 5-year extension would correspond to annual emission reductions of about 5 $MtCO_2$.[1043] In addition, Prakash et al. 2020 showed that the environmental impacts of a short-life laptop (3-year lifetime) for all environmental indicators were higher than for the long-life laptop (6-year lifetime) over a total period of 12 years. Despite a slightly improved energy efficiency of new laptops and the higher production cost of a long-life appliance, the shorter-life laptop resulted in a poorer performance in all of the environmental indicators. The acidification potential is 49% higher for a short-life laptop in comparison with a long-life appliance. The cumulative energy demand (CED) of a short-life laptop was shown to be ca. 25% higher, and the global warming potential is ca. 36% higher in comparison with a long-life laptop. Over a period of 12 years, a long-life notebook causes some 300 kg less CO_{2e} GWP emissions than those from a short-life appliance.

For **vacuum cleaners**, the recent Ecodesign review study (Rames et al. 2019) calculated a policy scenario which includes measures both to facilitate increased lifetime and information requirements on the content of recycled plastic in the product, the latter based on the calculation method proposed in standard prEN 45557:2019 for calculating the content of pre-and postconsumer recycled plastic. Lifetime requirements cover motor life, hose oscillation, and battery lifetime (of cordless models and robot models), as well as spare

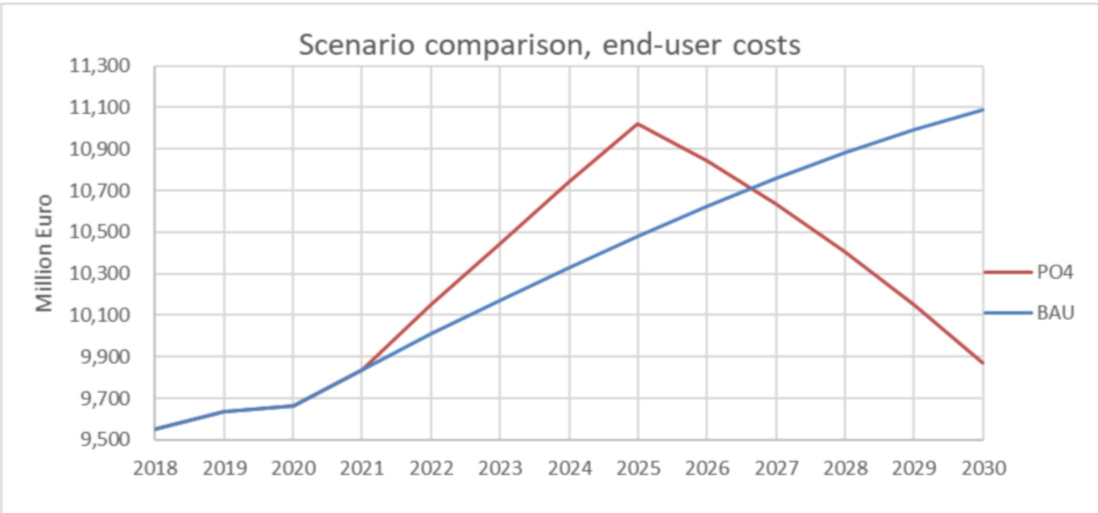
[1044] According to VDI Guideline 4600, the cumulative energy demand (CED) is defined as the total of the primary energy demand assessed in connection with the production, use and disposal of an economic good (product or service) or can be causally allocated to it.

parts availability, easily changeable breakdown/ repair-prone parts and information requirements on repairs. The impact of this policy scenario was compared to the business-as-usual (BAU) scenario. According to the review study (Rames et al. op cit, 2019), the savings result from an assumed 25% increase in the lifetime of vacuum cleaners, and an increased use of recycled plastic. Although the enhanced repair scenario means that more material (spare parts) are used per vacuum cleaner, and that the longer life/ repaired vacuum cleaners will forego potential energy improvements of newer models, owing to the longer lifetime, the average energy saving potential was calculated at 29% of the 'embedded' energy, or 4.21 TWh per year in 2030.[1045]

In addition, the EEB (EEB 2019) calculated the impacts of increased lifetimes of vacuum cleaners on the basis of an average 8-year lifespan. The analysis shows that a 1-year lifetime extension of all vacuum cleaners in the EU would save 0.1 $MtCO_2$ emissions per year by 2030; a lifetime extension of 3 years would save around 0.3 $MtCO_2$ and a 5-year extension would correspond to annual reductions of about 0.5 $MtCO_2$. These figures would be expected to increase if robots and cordless vacuum cleaners (not included in the calculations) continue to represent a growing share of the market, since these latter types of models usually have (up until now, that is) shorter lifetimes, and include batteries and more complicated components. As such, the robot and cordless vacuum cleaner models would be likely to have higher relative impacts for the manufacturing, distribution and disposal phase compared to the use phase (that is, prior to any lifetime extension redesign taking place).[1043]

According to the vacuum cleaners Ecodesign review study, shown here as Figure 1 below, consumer lifetime expenditure is significantly lower for the calculated durability scenario (PO4) compared to the BAU scenario in 2030 (Rames et al. 2019)[1045].

Figure 118: End-user expenditure for all vacuum cleaners in EU each year from 2018-2030 (Source: Rames et al. 2019)



[1045] Rames, M.; Skov Hansen, P. M.; Gydesen, A.; Huang, B.; Peled, M.; Maya-Drysdale, L.; Kemna, R.; van den Boorn, R. (2019): Review study on Vacuum cleaners, Final report, 2019. Online available at https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/vacuum-cleaners/vacuum_cleaner_review_final_report_.pdf, last accessed on 1 Jun 2020.

29.7.2 Possible trade-offs of durability measures

When calculating the saving potentials of durability and reparability measures via Ecodesign and Energy Labelling regulations, possible trade-offs with other implementing measures should also be analysed for each specific product category, and respected in the overall assessment:

- Durable design might require additional material (or materials with a higher energy/ material intensity, e.g., certain advanced metals technologies compared to more "standard" stainless steel, etc.) and resource consumption. Alternatively, or in addition, there might be higher energy content requirements for more durable products throughout their lifecycles e.g. for additional protective covers, or for a larger mass and volume needed to house different parts in a way that ensures full modularity/ accessibility/ repair of the device.
- Durable design might interfere with design strategies for lightweight design, modularity, reparability or recyclability. For example, if part of the design strategy of a product is to gain higher reliability by making it more robust and water/dust proof, e,g., via using certain sealing techniques (e.g. embedded batteries), this could make other aspects more difficult, such as the replacement of parts by users, the repair of the product, or easy (pre-) disassembly and removal of parts for recycling purposes at EoL.[1046]
- When considering durability, the overall trade-off between longer lifetime (reducing impacts related to the manufacturing and disposal of new products) and reduced environmental impacts of new products (due to energy and resource efficiency gains of the latest up-to-date products) needs to be considered over a certain period of total usage time. However, a level playing field of overall impacts per year considered (over the overall lifetime, and therefore also for extended lifetime scenarios) for comparative evaluation purposes can already be incorporated into both the "MEErP" methodology and into possible labelling options, it should be noted.[1047]
- Durability strategies might require higher investment costs and/or long(er) payback periods, e.g. due to more or higher quality material effort or additional components, costs for spare parts and repairs, costs for a commercial guarantee etc. According to Cordella et al. 2020[1048], a more durable design of smartphones, for example, is – at least presently - normally associated with higher-end products with higher related purchase prices, although it is also implemented in some products of the medium price range. Calculating the Least Life Cycle Costs of design options for durability measures should also take into account that labour costs for repair activ-

[1046] According to stakeholder feedback, both durability and repairability are important factors for the circular economy, but it seems to be not desirable to impair durability by designing for easy repair (such as facilitating access to parts) with the aim of improving repairability. It is suggested that possible implementing measures and requirements related to durability should be studied carefully so that repairability and durability (two different design objectives) do not interfere with each other's effects. Basically, the design issues of durability based on a quality and reliability to be different with repairability. The durability does so with increased reliability avoiding the need for repair, repairability expects the need for repair and designs for it accordingly.

[1047] According to stakeholder feedback, the ongoing policy work under the Ecodesign Directive regarding product lifetime should be carefully assessed and this assessment should be taken as a prerequisite to including durability aspects in scenarios for other initiatives like the MEErP methodology review.

[1048] Cordella, M.; Alfieri, F.; Sanfelix, J. (2020): Guidance for the Assessment of Material Efficiency: Application to Smartphones. EUR 30068 EN (doi:10.2760/037522, JRC11610), 2020. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC116106/jrc116106_jrc_e4c_task2_smartphones_final_publ_id.pdf, last accessed on 13 Jul 2020.

ities vary between the EU Member States. EU average repair costs have to be defined, whereas variations might be addressed in Sensitivity Analyses in the Impact Assessments.

Thus, a proper balance needs to be found with the positive impact of durability measures, being one possible route to reduce the environmental impact of products among many other options, and these in turn need to evaluated from the perspectives of manufacturers, consumers and society at large (i.e., societal socio-techno-environmental impacts).

29.7.3 (Rough) estimations of the overall saving potential and further impacts of durability measures

The overall saving potential of durability measures can only be estimated very roughly as it depends on several conditions. The calculations are based on the following assumptions:

- The total electricity use, total primary energy use and total greenhouse gas emissions of the product categories in scope provided in section 29.5 include the whole lifecycle. However, durability measures (lifetime extension through durable design, repairs etc.), have greater implications to the manufacturing phase whereas the use phase and end-of-life phase are assumed to be rather not affected by such measures[1049]. The share of the manufacturing phase to the life cycle impacts varies not only depends on the product categories but also on the materials and efficiency of single products as well as on the impact categories. Whereas for washing machines the share of the manufacturing phase comprises around 10% of the lifetime GHG emissions[1050], on the other hand, for smartphones the manufacturing stage contributes relatively 75% of the global warming potential[1051], due to the large material share of electronics and at the same time high energy efficiency in the use phase. As a simplified approach, across all product categories in scope an average relative share of the manufacturing phase (out of the total life cycle impacts) of 20% to the electricity use, primary energy use and GHG emissions is taken (own estimation).
- Further, the saving potential depends on the basic situation in each product category (e.g. basic lifetime, replacement cycles). For some categories, a higher saving potential can be expected than for others, as exemplified in section 29.7.1.; as a simplified approach, an estimated average will be taken across all product categories. Note that a detailed more sophisticated analysis of the saving potential of durability measures will be the task of the product-specific preparatory or revision studies.
- Finally, the saving potential depends on the number, kind and effectiveness of durability measures applied to each of the different product categories. For the estimation of the saving potential, we have based our calculations on the following durability scenarios. Please note that the durability measures subsumed under the scenarios are only for illustrative purposes, as the effectiveness of each of the single measures will again

[1049] According to stakeholder feedback, also the end-of-life phase is affected by improved durability measures as it would potentially increase re-use, preparation for re-use of products and would potentially improve recycling rates, closing material loops and bring higher recycling revenues.

[1050] Boyano et al. (2017): Ecodesign and Energy Label for household washing machines and household washer-dryers. Preparatory study – final report. (doi:10.2760/029939), 2017. Online available at https://ec.europa.eu/jrc/en/publication/ecodesign-and-energy-label-household-washing-machines-and-washer-dryers; last accessed on 03 Sep 2020

[1051] Alfieri et al. (2020): Revision of the EU Green Public Procurement (GPP) Criteria for Computers and Monitors (and extension to Smartphones). Technical report v2.0: Second draft criteria proposals, 2020. Online available at https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-07/200616_Technical_Report_GPP_Computers_v2.pdf, last accessed on 3 Sep 2020 depend on the particular situation in each product category, and is to be assessed in further detail in the preparatory or revision studies:

- "**Light" durability scenario**": overall effectiveness, i.e. annual saving potential of measures on electricity use, primary energy use and GHG emissions of the manufacturing phase is estimated to be **5%**; possible measures leading to this effectiveness might be, e.g., mainly easy to adopt information requirements "nudging" consumers to repairs
- **"Medium" durability scenario**: overall effectiveness, i.e. annual saving potential of measures on electricity use, primary energy use and GHG emissions of the manufacturing phase is estimated to be **15%**; possible measures leading to this effectiveness might be, e.g., mainly requirements facilitating reparability and repair of products through availability of spare parts; reparability information for repair services; remote access to error diagnostics; reparability scoring index labelled;
- **"Deep" durability scenario**: overall effectiveness, i.e. annual saving potential of measures on electricity use, primary energy use and GHG emissions of the manufacturing phase is estimated to be **30%**; possible measures leading to this effectiveness might be, e.g., mainly requirements improving the durability of the products; minimum durability of key components (e.g. battery); requirements to combat software-related obsolescence; use meters embedded within products, including consumer feedback mechanisms regarding optimized use and maintenance; commercial guarantees; product-specific labelling of minimum lifetime with civil law effect to be applied in the case of non-conformities.

Table 328. Estimated annual saving potential due to durability measures 2020, 2030 and 2050 of currently regulated ErP for ECO scenario for the sectors 'residential' and 'tertiary/services' (based on Ecodesign Impact Accounting study by VHK, 2019)

Based on ECO scenario for the sectors Residential and Tertiary/Services	2030	2050	2030	2050	2030	2050
	"Light" durability scenario (5% effectiveness)		"Medium" durability scenario (15% effectiveness)		"Deep" durability scenario (30% effectiveness)	
Electricity (TWh/a)	14	15	42	44	85	89
Electricity (PJ/a)	51	53	153	160	305	320
Primary Energy (TWh/a)	49	47	146	142	292	284
Primary Energy (PJ/a)	175	171	526	512	1052	1024
GHG emissions (Mt CO_{2eq}/a)	8	6	23	19	46	37

Depending on the applied durability scenario as outlined above, this results in estimated overall annual savings of 8-46 Mt CO_{2eq}/a GHG emissions in 2030 (6-37 Mt CO_{2eq}/a in 2050), 49-292 TWh/a primary energy in 2030 (47-284 TWh/a in 2050), or 175-1052 PJ/a primary energy in 2030 (171-1024 PJ/a in 2050). In addition to that, further savings might arise due to the following reasons:

- The estimated savings potential only includes the effects of the manufacturing stage. According to stakeholder feedback, however, also the end-of-life phase is affected by improved durability measures as it would potentially increase re-use, preparation for re-use of products and would potentially improve recycling rates, closing material loops and bring higher recycling revenues.
- The estimated saving potential above neither includes industrial product categories nor the application of the product categories in scope in the industrial sector (see explanations given in section 29.5). If durability measures would also be applied to these settings, the overall savings potential might increase accordingly. It is recommended to include systematic data-based assessments of the potential for improvement in durability in the product specific preparatory or review studies for each of the industrial

product groups like industrial fans, electric motors, water pumps, circulators, compressors, welding equipment and transformers.
- As no data is available so far in the Ecodesign Impact Accounting, the calculations do not take into account further product categories for which – as yet – there are no Ecodesign and/or Energy Labelling regulations in existence (these may be, inter alia, either currently under development within Ecodesign Working Plan 2016-2019, e.g., mobile phones, smartphones and tablets or electric kettles; or that may solely be included in the future, within the actual EELWP 2020-2024, as discussed for example for non-tertiary coffee machines, small home office networking equipment or small electric cooking appliances). Thus, further saving potential is expected if durability measures were also to be applied to these product categories.

It is rather difficult to establish the cost savings potential regarding of durability measures because they are also linked to manufacturing techniques, typical markets and initial acquisition costs of the respective product categories. As shown for the vacuum cleaners product group in Figure 118 above, costs and consumer expenditure might even increase in the short-term due to additional costs for maintenance and reparability measures, or higher acquisition costs for higher-quality products, but should then decrease over a longer period due to the lack of or decreased need for full product replacements. However, it should be noted that this is not a new phenomenon for new or revised product-specific regulations Ecodesign or Energy Labelling, since redesigning the products quite often means that there are initial higher production and often purchasing costs, but that these usually give payback to end-users in the short- to medium-term, as well as to manufacturers/ importers via either additional sales or product-related services.

Besides direct energy and GHG emissions savings, measures on prolonging the use of products also have significant reduction potential for further environmental and social impacts resulting from the extraction and use of materials of otherwise newly-manufactured products. Complex electronic equipment has significant environmental and social impacts resulting from the extraction and use of materials, including the mining and production of copper, critical raw materials (CRMs) and rare earth elements (REE), as well as from other transition metals such as tantalum, together with the environmental impacts associated with plastics and glass production. Durability strategies for products facilitate the EU being less dependent on imports of critical raw materials (CRM) from non-EU countries). Impacts include contributing to resource scarcity (positively), reducing water use, and diminishing pollution from chemicals (European Environment Agency 2020a)[1052]

The socio-economic impacts of increased reparability were analysed on an exemplary basis for four product categories: washing machines, dishwashers, coffee machines and vacuum cleaners (Deloitte 2016)[1053]. The study concluded that:
- The economic impacts of all scenarios were distributed differently among stakeholders. A small slowing down on the projected increase of the turnover appears, especially on manufacturers and retailers. Specifically for European manufacturers with global production chains, part of this decrease in turnover will appear outside of the EU, where a

[1052] European Environment Agency (2020a): Europe's consumption in a circular economy: the benefits of longer-lasting electronics, Briefing 02/2020. Online available at https://www.eea.europa.eu/themes/waste/resource-efficiency/benefits-of-longer-lasting-electronics, last updated on 22 Jun 2020, last accessed on 23 Jun 2020.

[1053] Deloitte (2016): Study on socioeconomic impacts of increased reparability, Final report. Prepared for the European Commission, DG ENV, 2016. Online available at https://op.europa.eu/en/publication-detail/-/publication/c6865b39-2628-11e6-86d0-01aa75ed71a1/language-en, last accessed on 13 Jul 2020.

large share of products are manufactured. On the other hand, the gains of turnover in the repair sector will occur largely for SMEs and social enterprises located in the EU. This increase might be partially absorbed by retailers and manufacturers, as new opportunities for development of in-house retail services might appear. Research and development activities are expected to increase. Simultaneously, the administrative burdens both for businesses and public authorities will be limited.

- The assessment results in positive social impacts for the EU. As in the case of the economic impacts, there will be some reductions on the projected increase of jobs, part of which will occur outside the EU. However, the creation of a significant amount of jobs in the repair sector corresponds to the development of quality jobs, largely in SMEs and smaller companies.

30 Innovative IT solutions facilitating market surveillance

30.1 Background and scope of this analysis

Ensuring compliance with legislation is not only key to achieving policy goals such as reduced greenhouse gas emissions or improved energy efficiency, but also to avoiding distortions of the market. Regulation (EC) No 765/2008[1054], superseded by Regulation (EU) 2019/1020[1055] applying from 2021, established the framework for market surveillance and compliance of products. Member States must ensure effective surveillance of their markets. National market surveillance authorities (MSA) verify whether products sold in the EU follow the requirements laid out in the legislation. The work of Market Surveillance Authorities also aims at protecting consumers from fraudulent products.

The Special Report 01|2020 of the European Court of Auditors (ECA) "EU action on Ecodesign and Energy Labelling: important contribution to greater energy efficiency reduced by significant delays and non-compliance" states that effective market surveillance should play a critical role in ensuring that products sold in the EU comply with Ecodesign requirements and that consumers benefit from accurate energy labels (ECA 2020)[1056].

According to the ECA report, the Commission supports MSAs with regard to the Ecodesign and Energy labelling legislation, more specifically it:

- facilitates the organisation of 'Administrative Cooperation Groups (AdCos)', a network of MSAs which meet twice a year to share experience and knowledge;
- publishes guidelines and best practice on market surveillance in general and for each product-specific regulation;
- in cooperation with MSAs, issues consolidated 'frequently asked questions' that provide answers to common issues encountered by MSAs for specific products;
- operates two databases to disseminate relevant information: Information and Communication System on Market Surveillance (ICSMS)[1057] and European Product Database for Energy Labelling (EPREL)[1058];
- provides funding to projects dedicated to strengthening market surveillance.

[1054] Regulation (EC) No 765/2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products; https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0765&from=EN; last accessed on 18 Oct 2020

[1055] Regulation (EU) 2019/1020 on market surveillance and compliance of products and amending Directive 2004/42/EC and Regulations (EC) No 765/2008 and (EU) No 305/201; https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1020&from=EN; last accessed on 18 Oct 2020

[1056] (ECA 2020): EU action on Ecodesign and Energy Labelling: important contribution to greater energy efficiency reduced by significant delays and non-compliance. https://www.eca.europa.eu/Lists/ECADocuments/SR20_01/SR_Ecodesign_and_energy_labels_EN.pdf, last accessed on 18 Oct 2020

[1057] The ICSMS database is operational and allows MSAs to upload their inspections and laboratory test results; to use the inspections and laboratory tests carried out by others to take corrective action against non-compliant products; to avoid duplication of work by not testing products that another MSA has already found to be compliant.

[1058] The EPREL database aims to provide MSAs with product technical information uploaded by manufacturers; the public with information about products and their energy labels; the Commission with up-to-date energy efficiency information for products for the purpose of reviewing energy labels.

However, the European Court of Auditors also pointed out on several obstacles which impede an effective market surveillance with regard to Ecodesign and Energy labelling legislation. Especially, non-compliance by manufacturers and retailers remains a significant issue. Further, for the Information and Communication System on Market Surveillance (ICSMS) operated by the Commission which should enable cooperation by allowing authorities to share inspection results, the ECA found that some functional limitations in the database reduced its effectiveness. Finally, several EU-funded projects aiming at improving market surveillance have delivered certain results, however, they have only provided a temporary solution for a recurring need. (ECA 2020)

Building upon these obstacles, focus of the following analysis is to identify opportunities for innovative solutions that could be forthcoming to facilitate improved market surveillance and standard setting. Special focus shall be on innovative IT techniques. Initial stakeholder feedback and recommendations regarding new digital tools or innovative IT solutions contributing to better enforcement include the following aspects:

- One stakeholder recommended the use of EPREL also for products with ecodesign requirements only for market surveillance authorities to benefit from its functionality. Ecodesign product information on publicly available websites. Ecodesign Directive 2009/125/EC and product-specific Ecodesign regulations are not clear how the information should be made available. Often the information of the different parameters is spread over several files of the website (commercial part, installation manual, user manual). For installers/end users it is very hard to compare the performances of different products. A prescribed template with the product information that should be on the website.
- The Working Plan should allow for "pilots", i.e. to try out new features of the (energy labelling) framework regulation such as electronic means for labelling products or showing the energy class during use on the product's interactive display (Energy Labelling regulation (EU)2017/1369, Article 16.3(f) and (n)).
- One stakeholder proposed an automatic search and assessment of customers' product reviews etc.
- Another stakeholder recommended "track and trace technologies"; e.g. efficient use of the product passport and other transparency and traceability mechanisms throughout the entire product lifecycle. One example could be the combination of "product passports" with tagging and standardised calculation tools.

In the following sections, different ideas for new digital tools or innovative IT solutions contributing to better enforcement are presented each with a short profile introducing the background and their potential purpose and advantages in the context of Ecodesign and Energy labelling.

Further general challenges and recommendations listed by stakeholders to facilitate market surveillance, however, going beyond the focus of this analysis on new digital tools or innovative IT solutions, are summarized for the sake of completeness in the Annex [to be added in the final draft version].

30.2 IT solutions facilitating Market Surveillance Authorities and standard setting under EU Ecodesign and Energy labelling

30.2.1 Product database EPREL

	Product database EPREL
Background	As of 1 January 2019, suppliers (i.e. manufacturers, importers or authorised representatives) mandatory need to register their appliances that require an energy label in the so called 'European Product Database for Energy Labelling' (EPREL)[1059], before placing them on the European market. Besides a publicly accessible part where consumers will be able to search the product database for energy labels and product information, the database also includes a compliance part accessible only to market surveillance authorities (MSA), suppliers and the European Commission personnel where further data product technical documentation necessary for the assessment of product compliance with the EU Energy Labelling Regulation is to be uploaded before any product model is placed on the EU market. The public part of the database includes following information: the name or trademark, address, contact details and other legal identification of the supplier; the model identifier; the label in electronic format; the energy efficiency class and other details from the label; details from the product information sheet in electronic format.
Information provided	The compliance part of the EPREL database includes the following additional information for the assessment of product compliance by Market Surveillance Authorities[1060,1061]: • the model identifier of all equivalent models already placed on the market • the technical documentation: - a general description of the model, enough for it to be clearly and easily identified; - references to the harmonised standards applied or other measurement standards used; - specific precautions that shall be taken when the model is assembled, installed, maintained or tested; - *the measured technical parameters of the model;* - *the calculations performed with the measured parameters;* - testing conditions as applicable if not described sufficiently; - additional parts of the technical documentation on a voluntary basis. It is not mandatory to upload the full test report, but it is sufficient to upload an extract of data from the test report created in an independent document or a similar document[1061]. However, there was a discussion about the values to be entered in the database. The initial regulations mentioned measured values (i.e. test results), declared values and intermediate results, but it was not always clear which data should be entered into the database. In order to avoid such confusion for manufacturers and national market surveillance authorities about the values to be included in technical documentation and uploaded in the product database, through an Omnibus regulation[1062] the Commission defined the "**declared values**" as basis for compliance verification by the market surveillance authorities.

[1059] https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/product-database_en
[1060] www.seai.ie/publications/EPREL-Supplier-Guidance_Final-5.pdf
[1061] https://ens.dk/sites/ens.dk/files/Energikrav/om-energikrav/eprel_lamp_guideline_en_190705.pdf
[1062] https://ec.europa.eu/info/sites/info/files/energy_climate_change_environment/draft_act_-annexes_-_el_omnibus_lw_clean_-_after_eleg_meeting_-disclaimer.pdf

	Product database EPREL
Product phase(s)	• Placing the product on the market
Data provider	• Suppliers, i.e. manufacturers, importers or authorised representatives
Already used in Ecodesign / Energy label context?	• Yes: Energy Labelling • No: Ecodesign
How could this IT solution facilitate MSAs and/or standard setting in the Ecodesign/Energy label context?	Beyond the current EPREL database system, the following ideas for further development could facilitate its usability for MSAs: • Filter /search tool to select certain lists of products; • Inclusion of a search tool to show all models that are technically equal; • Inclusion of the supplier's postal code to facilitate the allocation to the respective authority; • Export search results as excel files; • Automatic check of the technical documents at the moment they enter EPREL, providing a semi-automatic fixing of issues up front; • Inclusion of all product documentation (incl. full test reports) – however, this requires modifying the energy labelling framework; • Use EPREL in conjunction with web crawler (cf. section 30.2.5) to detect products absent from EPREL (especially imported products); • Extension of the EPREL database beyond Energy labelling to insert and check the information on Ecodesign requirements.

30.2.2 QR Codes

	QR Codes
Background	A QR Code is a two-dimensional version of the barcode consisting of black and white pixel patterns; they are suitable for storing links, texts, contact or WLAN access data, company information and others, being readable by using the mobile phone camera. In 2021, the EU energy labelling framework regulation (Regulation (EU) 2017/1369) will introduce a first set of new energy labels for dishwashers, washing machines, refrigerators, electronic displays and for lamps. With the revised design, the new energy labels will also include a visible QR code in the upper right corner.
Information provided	By scanning the QR code on the energy label, consumers will have access to more detailed product information in the European Product Registry for Energy Labelling, called EPREL (cf. section 30.2.1).
Product phase(s)	Placing the product on the market
Data provider	Suppliers, i.e. manufacturers, importers or authorised representatives
Already used in Ecodesign / Energy label context?	• Yes: Energy Labelling • No: Ecodesign
How could this IT solution facilitate MSAs and/or standard setting in the Ecodesign/Energy label context?	The QR code visible on the energy label is mainly targeted to consumers, for example at the point of sale; by scanning the code with a smartphone they shall get additional, official (non-commercial) product information which was inserted by manufacturers into the EPREL database. Also MSAs might use the QR code, for example during appliance inspection in shops, to get direct access to the EPREL database for verifying that the product comply with requirements on energy efficiency and that the information on the label is correct. Besides a QR code available on the Energy label, these codes could also be used for providing further product information, if for example physically connected directly

	QR Codes
	to the product.[1063] In that sense, they could serve e.g. as 'digital product passport' (cf. section 30.2.3).

30.2.3 Digital product passport

	Digital product passport
Background	The European Green Deal[1064] states that *Digitalisation can also help improve the availability of information on the characteristics of products sold in the EU. For instance, an electronic product passport could provide information on a product's origin, composition, repair and dismantling possibilities, and end of life handling*. The Sustainable Products Policy Initiative (SPPI) foreseen in the new Circular Economy Action Plan (CEAP)[1065] considers mobilising the potential of digitalisation of product information, including solutions such as digital passports, tagging and watermarks. To facilitate these digital technologies that can track the journeys of products, components and materials and make the resulting data securely accessible, the CEAP foresees a European "data space for smart circular applications" that will provide the architecture and governance system to drive applications and services such as product passports, resource mapping and consumer information. The data space for smart circular applications is part of a broader European strategy on data[1066] that aims to create a common European data space where personal as well as non-personal data, including sensitive business data in full respect of the EU data protection legislation. A digital product passport could be a unique product identifier, i.e. a single point of access to product relevant data, including data provided by different value chain actors. Besides static information collected along the supply chain and fixed at the moment of placing the product on the market, the product passport might also include dynamic information generated throughout the product's use. For the technical solutions, it must be ensured that even long-lived products can still be attributed. A digital product passport could be implemented for example as QR code, radio frequency identification (RFID), watermark (cf. section 30.2.4) or by other tagging. Other than for the web based EPREL database, the information of a digital product passport is directly available at the product itself. The data of the digital product passport should be aligned to the respective information included in the EPREL database.
Information provided	The following information might be included in a digital product passport[1067]: • Information on material composition, components, spare parts • Dynamic log of repairs, updates/upgrades, warranty renewals • Period of software support, secure data deletion instructions[1068] • Information on dismantling, disposal and recycling

[1063] One stakeholder commented that considering that the latest information can be provided, it should be provided "more reasonable" by an online electronic label that is relatively less affected by design changes than a physical label.

[1064] COM(2019) 640 final

[1065] COM(2020) 98 final

[1066] COM(2020) 67 final

[1067] One stakeholder commented that the guiding principle should be that only those data are collected that have a foreseeable benefit, i.e. it should be assessed, for which type of information, whether a centralised data access makes sense and if fundamental rights such as informational autonomy are assured. Also, the risk is seen that with data on components and spare parts, there is a risk of creating parallel data structures with the inherent risk of inconsistency.

[1068] One stakeholder commented that data deletion instructions are part of the user manual, which can be referred to in the product passport, but there is no real necessity to do so.

	Digital product passport
Product phase(s)	• Manufacturing[1069] • Placing the product on the market • Use phase • End-of-life phase
Data provider	Different value chain actors
Already used in Ecodesign / Energy label context?	• No • However, for example, a "battery passport"is currently under development[1070] which might be applied in the upcoming new EU Battery Regulation
How could this IT solution facilitate MSAs and/or standard setting in the Ecodesign/Energy label context?	A digital product passport providing all relevant information as required in Ecodesign and Energy label regulations, physically linked to the product, would facilitate the conformity assessment of market surveillance authorities in a way that the information is accessible in one place directly at the product under test and has not to be gained from different sources. The product passport could even include linkages to further regulatory requirements besides Ecodesign and Energy labelling, such as for example REACH or RoHS, i.e. information about hazardous substances.

30.2.4 Digital watermarks

	Digital watermarks
Background	The Sustainable Products Policy Initiative (SPPI) foreseen in the new Circular Economy Action Plan (CEAP)[1071] considers mobilising the potential of digitalisation of product information, including solutions such as digital passports, tagging and watermarks. Other than visible QR codes (cf. section 30.2.2), digital watermarks are imperceptible codes, covering for example the surface of a consumer goods packaging by being integrated into both printed materials (labels, sleeves, in-mould labels, films/pouches), as well as directly into a mould (PET bottles, HDPE bottles, thermoformed trays, injection moulded crates, etc.).[1072] They are carrying a wide range of attributes by printing QR- or barcodes on plastic products/components with invisible, but machine-readable ink. Most recently, the European Brands Association (AIM) has started the project "Holy-Grail 2.0" with more than 85 companies and organizations from the complete packaging value chain[1073]. The consortium aims to launch an industrial pilot to prove the viability of digital watermarks technologies for a circular economy by enabling better sorting and higher-quality recycling rates for packaging in the EU. The aim is that once the packaging has entered into a waste sorting facility, the digital watermark can be detected and decoded by a standard high resolution camera on the sorting line, which then – based on the transferred attributes (e.g. materials that are food safe vs. non-food materials) – is able to sort the packaging in corresponding streams. This would result in better and more accurate sorting streams, thus consequently in

[1069] Stakeholders pointed out that collecting data from the supply chain is often limited by commercial interests and intellectual property constraints, i.e. some information might only be known by the supplier of parts, not by the manufacturer of the product.

[1070] See https://www.smart-energy.com/industry-sectors/new-technology/how-a-battery-passport-can-foster-a-sustainable-transition-to-a-green-economy/; https://batterypassport.org/how-it-works/; https://www.weforum.org/global-battery-alliance/action

[1071] COM(2020) 98 final

[1072] One stakeholder commented that considering that the latest information can be provided, it should be provided "more reasonable" by an online electronic label that is relatively less affected by design changes than a physical label.

[1073] See https://www.aim.be/priorities/digital-watermarks/; https://www.aim.be/wp-content/themes/aim/pdfs/Digital%20Watermarks%20Initiative%20HolyGrail%202.0%20-%20general%20presentation%20for%20PDF.pdf?_t=1602239412; https://www.foodingredientsfirst.com/news/pepsico-pilots-invisible-digital-watermark-technology-to-boost-recycling.html; http://pr.euractiv.com/pr/pioneering-digital-watermarks-smart-packaging-recycling-eu-aim-european-brands-association; https://www.packagingdigest.com/sustainability/digital-watermarks-recycling-plastic-packaging-who-what-why-and-where

	Digital watermarks
	higher-quality recyclates benefiting the complete packaging value chain. In the first step of the HolyGrail 2.0 project, the technology will be validated at a test sorting facility on a semi-industrial scale. Brand owners and retailers will work together with packaging and technology suppliers to modify their packaging with digital watermarks. After that, the plan is upscale to industrial testing by introducing digitally watermarked packaging from a range of brand owners and retailers into national test market(s).
Information provided	The information foreseen in the watermark of the HolyGrail 2.0 project is following: • Manufacturer, stock keeping unit (SKU), • type of plastics used, • composition for multilayer objects, • indication of materials that are food safe vs. non-food materials.
Product phase(s)	End-of-Life (Recycling)
Data provider	Manufacturers
Already used in Ecodesign / Energy label context?	No
How could this IT solution facilitate MSAs and/or standard setting in the Ecodesign/Energy label context?	Currently, in the HolyGrail 2.0 project this technology is under piloting to be used mainly for facilitating recycling purposes at the end-of-life stage. However, once proven to be feasible and applied by a broader range of manufacturers, watermarks as information carrier could also include information for other purposes throughout the whole lifecycle of a product. Also MSAs or test houses might use the watermark during the appliance inspection or compliance testing, for example to get information about material composition. Besides the QR code used on the new Energy label (cf. section 30.2.2), watermarks might be used for additional information e.g. related to Ecodesign requirements incl. material efficiency requirements under EU Ecodesign (see also the concept of a 'digital product passport', cf. section 30.2.3).

30.2.5 Webcrawling

	Webcrawling
Background	Web crawlers, also called search bots, spider or robots, are computer programmes that automated search the Internet for certain information or data. They analyse content and create information which are then collected in local databases or tables. For example, crawlers can be used to collect public available email addresses to make them available for advertising or marketing purposes, or screen product information such as prices from price comparison portals. Other areas of application for crawlers are the collection of news or statistical data. Crawlers are composed of a code of algorithms and scripts that gives clear tasks and commands. The crawler independently and continuously repeats the functions defined in the code. Web crawlers take on time- and cost-intensive analysis tasks and can scan, analyse and index web content faster, cheaper and more comprehensively than humans.[1074]
Information provided	Product information provided online.
Product phase(s)	• Placing the product on the market • Use phase (e.g. product reviews[1075])
Data provider	Manufacturers, retailers, consumers, test organisations

[1074] https://www.bigdata-insider.de/was-ist-ein-webcrawler-a-704217/; https://www.ionos.de/digital-guide/online-marketing/suchmaschinenmarketing/was-ist-ein-crawler/

[1075] One stakeholder pointed out that customer reviews are not a reliable information source as they are prone to manipulation and in most cases refer to issues occurring within the liability period.

	Webcrawling
Already used in Ecodesign / Energy label context?	No
How could this IT solution facilitate MSAs and/or standard setting in the Ecodesign/Energy label context?	Product information as required in product-specific Ecodesign regulations is often widely spread on publicly available websites: according to the regulations, the information shall be included in instruction manuals for installers and end-users, and free access websites of manufacturers, importers and authorised representatives. Often the information of the different parameters is spread over several files of the website (commercial part, installation manual, user manual). For Market Surveillance Authorities, it is high effort to search for all product information for the conformity assessment. Using a web crawler could facilitate MSAs by doing an automatic search. Also, a web crawler might be used for the assessment of customers' product reviews or test results of consumer organisations. This could facilitate for example the assessment of material efficiency requirements by providing e.g. hints on products with poor design for reparability or durability.

30.2.6 Use meters

	Use meters
Background	Several appliances already have the capability to measure the real-life usage over a certain time and, for example, autonomously adjust the performance accordingly. Examples are smart control in domestic electrical storage water heaters that adapt the heating phase to the usage of hot water. The smart control mode detects user behaviour, i.e. the time when the consumer usually withdraws hot water, and specifically heats the water just in time before the predicted withdrawal pattern. Refrigerators with cool-down function adapt to predicted door opening patterns, i.e. the smart control learns from the user behaviour over a period of time and reduces the temperature (cool-down function) just before door openings as per predicted consumer usage. Some smart cooking appliances have the capability to measure the behaviour and preferences of the users, for example to propose user-specific recipes.[1076] These functions serve one the one hand as service-oriented functions to the users, on the other hand, measuring the real-life usage is also applied to use smart, predictive maintenance solutions for the appliances. Specialised firms[1077] offer predictive maintenance technology that is integrated for example into white goods via an embedded microchip reference design and firmware which will be added to the manufacturer's circuit board. Remote view of faults, right down to component level, allows an issue to be detected at its earliest onset. A predictive maintenance solution cannot only monitor and analyse energy consumption of appliances in real-time, but in turn determine where issues may be lying that are causing unnecessary wastage using component level diagnostics. Through real-time electrical energy analysis, insights around what cycles are being used and how, can uncover useful behavioural information that can help to develop future product enhancements, but also guide marketing activities.
Information provided	Information about real-life usage, fault diagnostics, maintenance[1078]

[1076] https://www.impulse.de/management/unternehmensfuehrung/thermomix-digitalisierung/3954203.html?conversion=ads

[1077] See https://verv.energy/technology; https://verv.energy/blog/5-reasons-appliance-predictive-maintenance-should-be-part-of-your-sustainability-strategy

[1078] One stakeholder commented that a use meter in the sense of a device that allows the customer to track the usage ("technical age") of a device may be useful and justifiable. Further data points such as use patterns etc. are personal data which do not belong to the hands of authorities according to the stakeholder's view. The use of smart meters may be sufficient as a means to analyse energy consumption patterns. Furthermore, it should be taken into consideration that the acess to this kind of data depends on a connectivity function of the product, which is not available for all types nor all grades of products.

	Use meters
Product phase(s)	Use phase
Data provider	Indirectly consumers by their use of appliances, available to manufacturers
Already used in Ecodesign / Energy label context?	Not known
How could this IT solution facilitate MSAs and/or standard setting in the Ecodesign/Energy label context?	Information about typical use patterns, overall service time, faulty components, maintenance and repairs are crucial especially in the preparatory work for the development of base cases, to calculate the environmental assessments and to derive targeted Ecodesign requirements, for example on durability and reparability, including determining standard use cycles. Often, this information is difficult to gain, with specific consumer research studies being rare and/or costly. Feeding these data into the Ecodesign process could facilitate even more real-life related scenarios, standards and requirements settings.

30.2.7 Standard tests with randomized test patterns to facilitate detecting circumvention

	Standard tests with randomized test patterns to facilitate detecting circumvention
Background	Harmonised standards being used for the conformity assessment of Market Surveillance Authorities, have to fulfil the needs on repeatability (i.e. to obtain the same results when tests are repeated in the same test laboratory at different times) and reproducibility (i.e. when the same test is conducted in another laboratory). To fulfil these requirements, some harmonised standard test methods are rather specific and not necessarily fully able to represent the typical user behaviour (e.g. standard tests of refrigerators without any door-openings during testing). This might imply the risk and likelihood of circumvention, i.e. that manufacturers design products to adapt to these test conditions in a way to achieve more favourable results for their products. According to the experience of the ANTICSS project on Anti-Circumvention of standards for better Market Surveillance[1079], when products are specifically pre-set or manually altered or are able to detect to be under test with the aim of 'circumvention', the products appear to conform to the legal requirements when tested strictly with the standardised test methods. To facilitate detecting circumvention, which is part of the verification procedure for market surveillance purposes according to the respective Annexes of the Ecodesign and Energy labelling regulations, some test houses started developing digitally randomized test patterns.
Information provided	Digitally randomized test patterns within the conditions of harmonized standard tests means for example that a random sequence of executing the standard programmes (e.g. different load profiles) is run. For products which are specifically designed to adapt to the standard test conditions in a way to achieve more favourable results, such digitally randomized test patterns could lead to the result that the favourable results cannot apply anymore, i.e. inexplicable deviations occur which might serve as hint for circumvention acts.
Product phase(s)	Placing the product on the market => conformity assessment by Market Surveillance Authorities / test laboratories
Data provider	Test laboratories commissioned by MSAs for testing products with regard to the conformity assessments

[1079] See https://www.anti-circumvention.eu/storage/app/media/D20a_ANTICSS_Consolidation_circumvention-habits_final.pdf

	Standard tests with randomized test patterns to facilitate detecting circumvention
Already used in Ecodesign / Energy label context?	Yes. For example, standard EN 50440:2015 on the efficiency of domestic electrical storage water heaters and testing methods foresees specific standard measurements for water heaters being declared as smart appliances. The tests shall be carried out by using for the first week a random sequence of load profiles chosen from the declared load profile and the load profile one below the declared load profile with smart control disabled, and for a second week a repetition of the same sequence with smart control enabled. It might become circumvention if the appliance is programmed in a way that it recognizes being under test (as the same load profiles will be used over a period of 5 days) and in consequence the product alters its performance and/or resource consumption during test. Also, from the ANTICSS project it is known that randomized test patterns are for example developed for the measurement of refrigerating appliances.
How could this IT solution facilitate MSAs and/or standard setting in the Ecodesign/Energy label context?	Digitally randomized test patterns can facilitate the detection of circumvention acts which would otherwise be hard to detect in standard testing when products are specifically designed to adapt to these harmonized test conditions in a way to achieve more favourable results for their products.

30.2.8 'Extended documentation package' informing about software specifications of products to avoid circumvention

	‚Extended documentation package' informing about software specifications of products to avoid circumvention
Background	Latest Ecodesign regulations include a paragraph on 'Circumvention and software updates' requesting that *the manufacturer, importer or authorised representative shall not place on the market products designed to be able to detect they are being tested (for example by recognising the test conditions or test cycle) and to react specifically by automatically altering their performance during the test with the aim of reaching a more favourable level for any of the parameters in the technical documentation or included in any documentation provided.* *The energy consumption of the product and any of the other declared parameters shall not deteriorate after a software or firmware update when measured with the same test standard originally used for the declaration of conformity, except with explicit consent of the end-user prior to the update. No performance change shall occur as a result of rejecting the update. A software update shall never have the effect of changing the product's performance in a way that makes it non-compliant with the ecodesign requirements applicable for the declaration of conformity*. However, the detection of such smart software related circumvention acts poses major challenges for MSAs. Learning from the 'diesel scandal' in the context of circumvention triggered through smart functionalities, the Commission published in 2017 a guidance document on the evaluation of Auxiliary Emission Strategies and the presence of Defeat Devices[1080]. The manufacturer shall provide a so called "Extended documentation package" to the approval authority with information on the operation of all emission strategies including a description of the parameters that are modified by any Auxiliary Emission Strategy (AES) and the boundary conditions under which the AES operate, and indication of the Emission Strategies which are likely to be active under the conditions of the test procedures set out in the Regulation. When issuing a type-approval, Type Approval Authorities are required to assess, on the basis of the technical information contained in the "extended documentation package", whether the emission control strategy constitutes a defeat device, and, if

[1080] https://ec.europa.eu/docsroom/documents/26183

	‚Extended documentation package' informing about software specifications of products to avoid circumvention
	so, whether this is justified pursuant to the Regulation, or whether the approval must be refused due to the existence of a prohibited defeat device.
Information provided	In accordance with the provisions included in the Commission Notice on 'Guidelines for specifying the conditions for the application of these defeat devices or auxiliary emission control strategies' with regard to Regulation 715/2007 on type approval of motor vehicles, a so called 'extended documentation package' is recommended to introduce also for EU Ecodesign and Energy label legislation. For example, the manufacturer should be obliged to provide an extended documentation package to Market Surveillance Authorities with information on the software specification of their products and the operation of all 'smart' strategies including a description of the parameters that are likely to be active under the conditions of the test procedures set out in the Regulation. The extended documentation package could be a separate technical file to back up conformity and might include the following information: • A declaration of the manufacturer that the appliance does not contain any (smart) control strategies being used for circumvention; • a description of the smart control strategies and devices employed, whether software or hardware, and any condition(s) under which the strategies and devices will not operate as they do during compliance testing; • a declaration of the software versions used to control smart functions, including the appropriate checksums of these software versions and instructions to the authority on how to read the checksums; the declaration shall be updated and sent to the Market Surveillance Authority that holds this extended documentation package each time there is a new software version that has an impact to the performance of the appliance. The extended documentation package shall remain strictly confidential. It may be kept by the Market Surveillance Authority (MSA), or, at the discretion of the MSA, may be retained by the manufacturer. In the case the manufacturer retains the documentation package, that package shall be identified and dated by the MSA once reviewed and approved. It shall be made available for inspection by the MSA at the time of compliance control. For conformity assessment, Market Surveillance Authorities are required to assess, on the basis of the technical information contained in the extended documentation package, whether the (smart) control strategy might be used for circumvention, and, if so, whether the smart control is still justified pursuant to the Regulation, or whether the compliance must be refused due to the application of circumvention.
Product phase(s)	• Placing the product on the market • Product usage
Data provider	Manufacturer
Already used in Ecodesign / Energy label context?	• No • However, applied in the regulatory context of Regulation (EC) No 715/2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6)
How could this IT solution facilitate MSAs and/or standard setting in the Ecodesign/Energy label context?	Products are increasingly controlled by 'smart' software algorithms which might also be misused by automatically altering the product's performance during compliance testing with the aim of reaching a more favourable level for any of the regulated parameters. Detection of the application of such smart control strategies under standard testing is rather difficult. An 'extended documentation package' with a description of the smart control strategies and devices employed and any conditions under which they will not operate as they do during compliance testing could facilitate MSAs to better assess the results of the compliance testing with regard to the potential of circumvention.

30.3 Possible actions and policy options in the Ecodesign and Energy Labelling Working Plan 2020-2024

The proposed IT solutions for facilitating Market Surveillance Authorities and standard setting under the EU Ecodesign and Energy labelling framework require actions at different levels and have interlinkages to other current or envisaged European policy initiatives[1081]:

- For using a product database concept as EPREL (cf. Section 30.2.1) for collecting information also on ecodesign requirements, the regulatory framework of the EU Ecodesign Directive 2009/125/EC would have to be adapted accordingly.
- Developing a digital product passport (cf. section 30.2.3) is foreseen under the framework of the Sustainable Products Policy Initiative (SPPI) as announced in the new Circular Economy Action Plan (CEAP). Pre-requisite for collecting such data is the linkage to the broader European strategy on data that aims to create a common European data space where personal as well as non-personal data, including sensitive business data in full respect of the EU data protection legislation.[1082]
- QR codes or digital watermarks (cf. sections 30.2.2 and 30.2.4) physically directly connected to products affects the manufacturing and might not be possible as a minimum requirement for all products. The potential for such digital tagging could be analysed for example during the preparatory or review studies. Also, the accessibility of the data provided with the codes or watermarks for the use by MSAs has to be managed (e.g. set-up of underlying databases).[1083]
- The use of webcrawling services (cf. section 30.2.5) has to carefully respect the legal requirements to make use of the gained information for market surveillance purposes. The objectives and respective research algorithms have to be carefully decided. Further, MSAs applying such tools would need trainings how to use and interpret the information in order to avoid potential additional effort.
- Making use of real-life data where embedded use meters are available in products has to fully respect the legal framework of general data protection. The data could serve as additional useful information facilitating the preparatory or revision studies as well as standard setting. However, as not all products are digitalized, there

[1081] One stakeholder recommends to add another bullet point as follows: The use of innovative IT solutions (as described in this report) should be further investigated in view of achieving energy efficiency at systems level, as advised by the MEErP (2011). In particular, solutions such as the full operational of EPREL database, webcrawling and the application of a QR code to components, may address the issue of installers needing easy access to component data to demonstrate compliance on the systems level. Indeed, in many cases of system requirements in energy label or ecodesign regulation it is (or proposed to be) the responsibility of the installer to demonstrate compliance. In order to do this the installer needs easy access to data on the performance of the components making up the system (possibly to enter into a tool to calculate the system efficiency listed above). In principle this is easy, especially since some if not all of the components will have requirements to provide information under ecodesign and/or energy label regulations placed on them. In practice, for example for the heater and water heater package energy label, this has been found to be a barrier. A full operational EPREL database, webcrawling and QR-codes may all contribute to addressing this issue

[1082] One stakeholder points out on several issues about a possible digital passport to be clarified, which is how the information requirements resulting from the multiple regulations can be managed and compiled efficiently, as to avoid duplication of efforts and unnecessary administrative and design burdens; how the requirements can be made proportionate, cost-effective, and protective of sensitive information for all actors across the supply chain; and, which specific information provision will be actually useful and valuable for MSA or other specific audiences.

[1083] Another stakeholder commented that, while in principle agree with some Ecodesign information to be provided to MS Authorities and to the customers, this should be through the manufacturer's unique company QR code, not through a particular one. Further, Market Surveillance (MS) on Ecodesign & Energy Labelling should not be different from Market Surveillance for other Directives (LVD, EMCD, MD, etc…), which would mean creating particular and additional QR code. Finally, the stakeholder does not believe that providing additional information through a web platform and database are the right solutions as a rogue operator will always be able to provide wrong information on a webpatform or a database, and as no "a priori' control is done on the validity of such information.

should be no minimum design requirements regarding embedded use meters in products.
- Information provided in digital formats used for conformity assessments by Market Surveillance Authorities need further standards how these information has to be provided, e.g. future statistical parameters on reliability/ failure rates, Reparability Scoring Index or minimum lifetimes.

Making use of the proposed IT strategies to facilitate market surveillance and standard setting, has to involve many market actors along the value/ supply chain, i.e., from the various industries responsible for the provision of data to suppliers, various end-product industries, manufacturers, distributors, consumers, standardisation organisations, test laboratories, recyclers, etc. This is especially necessary due to new data requirements, and potential impacts on data security etc.

30.4 Stakeholder comments

The stakeholder feedback included several challenges in the context of market surveillance beyond horizontal innovative digital solutions and urged for further improvements as summarized in the following.

Stakeholder feedback recommending strengthening the participation and benefitting from cooperation

- Strengthening the pan-EU cooperation in Market Surveillance;
- Intensifying cooperation among national MSAs;
- Participation of Member States in joint enforcement projects is recommended as not being voluntary but mandatory.
- Improved cooperation between market surveillance authorities and stakeholders:
    - *Consumer organisations* carry out product testing and have already observed non-compliant products in the market. In the area of product safety, for example, DG JUST had organised a joint workshop between market surveillance authorities and consumer organisations to discuss how the results from product testing can be better used for enforcement work. Such a workshop is proposed to be repeated in the area of Ecodesign and Energy Labelling.
    - *Industry*: Article 9 of Regulation 2019/1020 provides for joint-activities between MSAs and industry associations. MSAs could make use of the industry expertise as an advisory party. Members of the Ecodesign and Energy Labelling Consultation Forum (EECLF) could be actively encouraged to make use of this opportunity to develop for example market surveillance guidance for their products.
    - *Standardisation*: Whereas other stakeholder groups are commonly present in technical committees of the standardization bodies, this seems not the case for MSAs. A regular monitoring of the activities in the technical committees of products covered by Ecodesign and Energy Labelling and discussion with market surveillance (e.g. ADCO Ecodesign / Energy Labelling) would be a potential starting point. Also it is proposed to identify and analyse policy options in the product specific preparatory studies to increase the influence of market surveillance authorities during the development of test standards.

Stakeholder feedback with regard to tackling new challenges and requirements

- Complex products: According to stakeholders' feedback, there is a need for adapted verification procedures for complex products (see for example recommendations from the H2020 funded INTAS project1084 on the notification to MSAs, testing at manufacturers' sites, or in situ testing).
- Online market sales:
  - Whereas there is a lot of evidence about non-compliance in the area of safety, according to stakeholder feedback there is reasoned suspicion that also environmental criteria are often not complied with when products are sold via online marketplaces and shipped on directly to consumers. It is recommended, for example, a joint horizontal project could possibly work out guidance on how to better check compliance of products sold online. Further, a stakeholder proposes to define and analyse within the studies under the Ecodesign and Energy Labelling Working Plan policy options and legal possibilities to address the issue and to provide basic support for inspections within the online market. Also, it is recommended that market surveillance authorities should take into account the growing share of the online market, e.g. by increasing the number of online inspections. According to stakeholder feedback, however, there are barriers, e.g. after an inspector has revealed himself as a market surveillance authority. In some cases, products are suddenly no longer available, or the offer can no longer be found. A possible solution is seen in incognito test purchases by the MSA, which the MSA is allowed to carry out under Chapter V Article 14 (4) j) of the new Market Surveillance Regulation (EU) 2019/1020.
- Circular economy and material efficiency requirements:
  - The implications of material efficiency requirements for market surveillance should be explored[1085];
  - Solutions for improved market surveillance are essential, not only in terms of production and use of recycled materials in new products, but also when it comes to repair, reuse, and recycling at the end of life of the products. Transparency and traceability must be ensured, also for products, components and materials processed outside of the EU.
  - When it comes to achieving a higher degree of circularity in the design phase of products that can be enforced by market surveillance, sharing best practices and using market-based incentives should be prioritized.
  - Inspections by market surveillance authorities regarding circular economy requirements are possible in principle, but the test procedures are time-consuming and exceed the time span in which products are available on the market. For example, testing the lifetime of lighting products takes about half a year and promotional items are only available on the market for a few weeks. Further, contrary to the typical energy efficiency requirements, some material efficiency requirements cannot be verified only "at the time of placement on the market", such as, for example, verifying the existence of spare part provision X years after the placement on the market.

[1084] See https://intas-testing.eu/best-practice/market-surveillance-authorities, https://intas-testing.eu/storage/app/media/INTAS_D4.3_Final.pdf

[1085] See for example https://ecostandard.org/wp-content/uploads/ECODESIGN-AS-PART-OF-CIRCULAR-ECONOMY-IMPLICATIONS-FOR-MARKET-SURVEILLANCE.pdf

- Disclosing of circumvention acts beyond non-compliance: The H2020 funded ANTICSS project1086 has the overall objective to assess and clearly define 'circumvention' in relation to EU Ecodesign and Energy labelling legislation and relevant harmonised standards, assess the potential impacts of circumvention and to prevent future circumvention acts under EU Ecodesign and Energy labelling. Thorough definitions of circumvention have been developed by the ANTICSS project team. According to the understanding of the ANTICSS project team, circumvention can be clearly delimitated from 'non-compliance', thus going far beyond the current focus of MSAs. The Ecodesign and energy labelling legislation states that 'non-compliance' can be determined only by Market Surveillance Authorities through product inspection, i.e. laboratory testing, and/or checking of the data and information provided in the technical documentation and/or any other information provided by the manufacturer or supplier against the requirements and conditions as defined in the legislation and standards. In contrast, circumvention does not make a product appear as non-compliant during testing. In the first instance products appear to comply with all the requirements and conditions, but the test results are specifically influenced, resulting in a more favourable performance from the manufacturer's perspective, by the use of circumvention behaviour or by the exploitation of (possible) weaknesses or loopholes in standards and legislation.

Stakeholder feedback regarding methodological & standardization aspects

- Although improved market surveillance is stated as an eligibility criterion, very limited consideration is given to this point according to another stakeholder; it would be worthwhile that the preparatory and revision studies would consider the enforcement of the regulations to avoid unfair competition. Rather than opting for an horizontal initiative, each regulation could be accompanied with Commission Guidelines for Market Surveillance Authorities providing clarity to the market.
- One stakeholder requires developing and implementing a comprehensive market surveillance strategy for all products, components and materials.
- Further, the need for harmonisation of standards or setting of transitional methods is seen as well as the need for a scientific approach ensuring reproducibility of results in a test laboratory. In this context, also synchronisation of standards with regulatory processes is important to avoid situations when regulatory requirements are in place without a harmonised standard already published.
- One stakeholder points out that the methodology and/or proposed changes should leave none or minimal room for interpretation: Harmonised standards are essential to provide market surveillance authorities with the necessary test methods for technical inspections. In recent years, it has often been observed that test methods do not sufficiently reflect the application in households or are not sufficiently reproducible (vacuum cleaners), lead to a significantly high influence of the manufacturer on the test performance (air conditioning systems), lead to discussions whether loopholes have been created by a less specific description of the test condition (ovens), etc. All examples lead to limitations in market surveillance measures and must be avoided.
- Further, a need is seen in assessing and defining the standardisation needs for material efficiency aspects at product-specific level in order to support the ecodesign requirements in place, and if needed, the European Commission should issue the according standardisation request(s)

[1086] See https://www.anti-circumvention.eu/

- To overcome the difficulty of conformity testing regarding durability and lifetime requirements, screening methods would be desirable according to a stakeholder, for example by developing stress tests. The stress tests should provide information as to whether the product durability / lifetime can be determined in a much shorter period of time. This makes it possible to contact a manufacturer at an early stage and ask for clarification or, if no clarification is provided or no reason is seen, to follow up with a more time-consuming and standardised test. The development of screening methods and stress tests enables an informed decision to be made as to which products should be subjected to a durability / lifetime test, as an increased probability of failure is assumed. The development of stress tests ensures that products age prematurely, e.g. due to extreme ambient or operating conditions, and show signs of failure after hours or days rather than months or years.
- A general compliance challenge in most product categories is that manufacturers don't have a complete conformity assessment. Thereby the information is spread over many separate documents of test results, calculations, production files etc. It is often very time consuming for MSA's to get the right information. More detailed prescription of the required of the content of conformity assessment and technical files in article 8 and annexes of Ecodesign Directive 2009/125/EC and the related articles in the product specific regulations.
- One stakeholder recommends assessing the appropriateness of 3rd party conformity assessment for other product categories.
- Another stakeholder points out that distributors don't have responsibilities in the Ecodesign directive. Especially for products that are not covered by energy labelling this results in situations that MSAs are not able to act on circumvention, for example on intended use circumventions. Like water heaters that according to the manufacturer are not destined for drinking and sanitary water and so out of scope, however distributors sell them for all kinds of use. At the moment it is not possible for MSAs to take measures. It also limits the MSA's in the investigations to the placing on the market dates of products sold in shops. The distributor doesn't need to proof that the products are placed on the market before strict requirements came into force. It is recommended to add the role of distributor to the directive like in most product regulations.
- Within the ANTICSS project, "alternative test procedures" are developed to facilitate better detection of circumvention by MSAs. Only those aspects of the standard test conditions which are under suspect of manipulation are varied very slightly. At the same time, the alternative procedures are still designed as close as possible to the standard procedures with the aim to ensure comparability with the original measurement results. If the alternative approach leads to inexplicably relevant changes in the measurement results, this may indicate that the appliance might have been specifically optimised for the standard test. It is recommended that the use of such alternative test procedures for detecting circumvention by MSAs and test laboratories should be possible and facilitated.
- Facilitating inspections of online market sales: As products on the internet can increasingly only be purchased by credit card, inspectors have so far used their own for this purpose. It happens that as soon as the link with market surveillance activities becomes apparent, traders block the contact details provided for the purchase. This puts the employee at a disadvantage if subsequently making private Internet purchases. Alternatively, it is possible to use prepaid credit cards, but in this case a person with a real delivery address must be provided. In order to make purchases

incognito, it is considered necessary to provide MSAs with respective payment methods.
- Before introducing any regulatory change on market surveillance, one stakeholder recommends to make sure that there is available and scientific sufficient laboratory capacity and that resources are available to ensure enforcement activity of Member States.

Beyond these detailed comments on several aspects, one stakeholder pointed out as pre-requisite that before any transformation of market surveillance performance can take place an innovative solution for the underfunding at Member States level must be found. In this context, the European Commission launched in 2020 a Framework Contract for the Provision of Services and Technical Assistance for Testing Campaigns of Energy-related Products Subject to Ecodesign or Energy Labelling. The contract shall give the Commission the possibility to launch testing campaigns of products covered by Ecodesign and Energy labelling during a period of 4 years with the aim of providing a valuable contribution to the EU 2030 energy efficiency targets and contributing to the European Green Deal and its long-term carbon neutrality objectives. The concept of such testing campaign was initially raised in the context of the task force that DG Energy had set up with member states to deal with gap to the energy efficiency 2020 targets.

31 FIRMWARE AND SOFTWARE

31.1 Introduction and scope

31.1.1 Background for analysing firmware & software

At a rather mature stage in the existence and application of the 2009 Ecodesign Directive, as one of the main objectives of the Ecodesign and Energy Labelling Working Plan (EELWP) 2020-2024 it is pertinent to review if any new "horizontal" implementing measures might be needed to improve the application, implementation and monitoring of Ecodesign and Energy Labelling. It is also necessary to scrutinise and identify if there are remaining gaps or opportunities, or new product groups where substantial resource savings may still exist.

A particular focus under the EELWP aims to be on the analysis of the Information and Communication Technologies (ICT) product sub-groups. According to the European Digital Strategy 2020[1087], digital technologies are crucial for the EU to become climate neutral by 2050, the goal set in the European Green Deal; aim is at taking measures to improve the energy efficiency and circular economy performance of the ICT sector from broadband networks to data centres and ICT devices and – by launching a circular electronics initiative – improving rules to make devices last longer and make them easier to repair and recycle.

Analyses regarding Ecodesign and Energy Labelling possibilities for ICT products are already in progress – for example via an ICT Taskforce that has been set up – within several of the European Commission's Directorates-General (DGs). In this context, in July 2020, the European Commission published the "ICT impact study" (VHK and Viegand Maagøe 2020)[1088], covering the following product groups in its scope: data centres, telecom networks, electronic displays, audio/video equipment, personal ICT equipment, imaging equipment, home and office equipment, ICT in public spaces, building automation and other controls. Several of these product categories are already in scope of current or upcoming Ecodesign and Energy labelling regulations. Within this preparatory study for the EELWP 2020-2024, further not so far regulated ICT product groups like small home and office networking equipment (switches and routers), interconnected home audio, video & voice service equipment, base stations and subsystems as well as universal external power supplies, are analysed regarding their potential for product-specific ecodesign and energy labelling policy measures.

In the ICT impact study, one of the recommendations proposed for the energy efficiency improvement of telecommunication networks, is reducing the data traffic by good design of software and service; as example is mentioned the recent switch from Advanced Video Coding (AVC, H.264) to High Efficiency Video Coding (HEVC, H.265) which has cut video data traffic (85% of the total traffic) in half.

[1087] Factsheet "Supporting the Green Transition" within the European Digital Strategy 2020 "Shaping Europe's digital future" of the European Commission; February 2020; online available at https://ec.europa.eu/commission/presscorner/api/files/attachment/862091/Supporting_the_green_transition_en.pdf.pdf; last accessed 3 October 2020

[1088] https://circabc.europa.eu/ui/group/1582d77c-d930-4c0d-b163-4f67e1d42f5b/library/b6884364-4e14-44a1-9e23-03a7fed002af, last accessed on 3 October 2020

Also, the issue paper "Impacts of the digital transformation on the environment and sustainability" by Liu et al. (2019)[1089] on behalf of DG Environment summarizes the importance of software regarding impacts on the environment. According to Hilty et al. (2015)[1090], cited in the issue paper, the use of software products, although being immaterial goods, can bring about significant material and energy flows. Software characteristics determine which hardware capacities are made available and how much electric energy is used by end-user devices, networks, and data centres. Further, recent research results published by the German Environment Agency[1091] show that software has a significant impact on the resource efficiency of IT hardware and on how long it is used. Programmes executing the same functions can have very different levels of energy consumption depending on how they are programmed. According to the Agency, the research outcome will make it possible to providing support in designing resource-efficient software and establishing verifiable requirements of software for the efficiency of processing, storage and transfer of data.

These examples show that beyond dedicated ICT product categories there might be also significant energy efficiency improvement potential of software applications. Further, as most of today's products are controlled by and their main functionality relies on software, software also plays a major role with regard to the durability of products in the context of (missing) software updates, i.e., software-related hardware obsolescence.
Against this background, the following sections analyse possible implications of software on energy and environmental impacts of products as well as potential product-specific or horizontal policy options for software for the next Ecodesign and Energy Labelling Working Plan 2020-2024.

31.1.2 Overview of different types of "software"

"Software" can be divided into different types[1092]:

Firmware is a specific class of electronic software that provides the low-level control for a device's specific hardware, often stored on electrically programmable memory devices. Typical examples of devices containing firmware are embedded systems, consumer appliances (e.g. white goods, headsets, speakers, televisions, audio equipment, routers etc.), computers, computer peripherals, and others. Almost all electronic devices beyond the simplest contain some firmware. Examples of firmware in consumer products are for example: timing and control systems for washing machines; or controlling sound and video attributes, as well as the channel list, in modern televisions.

System software is a software for managing computer hardware behaviour, as to provide basic functionalities that are required by users, or for other software to run properly, if at all. System software includes the following: Operating systems, which are essential collections of software that manage resources and provide common services for other software

[1089] Liu et al. (2019): Impacts of the digital transformation on the environment and sustainability. Online available at https://ec.europa.eu/environment/enveco/resource_efficiency/pdf/studies/issue_paper_digital_transformation_20191220_final.pdf, last accessed on 8 October 2020

[1090] Hilty et al. (2015): Green Software: Establishing and exploiting potentials for environmental protection in information and communication technology (Green IT). Online available: https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_23_2015_green_software_0.pdf, last accessed on 8 October 2020

[1091] See https://www.umweltbundesamt.de/en/press/pressinformation/environmental-impact-of-software-is-now-measurable; last accessed on 8 October 2020

[1092] According to https://en.wikipedia.org/wiki/Firmware; https://en.wikipedia.org/wiki/Software; https://en.wikipedia.org/wiki/Outline_of_software#Software_products that runs "on top" of them; device drivers, which operate or control a particular type of device that is attached to a computer; and utilities, which are computer programs designed to assist users in the maintenance and care of their computers.

On the other hand, **application software** is software that uses the computer system to perform special functions or provide entertainment functions for end-users beyond the basic operation of the computer itself. There are many different types of application software, such as word processors, databases, image or video editing.

According to Specht (2018)[1093], the term “software” is particularly common in the computer sector. But also, other systems are software-controlled, for example devices like washing machines, ovens, televisions, MP3 players, navigation systems or DVD and Blu-ray players. As the software in these devices is firmly anchored with the hardware it is called an "**embedded system**". The software ensures that these devices follow a certain logic and that they can be controlled by using keys or other input options. They can be controlled in a way similar to computers - the difference is that the hardware is not compatible with other software (for example, an alternative operating system).

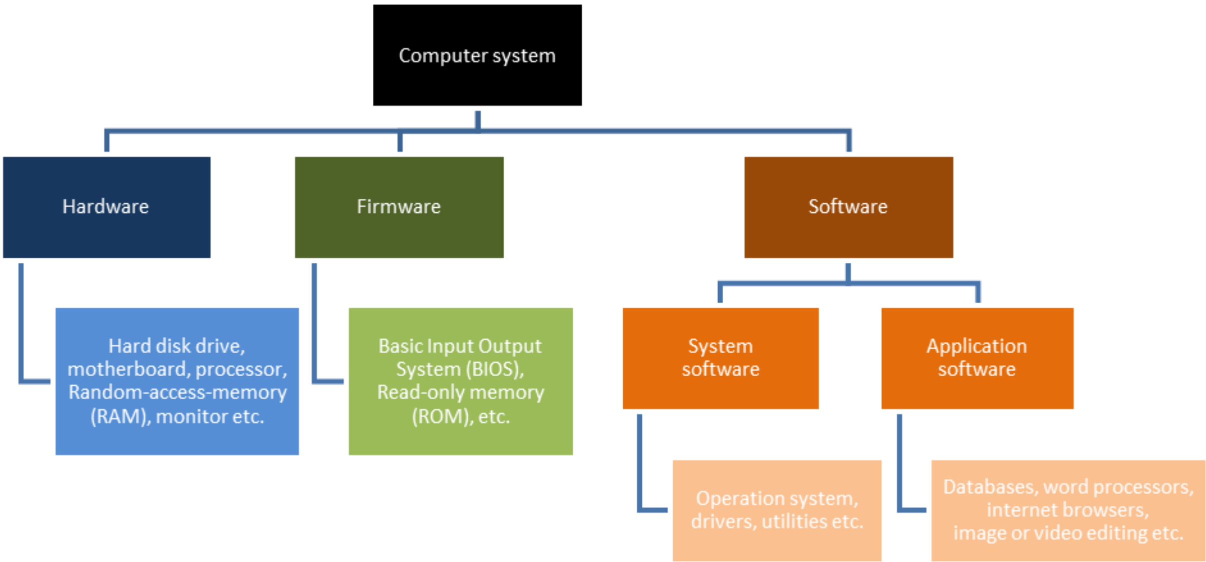


Figure 119: Overview of hardware, firmware and software in a computer system (own compilation)

In this sense, in the context of product policy measures, it has to be distinguished between *devices* which have dedicated software for product functionality (firmware, system software), and *devices* which enable any type of application software to run.

[1093] Specht, T. (2018): Was ist Software? Einfach erklärt. CHIP (ed.). Online available at https://praxistipps.chip.de/was-ist-software-einfach-erklaert_41276, last updated on 6 Sep 2018, last accessed on 24 May 2020

31.2 Environmental issues related to software

31.2.1 Software induced hardware obsolescence

As pointed out by several publications, e.g. Kern et al. (2018)[1094] or Leboucq (2017)[1095], software is becoming more relevant for analysing the environmental impacts of hardware due to its direct or indirect impact on hardware obsolescence.

Hardware could very quickly become obsolescent (i.e. necessary replacement even without the hardware being defect), if the update of firmware or software for example demands faster processors or larger memory capacity than provided with the existing appliance, if software or firmware updates to run the appliance properly or at all, or to ensure IT security and privacy are not provided anymore, or if uninstallation of one kind of software causes negative side effects to other installed software systems. In addition, many hardware devices are dependent on external software services. If the external services are switched off or changed, the hardware can no longer be used.

According to Asset Guardian Solutions Limited (2017)[1096], there are several causes of software obsolescence, both direct and indirect:

- Hardware: New hardware may not support old software, and it may not be possible to purchase old hardware that is supported. Obsolescence issues with hardware can cause obsolescence issues with software. The reverse is also true where new software does not run on old hardware. So, where strategies involve upgrading software, the impact on hardware also has to be considered.
- “Commercial off-the-shelf” (COTS) software[1097]: Software suppliers obsolete their software as part of their business model, to encourage users to invest in upgrades.
- Loss of software integrity: Uncontrolled changes leave documentation out of date and software unsupportable over time. Poor revision control, back-ups and media management damage the integrity of the software making it very difficult to support changes.
- Data formats change: Old software may employ data formats for saving information that themselves become obsolete and are not compatible with newer operating systems.
- Suppliers do not sell licenses any more: Suppliers of a system may stop selling or renewing licenses for old software preventing it from running (or running legally and properly licensed).
- Loss of expertise for old systems: Software may use old programming languages and old programming tools with which younger engineers have no experience. Knowledge of the requirements of a system and experience of the equipment under

[1094] Kern, E.; Hilty, L. M.; Guldner, A.; Maksimov, Y. V.; Filler, A.; Gröger, J.; Naumann, S. (2018): Sustainable software products - Towards assessment criteria for resource and energy efficiency. In: Elsevier - Future Generation Computer Systems (86), pp. 199–210. Online available at https://reader.elsevier.com/reader/sd/pii/S0167739X17314188?token=C7EBB0A7BBAD9DB2D7A9E2A1EA29DE94969FAED12F25A8B74AA36185863B05E79EAC39A4EF1FDBC2AD2138EEA39089C6, last accessed on 24 May 2020.

[1095] Leboucq, T. (2017): End of life: software-induced obsolescence and wastes? Greenspector (ed.). Online available at https://greenspector.com/en/end-of-life-software-induced-obsolescence-and-wastes/, last updated on 16 Aug 2017, last accessed on 24 May 2020.

[1096] Asset Guardian Solutions Limited (2017): Obsolescence Management of Software Components, Whitepaper, Asset Guardian Solutions Limited. Online available at https://www.assetguardian.com/obsolescence-management-of-software-components/, last updated on 28 Jun 2017, last accessed on 24 May 2020.

[1097] i.e. standard software produced in series without any individual additions or adaptations

control may be held by older engineers. Across industry, it is estimated that 50% of skilled labour will retire in next 10 years, so this can lead to obsolescence issues.
- Cyber Security breaches which cannot be fixed.

The European Commission has already tackled the issue of software-induced hardware obsolescence in part. For example, in the context of the implementation of the EU action plan for the Circular Economy, the Commission has carried out a study for the analysis and development of a possible scoring system to inform about the ability to repair and upgrade products (Cordella et al. 2019)[1098].

In this study, a general framework has been proposed that provides technical guidance for the identification of most relevant aspects and priority parts for products on the market, as well as for scoring and aggregating different aspects of repair and upgrade. Reparability and upgradability are defined as the ability to restore the functionality of a product after the occurrence of a fault, and the ability to enhance the functionality of a product. According to the study, both can refer to one or more parts of a product, where parts may be not only hardware, but also software or firmware. This means that besides hardware, explicitly also software and firmware can be classified as so called "priority parts", i.e. parts being necessary to deliver either primary or secondary functions of the product which shall be given high priority in a reparability scoring system. Relevant are on the one hand frequencies of upgrades to keep the product delivering user expectations which is particularly important because it can to some extent determine the likelihood of obsolescence of the product. On the other hand, upgrade of parts, software and firmware should also be considered whenever they are evaluated as necessary to ensure that the product fulfils users' expectations during the expected lifetime.

The proposed scoring system takes into consideration the following technical parameters related to software and firmware when assessing the reparability and upgradability of generic products with respective pass & fail criteria, rating classes as well as support to assessment and verification:

"Software and firmware":
- Pass / fail criteria (this applies to products for which software and firmware are considered a priority part; the duration X is to be defined at product group level):
  - Software/firmware updates and support are offered for a duration of at least X years after placing the last unit of the model on the market.
  - Full compatibility with open source Operating Systems and/or open source Virtual Machine software is ensured (where applicable).
  - Information is provided about how updates will affect the original system characteristics (e.g. Random-access memory, RAM, or Central Processing Unit, CPU), and there is to be always the option to not install, to install or to uninstall the update[1099].
- Rating classes (the duration of availability has to be defined at product group level. If needed, duration could be modulated in more categories and aligned to the requirement for spare parts. The inclusion of one or more factors has to be evaluated and adapted at product specific level):

[1098] Cordella, M.; Alfieri, F.; Sanfelix, J. (2019): Analysis and development of a scoring system for repair and upgrade of products, Final report. European Commission, Joint Research Centre. Seville, Spain, 2019. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC114337/jrc114337_report_repair_scoring_system_final_report_v3.2_pubsy_clean.pdf, last accessed on 24 May 2020.

[1099] Security patches should always be possible to install. These should be separated from functionality updates.

- A score is assigned for the product based on the period of time (to be defined at product group level) during which software/firmware updates and support are offered.
- A score is assigned for the product based on the target groups (all interested parties; or any self-employed professional as well as any legally established organization providing repair service; or service providers authorised by product manufacturer to offer repair service).
- A score is assigned for the product based on the cost of software/ firmware update service (for entire period of time; or for X years). However, Cordella et al. (2019) also recognised that scoring based on cost is more difficult to implement and verify.

• Support to assessment and verification:
  - Assessment: Declaration about the duration of availability of software and firmware over time, as well as information about costs, and information about how updates will affect the original system characteristics.
  - Verification: Check of actual availability, compatibility, and possibility to avoid/reverse the update.

"Diagnosis support and interfaces":

• Pass/fail criteria: none;
• Rating classes: A score is assigned for the product based on the availability of diagnosis support and interfaces to aid the identification of typical failure modes associated to the priority part. Publicly available hardware/software interface can include hardware functionality testing software tools developed by a third party, provided the software tools are publicly available and the manufacturer provides information on their accessibility and applicable updates. The product can be equipped with an appropriate interface for hardware and software to do fault diagnosis and reading, adjustment or resetting of parameters or settings:
  - Publicly available hardware/software interface: to be diagnosed, some of the main faults need the use of hardware, software and other support which is publicly available;
  - Proprietary interface: to be diagnosed, some of the main faults need the use of proprietary tools, change of settings or transfer of software which are not included with the product.
• Support to assessment and verification:
  - Assessment: Reference to the required hardware material /software tools required;
  - Verification: Check of actual availability and operability.

In the study of (Cordella et al.2019), the scoring system has been exemplary applied to the product groups laptops, vacuum cleaners and washing machines with product specific differences of the technical parameters, pass & fail criteria and rating classes:

• Duration of software updates to be offered: e.g. for laptops minimum 4 years (pass or fail) with highest scores for software/firmware updates/support offered for at least 7 years. For robot-type vacuum cleaners, the minimum period is 5 years (pass or fail) with highest scores for at least 8 years; for washing machines minimum 10 years (pass or fail), however without additional scores for a longer duration. For washing machines, in addition scores are assigned based on the cost of the software/firmware update as well as based on the target group (higher score when updates are offered publicly compared to offering only to professional repairers).
• Information about the impact of future updates on the original system characteristics (e.g. RAM, CPU) has to be provided, and there has to be always the option

to not install, to install or to uninstall the update: applicable to laptops and washing machines, but not to vacuum cleaners

- Diagnosis support and interfaces: For washing machines, a score is assigned for the product based on the availability of diagnosis support and interfaces to aid the identification of typical failure modes associated to the priority part, e.g. publicly available (higher score) or proprietary hardware/software interface. If used, for the assessment of this criteria, reference to the required hardware material /software tools is required. It is further explained that a publicly available hardware/software interface can include hardware functionality testing software tools developed by a third party, provided the software tools are publicly available and the manufacturer provides information on their accessibility and applicable updates. The product can be equipped with an appropriate interface for hardware and software to do fault diagnosis and reading, adjustment or resetting of parameters or settings (e.g. external memory device, data cable connection, or from a remote source using a network connection). The port, slot, or connector that is used for the hardware and software interface is accessible without tools.

(Cordella et al. 2019) states for washing machines that software and firmware updates are expected to have an increased relevance in the next few years in order to support intelligent system to monitor and control the washing machine through internet by an IoT based wireless sensor network; also, many failures could be resolved through software upgrade. New connected appliances have this feature along with diagnosis and self-repair guides with smart application apps.

However, the relevance of software updates and diagnosis support not only applies to washing machines or ICT products, obviously, but to far more kinds of appliances on the market as these are increasingly software-controlled. For some product categories, requirements on software updates are already addressed in current Ecodesign regulations (cf. section 31.3).

31.2.2 Energy and resource efficiency of software

Software cannot only contribute to hardware becoming prematurely due for replacement (software-induced hardware obsolescence) as described in the previous section, but software has also a measurable influence on the energy consumption of the hardware.

Within the research project "Development and application of criteria for resource-efficient software products with consideration of existing methods", sponsored by the German Federal Environment Agency, Gröger et al. (2018)[1100] has recently developed the methodological basis for determining the use of resources by software, comparing application software products with each other and making efficiency demands on them.
An evaluation methodology was developed based on three different impact areas of the properties of the analysed application software products:

[1100] Gröger, J.; Köhler, A.; Naumann, S.; Filler, A.; Guldner, A.; Kern, E.; Hilty, L. M.; Maksimov, Y. V. (2018): Entwicklung und Anwendung von Bewertungsgrundlagen für ressourceneffiziente Software unter Berücksichtigung bestehender Methodik (UBA TEXTE, 105/2018). Umweltbundesamt (ed.), 2018. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2018-12-12_texte_105-2018_ressourceneffiziente-software_0.pdf, last accessed on 25 May 2020.

- Resource efficiency: This impact area is intended to identify the extent to which hardware resources are used and amount of energy is required (hardware efficiency, energy efficiency, and resource management);
- Potential hardware useful life: This impact area represents the influence of the software on the hardware renewal cycles, e.g. by backward compatibility, platform independence and portability, or hardware sufficiency, and
- User autonomy: This impact area addresses the degree of autonomy of the user in dealing with the software product, e.g. by transparency and interoperability, uninstallability, maintenance functions, independence of out-side resources and quality of product information.

(Gröger et al. 2018) developed a catalogue of criteria for these impact areas to formulate requirements for resource efficiency of software products, which can be quantitatively and qualitatively verified on the basis of further indicators. The applicability of the initial criteria catalogue was tested by applying it to 11 different software products: 2 word processing programs, 3 Internet browsers, 3 content management systems and 3 database systems.

Standard usage scenarios were defined for these software product groups to be used as reference unit for all measurements of energy consumption and hardware usage. For the System Under Test (SUT), first the basic load of the device was determined by measurement, i.e. the average utilisation of the CPU, working memory and permanent storage, and the amount of data transmitted via the network without the application software to be tested. The application software to be measured was then installed and started on the device. As long as the software was still in an idle state, i.e. after the start but without execution of a usage scenario or interaction with the user, the idle load was measured. The third measurement was used to determine the (gross) utilisation of the system during the active operation of the application software by a standard usage scenario. Standardised evaluations ensured that software products that have gone through the same usage scenarios could be compared in terms of their energy efficiency and their use of hardware capacities. During the course of the scenario, usage of the hardware capacity and energy consumption were measured and the active tasks were recorded in the activity log of the load driver. It was possible to monitor and record the CPU, main and hard disk storage, network load and total system energy consumption.

The measurement results pointed out clear differences in energy consumption between the tested application software products with same functionality during their actual operation, see following figure.

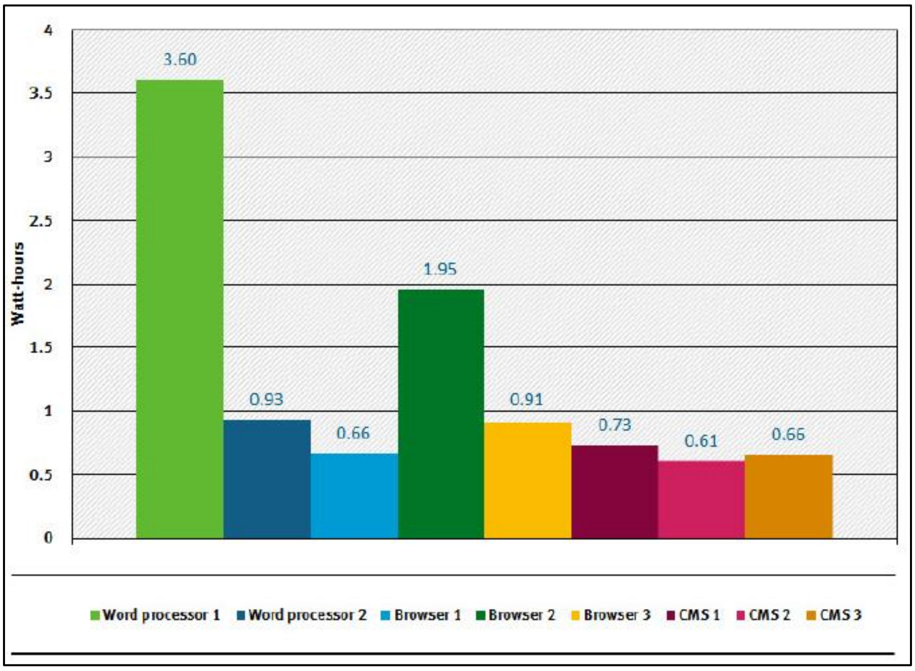


Figure 120: Comparison of energy consumption of the local device (SUT(Client)) during the execution of the standard usage scenario; source: Gröger et al. (2018)

According to Gröger et al. (2018), the energy consumption of the three analysed Content Management Systems (CMS) was relatively close within the range of approx. 0.61 to 0.73 watt hours (Wh). On the other hand, the three browsers showed clearer differences with approx. 0.66 Wh for browser no. 1 and 1.95 Wh for browser no. 2. Finally, the differences were most obvious between the two measured word processing programmes. Programme no. 1 consumed almost four times as much energy (3.6 Wh) as word processing programme no. 2 (0.93 Wh), although both programs run through the same standard usage scenario and perform the same tasks. Programme no. 2 required only about a quarter of the electrical energy and was therefore significantly more energy-efficient. One reason for the higher energy consumption of a software application was for example due to a lack of data compression.

The results of the measurements according to Gröger et al. (2018) further showed that there were also discernible differences between the software products in terms of hardware efficiency (processor utilization, working memory, permanent storage, bandwidth for network access).

Another criterion for example was the utilization levels of hardware resources if a software was in idle mode. Idle describes the state after the software has been started, but in which no user interaction takes place or calculations are performed. The results of the measurements by Gröger et al. (2018) for three different web browsers showed that browsers no. 1 and 2 increased the processor load (CPU) by around 1 percent in addition to the base load of the measurement system when being in idle. The idle mode of Browser 3, on the other hand, led to an additional utilization of the processor of 12 percent, i.e. browser 3 used twelve times the amount of hardware resources (based on CPU utilization), see following figure.

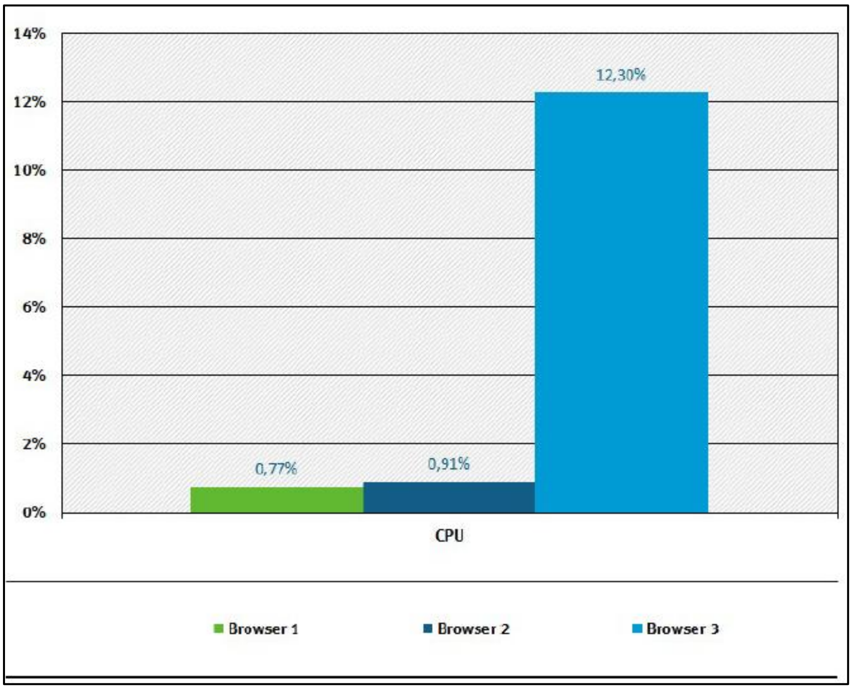


Figure 121: Hardware Utilization (CPU) of three web browsers in idle mode; source: Gröger et al. (2018)

This is particularly relevant against the background that the excessive use of hardware could also lead to programme execution taking too long, which might lead to companies, administrations or private users taking this supposedly slow hardware out of service and purchasing new, faster hardware (i.e. software-induced hardware obsolescence, see also section 31.2.1). On the other hand, there is also a connection between the functional scope of a software product and its hardware usage. As the number of functionalities offered by an application software increase, the demand on the hardware and energy consumption usually increase as well.

Based on the findings of the practical test, (Gröger et al. 2018) developed a reduced catalogue of criteria, which could be used as a basis for possible criteria, for example for the award of an eco-label for software, see following table. The criteria are partly based on measurement results (e.g. energy efficiency, hardware utilization), partly based on manufacturer’s information (e.g. transparency of data formats, platform independence) and can partly be determined by visual inspection (e.g. comprehensibility and manageability of product documentation).

Figure 122: Software criteria for the potential application in an eco-label; source: (Gröger et al. 2018)

Criterion
1 Resource efficiency
1.1.2 Minimum system requirements and resulting hardware requirements (incl. peripheral devices)
1.1.3 Hardware utilization in idle mode assuming a standard configuration
1.1.4 Hardware utilization during normal use assuming a standard configuration and a standard usage scenario
1.2 Energy efficiency
2 Potential useful life of hardware
2.1 Backward compatibility
2.2 Platform independence and portability
2.3 Hardware sufficiency
3 User autonomy
3.1.1 Transparency of data formats and data portability
3.1.2 Transparency and interoperability of the programs
3.1.3 Continuity of the software product
3.2.1 Uninstallability of programs
3.4.1 Offline capability
3.5.1 Comprehensibility and manageability of product documentation, licensing conditions and terms of use

In the beginning of 2020, the German ecolabel Blue Angel introduced award criteria for "Resource and Energy-Efficient Software Products"[1101]. The focus is on application software with a user interface running primarily on desktop systems, however, with the aim to expanding the scope later on to other architectures such as client server systems and mobile apps. The requirements distinguish between those applicable at the time of application of the ecolabel, taking into account the criteria as listed in the table above, requirements during the term of the ecolabel contract (i.e. further development and update of the product) and requirements at the end of the term of the ecolabel contract (i.e. submission of a resource efficiency report including the values measured during the term of the contract for a final evaluation of the software product).

As there is also a need to pay attention to resource efficiency for individually programmed application software, which is used, for example, by the public sector as special applications, (Gröger et al. 2018) further developed a guideline for the public procurement of sustainable software aiming at purchasers of software and explaining the most important criteria from the catalogue, which can already be defined as performance requirements in software procurement, see Gröger (2019)[1102].

[1101] Blue Angel award criteria: Resource and Energy-Efficient Software Products (DE-UZ 215). Online available at https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20215-eng%20Criteria.pdf, last accessed on 8 Oct 2020

[1102] Gröger, J. (2019): Leitfaden zur umweltfreundlichen öffentlichen Beschaffung von Software (UBA TEXTE, 62/2019). Umweltbundesamt (ed.), 2019. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020-01-21_texte_62-2019_leitfaden_beschaffung_umweltfreundliche_software_korr.pdf, last accessed on 25 May 2020.

31.2.3 Software updates and the potential of software in the context of circumvention

31.2.3.1 Software updates

Software updates can have multiple purposes, e.g. security updates, fault elimination or software enhancement, improving the operation of hardware, peripherals, the performance or overall lifetime, as well as adding new programmes, functions and features. The potential benefits of installing or drawbacks when rejecting them might be different depending on consumers' needs. For example, ensuring that the device remains cyber-secure after newly discovered cyber security vulnerabilities is rather important and might have severe consequences, if the update is not installed, whereas the availability of new convenience features might not be so relevant for some consumers.

Software updates are usually provided a certain time after placing the product on the market through external communication between the appliance and the manufacturer, third parties or even other users. The initial product functioning, but also the energy and resource efficiency of appliances can be modified through software updates.

To avoid potential misuse of software updates in the sense that updates have the effect of changing the initial product performance and deteriorating the energy efficiency or other performance parameters in a way that would make the product non-compliant with the ecodesign requirements, most Ecodesign regulations adopted at the end of 2019 include for the first time a dedicated Article on circumvention, which in the second part of this Article also addresses the issue of software updates, see section 31.3.1 below.

31.2.3.2 Potential use of software for circumvention of standards and regulations

Software in products might be programmed in a way that the product is able to recognize the – often very specific – conditions or test cycles of the standard test used for compliance verification and reacting specifically by automatically altering the product's performance during the test with the aim of reaching a more favourable level for any of the declare parameters. To avoid such potential misuse, most of those Ecodesign regulations adopted at the end of 2019 include for the first time a dedicated Article on circumvention, see section 31.3.1 below.

The Horizon 2020 funded research project "ANTICSS – Anti-circumvention of standards for better Market Surveillance" analysed especially the potential of so called "smart" products that might be using software for circumvention of regulatory requirements in the context of Ecodesign (Graulich et al. 2019)[1103].

There is no standard definition of "smart" appliances. For example, the Ecodesign Preparatory Study on "Smart Appliances" decided to set the final focus on demand side flexibility only[1104].

[1103] Graulich, K.; Stamminger, R.; Pakula, C. (2019): Analysis of the relation between 'smart' products and circumvention, ANTICSS Project, Task 2.4, 30 Jun 2019. Online available at https://www.anti-circumvention.eu/storage/app/media/uploaded-files/ANTICSS_Working-paper_Smart-products-and-circumvention.pdf, last accessed on 24 May 2020.

[1104] https://eco-smartappliances.eu/

In a broader approach related to the context of circumvention, Graulich et al. (2019), distinguished between products *marketed* as 'smart' and products *acting* 'smart', see also the figure below:

Products marketed as 'smart'	Products acting 'smart' (= intelligent)
For products marketed as 'smart appliances', there seems to be no clear definition. Often, either the utility or the possibilities for external communication via internet connection are highlighted under this term. Products are marketed as smart when for example providing automatic software updates, remote control function via smartphone app or for the purpose of demand side flexibility, as well as communication between appliances or to a smart home network. Also computer functions for appliances other than computers (e.g. smart TVs), additional functions like a webcam for controlling and communicating the status (e.g. smart fridge), as well as learning or AI-enabled appliances are promoted as smartness. These functionalities, however, do not necessarily provide the technical configuration to circumvent compliance testing.	Products with the technical operation principle and configuration to circumvent compliance testing, i.e. with the ability to detect being in a test situation and altering the product performance and/or resource consumption specifically during test in order to reach more favourable test results, are not necessarily marketed as smart products, for example the function 'internal adjustment'. Further, if a standard test situation is clearly differing from real-life conditions, e.g. through dedicated parameters such as stable ambient conditions over a certain time (apparent for refrigerators with no door openings under test), or a certain sequence of cycles, a more sophisticated or smart (= 'intelligent') processing might even not be necessary for the product to detect being under test; simple control logic programmed explicitly towards recognizing these test conditions and adjusting might be sufficient.

Figure 123*:* Different approaches: Products marketed as 'smart' and products acting 'smart'; source: Graulich et al. (2019)

Appliances *marketed* as "smart" seem to be characterized mainly[1105] by the offered services (utilities), a connection to internet, as well as the communication level (focus on external communication, i.e. between different appliances and/or the possibility of being controlled via internet). On the other hand, products designed in a way to be able to circumvent, i.e. altering their characteristics specifically during compliance testing (*acting* "smart"), might have to be characterized in a different way. While the presence of software within the appliance seems to be precondition of smartness, the act of circumvention might go beyond simple control logic which is implemented in nearly all appliances: sensor, processing software and actuator (reacting to (only) one input parameter). In comparison, 'smartness' related to circumvention seems to be a more sophisticated or 'intelligent' processing.

Based on a couple of suspect behaviour cases collected by literature research, stakeholder interviews as well as dedicated input of Market Surveillance Authorities, the ANTICSS project team considered the Ecodesign Article on circumvention which is focusing only on automatic performance alterations *during* the conformity testing as too restrictive.

The software of products when being placed on the market might also be programmed in a way that the performance of the appliance automatically changes within a short period *after* putting the product into service. The reason for this could be to gain most favourable results for the declared parameters during the conformity testing which might be only possible at the expense of consumers' convenience when using the product (e.g. extremely long cleaning cycles for the eco programme to reduce the necessary use of energy and

[1105] In principle, an appliance can be both, i.e. be marketed as smart (based on the first definition) but also acting smart (based on the second definition). What is important is to make sure that a clear description of what constitutes the products' 'smartness' is transparent and available so that e.g. MSAs can assess the product behaviour.

resources). An algorithm already programmed in the software of the product as delivered, i.e. not provided via external software update as this would be prohibited according to the most recent Ecodesign regulations (see sections 31.2.1 and 31.3.1), might change this setting after a certain time or number of cycles. Aim could be to get the product more attractive again to users (e.g. by reducing the overall cycle time) but at the expense of the declared energy or resource consumption usually measured directly after the product is placed on the market.

Against this background, the ANTICSS project introduced an extended definition of circumvention including the following software-related[1106] acts, see points a) and c) of next figure.

> ***'Circumvention'*** *is the act of designing a product or prescribing test instructions, leading to an alteration of the behaviour or the properties of the product, specifically in the test situation, in order to reach more favourable results for any of the parameters specified in the relevant delegated or implemented act, or included in any of the documentations provided for the product.*
> *The act of circumvention is relevant only under test conditions and can be executed e.g.*
>
> *a) by automatic detection of the test situation and alteration of the product performance and/or resource consumption <u>during test</u>, or*
>
> *b) by pre-set or manual alteration of the product, affecting performance and/or resource consumption during test or*
>
> *c) by pre-set alteration of the performance <u>within a short period after putting the product into service</u>.*

Figure 124: Definition of (software-related) circumvention by the H2020 project ANTICSS; source: Graulich et al. (2019)

Finally, (Graulich et al. 2019) draw the following conclusions regarding the relation between smart products and circumvention:

- Appliances with functions *marketed* as "smart" do not provide per se an indicator for circumvention.
- Products being able to *act* smart (= intelligent) in a way of circumventing under compliance testing are not necessarily *marketed* as smart.
- Software is a precondition for being smart.
- The act of software-related circumvention relevant only under test conditions can be executed either by automatic detection of the test situation and alteration of the product performance and/or resource consumption during test, or by pre-set alteration of the performance within a short[1107] period after putting the product into service.
- If some kind of 'intelligent' software is already implemented at the moment the product is placed on the market, those appliances might be more prone to use this software also for circumvention. On the other hand, if standard test conditions clearly differ from real-life conditions, also simple control logic might be sufficient to program appliances in a way to recognize these test conditions and adjust certain parameters accordingly.
- Not all 'smart appliances' are circumventing per se under EU Ecodesign and Energy label compliance testing:
  => On the one hand, some of the products' smartness is not at all related to the energy labelling or ecodesign regulated parameters, and/or the smart function even results in higher instead of lower energy consumption.

[1106] Point b) of the ANTICSS definition of circumvention is not necessarily related to software.

[1107] The length of such a period is also depending on the lifetime of a product or the number of cycles usually performed under standard measurement. It is to be defined at a product-specific level.

=> On the other hand, manufacturers explicitly have to use the smartness and program appliances in a way that they detect being in a test situation as well as alter the product performance and/or resource consumption specifically during test in order to reach more favourable test results.

Figure 125: Conclusions regarding the relation between smart products and circumvention; source: Graulich et al. (2019)

31.3 Software-related policy measures in present and draft EU Ecodesign regulations under review

31.3.1 Software updates in the context of circumvention

In most of the Ecodesign regulations adopted at the end of 2019 a dedicated article dealing with software updates is included[1108] and it is expected that this article will also be applied in future new or revised Ecodesign regulations:

Circumvention and software updates

[...]

The energy consumption of the product and any of the other declared parameters shall not deteriorate after a software or firmware update when measured with the same test standard originally used for the declaration of conformity except with explicit consent of the end-user prior to the update. No performance change shall occur as result of rejecting the update.

A software update shall never have the effect of changing the product's performance in a way that makes it non-compliant with the ecodesign requirements applicable for the declaration of conformity.

There are still some constraints to be noted:

- The deterioration of the energy consumption and any of the other declared parameters of the product is still allowed – in case the end-user agrees. However, from this article it is unclear how detailed the user will be informed in practice about the possible implications on decreasing energy and/or resource efficiency of the product to facilitate an informed decision. The request for consent has to be explicitly under knowledge of the effect on performance/energy; not a general consent to the execution of the update.
- Although a software update shall never have the effect of changing the product's performance in a way that makes it non-compliant with the ecodesign requirements, a potential deterioration of the energy efficiency class according to the respective Energy labelling regulation of the appliance is not regulated at all.
- Software updates are installed during the use of products, i.e. a certain time after the product has been placed on the market and has already been in use. To verify the compliance with the ecodesign requirements on software updates, Market Surveillance

[1108] The article is included in the following regulations: (EU) 2019/1781 for electric motors, (EU) 2019/1784 for welding equipment, (EU) 2019/2019 for refrigerating appliances, (EU) 2019/2020 for light sources, (EU) 2019/2021 for electronic displays, (EU) 2019/2022 for household dishwashers, (EU) 2019/2023 for household washing machines and washer-dryers, and (EU) 2019/2024 for refrigeration appliances with direct sales function. The article is not included in the regulations (EU) 2019/1782 for external power supplies; (EU) 2019/1783 for power transformers.

Authorities cannot do the usual verification procedure, i.e. testing products placed on the market but have to simulate a certain usage and/or have to install the available software updates on the product before testing.

31.3.2 Software in the context of circumvention

For the first time, the Ecodesign regulations adopted at the end of 2019[1109], include a dedicated Article on circumvention:

> The manufacturer, importer or authorised representative shall not place on the market products designed to be able to detect they are being tested (e.g. by recognising the test conditions or test cycle), and to react specifically by automatically altering their performance during the test with the aim of reaching a more favourable level for any of the parameters declared by the manufacturer, importer or authorised representative in the technical documentation or included in any documentation provided.

In combination, the Annex on "Verification procedure for market surveillance purposes" of the respective Ecodesign regulations includes the following paragraph:

> Where a model has been designed to be able to detect it being tested (e.g. by recognizing the test conditions or test cycle), and to react specifically by automatically altering its performance during the test with the objective of reaching a more favourable level for any of the parameters specified in this Regulation or included in the technical documentation, or included in any of the documentation provided, the model and all equivalent models shall be considered not compliant.

On the other hand, recital (35) of the Energy labelling Regulation (EU) 2017/1369[1110]:

> Energy consumption, performance and other information concerning the products covered by product-specific requirements under this Regulation should be measured by using reliable, accurate and reproducible methods that take into account the generally recognised state-of-the-art measurements and calculation methods. In the interests of the proper functioning of the internal market, standards should be harmonised at Union level. Such methods and standards should, to the extent possible, take into account the real-life usage of a given product, reflect average consumer behaviour and be robust in order to deter intentional and unintentional circumvention. Energy labels should reflect the comparative performance of the actual use of products, within the constraints due to the need of reliable and reproducible laboratory testing. Suppliers should therefore not be allowed to include software or hardware that automatically alters the performance of the product in test conditions. […]

[1109] Regulations (EU) 2019/1781 for electric motors, (EU) 2019/1783 for power transformers, (EU) 2019/1784 for welding equipment, (EU) 2019/2019 for refrigerating appliances, (EU) 2019/2020 for light sources, (EU) 2019/2021 for electronic displays, (EU) 2019/2022 for household dishwashers, (EU) 2019/2023 for household washing machines and washer-dryers, and (EU) 2019/2024 for refrigeration appliances with direct sales function

[1110] Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU; online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1369&from=EN; last accessed on 12 Jun 2020

As explained in section 31.2.3.2 above, the Ecodesign Article on circumvention focusing only on automatic performance alterations during the conformity testing might be too restrictive as the software of products when being placed on the market might also be programmed in a way that the performance of the appliance automatically changes within a short period after putting the product into service.

31.3.3 Software-induced hardware obsolescence

Some of the Ecodesign regulations adopted at the end of 2019 include different ecodesign requirements addressing software updates under resource efficiency or information availability aspects as the following extracts of the regulations show.

Servers and data storage products
According to regulation (EU) 2019/424[1111], servers and data storage products shall meet he following material efficiency requirements specifically related to software and/or firmware from 1 March 2021 (European Commission 2019):

- The latest available version of the firmware shall be made available from two years after the placing on the market of the first product of a certain product model for a minimum period of eight years after the placing on the market of the last product of a certain product model, free of charge or at a fair, transparent and non-discriminatory cost. The latest available security update to the firmware shall be made available from the time a product model is placed on the market until at least eight years after the placing on the market of the last product of a certain product model, free of charge.

Welding equipment
According to regulation (EU) 2019/1784[1112], welding equipment shall meet the following resource efficiency requirements specifically related to software and/or firmware from 1 January 2021:

- Availability of spare parts: Manufacturers, authorised representatives or importers of welding equipment shall make available to professional repairers at least the following spare parts for a minimum period of 10 years after the production of the last unit of a welding equipment model: inter alia: software and firmware including reset software.
- Access to repair and maintenance information: No later than two years after the placing on the market of the first unit of a model, and until the end of the period mentioned under the point above, the manufacturer, importer or authorised representative shall provide access to the welding equipment repair and maintenance information to professional repairers in the following conditions: Once registered, a professional repairer shall have access, within one working day after requesting it, to the requested repair and maintenance information. The information may be provided for an equivalent model or model of the same family, if relevant. The available repair and maintenance information shall include: inter alia: instructions for installation of relevant software and firmware including reset software.

[1111] Commission Regulation (EU) 2019/424 of 15 March 2019 laying down ecodesign requirements for servers and data storage products. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0424&from=EN, last accessed on 2 Jun 2020.

[1112] Commission Regulation (EU) 2019/1784 of 1 October 2019 laying down ecodesign requirements for welding equipment; online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1784&from=EN, last accessed on 24 May 2020

Household dishwashers

According to regulation (EU) 2019/2022[1113], household dishwashers shall meet the following resource efficiency requirements specifically related to software and/or firmware from 1 March 2021:

- Availability of spare parts: Manufacturers, importers or authorised representatives of household dishwashers shall make available to professional repairers at least the following spare parts for a minimum period of 7 years after placing the last unit of the model on the market: inter alia: software and firmware including reset software. Different to welding equipment, the time frame is related to "placing the last unit of the model on the market", whereas for welding equipment, it is related to "the production of the last unit of a welding equipment model".
- Access to repair and maintenance information: After a period of two years after the placing on the market of the first unit of a model, and until the end of the period mentioned under the point above, the manufacturer, importer or authorised representative shall provide access to the appliance repair and maintenance information to professional repairers in the following conditions: Once registered, a professional repairer shall have access, within one working day after requesting it, to the requested repair and maintenance information. The information may be provided for an equivalent model or model of the same family, if relevant. The available repair and maintenance information shall include: inter alia: instructions for installation of relevant software and firmware including reset software.

Household washing machines and household washer-dryers

According to regulation (EU) 2019/2023[1114], household washing machines and washer-dryers shall meet the following resource efficiency requirements specifically related to software and/or firmware from 1 March 2021:

- Availability of spare parts: Manufacturers, importers or authorised representatives of household dishwashers shall make available to professional repairers at least the following spare parts for a minimum period of 10 years after placing the last unit of the model on the market: inter alia: software and firmware including reset software. Different to welding equipment, the time frame is related to "placing the last unit of the model on the market", whereas for welding equipment, it is related to "the production of the last unit of a welding equipment model".
- Access to repair and maintenance information: After a period of two years after the placing on the market of the first unit of a model, and until the end of the period mentioned under the point above, the manufacturer, importer or authorised representative shall provide access to the household washing machine or household washer-dryer repair and maintenance information to professional repairers in the following conditions: Once registered, a professional repairer shall have access, within one working day after requesting it, to the requested repair and maintenance information. The information may be provided for an equivalent model or model of the same family, if

[1113] Commission Regulation (EU) 2019/2022 of 1 October 2019 laying down ecodesign requirements for household dishwashers. In: Official Journal of the European Union 5.12.2019 (OJ L 315), pp. 267–284. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2022&qid=1590352452158&from=EN, last accessed on 24 May 2020.

[1114] Commission regulation (EU) 2019/2023 of 1 October 2019 laying down ecodesign requirements for household washing machines and household washer-dryers. In: Official Journal of the European Union (OJ L315), pp. 285–312. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2023, last accessed on 24 May 2020.

relevant. The household washing machine or household washer-dryer repair and maintenance information shall include: inter alia: instructions for installation of relevant software and firmware including reset software.

Refrigerating appliances with a direct sales function
According to regulation (EU) 2019/2024[1115], refrigerating appliances with a direct sales function shall meet the following resource efficiency requirements specifically related to software and/or firmware from 1 March 2021:

- Availability of spare parts: Manufacturers, importers or authorised representatives of refrigerating appliances with a direct sales function shall make available to professional repairers at least the following spare parts for a minimum period of 8 years after placing the last unit of the model on the market: inter alia: software and firmware including reset software. Different to welding equipment, the time frame is related to "placing the last unit of the model on the market", whereas for welding equipment, it is related to "the production of the last unit of a welding equipment model".
- Access to repair and maintenance information: After a period of two years after the placing on the market of the first unit of a model or of an equivalent model, and until the end of the period mentioned under the point above, the manufacturer, importer or authorised representative shall provide access to the appliance repair and maintenance information to professional repairers in the following conditions: Once registered, a professional repairer shall have access, within one working day after requesting it, to the requested repair and maintenance information. The information may be provided for an equivalent model or model of the same family, if relevant. The available repair and maintenance information shall include: inter alia: instructions for installation of relevant software and firmware including reset software.

Electronic displays
According to regulation (EU) 2019/2021[1116], electronic displays shall meet the following information availability requirements from 1 March 2021:

- From 1 March 2021, the product manufacturer, importer or authorised representative shall make available the information set out below when placing on the market the first unit of a model or of an equivalent model. The information shall be provided free of charge to third parties dealing with professional repair and reuse of electronic displays (including third party maintenance actors, brokers and spare parts providers).
- Availability of software and firmware updates:
    - (a) The latest available version of the firmware shall be made available for a minimum period of eight years after the placing on the market of the last unit of a certain product model, free of charge or at a fair, transparent and non-discriminatory cost. The latest available security update to the firmware shall be made available until at least eight years after the placing on the market of the last product of a certain product model, free of charge

[1115] Commission Regulation (EU) 2019/2024 of 1 October 2019 laying down ecodesign requirements for refrigerating appliances with a direct sales function. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2024&from=EN, last accessed on 24 May 2020.

[1116]Commission Regulation (EU) 2019/2021 of 1 October 2019 laying down ecodesign requirements for electronic displays. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R2021&from=EN, last accessed on 24 May 2020.

- (b) Information on the minimum guaranteed availability of software and firmware updates, availability of spare parts and product support shall be indicated in the product information sheet as from Annex V of Regulation (EU) 2019/2013

For electronic displays, other than for welding equipment and household dishwashers, the software and firmware is not explicitly listed in the requirements on the availability of spare parts; however, even if subsumed under information requirements, de facto the requirements also address the availability of software and firmware updates as shown in the second paragraph point (a) above.

Also, standard EN 45554 'General methods for the assessment of the ability to repair, reuse and upgrade energy-related products' includes several references to software, defining firmware and software as parts constituent of a product[1117]. According to the standard, specific attention should be given to the role of software and firmware in the context of upgrades to enhance the functionality, performance, or capacity of a product; also, for certain products the availability of software and firmware support, including updates can be important to consider. Further, the standard includes reference to diagnostic support and interfaces, e.g., a repair, reuse or upgrade process can only be carried out through the use of software such as hardware functionality testing software tools. Software and firmware are also listed as 'spare parts', i.e. the availability of software and firmware may be assessed in the same way as for hardware parts.

31.4 Possible actions and policy options in the Ecodesign and Energy Labelling Working Plan 2020-2024

As listed in section 31.3 above, software is already addressed in different ways in the Ecodesign regulations adopted at the end of 2019, as well as in standard EN 45554: conditions for software updates, in the context of circumvention, as well as the availability of soft- and firmware as spare parts to avoid software-induced hardware obsolescence.
Starting from this basis and the background given in the previous sections, further actions are proposed for the next EU Ecodesign and Energy Labelling Working Plan 2020-2024:

Horizontal approach related to software-updates and the potential of software in the context of circumvention (i.e. measures that could be taken for all or a major number of products covered by Ecodesign and/or Energy labelling regulations)

- Consistent application of software related articles and paragraphs to further Ecodesign regulations (new or revisions) when software is a relevant part of the main functionality of the appliance.
- Software updates:
    - The current article only refers to the requirement that a software update shall never have the effect of changing the product's performance in a way that makes it non-compliant with the ecodesign requirements applicable for the declaration of conformity. It is recommended to add a complementary requirement (possibly under EU Energy label regulations) that software updates should not have the effect of changing the product's performance in a way that the declared energy efficiency class deteriorates.

[1117] This does not include application software which cannot be considered as a part specific to the product, see also Figure 119.

- The deterioration of the energy consumption and any of the other declared parameters of the product is still allowed – in case the end-user agrees. It is recommended to specify how detailed the user shall be informed in practice about the possible implications on decreasing energy and/or resource efficiency of the product to facilitate an informed decision. The agreement should not be just to the execution of the update but clearly to the energy/performance change.
- Provide instructions for Market Surveillance Authorities on the compliance verification of software-updates as these are usually installed only during the use of products, i.e. a certain time after the product has been placed on the market. To verify the compliance with the ecodesign requirements on software updates, Market Surveillance Authorities cannot do the usual verification procedure, i.e. testing products placed on the market but have to simulate a certain usage and/or have to install the available software updates on the product before testing.

- Software in the context of circumvention: an extension of the article on the definition of circumvention is recommended taking into account further possible acts of circumvention besides the detection of the test conditions and automatic performance alteration during the test. To prevent cases of circumvention being portrayed as 'smartness', the exact impact and alterations in performance/energy should be transparent.

Potential software-related ecodesign measures reducing the risk of software-induced hardware obsolescence of products (i.e. measures specific to products, which should be systematically analysed and considered in preparatory and review studies)

For product groups regulated under EU Ecodesign and/or Energy labelling with main functionalities depending on software (firmware, system software, or embedded systems) it is recommended that new or revised Ecodesign and Energy label regulations should take into account the following requirements with the aim of reducing the risk of software-induced hardware obsolescence:

- Availability of relevant soft-/firmware: The latest available version of the firmware / system software including reset software shall be made available from X years (to be defined product-specific) after the placing on the market of the first product of a certain product model for a minimum period of Y years (to be defined product-specific) after the placing on the market of the last product of a certain product model, free of charge or at a fair, transparent and non-discriminatory cost. *One stakeholder asked to consider that consumers already paid indirectly for firmware through buying the product with firmware; therefore, there is seen no argument against making soft-/firmware available free of charge or, otherwise, the need for requiring a non-discriminatory cost of available software should be elaborated. Further, also the importance to define a support period, appropriately, is pointed out by one stakeholder. Another stakeholder requests a definition of "including reset software", e.g. factory reset. Further, as stakeholder explained that the available period for updates is in many cases determined also by platform vendors, not only by manufacturers.*
- Availability of software-updates: The latest available security update to the firmware shall be made available from the time a product model is placed on the market until at least X years (to be defined product-specific) after the placing on the market of the last product of a certain product model, free of charge.
- Options for installing software-updates: When software updates are made available, the user should be given the options to not install, to install or to uninstall the update;

another option for the user could be the possibility of whether to install only security updates or also other (e.g. functional) updates. *Stakeholders commented that the requirement whether an end-user can choose to install or not install a software updates during the use phase of a product should not be a generic statement but differentiating between critical, relevant and non-critical updates; in case of the software having a safety, data security or compliance function, then the product should be exempted, in order to avoid potentially rendering a product unsafe with old software versions representing an entry point for hackers. Another stakeholder complemented that fixing vulnerabily issues sometimes requires significant changes deep in softwares, i.e. not being as simple as having a security update and having an operating system update separately, i.e. separation of updates may be technically (and commercially) difficult; therefore, such a requirement could have the potential to massively increase the costs of both developing and maintaining devices, resulting in higher prices. For example, if customers can refuse updates and choose to remain on version 1.0 of device software, while the current version is 5.0, all patches (e.g., security patches) and changes to related cloud services must be backported to work with each of versions 1.0 through 4.0 resulting in increased cost and potentially discouraging innovation. Further, for some products, uninstalling or reverting an update means that the previous version of the software needs to remain stored in the device, which may not be feasible from memory capacity and performance point of view.*

- Possibility of rolling back software to previous versions. *In this context, one stakeholder highlighted the following points: In some cases, user data will be lost in the process of reverting a software update to a previous version, impacting usability of the device. Reversing updates or giving the possible to users not to install updates, can make the device vulnerable to security issues. It may put the customers themselves, those around them, and other stakeholders such as content providers at risk. User selection of which software updates are installed can create incompatibilities between softwares in the device, leading to malfunctions.Another stakeholder complemented that with regard to software dependent on external OS, rolling back may not be available according to the condition of the OS which cannot be controlled by the manufacturer; further, even when it is available, management of memory may be difficult which leads unstable operation. Finally, much additional costs would be necessary to verify all combinations, so the realization is difficult also from a commercial point of view.*
- Software compatibility: Full compatibility of the device with open source Operating Systems and/or open source Virtual Machine software is ensured (where applicable). *However, stakeholders commented that this requirement is neither applicable to many products, e.g. in the IT sector, nor enforceable by market surveillance. Further, one stakeholder points out that such requirement could have severe impact on privacy and data security. In addition, allowing open source to run on devices may also lead to negative impact on product energy efficiency, as designing hardware and software to work together in its most optimal form leads to higher energy efficiency. In some cases, it can even bring the product out of compliance.*
- Uninstallation of software / data removal: It must be possible to completely remove the software product from the computer system after the end of its operating life without leaving any unnecessary traces of data. For this purpose, it should be possible for the user (e.g. a system administrator) to easily uninstall the software product including any additional components or libraries that may be installed by the software within a short period of time. *One stakeholder commented that the requirement to enforce complete removal of software should not be a generic statement; in case of the software*

having a safety function, e.g. for a home appliance, then the product should be exempted, in order to avoid potentially rendering a product unsafe. Another stakeholder points out that the suggested measure to 'completely remove the software product from the computer system' is not entirely clear: The complete removal of software from a device would render this one unusable, even to install other softwares. For some electronic products, the complete removal of the software would require an external function, it would not be possible for a device to completely delete the software by itself, so the possibility for the user to easily uninstall the software product would not be technically feasible.

- Release of hardware from manufacturer dependency at the end of the support period (jailbreak). If the product is dependent on external services provided by the manufacturer, a software update must be provided at the end of the support period so that the product can be used further without restrictions. *One stakeholder pointed out that this requirement could introduce additional concerns to be considered: For example, software running on the product might assume that certain security provisions provided by the core product are still in place, e.g. protection of stored personal data, encryption keys and other secrets. If this is no longer guaranteed because the product has been jailbroken, this could lead to unwanted disclosure of personal data. Jailbreak could lead to the underlying security provisions no longer being supported, and malicious software could take advantage of that. Another stakeholder commented in addition that such requirement may also create issues linked to products liability as the brand name on the hardware will always be associated with security issues. If regulations impose to jailbreak a product, negatively impacting data security, and an incident happens, the brand owner (hardware manufacturer) will get the negative press. In addition, it should be clarified what "dependent of external services means". In some cases, manufacturers will produce products with basic functionalities and provide additional functionalities in the form of software for a premium. Therefore, it is requested that dependency should not be considered when the software value provided is additional.*
- Studying the relevance of firmware-based usage "counters" (the parameters to be counted still to be defined at product specific level) for reparability aspects. These counters could be used as information for repairers in order to have more information if to change a component or not. See also Section 29 on durability. *One stakeholder commented that when introducing new technologies such as usage counters, enough examination should be carried out in advance including practicability, merits of introduction, cost-effectiveness, confidentiality management, or relation to patent technologies.*

In general, when setting requirements on software updates, the appropriate regulatory framework should be carefully considered to avoid a fragmented approach across different policy dossiers and DGs within the European Commission and the risk of double regulation. In this context, especially linkages to the regulation on software updates under consumer rights legislation and in particular the revised Sales of Good Directive should be considered.

Potential software-related measures related to consumer information/ labelling (i.e. measures that could be taken for all or a major number of products covered by Ecodesign)

- Instructions for installation of relevant software and firmware including reset software.
- Information on the minimum guaranteed availability of software and firmware including their updates (e.g. how many updates or during which time period similar updates as new software for products in the same series would be provided)

- Information requirements on how updates might affect the original system characteristics (e.g. Random-access memory, RAM, or Central Processing Unit, CPU).
- Requirements to inform users how specific updates might affect the energy or resource efficiency of the product.
- Description of the process for uninstalling the product software and secure data deletion.

One stakeholder requested to consider which of the above consumer information regarding software installation, guaranteed availability, update influence on system, energy and resource use, as well as uninstall / data deletion guidance should be in the product information sheet, and how user-friendliness in terms of software/firmware could be indicated on an energy label, in a way that will not overburden the label with information.

Specific ecodesign and labelling measures for application software as a new, kind of energy-related "product group" (i.e. requiring an own preparatory study)

Application software products, although being immaterial goods, can cause significant materials and energy flows. Software characteristics determine which hardware capacities are made available and how much electric energy is used by end-user devices, networks, and data centres. Recent research by the German Environment Agency has shown relevant differences in the energy consumption of different software application products with the same functionality and also discernible differences between the software products in terms of their hardware efficiency (i.e. their impact on processor utilization, working memory, permanent storage, and bandwidth for network access) (Gröger et al. 2018); (Kern et al. 2018). Therefore, it is recommended to include software applications as kind of 'energy-related product' into the Ecodesign and Energy Labelling Working Plan 2020-2024 for analysing and regulating their impacts on energy and resource consumption and other environmental parameters during use in a dedicated preparatory study. Potential ecodesign, labelling and information requirements (e.g. minimum system requirements, hardware utilisation and energy demand, support for the energy management system, etc.) can be derived for example from the development of the Blue Angel ecolabel for resource and energy-efficient software products, see section 31.2.2.

One stakeholder commented that bearing in mind that algorithms are complex intertwined text strings/sub-functions in different programming languages, it would be a fundamentally different type of "product group" (in comparison, a product often has physical means to perform function(s) whereas software has immaterial means (algorithms) performing function(s)) which possibly needs to have another type of requirements and verification procedures. Therefore, the scope of such regulation should be considered to ensure that the product requirements do not become too complex or that it risks compromising intellectual property.

Methodological developments or conditions to be ensured to enable these approaches

- It has to be clearly analysed and decided if the scope of the Ecodesign Directive 2009/125/EC formally allows the application to software products.
- Possible revision of the MEErP and/or EcoReport tool, if needed, facilitating systematic assessment of software aspects in products, potential trade-off analyses, and allowing the analysis and definition of implementing measures for application software products
- The study by Gröger et al. (2018) developed a possible method for carrying out software measurements to record energy consumption data and hardware utilisation. How-

ever, further research or methodological developments might be necessary. For example, the scope of the Blue Angel Basic Award Criteria so far only covers software products that belong to the group of application software with a user interface. To expand the scope for example to server-client software products, this will require, amongst other things, the definition of a reference system for servers. Further, research is also needed with regard to usage statistics to define standardised usage scenarios for each software category.

32 SCARCE AND CRITICAL RAW MATERIALS

Approaches to evaluate raw materials due to their scarcity (critical raw materials, CRM) and/or other environmental impacts.

32.1 Background

Since 2011, the European Commission is regularly publishing a list of so called Critical Raw Materials. According to the Critical Raw Materials Alliance[1118], Critical Raw Materials (CRMs) are those raw materials which are economically and strategically important for the European economy, but have a high-risk associated with their supply. They are classified as 'critical' because:

- They have a significant economic importance for key sectors in the European economy, such as consumer electronics, environmental technologies, automotive, aerospace, defence, health and steel.
- They have a high supply risk due to the very high import dependence and high level of concentration of set critical raw materials in particular countries
- There is a lack of (viable) substitutes, due to the very unique and reliable properties of these materials for existing, as well as future applications; combined with low recycling rates.

The Commission committed to updating the list at least every 3 years to reflect production, market and technological developments. The 2017 list entailed 27 Critical Raw Materials (European Commission 2017)[1119]:

Antimony, Baryte, Beryllium, Bismuth, Borates, Cobalt, Coking Coal, Fluorspar, Gallium, Germanium, Hafnium, Helium, Heavy Rare Earth Elements (HREEs)[1120], Indium, Light Rare Earth Elements (LREEs[1121]), Magnesium, Natural Graphite, Natural Rubber, Niobium, Platinum Group Metals (PGM), Phosphate Rock, Phosphorus, Scandium, Silicon Metal, Tantalum, Tungsten, and Vanadium.

The list was last updated in August 2020, with Helium removed, and Bauxite, Lithium, Strontium and Titanium (marked bold in the overview below) included new in the list, i.e. resulting in 30 Critical Raw Materials included in the European list of CRM in 2020 (European Commission 2020) [1122]:

1118 https://www.crmalliance.eu/critical-raw-materials

1119 European Commission (2017): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the 2017 list of Critical Raw Materials for the EU, COM(2017) 490 final, 2017. Online available at https://ec.europa.eu/transparency/regdoc/rep/1/2017/EN/COM-2017-490-F1-EN-MAIN-PART-1.PDF, last accessed on 19 Jun 2020.

1120 Y (Yttrium), Gd (Gadolinium), Tb (Terbium), Dy (Dysprosium), Ho (Holmium), Er (Erbium), Tm (Thulium), Yb (Ytterbium), and Lu (Lutetium)

1121 Sc (Skandium), La (Lanthanum), Ce (Cerium), Pr (Praseodymium), Nd (Neodymium), Pm (Promethium), Sm (Samarium) and Eu (Europium);

1122 European Commission (2020): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability. COM/2020/474 final; online available https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0474&from=EN, last accessed 19.09.2020

Antimony, Baryte, **Bauxite**, Beryllium, Bismuth, Borates, Cobalt, Coking Coal, Fluorspar, Gallium, Germanium, Hafnium, Heavy Rare Earth Elements (HREEs), Indium, Light Rare Earth Elements (LREEs), **Lithium**, Magnesium, Natural Graphite, Natural Rubber, Niobium, Platinum Group Metals (PGM), Phosphate Rock, Phosphorus, Scandium, Silicon Metal, **Strontium**, Tantalum, **Titanium**, Tungsten, and Vanadium.

Critical Raw Materials were also one of the priority areas in the EU Circular Economy Action Plan 2015 in order to foster their efficient use and recycling. According to European Commission (2018)[1123] the share of secondary sources in the raw material supply, i.e. the recycling input rate of CRMs is generally low due to several factors, e.g. that sorting and recycling technologies for many CRMs are not available yet at competitive costs, the supply of many CRMs is locked up in long-life assets which is implying delays between manufacturing and scrapping, and the demand for many CRMs is growing in various sectors and the contribution from recycling is largely insufficient to meet the demand.

Ensuring the security of supply of raw materials to European industry, as well as lowering the impacts of overall primary raw material extraction, resource efficient management throughout the lifecycle and the recycling of waste into secondary CRMs, i.e. substitution and recycling of CRM, are considered as risk-reducing measures according to the European Commission (2018).

Although Critical Raw Materials are not tackled explicitly in the Commission's Circular Economy Action Plan (CEAP) 2020[1124] under the European Green Deal, one of the main objectives of the CEAP is creating a well-functioning EU market for secondary raw materials which indirectly also contributes to reducing the impacts of primary raw material extraction and to higher independence from imports of CRM.

Also, one of the objectives of the Preparatory study for the Ecodesign Working Plan 2020-2024 is to evaluate the resource savings potentials of the materials used in energy-related products, taking into account the "criticality/ scarcity" of CRM, but from wider perspectives. In this respect, the following sections analyse existing and further measures that could be applied under the Ecodesign and Energy Labelling Working Plan 2020-2024 for evaluating raw materials. **The analysis does not only include Critical Raw Materials (CRM) due to their supply risks and scarcity, but also looks at a more comprehensive approach to assess raw materials due to their environmental impacts.**

[1123] European Commission (2018): Report on Critical Raw Materials and the Circular Economy, 2018. Online available at https://op.europa.eu/en/publication-detail/-/publication/d1be1b43-e18f-11e8-b690-01aa75ed71a1/language-en/format-PDF/source-80004733, last accessed on 19 Jun 2020

[1124] European Commission (2020): Circular Economy Action Plan - For a cleaner and more competitive Europe. Online available: https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf, last accessed 19.09.2020

32.2 Current approaches for Critical Raw Materials (CRM) under EU Ecodesign

CRM in the MEErP 2011 Guidance and in the EcoReport Tool
Regarding the Methodology for the Ecodesign of Energy-related Products (MEErP), the methodology report by VHK and COWI (2011)[1125] recommends that contractors carrying out preparatory studies should consider Critical Raw Materials, if applicable, as one element of the MEErP, for example to check possible design options that substitute or make it easier to recover CRM components.

The MEErP methodology has developed an indicator based on 14 materials that were included in the European list of Critical Raw Materials available at that time, i.e. the 2011 CRM list. Certain characterization factors were developed, taking into account the following aspects:

- Consumption in the EU,
- import dependency,
- substitutability, and
- post-consumer recycling rate.

The outcomes for each of the CRM were normalized to one reference material (antimony, Sb), i.e. results are expressed as kg Sb-equivalent per kg CRM, see following table according to BIO Intelligence Service (2013)[1126].

Table 329: Characterization factors to calculate the CRM indicator according to MEErP 2011 (source: BIO Intelligence Service 2013) for those CRM included in the 2011 European list

Critical Raw Material	Characterization factor kg Sb eq./kg
Germanium (Ge)	18
Beryllium (Be)	12
Tantalum (Ta)	9
Indium (In)	9
Platinum Group metals (PGM)	8
Gallium (Ga)	8
Antimony (Sb)	1
Tungsten	0.2
Niobium (Nb)	0.04
Rare earth elements (Sc, Y, Nd)	0.03
Cobalt (Co)	0.02
Graphite (C)	0.01
Fluorspar (CaF2)	0.001
Magnesium (Mg)	0.0005

[1125] VHK and COWI (2011): Methodology for Ecodesign of Energy-related Products - MEErP 2011 - Methodology Report, Part 1: Methods. Online available at https://ec.europa.eu/docsroom/documents/26525/attachments/1/translations/en/renditions/native, last accessed on 16 Jun 2020

[1126] BIO Intelligence Service (2013): Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP), Part 2 – Enhancing MEErP for Ecodesign. Prepared for: European Commission – DG Enterprise and Industry. Online available at https://ec.europa.eu/docsroom/documents/106/attachments/1/translations/en/renditions/pdf, last accessed on 16 Jun 2020.

According to the MEErP methodology report, it should be analysed in the product-specific Ecodesign preparatory studies if the products in scope include critical raw materials and if there are differences between different product designs and possible improvement options. The MEErP methodology guidance also provides a list of possible applications of these 14 CRMs in products. For example neodymium is used for magnets in motors, indium is used in flat panel TVs and cobalt for batteries.

The Critical Raw Material Index for a product takes into account the material fractions of each CRM in grams per product multiplied with the respective characterization factors. The Index, however, is not included in the overall environmental assessment but has to be calculated separately in the EcoReport Tool.

Examples of CRM discussed in Ecodesign Preparatory studies

In its 2018 report on Raw Materials and the Circular Economy[1127], the European Commission provided an overview if and how previous Ecodesign preparatory studies addressed Critical Raw Materials issues, see Table 330.

Table 330: Analysis of previous Ecodesign preparatory studies addressing CRM issues; source: European Commission (2018), updated by most recent prep. studies

Year of conclusion	Preparatory study on:	Details mentioned and discussed
2007	Space and combination heaters	PGMs in catalytic combustion
2007 + review study	Personal computers and servers	Silicon in computers. The revision study specifically mentions the EU CRMs and analyses their content in the products
2010	Sound and Imaging Equipment	Silicon in the products
2007 + review study	Televisions / electronic displays	Indium (as ITO) in the products. Potential measures on the declaration of indium were discussed in the review process
2007	Linear and compact fluorescent lamps	Presence of REEs, gallium and indium
2007 + review study	Domestic washing machines	REEs in motors
2007 + review study	Domestic dishwashers	Specifically mentions the EU CRMs and discusses the content of REEs in motors
2007	Simple set top boxes	Silicon metal in products
2007	Domestic lighting; incandescent, halogen, LED and compact fluorescent lamps	Some CRMs (such as gallium and indium) in the products.
2008	Electric motors	REEs used in high performance motors
2009	Room air conditioning appliances, local air coolers and comfort fans	REEs and their relevance for high efficiency motors
2009	Directional lighting: luminaires, reflector lamps and LEDs	Some CRMs (such as gallium and indium) in the products
2011 + review study	Ventilation fans in non-residential buildings	REEs and the relevance of their recycling
2014	Uninterruptible Power Supplies	Some CRMs (such as gallium, cobalt, silicon) to improve efficiency
2014	Electric Motors and Drives	Some REEs in high-performance magnets

[1127] European Commission (ed.) (2018): Report on Critical Raw Materials and the Circular Economy, 2018. Online available at https://op.europa.eu/en/publication-detail/-/publication/d1be1b43-e18f-11e8-b690-01aa75ed71a1/language-en/format-PDF/source-80004733, last accessed on 19 Jun 2020

Year of conclusion	Preparatory study on:	Details mentioned and discussed
2015	Power cables	No CRM was found relevant for this product group
2015	Enterprise servers	The study specifically refers to CRMs and was a first example of a study which assesses the content of CRMs in the products
2015	Light Sources	The study specifically refers to the CRMs and was a first example of a study which specifically assesses the content of CRMs in the products
2018 (material efficiency report)	Computers	The dedicated material efficiency report for personal computers addressed CRMs (cobalt in batteries, rare earth elements such as neodymium, dysprosium, praseodymium in HDD magnets; palladium in PCBs), proposing requirements on information provision on the content of CRMs
2020	Solar photovoltaic modules, inverters and systems	The study specifically refers to CRMs, identifying indium, gallium and silicon metal as being of particular relevance to the solar photovoltaic product group, proposing a minimum Ecodesign requirement on material disclosure
2020	Smartphones	The study specifically refers to CRMs (Tantalum, Indium, Gallium, Platinum Group Metals, Rare Earth Elements and Magnesium, as well as Cobalt)

Current regulations specifically addressing Critical Raw Materials

Although according to the analysis above a number of preparatory study addressed the issue of Critical Raw Materials, there are only few implementing measures specifically on CRM in the adopted Ecodesign regulations, with focus solely on product information requirements:

- Commission Regulation (EU) 2019/1784 on welding equipment[1128] specifically points out in recital (9) that the regulation lays down requirements on non-energy-related aspects, including critical raw materials, that are addressed in the information requirements:
  - Manufacturers, their authorised representatives or importers shall ensure that the following information is provided in the instruction manuals for installers and end-users, and for at least 10 years after the first unit of a welding equipment model is placed on the market, on the free-access websites of manufacturers, their authorised representatives or importers:
    - A list of critical raw materials present in indicative amounts higher than 1 gram at component level, if any, and an indication of the component(s) in which these critical raw materials are present.

[1128] Commission Regulation (EU) 2019/1784 of 1 October 2019 laying down ecodesign requirements for welding equipment pursuant to Directive 2009/125/EC of the European Parliament and of the Council, Version of 1 Oct 2019. In: *Official Journal of the European Union* 25.10.2019 (OJ L 272), pp. 121–135. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1784&from=EN, last accessed on 24 May 2020.

- Commission Regulation (EU) 2019/424 on servers and data storage products[1129]:
  - From 1 March 2020, the following product information on servers and online data storage products shall be made available from the time a product model is placed on the market until at least eight years after the placing on the market of the last product of a certain product model free of charge by manufacturers, their authorised representatives and importers to third parties dealing with maintenance, repair, reuse, recycling and upgrading of servers (including brokers, spare parts repairers, spare parts providers, recyclers and third party maintenance) upon registration by the interested third party on a website provided:
    - indicative weight range (less than 5 g, between 5 g and 25 g, above 25 g) at component level, of the following critical raw materials:
      - (a) Cobalt in the batteries;
      - (b) Neodymium in the HDDs;
  - Further, regulation (EU) 2019/424 on servers and data storage products includes recommendations regarding the next review by March 2022: The Commission shall assess this Regulation and review the requirements in the light of the technological progress and shall address in particular the appropriateness, inter alia:
    - To update the material efficiency requirements for servers and data storage products, including the information requirements on additional critical raw materials (tantalum, gallium, dysprosium and palladium), taking into account the needs of the recyclers.

Standard EN 45558:2019 with regard to a 'General method to declare the use of critical raw materials in energy-related products'

The availability of information on the use of critical raw materials in energy-related products (ErP) is intended to improve the exchange of information e.g. for recycling of these materials. Therefore, in a series of standards related to material efficiency aspects of ErP, the CEN-CENELEC Joint Technical Committee 10 on Energy-related products - Material Efficiency Aspects for Ecodesign (CEN-CLC/JTC 10) has developed a horizontal standard EN 45558:2019 with the objective to provide a general methodology for declaration of the use of critical raw materials in energy-related products in support of the implementation of the Ecodesign Directive (2009/125/EC) in product-specific measures and to provide a means for information on the use of CRMs to be exchanged up and down the supply chain and with other relevant stakeholders.

The standard provides guidance to manufacturers and their suppliers on how to provide material declaration of CRMs, such as name, amount and location of the substance in the product, as well as exemptions, if applicable, differentiating between regulated and non-regulated CRMs. Especially information on the location of CRMs in the product can support recycling, product design, and traceability. Aim is giving the supply chain some level of

[1129] Commission Regulation (EU) 2019/424 of 15 March 2019 laying down ecodesign requirements for servers and data storage products pursuant to Directive 2009/125/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 617/2013, Version of 15 Mar 2019. In: *Official Journal of the European Union* 18.3.2019 (OJ L 74), pp. 46–66. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0424&from=EN, last accessed on 2 Jun 2020.

certainty regarding what to report, how to report and a standardized mechanism to communicate the data throughout the supply chain.[1130]

32.3 Beyond scarcity and supply risks: Environmental criticality of raw materials

The concept of Critical Raw Materials (CRM) is mainly based on *economic* factors: a significant economic importance in combination with a high supply risk; meaning that the CRM concept addresses the topic rather from scarcity than from environmental perspective, although some environmental aspects are indirectly addressed in the evaluation of the supply risk[1131].

However, the consideration of environmental aspects in the assessment of the raw material supply situation (criticality) is also gaining further relevance for economic operators such as manufacturers and suppliers, as environmental damage caused e.g. by disaster events such as tailing dam failures can increasingly represent a reputational risk for downstream companies. Also, for example, the Product Environmental Footprint method includes a category "Resource use, minerals and metals"[1132].

In addition, the fact that many mining and processing practices are associated with substantial environmental impacts such as ecosystem damage, soil removal, and the use of water, energy, and chemicals, the resulting risks for the local and even regional environments can represent a future supply risk if such external environmental and social costs are increasingly internalised through effective implementation of standards, thus leading to an increase in raw material prices (ecological raw material availability).[1133;1134]

Therefore, in its latest German Resource Efficiency Programme III 2020-2023, the German government included a priority measure with the aim to continue working intensively to ensure that environmental aspects are taken into account when drawing up the European Commission's list of Critical Raw Materials. In that sense, policy measures on primary raw material supply, recycling and material efficiency in production shall also be geared to ecologically critical raw materials, i.e. raw materials that are of high economic importance and whose primary extraction has a high potential for environmental hazards[1133].

Whereas indicators and information systems are already well developed for geological, technical, structural, political, regulatory, and economic supply risks, there was no holistic

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[1130] https://www.cencenelec.eu/news/brief_news/Pages/TN-2019-017.aspx

[1131] COM(2020) 474 final: "Supply risk looks at the country-level concentration of global production of primary raw materials and sourcing to the EU, the governance of supplier countries including environmental aspects, the contribution of recycling (i.e. secondary raw materials), substitution, EU import reliance and trade restrictions in third countries." Cf. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0474&from=EN

[1132] https://ec.europa.eu/environment/eussd/smgp/dev_methods.htm

[1133] Bundesumweltministerium (ed.) (2020): Deutsches Ressourceneffizienzprogramm III, 2020 – 2023. Programm zur nachhaltigen Nutzung und zum Schutz der natürlichen Ressourcen, 2020. Online available at https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Ressourceneffizienz/progress_iii_programm_bf.pdf, last accessed on 17 Jun 2020.

[1134] Manhart, A.; Vogt, R.; Priester, M.; Dehoust, G.; Auberger, A.; Blepp, M.; Dolega, P.; Kämper, C.; Giegrich, J.; Schmidt, G.; Kosmol, J.: The environmental criticality of primary raw materials – A new methodology to assess global environmental hazard potentials of minerals and metals from mining. In: Mineral Economics (2019), vol. 32, pp. 91–107. Online available at https://link.springer.com/content/pdf/10.1007/s13563-018-0160-0.pdf, last accessed on 17 Jun 2020 method and information system available for environmental concerns associated with the mining of raw materials. Therefore, on behalf of the German Federal Environment Agency, a method ("OekoRess") was developed allowing the identification of raw material-specific environmental hot spots as well as rankings and prioritizing of raw materials.

In this context, the term "Environmental Hazard Potential" (EHP) was introduced, defined as the sum of all environmental impacts that are likely to occur if no appropriate countermeasures are taken. The resulting raw material-related evaluation — consisting of indicators with associated EHPs — aims at contributing to the knowledgebase and identifying potential hazards as a risk radar. In analogy to criticality assessments, this assessment aims at raising attention for raw materials of particular high concern and highlight raw material-specific risks, in this case from an environmental perspective.[1134]

Environmental Criticality of Raw Materials – detailed results of Material Profiles
The methodology was applied to more than 50 materials listed in the table below. Also most of the Critical Raw Materials of the 2020 EU CRM list are covered by this method (marked bold), except for Hafnium, Natural Rubber, Phosphorus, and Silicon metal.
The evaluation of aggregated Environmental Hazard Potentials (EHP) is based on 8 indicators. Detailed results of the disaggregated analysis is given for all materials in the project report (Dehoust et al. 2020)[1135].

- Preconditions for acid mine drainage
- Paragenesis with heavy metals
- Paragenesis with radioactive substances, i.e. mining from deposits with naturally occurring high concentrations of radioactive substances
- Mining method (differentiating between mining in open pits from unconsolidated sediments, in open pits from solid rock, or extraction from underground mining)
- Use of auxiliary substances such as leaching and/or amalgamation processes; chemicals for flotation processes
- Accident hazards due to floods, earth quakes, storms, landslides
- Water Stress Index (WSI) and desert areas
- Designated protected areas and AZE (Alliance for Zero Extinction) sites

[1135] Dehoust, G.; Manhart, A.; Dolega, P.; Vogt, R.; Kemper, C.; Auberger, A.; Becker, F.; Scholl, C.; Rechlin, A.; Priester, M. (2020): Environmental Criticality of Raw Materials, An assessment of environmental hazard potentials of raw materials from mining and recommendations for an ecological raw materials policy (UBA TEXTE, 80/2020). Umweltbundesamt (ed.), 2020. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020-06-17_texte_80-2020_oekoressii_environmentalcriticality-report_.pdf, last accessed on 17 Jun 2020.

Table 331: Overview of aggregated Environmental Hazard Potentials (EHP) for a range of materials according to (Dehoust et al. 2020)

Material (bold: CRM according to 2020 list)	Aggregated Environmental Hazard Potential (EHP)
1. Aluminium	Medium to high EHP
2. Antimony	High EHP
3. Baryte	No aggregated EHP available
4. Bauxite	Medium EHP
5. Bentonite	No aggregated EHP available
6. Beryllium	**Medium to high EHP**
7. Bismuth	High EHP
8. Borates	**Medium to high EHP**
9. Chromium	Medium EHP
10. Clay (Kaolin and kaolinitic clay)	Low EHP
11. Cobalt	High EHP
12. Coking coal	Low EHP
13. Copper	High EHP
14. Diatomite	No aggregated EHP available
15. Feldspar	No aggregated EHP available
16. Fluorspar	Low to medium EHP
17. Gallium	**Medium to high EHP**
18. Germanium	High EHP
19. Gold	High EHP
20. Gypsum	Medium EHP
21. Heavy rare earth elements (HREE)	**Medium to high EHP**
22. Indium	High EHP
23. Iron	Medium EHP
24. Iron ore	Medium EHP
25. Lead	High EHP
26. Limestone	No aggregated EHP available
27. Light rare earth elements (LREE)	High EHP
28. Lithium	Medium EHP
29. Magnesite	Medium EHP
30. Magnesium	Medium EHP
31. Manganese	Medium EHP
32. Molybdenum	High EHP
33. Natural graphite	Low EHP
34. Nickel	High EHP
35. Niobium	**Medium to high EHP**
36. Palladium	High EHP
37. Perlite	No aggregated EHP available
38. Phosphate rock	High EHP
39. Platinum	High EHP
40. Platinum group metals (PGM)	No aggregated EHP available
41. Potash	Low EHP
42. Rare Earths	No aggregated EHP available
43. Rhenium	High EHP
44. Rhodium	High EHP
45. Scandium	**Medium to high EHP**
46. Selenium	High EHP
47. Silica sand	**Medium to high EHP**
48. Silver	High EHP
49. Talc	No aggregated EHP available
50. Tantalum	Low to medium EHP
51. Tellurium	High EHP
52. Tin	Medium EHP
53. Titanium	Medium EHP
54. Tungsten	Low to medium EHP
55. Vanadium	High EHP
56. Zinc	High EHP

Comparing the list of aggregated Environment Hazard Potentials (EHP) to the current list of Critical Raw Materials 2020, two aspects are relevant:

- In the 2020 list of Critical Raw Materials, there are CRM listed with only low, or low to medium EHP: Coking Coal, Fluorspar, Magnesium, Natural Graphite, Tantalum, or Tungsten. They might be important from economic perspective, but are not so much relevant in terms of their environmental potential resulting from mining.
- On the other hand, the list above includes a number of raw materials with high environmental hazard profiles which, however, are not part of the 2020 CRM list, i.e. not relevant from economic perspective facing supply risks or lacking of substitution: Copper, Gold, Lead, Molybdenum, Nickel, Palladium, Platinum, Rhenium, Rhodium, Selenium, Silver, Tellurium, and Zinc.

32.4 Possible actions and policy options in the Ecodesign and Energy Labelling Working Plan 2020-2024 regarding CRM and other relevant raw materials

As analysed in the section above, the issue of Critical Raw Materials was on the one hand already included in the MEErP methodology and the EcoReport tool, however, based only on the EU list of CRM of 2011, and on the other hand, CRM were also partly addressed in recent preparatory and revision studies, however, resulting in only few implementing measures, namely information requirements, under EU Ecodesign regulations so far.

Starting from this basis and with the new standard EN 45558:2019 in place how to declare the use of critical raw materials in energy-related products, further actions are proposed for the next EU Ecodesign and Energy Labelling Working Plan 2020-2024.

Methodological developments or conditions: Update of the current list of CRM in the MEErP and EcoReport tool

Table 332 provides an overview of raw materials categorized according to their aggregated Environmental Hazard profiles based on Dehoust et al. (2020); the columns differentiate between those included in the EU list of CRM 2020, either already taken into account in the current MEErP guideline and EcoReport tool or not yet included, and those which are not on the 2020 EU list of CRM, and also not included in the MEErP/ EcoReport tool so far.

Table 332: Overview of raw materials included in the EU list of CRM 2020, in the MEErP EcoReport tool and their aggregated Environmental Hazard Potentials (EHP); source: own compilation based on Dehoust et al. (2020), European Commission (2020) and VHK & COWI (2011)

EHP	2020 CRM list		Not on 2020 CRM list / not included in MEErP/EcoReport
	already included in MEErP/EcoReport	not yet included in MEErP/EcoReport	
No or no aggregated EHP available	☑ Platinum Group Metals (PGM)	- Baryte	- Bentonite - Diatomite - Feldspar - Limestone - Perlite - Potash - Rare earths - Talc
Low EHP	☑ Natural Graphite	- Coking Coal	- Clay (Kaolin and kaolinitic clay)
Low to medium EHP	☑ Fluorspar ☑ Tantalum ☑ Tungsten		
Medium EHP	☑ Magnesium	- Bauxite - Lithium - Titanium	- Chromium - Gypsum - Iron - Iron ore - Magnesite - Manganese - Tin
Medium to high EHP	☑ Beryllium ☑ Gallium ☑ Niobium	- Borates - Heavy rare earth elements (HREE)[1136] - Scandium	- Aluminium - Silica sand
High EHP	☑ Antimony ☑ Cobalt ☑ Germanium ☑ Indium	- Bismuth - Light rare earth elements (LREE)[1137] - Phosphate rock - Vanadium	- Copper - Gold - Lead - Molybdenum - Nickel - Palladium - Platinum - Rhenium - Rhodium - Selenium - Silver - Tellurium - Zinc

Currently, the MEErP methodology is under revision. This could be used to update the current list of CRM in the MEErP and EcoReport tool as well, with the following options being possible:

- Adding all the missing Critical Raw Materials of the 2020 EU list of CRM to the EcoReport tool; still using the characterization factors to calculate the CRM indicator according to MEErP 2011 methodology (cf. section 32.2)
- Adding additional raw materials (not only CRM) to the EcoReport tool due to their relevant Environmental Hazard Potential (for example, the categories "high", "medium to high" or even "medium" EHP marked grey in the last column of Table 332

[1136] Only partly included in MEErP: only Y (Yttrium)
[1137] Only partly included in MEErP: Sc (Scandium) and Nd (Neodymium)

above); still using the characterization factors to calculate the CRM indicator according to MEErP 2011 methodology

- Taking into account all CRM of the 2020 list as well as additional raw materials with relevant Environmental Hazard Profile; revising the current approach of characterization factors and weighting of the raw materials as applied in the MEErP 2011 methodology with the objective to better take into account the different Environmental Hazard Potentials in combination with the scarcity of the materials. For example, whereas Cobalt has a comparably low ranked characterization factor applying the current MEErP methodology 2011 (cf. Table 329), it has a high environmental hazard profile according to the classification of Dehoust et al. (2020) where a broader set of environmental risks were analysed. Using the scientific approach as proposed by Dehoust et al. (2020) in combination with the classification as CRM could lead to a revised prioritisation scheme for the relevance of raw materials with regard to setting potential implementing measures[1138].
    - Highest priority: raw materials categorized as CRM with high EHP
    - Second highest priority: raw materials not being CRM but still with high EHP and/or CRM with medium to high EHP.
- On the basis of the prioritisation scheme, identifying and providing an overview of the most relevant products or product groups in the scope of Ecodesign and Energy Labelling in which these raw materials are predominantly used. These might include but are not limited to for example stainless steel products (such as household appliances, construction products) with regard to the use of primary nickel; aluminium building products, such as window frames; electric motors and electrical installations using primary copper; and others.
- Exploring means of evaluating the "Circular Economy" value of Critical Raw Materials (CRM) and other materials with high Environmental Hazard Potential (EHP), with a view to retaining these materials within the EU.

Potential measures related to information and product design (i.e. measures specific to products, which should be systematically analysed and considered in preparatory and review studies)

Basic condition for setting potential implementing measures is ensuring a systematic analysis throughout all future preparatory and review studies of the existence, location in components and – ideally - amount of those priority raw materials either categorized as Critical Raw Materials (CRM) and/or having a high Environmental Hazard Potential (EHP) according to the prioritisation scheme as proposed above.

Implementing measures with focus on these priority raw materials should be aimed at reducing the pressure on further resource extraction needs for the purpose of manufacturing new products, thus facilitating the EU being less dependent on imports of Critical Raw

[1138] According to stakeholder feedback, the decision for the options which list of raw materials should be considered in the MEErP and EcoReport tool, should be discussed with regard to the objectives of the Ecodesign Directive, the objectives of the selected evaluation approaches as well as possible measures. The EU Criticality Assessment poses other questions than the EHP approach. Example: CRMs should be used in circular way in order to secure these materials for the (cicular) economy - product groups containing CRMs should therefore be subject to material-efficiency requirements and the EN45558 (developed in the framework of M/543 of the COM) would support such implementation. The same applies for materials with EHP and high economical relevance (environmentally critical raw materials), if following the assumption that internalizing external costs of mining might lead to price peaks and related supply risks in the future. Product groups containing materials with high EHP (regardless of their economic relevance) should be subject to material efficiency measures in order to reduce material related environmental pressure of products.

Materials (CRM) from non-EU countries and reducing the overall environmental impacts of resource extraction.

- Implementing measures facilitating **durability** of the products and/or components containing these relevant raw materials;
- Implementing measures facilitating the **recyclability** of the products and/or components containing these relevant raw materials, such as
  - Requirements on design for disassembly
  - Requirements on information and declaration for facilitating recycling operations based on the guidance of standard EN 45558:2019 with regard to substance, amount and location in components of the ErP. However, one stakeholder comments that the proposal of locating and evaluating amount of EHP materials (silver, copper, etc…) would lead to the unacceptable position of disclosing some strategic company know how, possibly patented.
  - Requirements on dismantling information for facilitating recycling operations such as the sequence of dismantling steps, tools or technologies needed to access the targeted component
- Promoting the **use of recycled raw materials** which, however, requires reliable tracing and verification methods for Market Surveillance Authorities
  - Design requirements setting a minimum share of recycled raw materials. However, one stakeholder points out that it is premature to envisage minimum quotas of recycled materials in products as the technologies in some cases are not yet there or in their infancy. Another stakeholder complements that on the one hand, such requirement can stimulate the market for recycled materials, which may be a benefit, whereas on the other hand, it can lead to problems in periods during which supply is still constrained. Finally, one stakeholder requests that functionality and safety should not be interfered by determining the use of recycled raw materials.
  - Labelling requirements on the applied share of recycled raw materials
- Implementing measures for enhancing the recovery rate from the waste flows or streams. However, one stakeholder remarks that such measures shall rather be implemented in regulations dealing with recycling, as Ecodesign regulations are not proper vehicles for such measures.
- Increasing the collection/take back rate of appliances/goods that contain CRM. Again, one stakeholder remarks that such measures shall rather be implemented via the WEEE Directive, as Ecodesign regulations are not proper vehicles for such measures.

32.5 Outlook: Assessing social aspects of raw materials

Beyond scarcity, i.e. supply risks of certain raw materials, and environmental impacts of the raw materials extraction, the raw materials extraction can further bear social impacts and risks in the supply chain of manufacturers.

A methodology composed of multiple indicators to combine social impacts together with supply and environmental risks and impacts was developed and used to evaluate 45 mined elements and materials commonly used in consumer electronic products by Apple

(2019)[1139], the so called Material Impact Profiles (MIP). The social indicators in the MIPs include the prominence of artisanal mining, the potential for child or forced labour related to the country of origin and often to conditions specific to a particular mining region of that country, as well as the level of corruption and conflict in the producing countries. The analysis resulted in three scores for the materials, one each for supply, environmental, and social impacts, where a higher score represents a greater global impact per unit of material extracted). The numerical values were finally normalized so they can be easily compared and assigned low, medium, and high rankings based on their relative impacts.

Although the current regulatory frameworks of the Ecodesign Directive 2009/125/EC and Energy Labelling Regulation (EU) 2017/1369 do not cover social aspects of products in their supply chain, these aspects could for example be part of the "Sustainable Products Initiative" envisaged by the European Commission. This initiative aims not only at widening the scope of the Ecodesign Directive beyond energy related products to be made applicable to the broadest possible range of products, but, and where necessary, through complementary legislative proposals, the Commission plans also to establish sustainability principles and other mechanisms to regulate sustainability-related aspects in a wide range of product related instruments[1140]. In this respect, one stakeholder commented being in general positive to the introduction of due diligence requirements in the supply chain of CRM and recommends that the specific requirements should be based on internationally recognized due diligence guidelines, including the OECD's guidelines for multinational companies and the ILO's tripartite declaration on the principles on multinational companies and social policy. Further, it is seen as important to ensure alignment with the upcoming general requirements for due diligence for companies and other product specific requirements (such as the new requirements in the batteries regulation).

[1139] Apple (2019): Material Impact Profiles – Which materials to prioritize for a 100 percent recycled and renewable supply chain; online available: https://www.apple.com/euro/environment/pdf/a/generic/Apple_Material_Impact_Profiles_April2019.pdf; last accessed 20.09.2020

[1140] European Commission: Sustainable products initiative. Inception Impact Assessment. Ref. Ares(2020)4754440 - 11/09/202; online available https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12567-Sustainable-Products-Initiative, last accessed 20.09.2020

ANNEX: ADDITIONAL REFERENCES AND LITERATURE

Professional laundry appliances

1. CEN TC214 WG05 Eco Design ENER Lot 24 Performance Measurement of Washing Machines and Dryer for industrial use
2. CLC TC59X SWG1.12 Commercial laundry machines,
3. CLC TC59X/SWG1.12 – meeting minutes September 13, 2017.
4. Commission Decision (EU) 2016/611 of 15 April 2016 on the reference document on best environmental management practice, sector environmental performance indicators and benchmarks of excellence for the tourism sector under Regulation (EC) No 1221/2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS) (notified under document C(2016) 2137), OJ L 104, 20.4.2016, p. 27–69
5. EN 17116-2:2018 Specifications for industrial laundry machines - Definitions and testing of capacity and consumption characteristics - Part 2: Batch drying tumblers (successor of EN 17116-2:2017)
6. EN 17116-3:2019 Specifications for industrial laundry machines - Definitions and testing of capacity and consumption characteristics - Part 3: Continuous tunnel washer (successor of EN 17116-3:2017)
7. EN 17116-4:2019 Specifications for industrial laundry machines - Definitions and testing of capacity and consumption characteristics - Part 4: Washer-extractors (successor of EN 17116-4:2017)
8. EN 50594:2018 Household and similar electric appliances -Methods for measuring the performance of tumble dryers intended for commercial use (successor of prEN 50594:2017)
9. EN 50640:2018 Household and similar electric appliances - Methods for measuring the performance of clothes washing machines intended for commercial use (successor of prEN 50640:2017)
10. https://www.danube-international.com/img/galeria//IMG_5026.JPG, retrieved May 7, 2020.
11. https://www.domuslaundry.com/img/galeria/dhs-120_touch_tilt-262.jpg, retrieved May 7, 2020.
12. https://www.milnor.com/wp-content/uploads/2014/06/20140618ARCO-MURRAY-cwww.JackRamsdale.com2481-417x600.jpg, retrieved May 7, 2020.
13. M/539 COMMISSION IMPLEMENTING DECISION of 11.12.2015 on a standardisation request to the European Committee for Standardisation as regards non-household washing machines, dryers and dishwashers, in support of the implementation of Directives 2009/125/EC and 2010/30/EU of the European Parliament and of the Council
14. Rüdenauer, Ina e.a. (Öko-Institut e.V. Institute for Applied Ecology, Germany), Mudgal, Shailendra e.a. (BIO Intelligence Service, France), Seifried, Dieter (Büro Ö-Quadrat, Germany), Preparatory Studies for Eco-design Requirements of Energy-using Products - Lot 24:Professional Washing Machines, Dryers and Dishwashers, 2011
15. Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data [DS-066341]: 28942230 - Household or laundry-type washing machines of a dry linen capacity > 10 kg (including machines that both wash and dry) AND 28942270 - Drying machines, of a dry linen capacity > 10 kg (PRODVAL)
16. Styles D., Schönberger H., Galvez Martos J. L., Best Environmental Management Practice in the Tourism Sector, EUR 26022 EN, doi:10.2788/33972. Extract 5.4 Optimised small-scale laundry-operations, Extract 5.5 Optimised large-scale or outsourced laundry operations. https://ec.europa.eu/environment/emas/takeagreenstep/pdf/BEMP-5.5-FINAL.pdf
17. VHK for Ecofys specific contract 2015-2017. From 2018 VHK specific monitoring contract.

Professional dishwashers

1. Belke, M.Sc. Lara and Stamminger, Prof. Dr. Rainer (Household and Appliance Technology Section Institute for Agricultural Technology Rheinische Friedrich-Wilhelms-Universität Bonn), Report on the Dishwasher Round Robin Test Commercial Dishwashing, 2016
2. CLC TC59X SWG1.12 Commercial laundry machines, CLC TC59X WG2.1 Commercial dishwashers
3. CLC TC59X/WG2.1 - meeting minutes March 30, 2017.
4. Commission Decision (EU) 2016/611 of 15 April 2016 on the reference document on best environmental management practice, sector environmental performance indicators and benchmarks of excellence for the tourism sector under Regulation (EC) No 1221/2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS) (notified under document C(2016) 2137), OJ L 104, 20.4.2016, p. 27–69
5. EN 63136:2019 Electric dishwashers for commercial use - Test methods for measuring the performance (successor of EN 50593:2017)
6. M/539: COMMISSION IMPLEMENTING DECISION of 11.12.2015 on a standardisation request to the European Committee for Standardisation as regards non-household washing machines, dryers and dishwashers, in support of the implementation of Directives 2009/125/EC and 2010/30/EU of the European Parliament and of the Council
7. Rüdenauer, Ina e.a. (Öko-Institut e.V. Institute for Applied Ecology, Germany), Mudgal, Shailendra e.a. (BIO Intelligence Service, France), Seifried, Dieter (Büro Ö-Quadrat, Germany), Preparatory Studies for Eco-design Requirements of Energy-using Products - Lot 24:Professional Washing Machines, Dryers and Dishwashers, 2011
8. Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data [DS-066341]: 28295000 - Non-domestic dish-washing machines
9. Styles D., Schönberger H., Galvez Martos J. L., Best Environmental Management Practice in the Tourism Sector, EUR 26022 EN, doi:10.2788/33972. Extract on 8.3 Optimised dishwashing, cleaning and food preparation. https://ec.europa.eu/environment/emas/takeagreenstep/pdf/BEMP-8.3-FINAL.pdf
10. VHK for Ecofys specific contract 2015-2017. From 2018 VHK specific monitoring contract.
11. VHK, Specific contract preparatory IA on professional wet appliances, May 5, 2014

Low temperature emitters

1. EN 14825:2018, Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling, Testing and rating at part load conditions and calculation of seasonal performance (December, 2018).
2. EN 16430-2:2015, Fan assisted radiators, convectors and trench convectors, Part 2: Test method and rating for thermal output (January, 2015).
3. EN 442-1:2014, Radiators and convectors, Part 1: Technical specifications and requirements (December, 2014).
4. EN 442-2:2014, Radiators and convectors, Part 2: Test methods and rating.
5. European Commission, Review Study of Commission Ecodesign and Energy labelling Regulation on Space and Combination heaters – Task 4 (July, 2019).
6. European Commission, Heating and Cooling: facts and figures, Last updated: 23 April 2020 https://ec.europa.eu/energy/topics/energy-efficiency/heating-and-cooling_en.
7. Global Market Insights, Europe Hydronic Radiators Market Forecsts – 2019-2025 Report (May, 2019) https://www.gminsights.com/industry-analysis/europe-hydronic-radiators-market.
8. Standard Assessment Procedure (SAP 2012) for Energy Rating of Dwellings.
9. European Commission, Technical Assistance Impact Assessment Revision of Space and Water Heater Regulations, Discussion Document for 1stWG2 meeting on TESTING (March 2020)
10. https://www.ecoboiler-review.eu/

Windows

1. Martijn van Elburg (VHK), Norbert Sack (ift Rosenheim), Sarah Bogaerts e.a. (VITO); LOT 32 / Ecodesign of Window Products. TASK 7 – Policy Options & Scenarios, Final report, consolidated version of 22 June 2015; 22 June 2015; Specific contract No ENER/C3/2012-418-Lot1/03
2. https://www.europarl.europa.eu/doceo/document/E-9-2019-002916-ASW_EN.html [EC reply of 8 Nov 2019 in response to question from EP of 23 Sep 2019: https://www.europarl.europa.eu/doceo/document/E-9-2019-002916_EN.html]
3. REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC
4. https://www.window.de/verband-fenster-fassade/

Water decalcifiers / softeners

1. https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics
2. https://ec.europa.eu/eurostat/statistics-explained/index.php/People_in_the_EU_-_statistics_on_household_and_family_structures
3. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CONSIL:ST_6060_2020_REV_1&from=EN
4. https://waterontharderkiezen.be/faq
5. https://waterontharderkiezen.nl/modellen-waterontharders/prijzen
6. https://www.alliedmarketresearch.com/europe-water-softeners-market-A06069
7. https://www.boshuis.nl/
8. https://www.dewatergroep.be/nl-be/drinkwater/waterkwaliteit-en-hardheid/waterhardheid
9. https://www.ecowater.be/nl/nieuws/bespaar-tot-650-euro-jaar-met-een-waterontharder
10. https://www.ecowater-softeners.co.uk/frequently-asked-questions-about-water-softeners
11. https://www.eddy.uk.com/
12. https://www.epa.gov/sites/production/files/2017-01/documents/ws-products-noi-water-softners.pdf
13. https://www.epa.gov/sites/production/files/2017-01/documents/ws-products-presentation-water-softeners.pdf
14. https://www.europeandrinkingwater.eu/fileadmin/edw/documents_links/MaiD_Report_1_final_11.9.2017.pdf
15. https://www.healthline.com/health/hard-water-and-soft-water#hard-water-benefits
16. https://www.lenntech.nl/waterhardheid.htm
17. https://www.nsf.org/newsroom_pdf/European_Stds_Guide_LT_EN_LDW10050309.pdf.
18. https://www.waterontharder-expert.be/onderhoud
19. https://www.waterverzachteraquagroup.be/waterverzachter/heeft-een-waterverzachter-onderhoud-nodig https://radio2.be/de-inspecteur/moet-je-waterontharder-elk-jaar-een-onderhoud-krijgen
20. https://www.waterverzachteraquagroup.be/waterverzachter/water-en-zoutverbruik
21. https://orbit.dtu.dk/en/publications/f%C3%B8r-og-efterm%C3%A5linger-af-effekter-af-bl%C3%B8dg%C3%B8ring-i-br%C3%B8ndby-et-samar
22. https://www.hofor.dk/baeredygtige-byer/udviklingsprojekter/bloedere-vand/
23. Kozisek, F. (2020), Regulations for calcium, magnesium or hardness in drinking water in the European Union member states. Regulatory Toxicology and Pharmacology, vol. 112. Available at https://www.sciencedirect.com/science/article/abs/pii/S0273230020300155

Tertiary hot beverage equipment

1. BIO by Deloitte; Oeko-Institut; ERA Technology Ltd. (2015): Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC. Task 3 Final Report. Hg. v. European Commisssion (DG ENTR), zuletzt geprüft am 21.08.2020.
2. Bio Intelligence Service (Bio IS); ARTS (2011): Preparatory Studies for Ecodesign Requirements of EuPs. Lot 25: Non-tertiary coffee machines. Hg. v. European Commission (DG ENER).

3. European Vending and Coffee Service Association (Hg.) (2015): Europe. The vending market in 2015. Power point presentation. Online verfügbar unter https://docplayer.net/42946165-Europe-the-vending-market-in-2015.html, zuletzt geprüft am 01.09.2020.
4. European Vending and Coffee Service Association (Hg.) (2019): Europe. The vending market in 2018. Power point presentation. Online verfügbar unter https://www.vending-europe.eu/wp-content/uploads/2020/01/EUROPE-2018-EVA-Market-Report-contents-and-defintions.pdf, zuletzt geprüft am 01.09.2020.
5. Eurostat (Hg.) (2008): NACE Rev.2. Statistical classification of economic activities in the European Community (Eurostat Methodological and Working Papers). Online verfügbar unter http://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF, zuletzt geprüft am 01.09.2020.
6. Rothwell, Ian; Bush, Eric (2017): Preliminary study on tertiary hot beverage equipment. Standards, energy consumption and effective measures for exploiting saving potentials. Hg. v. Swiss Federal Office of Energy SFOE. Online verfügbar unter https://www.bfe.admin.ch/bfe/de/home/news-und-medien/publikationen/_jcr_content/par/externalcontent.external.exturl.pdf/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZW4vcHVibGljYX/Rpb24vZG93bmxvYWQvODgzMy5wZGY=.pdf.
7. Wierda, Leo; Kemna, René (2018 (rev. 2019)): Ecodesign Impact Accounting. Status Report 2018. Hg. v. D. EnergyG European Commission. Van Holsteijn en Kemna B.V. Online verfügbar unter https://ec.europa.eu/energy/sites/ener/files/documents/eia_status_report_2017_-_v20171222.pdf, zuletzt geprüft am 13.08.2019.

Universal external power supplies

1. Ipsos, Trinomics, Fraunhofer FOKUS, Economisti Associati (2019): Impact Assessment Study on Common Chargers of Portable Devices. Edited by Publications Office of the European Union. European Commission. Luxembourg.

Lightweight design

1. 7th Environmental Action Plan (EAP), Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet',OJ L 354, 28.12.2013, p. 171–200
2. Commission's Standardisation Request M/543 on Material Efficiency Aspects of ErP, 2017
3. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Closing the loop - An EU action plan for the Circular Economy, COM/2015/0614 final, Brussels 2.12.2015.
4. Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste OJ L 150, 14.6.2018, p. 109–140
5. Flynn, V., Circular economy needs impact analysis – ministers, ENDS Daily, 1 Mar 2016.
6. Flynn, V., Strong support for circular economy ecodesign at Council, ENDS Daily, 7 Mar 2016. See also http://www.consilium.europa.eu/en/meetings/env/2016/03/04/#
7. Gregory, S.A. and Commander, M.W., New materials adoption study:…, Design Studies 1, nr. 2, Oct. 1979, 107-112. Cited in https://www.vhk.nl/downloads/Reports/1981/Energy_conscious_design1981.pdf
8. https://www.youtube.com/watch?v=maWOh4SdXV4
9. https://www.zeiss.com/microscopy/int/cmp/mat/20/energy-materials/ebook/thank-you.html
10. https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/automotive%20and%20assembly/pdfs/lightweight_heavy_impact.ashx
11. https://www.materialise.com/en/manufacturing/3d-printing-technology/metal-3d-printing
12. Kemna, R., Methodology for Ecodesign of Energy-related Products (MEErP), VHK fort he Commission, 2011.
13. VHK, EIA II - Special Report Materials 2016, for the European Commission, 2016

Hair dryers

1. BIO by Deloitte; Öko-Institut; ERA Technology Ltd. (2015): Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC. Task 3 Final Report. European Commisssion (Hg.), 2015, zuletzt geprüft am 21.08.2020.
2. Bureau of Energy (2018): Revised Energy Efficiency Criteria and Labeling Method for Energy Label Qualified Hair dryers. Online verfügbar unter https://www.energylabel.org.tw/englishlabel/application_en/efficiency/upt.aspx?Cid=10&subID=139, zuletzt geprüft am 01.10.2020.
3. European Agency for Safety and Health at Work (2014): Occupational health and safety in the hairdressing sector, 2014. Online verfügbar unter https://osha.europa.eu/en/publications/occupational-health-and-safety-hairdressing-sector, zuletzt geprüft am 01.10.2020.
4. Gattermann, M.; Manhart, A. (2012): PROSA Haarpflegegeräte – Entwicklung der Vergabekriterien für ein klimaschutzbezogenes Umweltzeichen [Product Sustainability Assessment Hair Care Products - Development of Award Criteria for a climate-related Environmental Label]. Öko-Institut e.V. (Hg.), 2012.
5. Greenmark Labelling Program, T. (Hg.) (2019): Green Mark No. 69: Hand-held hairdryers, 13.02.2019. Online verfügbar unter https://greenliving.epa.gov.tw/newPublic/Eng/GreenMark/Criteria#.
6. Owen, P. (2012): Powering the Nation; Household electricity-using habits revealed. A report by the Energy Saving Trust, the Department of Energy and Climate Change (DECC), and the Department for Environment. In: *Food and Rural Affairs (Defra)*.
7. Pattana, S.; Kammuang-lue, N.; Wiratkasem, K.; Tantakitti, C. (2017): Draft of the MEPS and HEPS for hair dryer in Thailand. 4th International Conference on Power and Energy Systems Engineering (CPESE). In: *Energy Procedia* (25-27). Online verfügbar unter https://www.sciencedirect.com/science/article/pii/S1876610217354723, zuletzt geprüft am 01.10.2020.
8. RAL gGmbH (Hg.) (2019): Blauer Engel. Das Umweltzeichen. Haartrockner. DE-UZ 175. Vergabekriterien. Ausgabe Januar 2019, Version 1. [Blue Angel. The Envinronmental label. Hairdryers. Award criteria. Edition January 2019, version 1], 2019. Online verfügbar unter https://www.blauer-engel.de/de/produktwelt/elektrogeraete/haartrockner/haartrockner-ausgabe-januar-2019.
9. Stiftung Warentest (2009): Vorsicht, heiß [Caution, hot]. In: *test*, S. 28–33.
10. Stiftung Warentest (2015): Mähnen zähmen [Tame the mane]. In: *test* (10), 64-68.
11. Stratmann, B. (2018): Hintergrundbericht: Aktualisierung des Umweltzei-chens DE-UZ 175 für Haartrockner, Ausgabe August 2012, Version 4 [Background report: Update of the Environmental Label DE-ZU 175 for hair dryers, edition August 2012, version 4] (unpublished report for the German Environmental Agency). Öko-Institut e.V. (Hg.), 2018.
12. van Elburg, M.; van der Voort, M.; van den Boorn, R.; Kemna, R.; Li, W. (2011): Study on Amended Working Plan under the Ecodesign Directive. Final report Task 3, 16.12.2011.

Greenhouse covers

1. Ahamed, M. S.; Guo, H.; Tanino, K. (2019): Energy saving techniques for reducing the heating cost of conventional greenhouses. In: *Biosystems Engineering* 178, S. 9–33. DOI: 10.1016/j.biosystemseng.2018.10.017.
2. Al-Helal, I.; Alsadon, A.; Shady, M.; Ibrahim, A.; Abdel-Ghany, A. (2020): Diffusion Characteristics of Solar Beams Radiation Transmitting through Greenhouse Covers in Arid Climates. In: *Energies* 13 (2), S. 472. DOI: 10.3390/en13020472.
3. Baeza, E.; Hemming, S.; Stanghellini, C. (2020): Materials with switchable radiometric properties, Could they become the perfect greenhouse cover? In: *Biosystems Engineering* 193, S. 157–173. DOI: 10.1016/j.biosystemseng.2020.02.012.

4. BIO by Deloitte; Öko-Institut; ERA Technology Ltd. (2015): Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC. Task 3 Final Report. European Commisssion (Hg.), 2015, zuletzt geprüft am 21.08.2020.
5. Carbon Trust (2004): Energy Benchmarks and Saving Measures for Protected Greenhouse Horticulture in the UK, 2004.
6. Dehbi, A.; Mourad, A.-H. I. (2016): Durability of mono-layer versus tri-layers LDPE films used as greenhouse cover: Comparative study. In: *Arabian journal of chemistry* 9, S. 282–289, zuletzt geprüft am 28.08.2020.
7. Friman Peretz, M.; Geoola, F.; Yehia, I.; Ozer, S.; Levi, A.; Magadley, E.; Brikman, R.; Rosenfeld, L.; Levy, A.; Kacira, M.; Teitel, M. (2019): Testing organic photovoltaic modules for application as greenhouse cover or shading element. In: *Biosystems Engineering* 184, S. 24–36. DOI: 10.1016/j.biosystemseng.2019.05.003.
8. Golaszewski, J.; Visser, C. de; Brodzinski, Z.; Myhan, R.; Olba-Ziety, E.; Stolarski, M.; Buisonjé, F. de; Ellen, H.; Stanghellini, C.; van der Voort, M.; Baptista, F.; Leopoldo Silva; Murcho, D. et al. (2012): State of the art on energy efficiency in agriculture. County data on energy consumption in different agroproduction sectors in the European countries. AgrEE project deliverable 2.1, zuletzt geprüft am 28.08.2020.
9. Kempkes, F.; Stanghellini, C.; Hemming, S.; Dai, J. (2008): Cover materials excluding near infrared radiation. Effect on greenhouse climate and plant processes. In: *Acta Hortic.* (797), S. 477–482. DOI: 10.17660/ActaHortic.2008.797.69.
10. Maraveas, C. (2019): Environmental Sustainability of Greenhouse Covering Materials. In: *Sustainability* 11 (21), zuletzt geprüft am 06.08.2020.
11. Montero, I.; Antón, A.; Torrellas, M.; Ruijs, M.; Vermeulen, P. (2011): Environmental and economic profile of present greenhouse production systems in Europe. Annex. EUPHOROS deliverable No. 5, September 2011. Online verfügbar unter http://www.wur.nl/upload_mm/b/a/4/533c4798-b539-4a22-9311-c52a5fcf6629_Environmental%20and%20economic%20profile%20of%20present%20greenhouse%20production%20systems%20in%20Europe.%20Annex.pdf, zuletzt geprüft am 27.08.2020.
12. Mourad, A.-H.I.; Dehbi, A. (2014): On use of trilayer low density polyethylene greenhouse cover as substitute for monolayer cover. In: *Plastics, Rubber and Composites* 43 (4), S. 111–121.
13. Rodríguez-Seijo, A.; Pereira, R. (2019): Microplastics in Agricultural Soils: Are They a Real Environmental Hazard? In: Sanchez-Hernandez, J.C. (ed.): Bioremediation of Agricultural Soils. Taylor & Francis / CRC Press. 1st edition, Chapter 3. https://www.researchgate.net/publication/322754449_Chapter_3_Microplastics_in_Agricultural_Soils_Are_They_a_Real_Environmental_Hazard
14. Sánchez-Valdés, S.; Ramírez-Vargas, E.; Martínez-Colunga, J. G.; Ramos-DeValle, L. F.; Morales-Cepeda, A.; Rodríguez-Fernández, O. S.; Lozano-Ramírez, T.; Flores-Gallardo, S.; Méndez-Nonell, J. (2018): Improvement of the Photostability of Low-Density Polyethylene and Ethylene Vinyl Acetate Blends with Nanoclay, Toward Durable Nanocomposites for Potential Application in Greenhouse Cover Films. In: *Polymer-Plastics Technology and Engineering* 57 (16), S. 1706–1714. DOI: 10.1080/03602559.2017.1419489.
15. Schockert, K. (2015): Aktuelle Gewächshaus- Eindeckmaterialien. Presentation at the „Lehrerfortbildung Landesakademie Esslingen", 9.11.2015. Esslingen, 09.11.2015. Online verfügbar unter https://www.schule-bw.de/faecher-und-schularten/berufliche-bildung/gartenbau/pdf_dateien/technik_02/aktuelle_gh_eindeckmaterialien_schockert.pdf.
16. Seven, S. A.; Tastan, Ö. F.; Tas, C. E.; Ünal, H.; Ince, İ. A.; Menceloglu, Y. Z. (2019): Insecticide-releasing LLDPE films as greenhouse cover materials. In: *Materials Today Communications* 19, S. 170–176. DOI: 10.1016/j.mtcomm.2019.01.015.
17. SolaWrapFilms (2020): Diffuse Light and it's Effects in Greenhouses. Online verfügbar unter https://www.solawrapfilms.com/greenhouse-plastic-blog/diffuse-light-and-its-effects-in-greenhouses/, zuletzt aktualisiert am 22.08.2020, zuletzt geprüft am 24.08.2020.

18. Sophianopoulos, D.; Katsoulas, N. (2011): Additional design requirements of steel commercial greenhouses in high seismic hazard EU countries. 7th National Conference on Steel Structures, 2011. Online verfügbar unter https://www.researchgate.net/profile/Dimitrios_Sophianopoulos/publication/284031742_Additional_Design_Requirements_of_Steel_Commercial_Greenhouses_in_High_Seismic_Hazard_EU_Countries/links/564b5d3008ae4ae893b7bff1/Additional-Design-Requirements-of-Steel-Commercial-Greenhouses-in-High-Seismic-Hazard-EU-Countries.pdf?origin=figuresDialog.
19. Tantau, H.-J.; Max, J. F.J.; Elsner, B. v.; Ulbrich, A. (2012): Solar transmittance of greenhouse covering materials. In: *Acta Hortic.* 956, S. 441–448, zuletzt geprüft am 24.08.2020.
20. Valera, D. L.; Belmonte, L. J.; Molina-Aiz, F. D.; López, A.; Camacho, F. (2017): The greenhouses of Almería, Spain, Technological analysis and profitability. In: *Acta Hortic.* (1170), S. 219–226. DOI: 10.17660/ActaHortic.2017.1170.25.
21. Vanthoor, B.; Stanghellini, C.; van Henten, E.; Gázquez Garrido, J. C. (2008): The Combined Effects of Cover Design Parameters on Tomato Production of a Passive Greenhouse. In: *Acta Hortic.* (801), S. 383–392. DOI: 10.17660/ActaHortic.2008.801.40.

Post-consumer recycled content

1. 'A European Strategy for Plastics in a Circular Economy' (COM(2018)0028)
2. Gian de Belder (P&G), HolyGrail 2.0 presentation, 2019.
3. http://www.container-recycling.org/index.php/estimated-yield-rates-from-collected-plastic#
4. https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy.pdf
5. https://ec.europa.eu/growth/industry/sustainability/ecodesign_en (EcoReport)
6. https://news.samsung.com/global/samsung-electronics-to-replace-plastic-packaging-with-sustainable-materials
7. https://ta-netzsch.com/how-to-control-the-quality-of-recycled-plastic-materials
8. https://www.basf.com/be/en/who-we-are/sustainability/whats-new/sustainability-news/2019/BASF-signs-dutch-green-deal.html
9. https://www.eea.europa.eu/highlights/reuse-and-recycling-are-key
10. https://www.eera-recyclers.com/files/cen-clc-tc10sec132dc-secr-enquiry-pren45557-recycled-material-content.pdf
11. https://www.electroluxgroup.com/sustainabilityreports/2019/key-priorities-and-progress-2019/our-nine-promises/make-better-use-of-resources/
12. https://www.intertek.com/analytical-laboratories/recycled-plastics/
13. https://www.philips.com/a-w/about/sustainability/sustainable-planet/circular-economy/recycle.html
14. https://www.shell.com/business-customers/chemicals/media-releases/2019-media-releases/shell-uses-plastic-waste-to-produce-chemicals.html
15. https://www.sony.net/SonyInfo/csr_report/environment/products/plastics.html
16. https://www.waste360.com/e-waste/apple-adds-more-recycled-materials-new-iphones
17. Kemna, R. , Methodology for Ecodesign of Energy-related Products (MEErP), Part 2, VHK for the Commission 2011.
18. VHK, EIA II - Special Report Materials 2016, for the European Commission, 2016
19. Viegand Maagoe A/S, VHK, Review study of Vacuum Cleaners, Ecodesign study for the European Commission, Final Report, June 2019.

Ecological profile

1. European Parliament (2009): Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products, Version of 21 Oct 2009. In: Official Journal of the European Union 31.10.2009 (OJ L 285), pp. 10–35. Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0125&from=EN, last accessed on 24 May 2020
2. VHK and COWI (2011): Methodology for Ecodesign of Energy-related Products - MEErP 2011 - Methodology Report, Part 1: Methods. In collaboration with Kemna, R.; Azaïs, N.; van Elburg,

M.; van der Voort, M. and Li, W., 2011. Online available at https://ec.europa.eu/docsroom/documents/26525/attachments/1/translations/en/renditions/native, last accessed on 16 Jun 2020

3. Ecodesign EcoReport tool 2014 - unprotected (2014). Version 3.06 VHK for European Commission 2011; modified by IZM for European Commission 2014. Online available at https://ec.europa.eu/docsroom/documents/5308/attachments/1/translations/en/renditions/native, last accessed on 16 Jun 2020
4. Donatello, S.; Fernández Carretero, A.; Garbarino, E.; Sanfelix, J.; Wolf, O. (2020): Revision of EU Ecolabel criteria for Hard Coverings, Technical Report v.3.0: Draft criteria proposals, 2020. Online available at https://susproc.jrc.ec.europa.eu/Hard_coverings/docs/Technical_Report%20_3-0.pdf, last accessed on 25 Jun 2020.
5. Rohde, C.; Hettesheimer, T.; Waide, P. (2017): Technical assistance study for the assessment of the feasibility of using "points system" methods in the implementation of Ecodesign Directive (2009/125/EC), Task 4 - Machine Tools Case Study. Waide Strategic Efficiency, VITO, Fraunhofer, Viegand Maagøe, VHK, 2017. Online available at https://points-system.eu/sites/points-system.eu/files/Points%20System%20for%20Ecodesign%20-%20%20Task%204%20-%20Machine%20%20Tools%20-%20final_0.pdf, last accessed on 25 Jun 2020.
6. Waide, P. (2017a): Technical assistance study for the assessment of the feasibility of using "points system" methods in the implementation of Ecodesign Directive (2009/125/EC), Task 1 - Stakeholder Consultation. Waide Strategic Efficiency, VITO, Fraunhofer, Viegand Maagøe, VHK, 2017. Online available at https://points-system.eu/sites/points-system.eu/files/Points%20Systems%20for%20Ecodesign%20-%20Task%201%20-%20final.pdf, last accessed on 25 Jun 2020.
7. Waide, P. (2017b): Technical assistance study for the assessment of the feasibility of using "points system" methods in the implementation of Ecodesign Directive (2009/125/EC), Task 3 - Method Development. Waide Strategic Efficiency, VITO, Fraunhofer, Viegand Maagøe, VHK, 2017. Online available at https://points-system.eu/sites/points-system.eu/files/Points%20System%20for%20Ecodesign%20-%20Task%203%20-%20final_0.pdf, last accessed on 25 Jun 2020.
8. Waide, P.; Peeters, K.; Rohde, C. (2017): Technical assistance study for the assessment of the feasibility of using "points system" methods in the implementation of EcodesignDirective (2009/125/EC), Task 2 - A review of state-of-the art methods. Waide Strategic Efficiency, VITO, Fraunhofer, Viegand Maagøe, VHK, 2017. Online available at https://points-system.eu/sites/points-system.eu/files/Points%20System%20for%20Ecodesign%20-%20Task%202%20-%20final_0.pdf, last accessed on 25 Jun 2020.
9. DG JRC (2020): EU Ecolabel criteria for awarding the EU Ecolabel for hard covering products, Annex. Draft legal text (Annex) for penultimate EUEB meeting (18-19 Feb), 2020. Online available at https://susproc.jrc.ec.europa.eu/Hard_coverings/docs/Annex_HC_23-01-2020_highlighted.pdf, last accessed on 25 Jun 2020.
10. Cordella, M.; Alfieri, F.; Sanfelix, J. (2019): Analysis and development of a scoring system for repair and upgrade of products, Final report. European Commission, Joint Research Centre. Seville, Spain, 2019. Online available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC114337/jrc114337_report_repair_scoring_system_final_report_v3.2_pubsy_clean.pdf, last accessed on 24 May 2020.