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Development of the Closed Cycle and Waste Management Policy Towards a Sustainable Substance Flow and Resources Policy, FKZ 90531411

Sub-project "Identification of Relevant Substances and Materials for a Substance Flow-Oriented Resource-Conserving Waste Management"

Final Report

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1 Introduction

1.1 Synopsis of project objectives

The joint Öko-Institut and IFEU-Institut project with the short title "Sustainable Materials Management – Important Potentials in Germany" documented in this report on behalf of the Federal Environment Ministry (BMU) concludes an Öko-Institut research project for the BMU dealing with the correlations between closed cycle and waste management policies and substance flow concepts. In the report on this "Literature and Data Research for Generating the Basis for the Development of Closed Cycle and Waste Management Policy Towards a Sustainable Substance Flow and Resources Policy" [Öko-Institut 2004a], initial screening of particularly relevant substance and material flows in Germany was recommended. It was also proposed to harmonise the substance and materials flows identified as priority flows in terms of their previous addressing by closed cycle and waste management policies in Germany and the EU.

The national sustainability strategy passed by the Federal Government in 2002 [Federal Government 2002] forms an important general framework for the targeted development of closed cycle and waste management policy towards a sustainable substance flow and resources policy. Within this sustainability strategy, 21 demanding sustainability targets were defined, among them important environmental targets. In the context of the BMU project "Identification of Relevant Substances and Materials for Substance Flow-Oriented Resource-Conserving Waste Management", primary objectives until 2020 chiefly include Germany's doubling of both energy productivity (ratio of gross domestic product to primary energy consumption), based on 1990 figures, and raw materials productivity (ratio of gross domestic product to the use of raw materials), based on 1994 figures. These targets demand significant optimisation of energy and raw materials management. Progress has been made towards these long-term targets. The past successes of closed cycle and waste management policy have played a decisive role here.

In connection with the project described below, the BMU expects to acquire important information regarding additional relevant potentials for saving energy and conserving raw materials and for further minimising pollutant input to the environment. This will support optimum bundling of further activities (e.g. promotion of innovative technologies, further investigation requirements) to allow the defined sustainability targets to be achieved. Some important questions addressed by the project include:

- Where do we find the greatest additional potentials?
- How relevant is material storage in the technosphere with regard to conserving primary resources?

- Where does the greatest need for action remain, i.e. which potentials promise the greatest effects?
- What are the next priorities?

In this way, closed cycle and waste management policy can be developed further to form a sustainable substance flow and resources policy. The project concentrates exclusively on the national level; however, attention is drawn in this context to the EU resources strategy and the EU strategy on waste prevention and recycling, as well as the activities of the OECD concerning "Sustainable Materials Management". The primary aims of the BMU project are:

- Establishing priorities: identification of relevant substances and materials.
- Looking to the future: trends and scenarios, development of substance and material storage.
- Calibration: previous addressing by closed cycle and waste management policy.
- Policy advice: identification of the greatest potentials with regard to the Federal Government's sustainability strategy (raw materials productivity, energy productivity).
- Important by-product: uncovering relevant data gaps.

The project targets can generally be viewed as an important intermediate stage under the umbrella of further developing closed cycle and waste management policy towards a sustainable substance flow and resources policy. In 2006, further concrete steps will follow the focal points defined by this project.

1.2 The role of the steering committee

An important element involved in successful project implementation was the appointment of an independent steering committee, comprising experts from the material flow analysis, substance flow management and closed cycle and waste management policy sectors. Beside two specialist representatives from the Federal Environment Agency, a total of five eminent experts from both academic and non-academic research and from environmental associations were recruited for the steering committee.[1] The job of the steering committee consisted of providing the project team and the BMU with timely specialist advice, and supporting the project both critically and constructively. In this way, the methods employed by the Öko-Institut and IFEU-Institut in the course of the project could be accompanied by the views of independent experts and a broad base for acceptance of the results in professional circles aimed for. In all, three sessions were convened in Berlin in the course of the approximately 6 month project (in July, September and November 2005). Beside distributing the minutes of the meetings and presentations, the members of the steering committee were kept up-to-date with further documents

[1] The members of the steering committee are listed by name in Annex 2.

concerning intermediate stages and results and, in their turn, supported the project team with timely advice and suggestions.

The project objectives and definitions, and the methodical approach to be adopted, were the main points discussed during the first meeting of the steering committee. Among other things, the steering committee provided important information on definitions. Above all, it became clear that the use of some terminology, such as substance, material, substance flow analysis, material flow analysis, etc., was not uniform throughout German-speaking countries. Rightly, some emphasis was placed on this point for the sake of avoiding misunderstandings (see next section). The second meeting of the steering committee was reserved for a discussion of important intermediate results. The steering committee supported the project team in their wish to place a professional synopsis of the substance and material flows at the core of the project and not to investigate individual details to an unsuitable depth. The project team and the BMU were also advised to emphasise pollutant aspects only in cases of particular relevance and, due to the tight schedule, not to carry out their own substance flow analyses.

In the third and final meeting of the steering committee, only the project results were presented and discussed extensively with the experts. It was agreed that the project results provide a good basis for the in-depth investigations and activities of the BMU, which will follow the project.

In comparison to many other projects, the bimonthly cycle of steering committee sessions can be viewed as very dense. However, because of this and the above-average commitment of the steering committee members, the project enjoyed excellent support and came to fruition very efficiently. The Öko-Institut and IFEU-Institut project team would therefore like to express their thanks at this point to the members of the steering committee.

1.3 Important definitions

Both the discussion at the first meeting of the steering committee and the research carried out on this topic by the Öko-Institut and the IFEU-Institut made it clear that different definitions, or at least unclear usage, of terms such as "substance", "material", "substance flow analysis", etc., often exist in various academic texts and in numerous professional publications. This problem largely occurs in German-speaking countries (this is not meant to question the quality of the wide range of work on the topic, e.g. by numerous select committees in Germany).

The project team therefore gratefully accepted Prof. Brunner's (member of the steering committee) suggestion to orient themselves, when communicating in regard to project work, on the terminology and definitions of Regulation Sheet 514, "The Application of Substance Flow Analyses in Waste Management" (*Die Anwendung der Stoffflussanalyse in der Abfallwirtschaft*), published by the Austrian Water and Waste Management Association (*Österreichischen Wasser- und Abfallwirtschafts-*

Verband) [ÖWAV 2003]. The definitions used there are characterised by their clarity while at the same time, as a result of experience gathered during its compilation, allowing sufficient leeway, i.e. without unnecessarily restrictive boundaries. These would not have been practical in terms of this project.

The most important definitions with regard to the BMU project are reproduced below [ÖWAV 2003]:

*A **substance** consists of identical individual components and is consequently either a chemical element (the individual component is the atom, e.g. nitrogen, carbon or copper) or a pure chemical compound (the individual component is the molecule, e.g. NH_3, CO_2 or copper sulphate). Drinking water, for example, is not a substance because it does not consist of pure water, but instead also includes calcium and numerous trace elements. Nor is PVC because it also contains additives, beside polymerised vinyl chloride.*

***Material** is a general term, which can include both goods and substances and thus comprises raw materials and all substances ever altered by man using physical or chemical processes. The term material is used if goods <u>and</u> substances are considered, or if one does not want to immediately specify at which level (goods or substances) an investigation should take place.*

*By means of a **substance flow analysis (SFA)** all occurring import, export, input and output flows of goods and substances are quantified and the processes within this system balanced for exactly defined temporal and spatial boundaries. The law of mass conservation is taken into consideration during balancing. The investigated system can consist of a single process or be a combination of numerous processes including sub-processes.*

*The **goods flow analysis (GFA)** corresponds to the definition of the substance flow analysis. The difference to the substance flow analysis is that a goods flow analysis investigates goods flows only.*

***The material flow analysis (MFA)** also corresponds to the definition of the substance flow analysis. In analogy to the use of the term "material", the term "MFA" can be applied to both goods and substance balances. MFA is an often-used term, which is not always used in the strict sense as defined in the regulation sheet.*

2 Investigation methodology

As was seen in the previous section, the term **material flow analysis** can be widely understood and adopted. Material flow analyses can therefore be performed for different points of research interest. Depending on the approach adopted the material flow analysis may be a:

1. Substance flow analysis: Here, the life cycle of the defined elements or molecules is traced. Research interest is centred on the cycles these substances are involved in and their eventual fate. Two important examples of this are the cadmium balance and the nitrate balance.
2. Goods flow analysis: These analyses consider the life cycle of the goods in a defined sector; they include their manufacture and their eventual fate. The objects investigated here are the associated general environmental effects, efficient resource use and the fate of waste. Two examples of goods flow analyses are the "textile chain" or the iron & steel sector. In a cross-sector material flow analysis spanning a number of needs areas, a variety of goods flow analyses are integrated in order to model complex needs areas such as housing or transportation.

This catalogue makes it clear that the type of material flow analysis and the questions formulated for it largely determine the research interest.

The substance flow analysis thus explains the origin and fate of defined elements or molecules and their natural and anthropogenic sources and sinks. If undesired concentrations occur, the analysis may serve as a decision aid when taking possible measures into consideration. This extensive type of analysis is highly efficient when applied to defined elements or molecules. However, because it is not linked to the economic environment, further sector-related information is required.

The goods flow analysis, in contrast, stands upon a much broader base. The direct allocation of individual processes to the economy as a whole is seen as an advantage of the goods flow analysis, both with regard to economic interactions and to their environmental effects. This allows the interactions to be demonstrated and the associated protagonists to be identified. An attempt is made to articulate the environmental impacts of the economic interconnections of supply and demand structures. The German steel industry, for example, is highly interesting solely as a relevant emitter of greenhouse gases. Its true meaning, however, only becomes clear if the steel industry is viewed as a component of the value chain, i.e. steel is viewed in a material context alongside its competitors.

Material flow analyses with core elements corresponding to the goods flow analysis type were adopted to achieve the project objectives. Because the term material flow analysis includes goods flow analysis and is also considerably more widespread in German- and English-speaking countries, **material flow analysis** (MFA) will be used in further documentation. It was agreed with the BMU that no source data would be collected to establish the necessary priorities for the particularly relevant materials in the course of the six month project. Instead, the plentiful datasets provided in professional literature were utilised.

3 Prequalification of important material flows

In this study the environmental impacts of activities in Germany (production and consumption) are modelled by material flow analyses and priorities established for a sustainable substance flow and resources policy. However, it is necessary to identify and delineate both the environmental impacts and the economic activities in order to facilitate a systematic approach. Due to the brief duration of this project it was necessary to balance the depth and breadth of the work in coordination with the steering committee. A two-stage procedure was adopted: rough prequalification in the first stage followed by a detailed analysis of fewer but particularly relevant activities in the second stage.

During the prequalification (first) stage:

1. Criteria were formulated for an initial evaluation, comprising important environmental impacts.
2. Material flows of economic activities were structured.
3. The environmental impacts were identified on the basis of the previously formulated criteria for the specified activities.
4. Priorities were established.

The prequalification is described in the following section. A detailed analysis of those material flows identified as relevant follows in Chapter 4.

3.1 Criteria for an initial evaluation of material flows

The prequalification criteria must generally satisfy two conditions. On the one hand, they must, as far as possible, address the environmental impacts under consideration and material data must be available for them on the other hand. The steering committee therefore decided that the number of criteria should be restricted for the sake of timely and efficient prequalification. The use of a series of criteria, in particular special ecological criteria, i.e. criteria that are only highly relevant in very few material flows, was postponed until the subsequent detailed phase for the selected material flows.

The following seven ecological criteria were selected for prequalification and suitable data researched:

- emission of greenhouse gas (CO_2 equivalent),
- emission of acidifiers (SO_2 equivalent),
- mineral resources,
- metallic resources,
- biotic resources,
- cumulated energy demand (CED) – total,

- cumulated energy demand (CED) – fossil.

CED – fossil was recorded, but the results were not taken into consideration in the final evaluation because CED – fossil, on the whole, develops parallel to greenhouse gas emissions for the economic activities considered here, and also forms an important component of CED – total. This would have meant that this criterion would have been "doubly" accounted for.

It became clear during data research that data are available for these criteria for most of the investigated material flows (questions of data quality will be addressed in depth in the detailed phase).

In addition, the economic influence of the activities is taken into consideration indirectly via the monetary production volume and the weight of the goods.

3.2 Economic activities: Sector perspective, consumer perspective

In order to allow handling for the selection process the economic activities must be defined. The requirement of data availability was considered as a criterion here because the activities must also be underpinned by economic indicators.

Two options were identified, which describe an extensive, but also efficient, route:

1. Sector perspective: Activities are classified and described on the basis of production statistics. Classification encompasses production in Germany and corresponds to the usual sectors and branches.
2. Consumer perspective: Classification encompasses the goods consumed in Germany including imported consumer goods and is represented by means of consumption statistics (SEA[2] = System of Income and Expenditure for Private Households – *Systematik der Einnahmen und Ausgaben der privaten Haushalte*).

Both approaches have their advantages. The sector perspective concentrates scrutiny on goods produced in Germany. Within this view the focus is on the environmental impacts associated with production in Germany. This view will primarily illuminate the technological situation of the sectors (efficiency, etc.). The principal protagonist is represented by German industry. In contrast to this, the consumer perspective focuses on goods consumed in Germany. Some consumer goods are only produced in very small numbers in Germany. Here, the consumption properties of the products move to the forefront, e.g. waste properties.

Both areas (sector perspective, consumer perspective) were taken into consideration in this study, in order to come to as broad a conclusion as possible, not least with regard to the different policy areas addressed. This is simplified by wide-ranging overlapping of the two approaches with regard to the data used.

[2] Expenditure of private households according to purpose, SEA.

The focal point for prequalification was placed on the sectors and on consumption. However, resource questions play a vital role – as will be demonstrated.

3.2.1 Sector perspective

The goods supplied by the production industry in Germany are noted in the production statistics. A classification using 47 groups of goods (sectors, branches) was used in the presentation of this project. The selection procedure was performed on the basis of approx. 1,700 items listed in the production statistics. From this the 200 most relevant items were identified by volume and value respectively. An initial filter was applied for this first selection at the boundary representing more than 700,000 t/a or more than 1.3 billion euros gross added value/a. Consistent statistical data are available for both the volume and the value criteria. This is an interesting criterion because gross added value/a of a product and the complex upstream chains often associated with high gross added value express the economic importance for Germany of that product. For example, high gross added value can be used to express numerous pre-processing stages, numerous semi-finished products and building elements, as well as high energy and material use both in pre-processing or final stages. This criterion therefore provides a good contrast to the volume criterion.[3]

These 200 items were allocated to the 47 sectors.[4] This results in the volume (of the most relevant items) and the most important individual item for each sector. For 14 sectors, this procedure produced only one item, which dominated in volume and value. For the other sectors one item was identified as "typical". This was often the most relevant item in terms of volume. A single item, whose specific environmental properties were as representative of the whole goods group as possible, was thus selected from each sector (goods group). This was then extrapolated to arrive at the environmental impacts of each sector by multiplying the ascertained volume by the specific environmental impacts of the selected individual items.

The remaining sectors and produced goods are shown in Table 3.1 together with the selected item which was researched and adopted.

3 Gravel, for example, displays high relevance from a volume perspective. The gross added value per tonne, in contrast, is quite low. The opposite is generally true for many electronic products.

4 From the total of 47 sectors, 13 were not considered for further prequalification for a number of reasons (see Section 3.6). The list of sectors was therefore reduced to 34 for further work.

Table 3.1 Identified sectors/produced goods, their volumes and processes (2000)

Volume in Mt	Sectors/produced goods	Utilised data/processes
35.0	Pig iron/steel products	Hot wide strip
3.4	Pipes	Steel pipe
5.6	First processing of iron and steel	Hot rolled steel
16.2	Vehicle manufacturing	Passenger cars
118.4	Coking plant/mineral oil	Diesel
18.9	Crude oil/natural gas	Natural gas-German
5.3	Synthetics	LDPE/HDPE mix
0.1	Chemical fibre fabrics	PET
1.1	Rubber goods	Rubber EPDM
445.6	Non-metals extraction	Gravel
5.1	Natural stone	Stone slabs
48.3	Cement/lime/gypsum	Cement
184.0	Concrete products	Concrete
15.0	Bricks and other building ceramics	Bricks
21.6	Crop production	Maize (conventional)
6.1	Grinding and peeling mills	Milling/wheat
14.6	Other foodstuffs industry	Sugar
13.0	Fruit/vegetables/oils/fats	Juice
31.2	Beverages manufacturing	Beer
39.7	Livestock farming	Cows milk
6.5	Meat processing	Pork
17.2	Milk processing	Milk
47.6	Forestry	Norway spruce
27.6	Wood industry	Chipboard
21.1	Paper industry	Printing papers
9.2	Publishers and printing	Newspapers
0.8	Furniture	Bedroom furniture
128.2	Coal mining, peat extraction	Lignite (Rhine-Lausitz-Leipzig mix)

1.5	Non-ferrous metals	Aluminium (primary and secondary mix)
4.7	Glass	Glass for jars
0.8	Ceramics	Bricks
16.7	Other mineral products	Asphalt

3.2.2 Consumer perspective

The population's consumption of German and imported goods is modelled using data derived from federal statistics by means of a list of 108 consumer goods groups[5]. Similar products and services provided by industry and commerce are summarised in each consumer goods group (short: consumer goods). The consumer goods thus consist of a various number of products, which may also be very inhomogeneous. Only material goods are considered for this project. Services and the like are not taken into consideration. Housing is regarded as investment, not consumption. Nevertheless, it represents the only large budgetary investment sector and is thus bound to consumption. This sector was also incorporated into consumer goods due to its great importance to substance flows and resources. 19 relevant consumer goods groups remain for further prequalification.[6]

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[5] Expenditure of private households according to purpose, SEA.

[6] Another interesting group is represented by information processing devices (computers, etc.). It has not yet been possible to find convincing LCA data in this regard.

Table 3.2 Identified consumer goods, their volumes and processes (2000)

Volume in Mt	Consumer goods (short designation)	Utilised data/processes
4,0	Motor vehicles	Passenger car (Golf A4, 1.4 L, 55 kW, petrol)
59,7	Passenger car fuels	Diesel
25,8	Fuel oil	Oil (light)
21,9	Gas	Natural gas (Germany mix)
156,9	Residential buildings	Residential buildings (new and maintenance)
4,6	Household maintenance	Sawn timber/veneer
18,0	Bread	Bread (German bread industry)
16,1	Vegetables	Potatoes (German)
9,1	Beverages	Fruit juice
5,8	Products containing sugar	Marmalade
5,8	Beer	Beer
4,9	Fruit	Apples
5,5	Meat products	Deep-frozen pork
11,3	Dairy products	Dairy products (mix)
4,4	Furniture	Sawn timber/plastics
4,0	Newspapers	Newsprint (from regional stores, EU)
13,6	Solid fuels	Lignite (Leipzig/Lausitz/Rhine mix)
3,7	Garden products	Concrete paving
3,2	Durables	Leather/iron

3.2.3 Data sources and result presentation

A range of data sources were utilised for data research; in particular the databases GEMIS, BASiS-2, Eco-Invent and diverse IFEU-Institut projects, themselves based on data from several dozen sources. The data adopted are generally LCA (life-cycle assessment) data. All data comprise the pre-chain up to resource utilisation, regardless of whether the production steps actually take place and the associated environmental impacts occur within Germany. Energy carriers represent an exceptional case. The calorific value is no longer taken into consideration when calculating their CED.

The results for both approaches are presented in the following diagrams. These diagrams have proven to be particularly meaningful and useful:

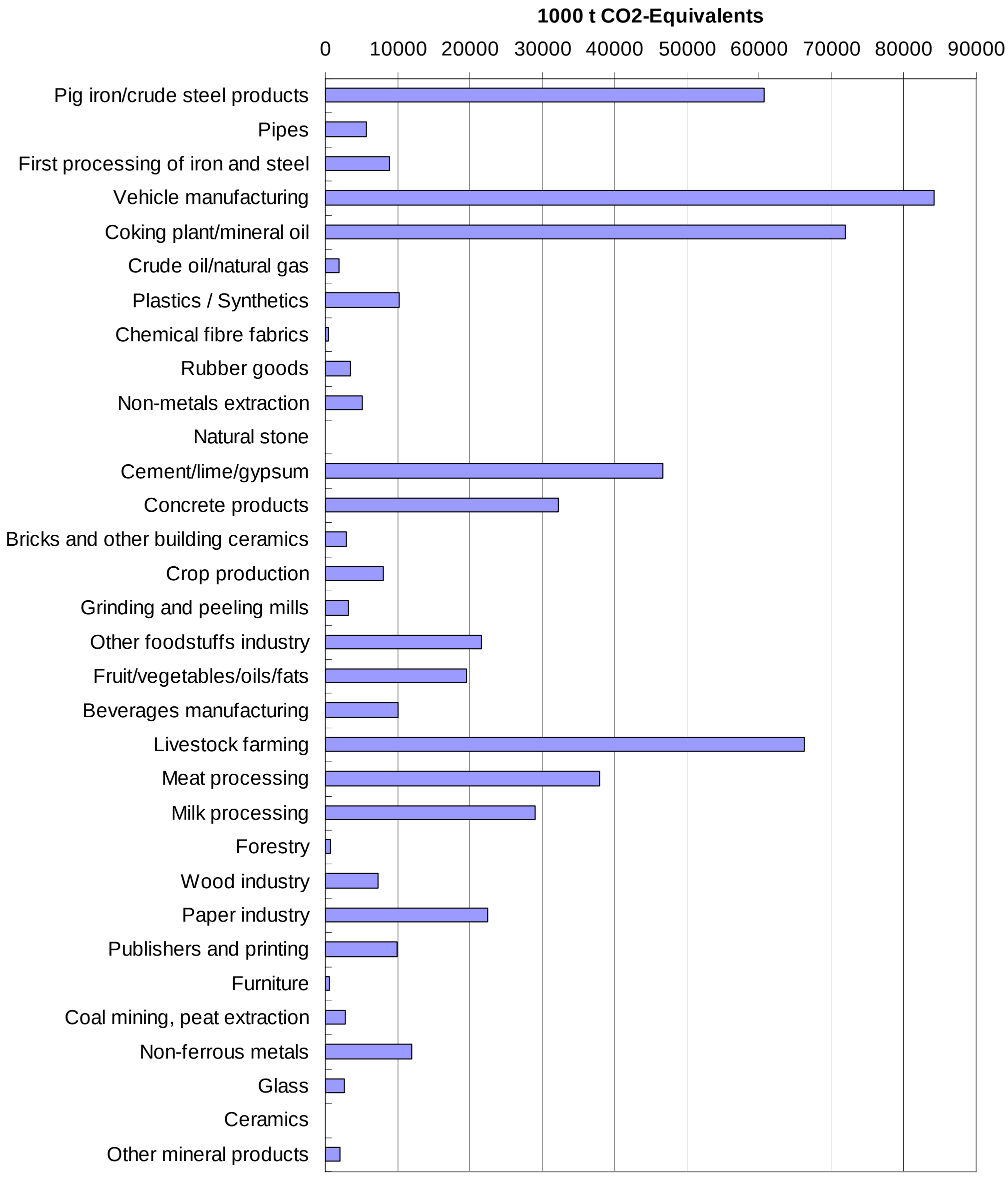
1. Greenhouse gas emissions: The absolute results (multiplication of the specific values by the national quantity) are given in Fig. 3.1 using the greenhouse gases criterion as an example.
2. All criteria (with more than 5%): The percentage of a single item in the sum of all goods was calculated for all criteria. In Fig. 3.2, "Percentage of important produced goods for the adopted criteria", the goods with a percentage of 5% in at least one criterion are listed from the 5% threshold. This type of presentation aims to increase the clarity of the visualisation.
3. Cumulated percentage per criterion: In Fig. 3.3, "Produced goods – Criterion-specific cumulated percentage for 13 of 34 selected produced goods", the cumulated percentage of a reduced number of goods flows is shown in the graphs. The end points of the graphs (right) illustrate the degree to which the incorporated goods participate in the total result.
4. Cumulated percentage per individual item: Finally, Fig. 3.4 shows "Produced goods – Cumulated percentages of the individual criteria relative to the respective total impact of the 34 produced goods (without consideration of the CED fossil criterion)". The percentages are equivalent, not weighted. This presentation illustrates the prioritisation within the project with regard to a subsequent intensified analysis and presentation of the material flows.

The consumer goods diagrams display the same sequence of result diagrams as the produced goods ("sector perspective"). Prioritisation itself was a central object of discussion at the second session of the steering committee.

3.3 Prequalification of produced goods/sectors

Fig. 3.1 shows the results for the greenhouse gas emissions of the produced goods. The four sectors with the highest emissions are vehicle manufacture, pig iron & steel, coking plant/mineral oil (refineries) and livestock farming. Other important sectors include primary chemical products, cement/lime/gypsum, concrete products, and meat and milk processing.

Figure 3.1 Produced goods – Total greenhouse gases in 1000 t CO_2 equivalent

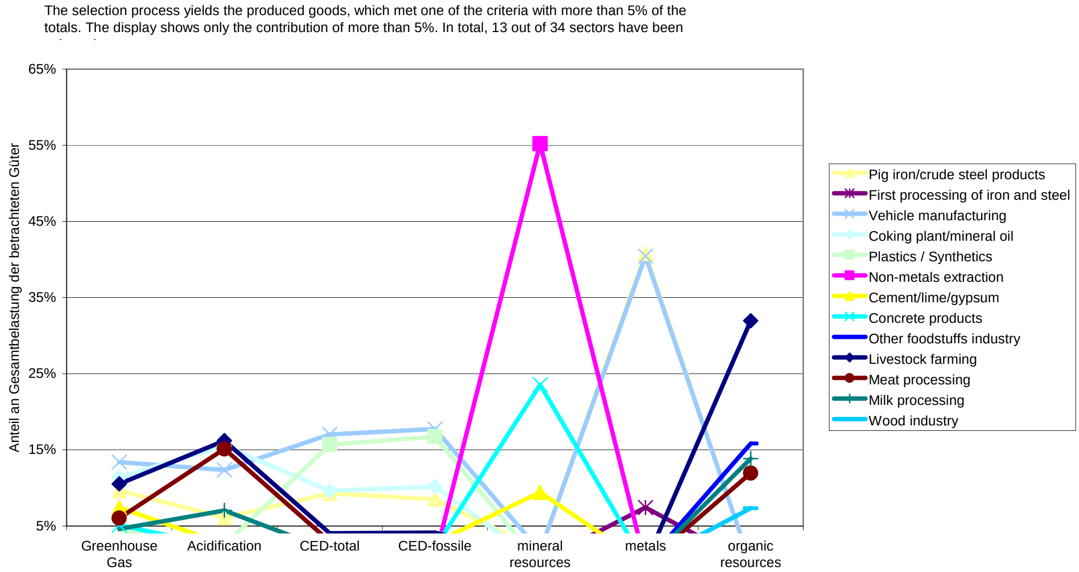


The principal sectors for the total CED/fossil criterion are represented by vehicle manufacturing, coking plant/mineral oil, primary chemical products and cement/lime/gypsum. In relation to these, the meat and milk processing sectors and livestock farming are of minor importance. The non-energy greenhouse gas emissions (methane, nitrous oxide) play a particularly large role in these sectors.

The reverse is true for the "acidification" criterion. Here, the sectors livestock farming and meat processing, and dairy farming are considerably more important due to the non-energy-related ammonia emissions.

It can be seen in Fig. 3.2 that the sectors livestock farming, meat processing and dairy farming, other foodstuffs industry and the wood industry are particularly relevant to the "biotic raw materials" criterion. The "metallic raw materials" criterion is dominated by the pig iron and steel sector and steel processing. The non-metals quarrying and concrete production sectors, as well as cement, lime and gypsum production govern the "mineral raw materials" criterion.

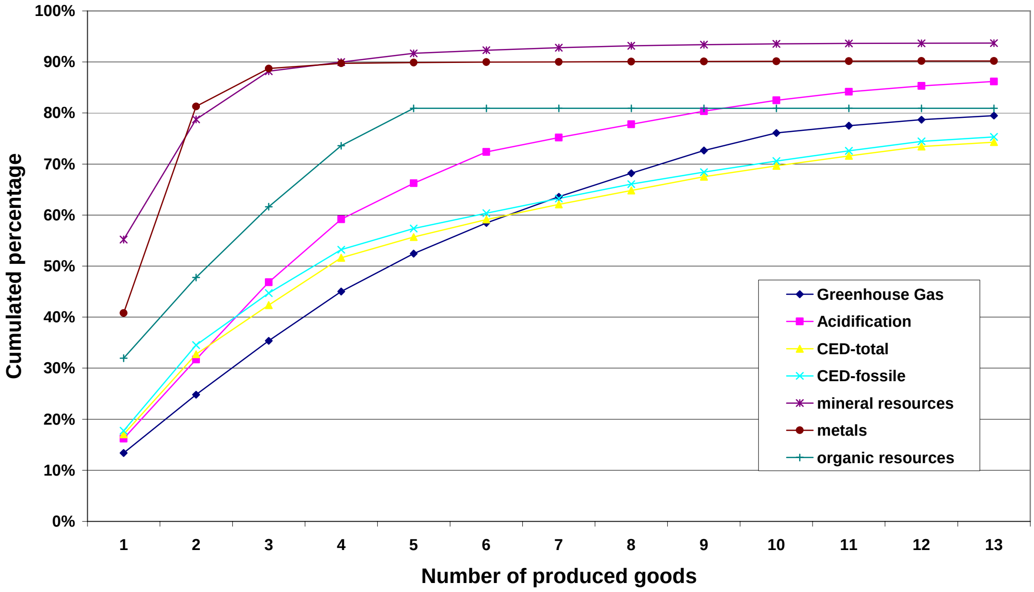
Figure 3.2 Produced goods – Percentage of important produced goods for the adopted criteria



The cumulative contribution to the individual criteria is shown in Fig. 3.3. This allows an estimate of how many sectors are necessary for useful modelling of the respective criterion. It should be noted here that the sector contributions for each criterion are sorted according to contribution. A sector is therefore listed at the first position for a given criterion if the sector makes the greatest contribution. The same sector may be located at a different position for a different criterion, depending on its contribution.

The diagram clearly demonstrates that coverage is good using 13 selected sectors for the different criteria. The criteria "mineral raw materials" and "metallic raw materials" achieve very high coverage of more than 90%. The poorest coverage was observed for the criteria "CED (total, fossil)" at approx. 75% and "greenhouse gases" at approx. 79%. No further great advantages were achieved by adding further sectors for either of the criteria. The remaining 21 sectors display relatively uniform contributions for both "greenhouse gases" and "CED".

Figure 3.3 Produced goods – Criterion-specific cumulated percentage for 13 of 34 selected produced goods



Prequalification was carried out by means of the relative contributions of the sectors to the individual criteria. All sectors that achieved at least 5% of a given criterion here were taken into due consideration. This procedure was verified by double-checking the coverage rate of the cumulative sector percentages. The result demonstrates that the selected 13 sectors represent the optimum. The advantage gained by including additional sectors in the coverage is disproportionately low in relation to the 13 selected sectors.

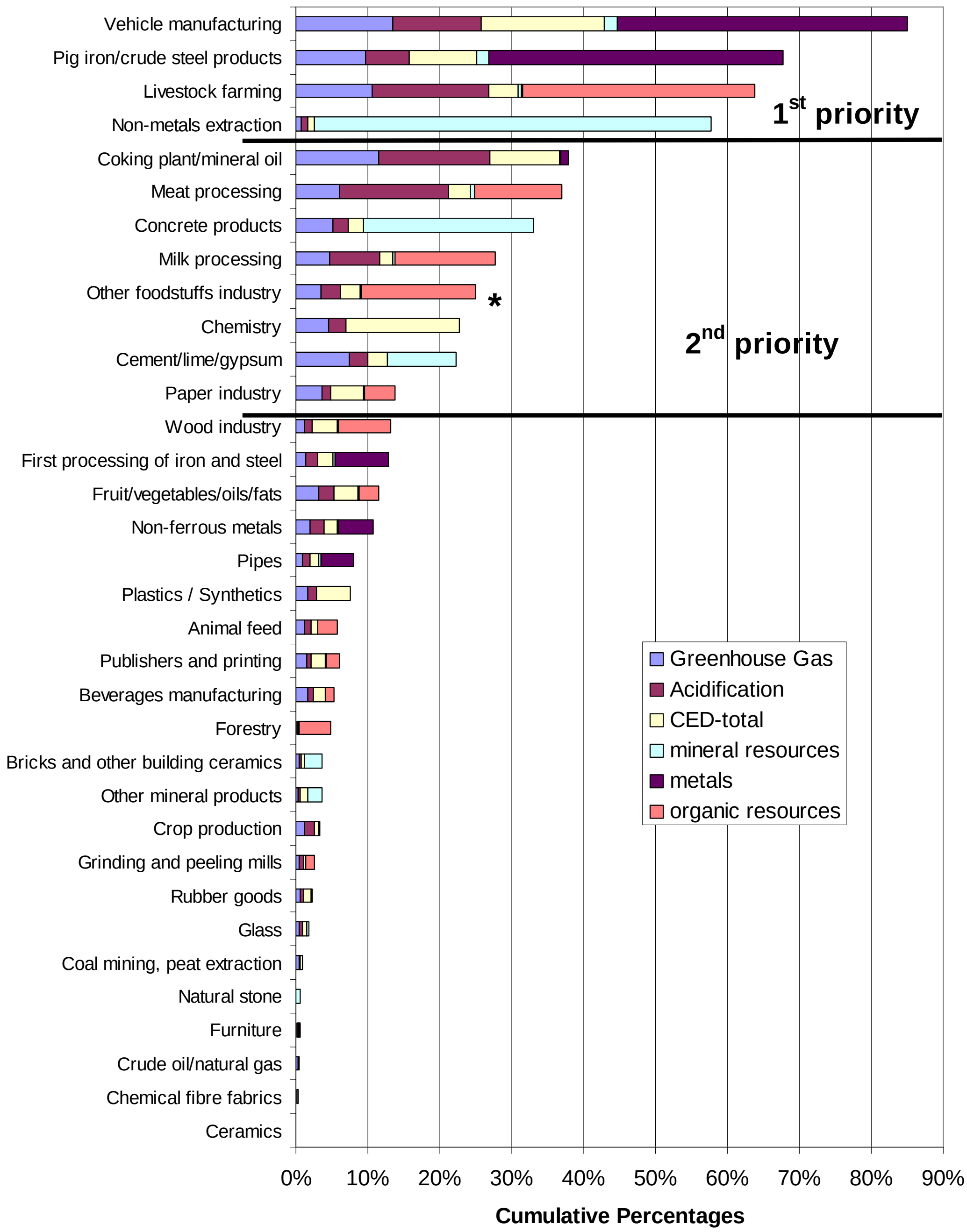
In order to illustrate this result the contributions of the sector for each criterion were cumulated in Fig. 3.4 without weighting. The criterion CED fossil was not utilised for this presentation in order to avoid overweighting of the CED (because CED total is already incorporated in the evaluation). The sectors are presented according to the sum of their contributions. The sectors discussed in the individual evaluations – vehicle manufacturing, livestock farming, pig iron & steel and mineral resources quarrying – are located at the top of this list. Their evaluations took first priority. Clearly differentiated from the other sectors are the sectors meat processing and milk processing, other foodstuffs industry, coking/mineral oil and chemical products and cement. In addition, the steel processing and wood industry sectors also display significant percentages.

The above sectors, with the exception of the other foodstuffs industry, were selected for further processing. The other foodstuffs industry sector proved to be too multi-faceted to be usefully processed in the context of this project. Instead, the paper industry sector was included in the in-depth investigation.

Those sectors identified by the interim results as being particularly important can be represented by the following 10 particularly relevant produced goods or goods groups in the context of the material flow approach:

- pig iron/steel and vehicles (passenger cars, etc.),
- petroleum products and plastics,
- mineral resources, cement, concrete,
- meat and dairy products,
- paper.

Figure 3.4 Produced goods – Cumulated percentages of individual criteria relative to the respective total impact of the 34 produced goods (without consideration of the CED fossil criterion)

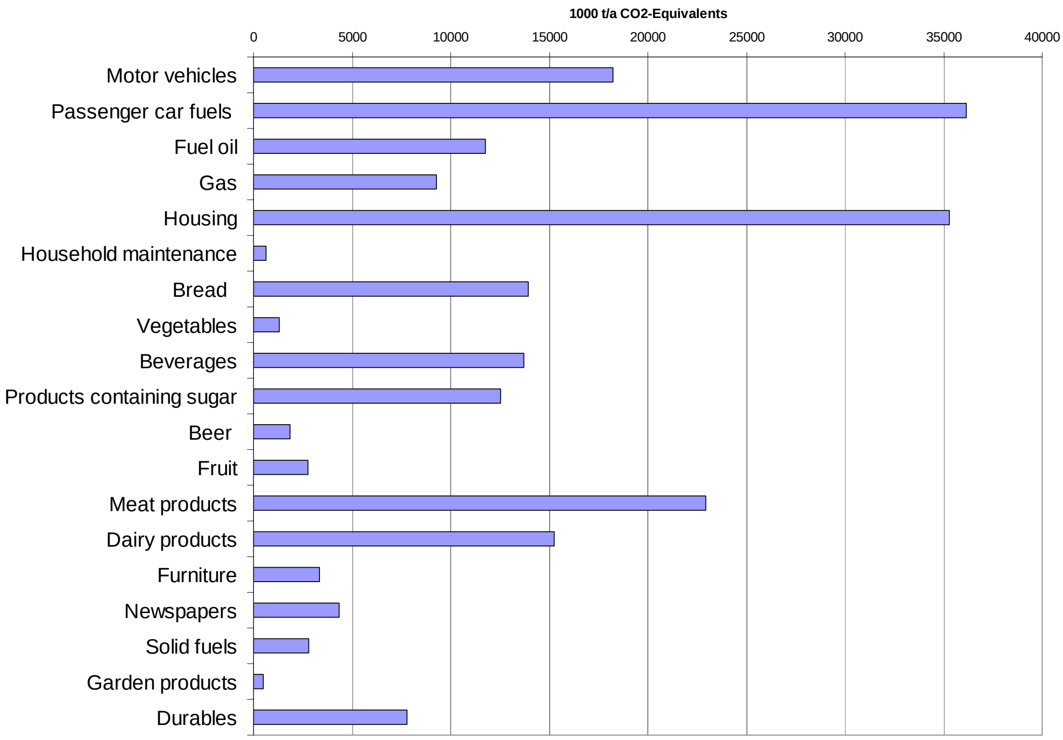


** ignored produced goods*

3.4 Prequalification of consumer goods

The same procedure was followed for prequalification of consumer goods as for produced goods.

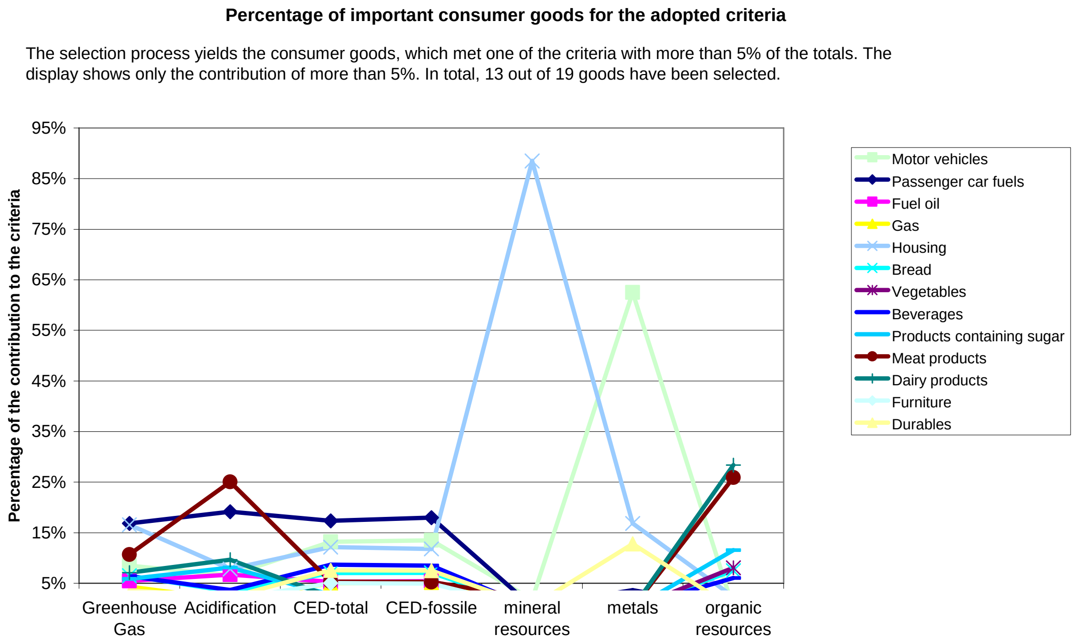
Figure 3.5 Consumer goods – Total greenhouse gases in 1000 t CO_2 equivalent



The results for the greenhouse gases criterion are shown for prequalification of consumer goods in Fig. 3.5. It was possible here to identify the consumer goods corresponding to production. The motor vehicle consumer goods come from the vehicle manufacturing sector. The consumer goods passenger car fuels, fuel oil and gas correspond to the coking plant/petroleum sector. Housing acquires its goods primarily from the non-metals and cement/lime/gypsum sectors. Meat and dairy products can be allocated to the meat and milk processing sectors. Overall, the consumer goods reflect the results of the sector prequalification. Passenger cars, vehicle and heating fuels, housing and fodder are also found as the most relevant goods in the consumer goods field.

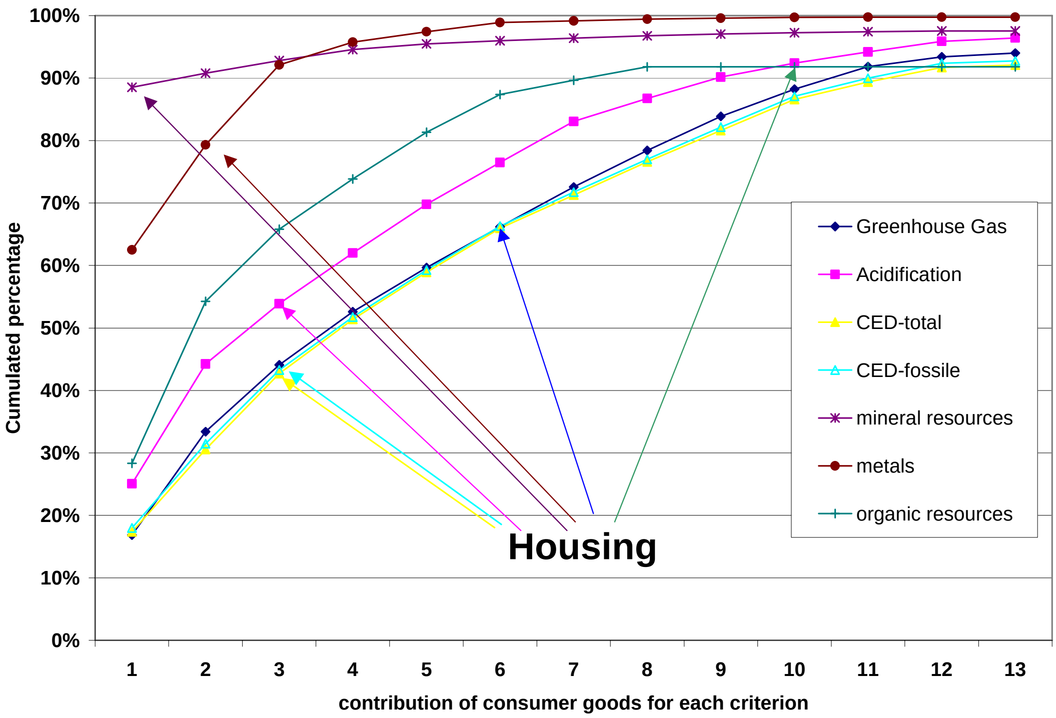
If the criterion for prequalification is once again specified as achieving a 5% contribution to the overall result, a similar picture is seen to that for the sectors (see Fig. 3.6). Housing represents the dominating consumer goods for mineral raw materials, whilst the passenger car consumer goods display a high contribution for metallic raw materials.

Figure 3.6 Consumer goods – Percentage of important produced goods for the adopted criteria



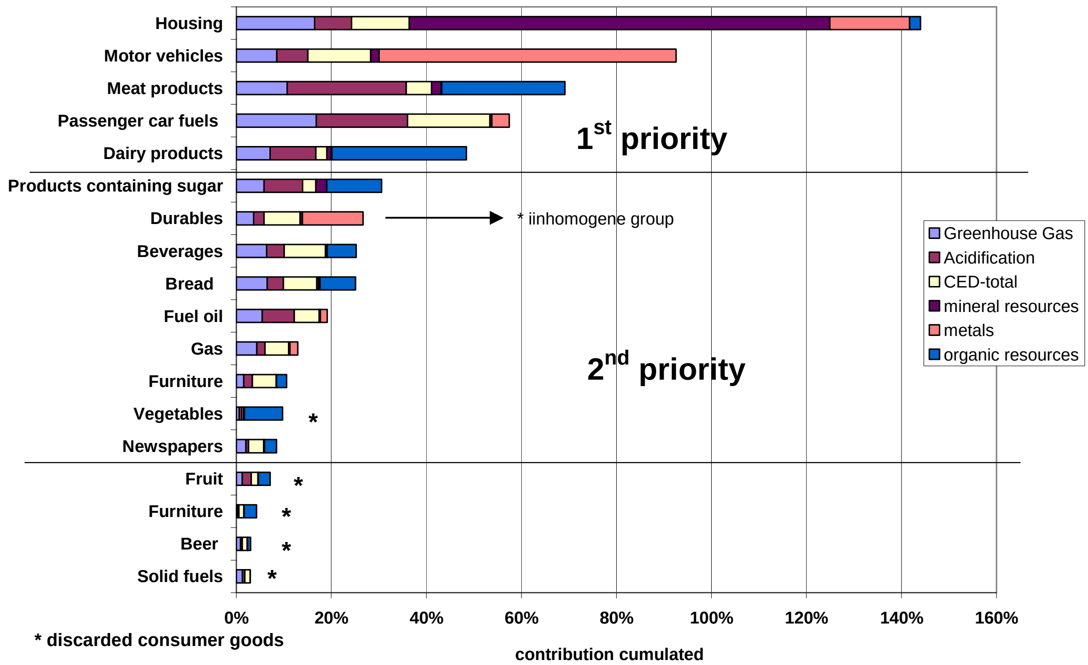
If this method is used to select the 13 most relevant consumer goods and the degree of coverage of these goods is observed for each criterion in relation to the total contribution, a considerably higher coverage is noted than for the analysis of the sectors (see Fig. 3.7). The degree of coverage is greater than 90% for each criterion. It remains to be noted that the outstanding consumer goods can only make a minor contribution. The prequalification is therefore justified.

Figure 3.7 Consumer goods – Criterion-specific cumulated percentage for 13 of 19 selected produced goods



The contributions of each criterion for the individual consumer goods are presented once again for clarity in Fig. 3.8. The five consumer goods housing, motor vehicles, meat products, passenger car fuels and dairy products display by far the greatest contributions. They are classified as priority 1. Further relevant consumer goods include products containing sugar, personal durables, beverages (fruit juice, etc.), bread, fuel oil and gas, and furniture.

Figure 3.8 Consumer goods – Cumulated percentages of individual criteria relative to the respective total impact of the 19 consumer goods (without consideration of the CED fossil criterion)



The priority 1 and 2 consumer goods shown in Fig. 3.8 were selected, with the exception of personal durables, which are highly heterogeneous and only accessible to further processing with great difficulty. After discussion in the steering committee, newspapers were added to the in-depth investigation. The following 12 particularly relevant consumer goods were therefore investigated in more detail in the context of the material flow approach:

- cars,
- fuel oil, natural gas and motor fuels,
- residential buildings,
- bread, products containing sugar, and drinks (fruit juices, etc.),
- meat and dairy products,
- paper products (newspapers, etc.) and furniture.

3.5 Reflections on methodology

This section will briefly reflect on the methodology selected for prequalification of those produced and consumer goods that are particularly relevant to the project from an environmental point of view and the material flows associated with them. The steering committee submitted a proposal to include the platinum group metals (PGM) as consumer goods. The PGM were chosen on the basis of the very low relevance of these precious metals from a volume perspective, because the initial prequalification of consumer goods was from a purely volume-related perspective. A comparison to less relevant consumer goods, from a volume perspective, but for whose manufacture substantial environmental impacts in the upstream chains are nevertheless expected, is very interesting from a methodological point of view. The project team was therefore very positive about this proposal. In addition, the material flows of the most important platinum group metals (platinum, palladium and rhodium) and their associated environmental impacts were thoroughly investigated in a completed project in which the Öko-Institut participated [PGM 2005]. The following details include a comparison of the criteria CO_2 equivalent and SO_2 equivalent.

According to [PGM 2005] demand in Germany in 2001 was around 38 tonnes of the three named PGM. Of this total demand, around 21 tonnes were covered by particularly environmentally intensive primary production[7]. Emissions of approx. 330,000 tonnes of CO_2 equivalent and approx. 21,000 tonnes of SO_2 equivalent are associated with the supply of around 38 t of PGM required for various consumer goods (passenger car catalytic converters, jewellery, electronic products, dental products, etc.). These accumulate primarily outside of Germany during raw material extraction and beneficiation at the ore deposits. In the case of CO_2 equivalents it can be said that the magnitude of the emissions – not least against the background of a total demand of 38 t – is certainly remarkable and should certainly not be ignored. However, comparison with the corresponding data for the pre-qualified consumer goods shows that much greater emissions must generally be discussed here. The frontrunners for this criterion are, respectively, residential buildings and motor fuels at approx. 35 Mt/a, followed by meat products (around 23 Mt/a) and cars (18 Mt/a).[8] The CO_2 equivalent emissions given for the PGM are substantially exceeded by all other pre-qualified consumer goods, usually by a number of magnitudes (see data in Annex 3).

In the case of the SO_2 equivalent, on the other hand, it can be seen that the PGM have a greater relevance. The pre-qualified consumer goods with the highest emissions are meat products (320,000 t), motor fuels (245,000 t), dairy products (125,000 t), products containing sugar (105,000 t), residential buildings (100,000 t), fuel oil (80,000 t) and cars (80,000 t). In terms of SO_2 equivalents the PGM emissions may not achieve the peak field occupied by the pre-qualified consumer goods, but it does reach the same magnitude of emissions as the following pre-qualified consumer goods (see data in Annex 3). The considerably greater

[7] The primary production of PGM exceeds the specific impacts in contrast to PGM from recycled materials in terms of the emission of greenhouse gases by a factor of approx. 10, in the case of acidifier emissions by more than a factor of 100 [PGM 2005].

[8] All data always include all emissions including all upstream chains. However, emissions arising from the use of consumer goods (e.g. combustion of passenger car fuels, heating of housing, etc.) are never taken into consideration.

relevance of the PGM in terms of SO_2 equivalent can be explained by the high level of emissions throughout preparation of the sulphide ores during primary extraction [PGM 2005].

Based on the PGM example it can thus be inferred for the evaluation that the choice of methodology certainly led to the correct emphasis. However, it should not be forgotten that other consumer and produced goods may also exhibit a certain relevance – at least to a degree.[9] However, in the case of the PGM it must be emphasised that the most important application (passenger car catalytic converters) is already incorporated in the prequalification of cars as consumer goods. That is, a large proportion of the ensuing environmental impacts for PGM are included in the complex cars consumer goods. This also applies in part to the non-ferrous metals, which were included in the prequalification of the 34 most relevant produced goods in terms of volume and value, but were no longer counted amongst the most important produced goods when defining the seven general environmental criteria. Nevertheless, it cannot be doubted that the potentials for reducing environmental impacts with regard to the material flows of non-ferrous metals (e.g. by forcing secondary metal exploitation) are interesting. The same may apply to some produced goods that cannot be investigated in this project due to data gaps, etc.

3.6 Identification of important data gaps

Data gaps were discovered during prequalification. Two types must be differentiated:

1. Complex statistical items.
2. Missing life cycle assessment data (LCA).

Some statistical items are composed of numerous sub-items, with no governing sub-item in terms of volume. This complicates an analysis of the item and identification of a relevant process or product. One example of this is the "primary chemical products" sector. In this example it was possible to find a process because the chemicals industry enjoys a high degree of transparency and many previous works exist dealing with LCA or substance flow analyses. It was possible to estimate the (material) composition for the "personal durables" consumer goods, but the group is structured so in-homogeneously and variably that specific in-depth work is almost impossible.

Amongst consumer goods there are collective items for which no significant governing item could be found. Some of the most relevant collective consumer goods items in terms of volume are:

9 Representatives of the Federal Environment Agency correctly noted that in some sectors the product in second position may also be very relevant when prequalifying the primary product from the original 34 sectors (and thus 34 products). Appropriate analyses will be the object of further investigations.

1. Housekeeping products
2. Glassware, tableware, etc
3. Other personal hygiene articles and products
4. Pets (including durables and perishables for animals)
5. Garden equipment, hand tools and other durables (non-motorised) for housekeeping
6. Spares and accessories for private vehicles
7. Games, toys and hobby materials
8. Equipment and paraphernalia for sports, camping and relaxation
9. Small electrical devices for the household
10. Other clothing articles and accessories

These items were not processed further, so no information was collected as to whether or not LCA data are available. It may be assumed, however, that only little data is available, if at all.

No relevant governing sub-items could be named for the following items within the sectors (produced goods):

1. Electricity generation and distribution equipment
2. Broadcasting, TV, communications engineering
3. Medicine, measuring and control engineering
4. Metal products (screws, etc)
5. Paints/printing inks, putties

Missing LCA data were researched without success for the following items:

1. Computer/TV
2. Soaps/detergents
3. Clothing
4. Coffee/tea/cocoa
5. Home textiles

It should be noted at this stage that LCA data were found for the first three items, but that they were only partially reproduced. The work available on these items only deals with special aspects or components.

Additionally, the sectors "horticulture and landscaping", "cigarettes" and "recycling" were not followed up in detail due to methodical difficulties (services sector) or missing data and lack of relevance.

3.7 Summary evaluation of prequalification

A prequalification of German produced goods (sectors) and German consumed goods (consumer goods) was performed. The selection was based on the production statistics for the sectors in question and the consumer goods statistics (SEA). This means that two statistical systems were employed, which both aim in principle for a complete survey of the data, thus creating a very broad base for further investigations.

The most relevant goods groups in terms of volume and value were identified from these statistics. The formation of goods groups (sectors) is necessary in order to make the selection procedure feasible. It was possible to identify primary processes or representative products for the identified consumer goods and sectors for which LCA data and MFA data are available.

Overall, data availability should be classified as high. Data gaps were only observed for items displaying low volume relevance. A high proportion of the sector items not included were items identified by means of value determination or which represent complex collective items.

It should be noted at this point that the complex sectors mentioned in the previous chapter (electricity generating equipment, broadcasting and communications engineering, and medicine and control engineering), for which no relevant sub-items were found, must also be regarded as very interesting. Their volume may be less than 1 Mt/a, but they nevertheless display very high gross added value. They are located at the end of a long value chain and it must therefore be assumed that their cumulated demand for primary materials (steel, copper, etc.) and energy carriers is substantially greater than the volume of their products would have us believe.

Prequalification of the sectors on the production side as well as the consumer goods result in corresponding products. This result thus confirms the selection procedure on the one hand. The most important consumer goods are reflected in the most important sectors. On the other hand it can be seen that despite global import/export dealings the most relevant consumer goods in terms of volume find their counterparts in the German producing industry. This result should be emphasised and will be analysed in the following chapter.

4 In-depth analysis of the selected sectors and goods in material flow systems

By adopting the methods previously described here all selected produced goods, their corresponding sectors and the particularly relevant selected consumer goods can be assigned to six material flow systems: for example, in a material flow context the pre-qualified goods non-metals, cement and concrete, together with the most important application, housing. The six material flow systems are:

1. Iron ore-steel-vehicle manufacture-car consumption.
2. Crude oil/natural gas-petroleum-processing-
   fuel consumption (lateral industry: plastics).
3. Mineral resources-cement-concrete-residential buildings.
4. Biomass-plant processing-bread consumption.
5. Biomass-animal feed-livestock farming-meat consumption.
6. Biomass-forestry-paper-furniture consumption.

The subsequent in-depth analysis was performed in the context of these six material flow systems. Further important environmental aspects (e.g. high contaminant loads from heavy metals) were taken into consideration for this purpose. These also included primarily such aspects as development perspectives (increasing or decreasing future significance), ecological and technical potentials, the existence of recent innovations and the existing density of regulations.

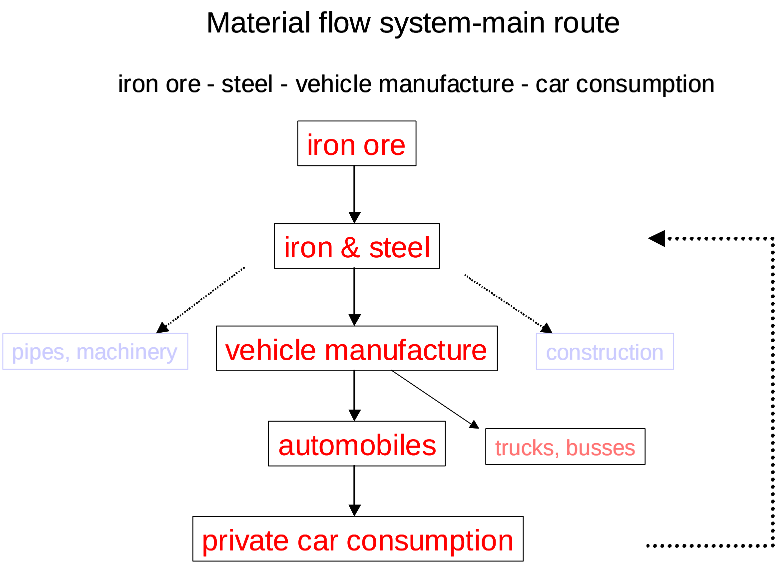
4.1 Iron ore-steel-vehicle manufacture-car consumption

4.1.1 Material flow system synopsis: Main route

On the supply side of the value chain, the iron ore-steel-vehicle manufacture-car consumption material flow system represents steel production, processing and its special principal application in vehicle and automobile manufacturing. The principal product on the demand side is represented by passenger car consumption. The value chain symbolises one of the most important chains, both economically and ecologically. The material flow system is roughly outlined in Fig. 4.1[10].

[10] The figure is not intended to represent the material flow system in all its details. For example, representation of the import/export flows, residual substances and emissions, and numerous other important details was dispensed with in favour of clarity.

Figure 4.1 Material flow system – Main route: Iron ore-steel-vehicle manufacture-car consumption



4.1.2 The steel industry

4.1.2.1 Facts and figures

The two principal routes for steel production in Germany are the oxygen steel and the electrosteel methods. The chain of production for oxygen steel consists of the individual processes sintering, blast furnace and oxygen steel. Electrosteel, in contrast, is produced directly from steel scrap.

Oxygen steel/blast furnace: The production of steel or iron from iron ore is carried out in an integrated steelworks with coking plant, sintering plant, blast furnace, oxygen steelworks, and foundry and rolling mills. The ore is conditioned in the sintering plant and the sinter melted in the blast furnace together with coke to form pig iron. Metallurgical processing is carried out in the oxygen steelworks. The molten crude steel is cast in slabs, etc., in the foundry and subsequently rolled to the finished product in the rolling mill. Integrated steelworks have capacities of 2-8 Mt/a.

Electrosteel: In steelworks producing electrosteel, steel scrap is melted in an arc furnace, metallurgically processed, cast and rolled. Beside steel scrap, input may also be pig iron or sponge iron. Coke and gas are used as primary energy carriers, beside electricity. In general, steelworks producing electrosteel have a considerably lower output per plant (than oxygen steelworks) of up to approx. 500,000 t/a; they are also known as "mini mills".

Steel production, steel consumption and employment:

Current situation:

- German production (2000):

  Blast furnace pig iron: approx. 31 Mt (corresponds to 5.1% of worldwide production)
  Crude steel: approx. 46 Mt (72% oxygen steel, 28% electrosteel) (corresponds to 5.4% of worldwide production)
  The German steel industry specialises primarily in high-quality steels.

- Steel consumption in Germany:

  506 kg/capita (2000)
  The trend is towards stagnating or decreasing per capita consumption in the industrial nations, which is also related to the use of high-quality steel (lower specific consumption for the same functions, e.g. lighter, less material-intensive bridges) [DIW 2002].

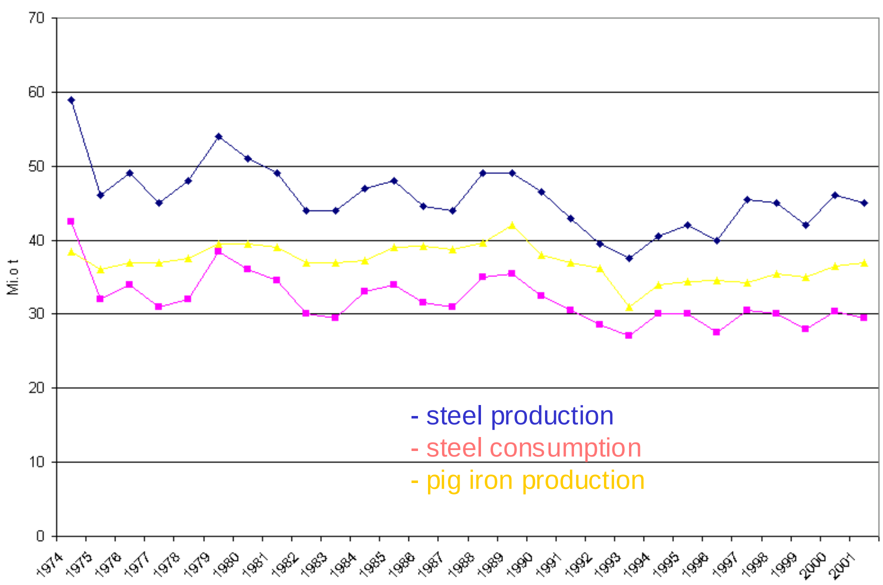
- Employment:

  The number of people employed by the German steel industry is continuously decreasing: from approx. 288,000 at the beginning of the nineteen-eighties to 93,000 in 2004 (Stahl-Zentrum, http://www.stahl-online.de).

Historical development:

- Production of blast furnace pig iron and crude steel has remained relatively stable over the past twenty years: it varied between approx. 37 Mt and approx. 49 Mt (crude steel), and 27 Mt and 37 Mt (blast furnace pig iron); see Fig. 4.2.

Figure 4.2 Production of crude steel and consumption of steel (steel use) in Germany. Source: Steel Industry Statistics Yearbook after Jochem [Jochem 2004]



Steel recycling:

Current situation

- Employees in the steel recycling industry: 35,000 [BDSV 2004]
- Annual turnover for steel recycling including automobile and electrical scrap recovery sectors, as well as other disposal services: approx. €12 billion [BDSV 2004].
- Annual investment volume approx. €500 million [BDSV 2004].

Historical development:

- In absolute terms the proportion of in-house waste from steelworks (blast furnace) and foundries has declined since the end of the nineteen-seventies (reason: continuous improvement in steelworks' and foundry efficiency in the past). At the same time delivery of scrap from domestic sources to the steelworks by the steel recycling industry increased considerably, similar to the sum of recorded steel scrap. This is why the percentage of supply from the steel industry rose clearly from scarcely 55% in 1978 to 74% (increase of old scrap proportion) at the end of the last decade (see Table 4.1).

Table 4.1 Development of the occurrence of steel scrap in Germany (in Mt)

Year	Old and new scrap supply (domestic)	Steelworks in-house waste	Foundry in-house waste	Sum of steel scrap	Proportion supply/total
	(1)	(2)	(3)	(1)+(2)+(3)	[(1)+(2)+(3)]/(1)
1978	11.5	7.0	2.3	20.9	55.1%
1980	11.1	7.1	2.3	20.6	54.1%
1985	12.3	5.0	2.2	19.5	62.9%
1990	13.6	4.2	2.3	19.9	68.5%
1995	20.1	4.9	1.8	26.9	74.8%
1996	18.4	7.7	1.8	28.0	65.8%
1997	20.2	5.3	1.9	27.3	74.1%
2000	20.8	5.0	2.2	28.0	74.2 %

Deviations in the sum or the proportions are caused by rounding, source: 1978-1990: Federal Statistical Office, Düsseldorf branch, after [BDSV 1998], 2-6; 2000: VW steel after [Jochem 2004].

70%-75% of old scrap consists of machine and plant scrap, tracks and railway materials and demolition and wrecking scrap. In contrast to other sources, the old supply of old scrap is only sporadic (originating from high storage volumes). [Jochem 2004]. The new scrap collection efficiency is 95%. The proportion of steel scrap in crude steel production in 2000 was 42% [Jochem 2004].

Economic relationships

Import and export

- At 33% and 28% respectively, Germany is currently the largest blast furnace pig iron and crude steel producer in the EU15 [Eurostat 2003].
- Germany is a net exporter of crude steel [Jochem 2004].
- Hot steel products are exported net: in 2000: 23 Mt export (80% to Europe, USA 7%), 19 Mt import (98% from Europe, with 78% EU) [Jochem 2004]. Mainly expensive and high-quality steels are exported, while cheaper and low-quality steel is imported.

Input and output

- In Germany; flat products (strips) are manufactured almost exclusively from oxygen steel long products mainly using the electrosteel route. Of the approximately 39 Mt hot-rolled steel products around 26 Mt were flat products and approximately 13 Mt long products (reference year 2000; [Jochem 2004].

Steel scrap:

- Import and export: while steel imports have only increased very little in absolute terms since the end of the nineteen-seventies, exports increased by more than one-and-a-half times.

The considerable increase in importance of the German steel recycling industry since the end of the nineteen-seventies is reflected in the figures in Table 4.2.

Table 4.2 Supplies to the German steel recycling industry in Germany (in Mt)

Year	Supply to steelworks (incl. import)	Supply to foundries (incl. import)	Export	Sum of supplies	Import
	(1)	(2)	(3)	(1)+(2)+(3)	(4)
1978	8.3	2.1	2.5	12.9	1.4
1980	7.7	2.2	2.7	12.5	1.4
1985	8.1	2.3	3.3	13.7	1.4
1990	7.4	2.5	4.5	14.5	0.9
1995	10.9	2.6	8.2	21.7	1.6
2000	14.7	3.0	6.9	24.6	3.5

Source: Federal Statistical Office, Düsseldorf branch, after BDSV.

Ecological indicators: Data relating to environmental criteria:

- **Steel production** is one of the principal emitters of CO_2 in Germany [Moll 2005].
- **Steel and iron production** displays high emissions of other air pollutants. Traditional air pollutants such as CO, NOx and SO_2 primarily occur in the blast furnace path, although the sintering process and coking plant are particularly important from an environmental perspective [Moll 2005].
- Airborne emissions such as dust, heavy metals and organic pollutants play an important role in ecological terms with regard to **electrosteel production** [Moll 2005].
- **Waste management**: Large amounts of slag, dust and sludge accumulate during steel production. While the greatest part of the slag can be recycled for high-quality uses, e.g. as granulated slag, other wastes must be processed further or disposed of.
- **Water/waste water**: Blast furnaces require large amounts of cooling and process water. Considerable differences in the cooling water requirement can be recognised as a function of the natural water supply.
- **Steel recycling:** If products containing steel are recycled it can be assumed that 85–90% of the steel component can be reutilised [Jochem 2004].

The enormous importance of the steel industry in utilising diverse raw materials can be seen in Table 4.3. In this regard the steel industry is also one of the most important primary product sectors in Germany.

Table 4.3 Raw material use in the steel industry in 2002

	Oxygen steel		**Electrosteel**		**Total**	
	1000 t	kg/t	1000 t	kg/t	1000 t	kg/t
Pig iron	-		599	45	599	13
Iron ores	41,664	1,310	167	13	42,697	949
Ferro alloys	300	9	678	51	978	22
Rolling mill scale, etc.	3,212	101	264	20	3,212	71
Blast furnace dust	331	10			331	
Scrap	6,038	190	13,222	1,001	19,260	428
Admixtures	6,259	197	705	53	6,964	155
Refractories	605	19	70	5	675	15
Coke and breeze	11,047	347			11,047	245
Bituminous coal	2,717	85			2,717	60
Heavy oil	1,030	32			1,030	23
Total	73,203	2,301	15,705	1,189	88,644	1,969

EEFA 2005 calculations, according to the steel industry association: Steel Industry Statistics Yearbook (various years); Federal Statistical Office: Iron and steel, Production Industry Technical Series 4/Series 8.1 3. Quarterly 2003)

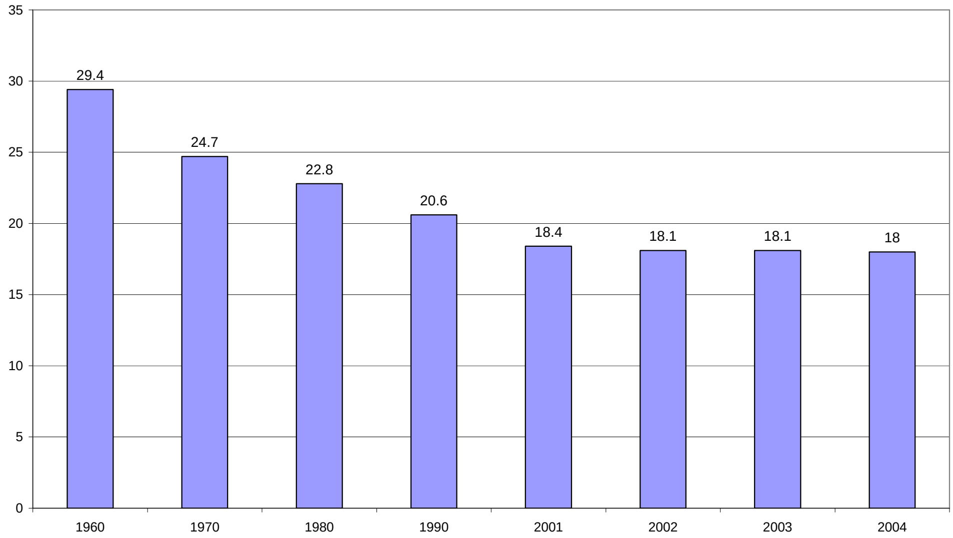
Environmental effects of upstream processes (foreign):

- **Ore working and beneficiation/dressing**: Iron ore is no longer mined in Germany. The German steel industry obtains high-quality ore from Brazil, Australia, Africa and Sweden, where the iron ore is concentrated and conditioned. The land utilisation associated with mining and its infrastructure is relevant from an environmental perspective. Mining waste, which may be partially contaminated, is particularly relevant. The iron ore is transported over long distances to the production facilities in Europe. In order to make the transport as cost efficient as possible special infrastructure was created, e.g. transfer in Rotterdam, extensive channelling of the Rhine.

Energy consumption and CO_2 emissions:

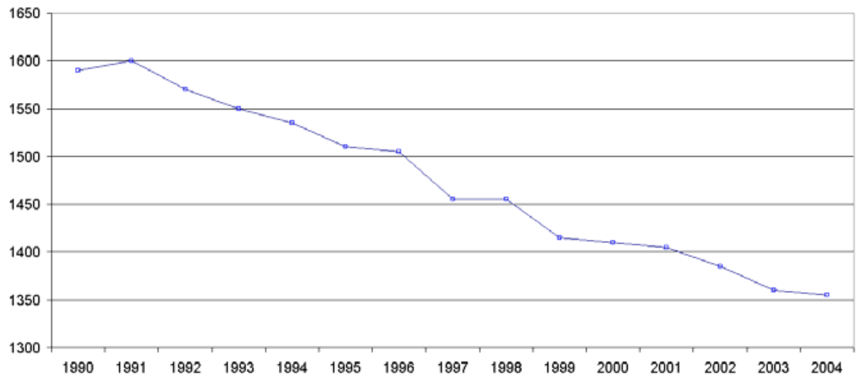
The development of specific energy consumption (between 1960 and 2004) and specific CO_2 emissions (between 1990 and 2004) for crude steel production is shown in Figures 4.3 and 4.4.

Figure 4.3 Specific energy input in GJ/t for crude steel production



Source: Stahlzentrum [Stahl 2005]

Figure 4.4 Specific CO_2 emissions in kg/t for the crude steel industry



Source: Stahlzentrum [Stahl 2005]

4.1.2.2 Dynamics and trends

Jochem [Jochem 2004] assumes a decline in crude steel production to around 41 Mt by 2030. It is also assumed that steel consumption in Germany will decline due to progress in materials research and the associated decrease in specific materials consumption. An increase in old scrap volume from the current 30% of produced crude steel volume to 60% is projected [Jochem, 2004].

4.1.2.3 Potentials

The energy use in steelworks has been substantially reduced in the past. However, considerable potentials can be identified in the individual processes, based on work by the Fraunhofer Institute [ISI 2001]:

1. Sintering process: Typical sintering processes require approx. 1.5 GJ/t of energy, in particular blast furnace gas. A reduction of 12% is technically possible by intelligent heat utilisation (pre-heating of burner air, material pre-heating). It has been estimated that a reduction of 7% is economically feasible.
2. Blast furnace – pig iron production: The blast furnace represents the process with the highest specific energy consumption in the steel production process. By decreasing the reducing agent requirement (coke), by replacing coke with coal injection or heavy oil, by reducing cooling losses and by heat reclamation, a technical saving potential of 5% is possible (from 11.3 GJ/t to 10.7 GJ/t), 1-2% may be economically realised.
3. Oxygen steel production: The efficiency of this process step can be increased by further expanding utilisation of converter gas.
4. Electrosteel steelworks: By employing direct current technology, optimised process control, scrap pre-heating and heat reclamation from slag, both the electricity and the fuel requirement can be lowered. The technical potential is given as approx. 20% (from 0.6 MJ/t fuel to 0.5 MJ/t, from 1.8 MJ/t electricity to 1.4 MJ/t), 5-10% is economically achievable.
5. Foundries and hot-rolling mills: Further technical savings potentials of approx. 33% can be identified which can be exploited by the use and further development of existing technologies and their implementation with regard to similar products. In this category belong direct hot forming, near-net shape direct strip casting and measures for heat reclamation. It is estimated that approx. 5-8% may be economically achieved.
6. Savings potentials can be achieved by moving steel production from the sintering/blast furnace/oxygen steelworks process chain to the electrosteel route. However, this is also associated with a change in the raw material base from iron ore to scrap and a change in energy consumption from coal/coke to electricity. An increase of around 16 Mt is expected by 2020. This represents an energy saving potential of 30–60 PJ. [Final Report of the Select Committee on "Sustainable Energy Supplies", 602f.].

Emissions (CO_2, NOx, SO_2) are generally coupled to energy consumption. Steelworks continue to be huge dust emitters. However, the great quantities of air that are captured and extracted lead in turn to considerable electricity consumption. The high-grade-steel works can be named here as relevant specific sources for the heavy metals chromium and nickel.

Steel making in the blast furnace, in particular, produces large amounts of residual substances and waste. The most relevant residual substance in terms of quantity, blast furnace slag, can be marketed as granulated slag. Other residual substances are enriched in heavy metals and can be neither recycled internally nor otherwise recovered without treatment. The high proportion of zinc (1-10%) and lead (0.5-3%), for example, do not allow internal reclamation of the blast furnace gas sludges in the blast furnace process (enrichment). They were previously sent to landfill. Broad implementation of technically complex recovery measures stands in contrast to inexpensive disposal. Nevertheless, disposal is not without its problems because blast furnace gas sludge contains, among other things, as much as 20 to 50% carbon. An alternative to landfill is external treatment and recovery by means of the DK process or the INMETCO direct reduction method [Rentz 1996]. Dust fractions with very high zinc and lead content are extracted using this method, beside a pig iron fraction, and are accepted and processed by smelters as a recyclable substance. The DK process is employed on a large technical scale by a Duisburg, Germany company. They accept the blast furnace gas sludges, which can not otherwise be recovered, from a number of European smelters, e.g. from The Netherlands and Belgium, and recycles them. Some sludges that had initially been stored on heaps were also disposed of in this way.

The raw material base for the electrosteel furnace is steel scrap. The better the quality of the scrap, the better are the steel qualities produced. Beside the availability of scrap, a large potential for reducing environmental impacts thus relies on the high quality of the scrap due to reduction of impurities by improving collection, dismantling, shredding, segregation, etc. The EU end-of-life vehicle directive already provides legislative regulations, for example. On a long-term basis it is expected that the purity of the scrap will improve due to better product design of steel goods (e.g. prohibition of six heavy metals for numerous components used in passenger car manufacture). The steel associated with the existing goods and investments (material store in the technosphere) represents a large recycling potential, which will be available in the future as scrap.

Steelworks are very long-term investments. They are subject to an approx. 20 to 30 year investment cycle. A large proportion of the energy saving measures mentioned above, and the optimisations specified in the European BAT document, can be achieved within this cycle [BAT Steel 2001]. After restructuring in the nineteen-nineties by amalgamating steelworks in the Ruhr and building new electrosteel works (Eisenhüttenstadt, Luxemburg), there are no longer any "small" producers remaining operating inefficient works. In its voluntary agreement on CO_2 reduction the German steel industry promised to reduce its specific carbon dioxide emissions by 22% between 1990 and 2012. This target will be achieved by a mixture of process engineering innovations and increased use of secondary raw materials. The specific CO_2 output has already been reduced from approx. 1,600 kg/t to almost 1,350 kg/t between 1990 and 2004.

In addition, further long-term reductions in energy consumption can be estimated; they are summarised after Jochem [Jochem 2004] in Table 4.4 below.

Table 4.4 Future primary energy consumption in the steel industry

	Unit	2000	2030	Change relative to 2000
Crude steel production	Mt/a	46.38	46.38	0.0%
Electrosteel proportion – base scenario	%	28.7	28.7	0.0%
PEC electrosteel	GJ/t	5.4	4.3	-20.4%
PEC oxygen steel	GJ/t	20.6	18	-12.6%
Base scenario	PJ/a	753	652	-13.4%

The specific energy consumptions are reduced for the electrosteel route by approx. 20% and by approx. 13% for the oxygen steel route. The proportion of electrosteel for the base scenario is assumed to be constant, resulting in a reduction of primary energy consumption of approx. 13% from 753 PJ to 652 PJ.

The proportion of electrosteel in Germany has increased since around 1990. The proportion of electrosteel in 2030 is estimated to reach between 33% (lower scenario) and 45% (upper scenario). This further reduces the energy consumption of the steel industry (see Table 4.5).

Table 4.5 Future primary energy consumption in the steel industry as a function of the proportion of electrosteel

	Unit	2000	2030	Change relative to 2000
PEC lower scenario	PJ/a	753	625	-17.0%
PEC upper scenario	PJ/a	753	549	-27.1%
Base scenario	Mt scrap	13.3	13.3	0.0%
Lower scenario	Mt scrap	13.3	15.3	15.0%
Upper scenario	Mt scrap	13.3	20.9	56.8%

A reduction in primary energy consumption of around 17% can be calculated for the lower scenario and around 27% for the upper scenario.[11] The scrap requirement increases if the proportion of electrosteel increases. A scrap requirement of 15.3 Mt/a is projected for the lower scenario, representing an increase of around

[11] This reduction potential corresponds to approx. 10–15 Mt/a CO_2 equivalent, representing around 1.0 to 1.5% of the total German emissions in 2002.

2 Mt/a. The upper scenario requirement is approx. 21 Mt/a, an increase of approx. 57% relative to the requirement in 2000.

If Jochem [Jochem 2004] is followed further, crude steel production in 2030 will fall by around 11% relative to 2000 to approx. 41.3 Mt/a. In relation to the above calculations the primary energy requirement is reduced to 581 PJ/a in the base scenario, 557 PJ/a in the lower scenario and 489 PJ/a in the upper scenario, giving achievable reductions of 23%, 26% and 35% respectively.

The composition and volume of the accumulated blast furnace gas sludge in the blast furnace route is considerably influenced by the technology and raw materials used. According to Rentz [Rentz 1996] calculations must assume approximately 3 to 10 kg blast furnace gas sludge per tonne of pig iron. This results in approx. 100,000 to 350,000 t/a of blast furnace gas sludges to be traditionally disposed of. Existing recovery methods can be employed for this purpose [Rentz 1996].[12]

4.1.2.4 Options for action

The following options for action may be derived from the potentials examined. The imminent additional investment cycle expected for the coming years in the steel industry offers some excellent opportunities for energy saving and for contributions to achieving the voluntary agreement (CO_2 emissions). The EU's Best Available Techniques Reference Document on the Production of Iron and Steel [BAT Steel 2001] provides the basis for exploitation of the technical potentials sketched in Section 4.1.2.3.

The largest additional future potential and thus the most important option for action lies in the continued advancement of the electrosteel route. Provision of considerably greater quantities of scrap and the quality assurance of scrap play an elementary role here. Examination of the degree of absorption and a detailed forecast of the currently available scrap iron store, and that which can be utilised in the future, offer the possibility of providing the necessary planning security by investing in the electrosteel route.

An important option for action in terms of a resource-conserving waste policy is represented by the recovery of blast furnace gas sludge. On the one hand, further landfill of contaminated blast furnace gas sludge can be substantially reduced and, on the other hand, the metals iron, lead and zinc be extracted.

[12] In the course of this project no indications could be found that blast furnace gas sludge from German steelworks has ever previously been recycled. Further investigations, outside of the scope of this project, are necessary.

4.1.3 Synopsis of vehicle manufacturing in Germany

4.1.3.1 Facts and figures

The vehicle manufacturing sector comprises the manufacture of vehicles including production of the materials used in the vehicles. The vehicle manufacturing sector comprises the manufacture of passenger cars and lorries including the manufacture of parts and accessories. "Other vehicle manufacturing" consists of shipbuilding and rail, air and space vehicle manufacture, and the manufacture of motorcycles, bicycles, etc. Road vehicle manufacturing (passenger cars, lorries) is the most important from both economical and ecological perspectives. For the purpose of this paper the emphasis was placed on vehicle manufacturing.

<u>Economic indicators:</u>

Vehicle manufacturing in general

- Turnover in the automobile industry: €227.7 billion (2004), which corresponds to 18.6% of the total turnover of the manufacturing industry.
- Employment in the German automobile industry: 773,200 (2004) (corresponds to 13.1% of all employees in the manufacturing industry). This is 130,000 more than ten years ago. 407,700 employees were recorded in the passenger car and commercial vehicles field, 329,300 in related industries and 36,200 in the manufacture of trailers, bodies and containers.
- German production for 2004 [VDA 2004)]:

  5,192,000 passenger cars (93.2%)

  208,000 lorries < 6 t gross permissible weight (3.7%)

  160,000 lorries > 6 t gross permissible weight (2.8%)

  10,000 busses (0.1 %)

  5,570,000 total vehicles

The development of German passenger car production is shown in Figure 4.5.

Figure 4.5 Development of German passenger car production [VDA 2004]

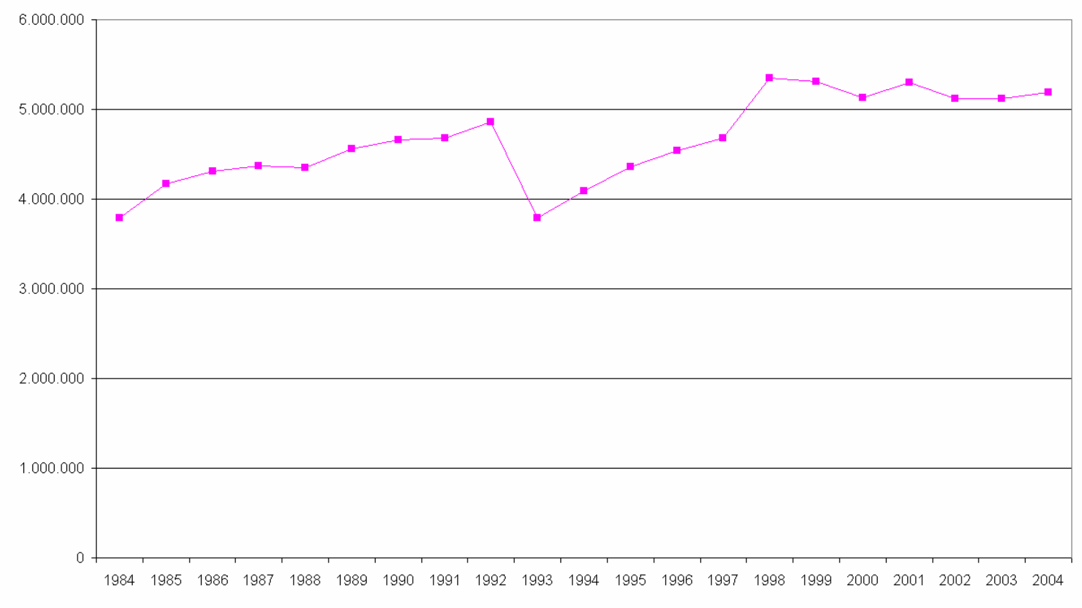


Figure 4.6 shows the distribution of German passenger car production according to engine capacity classes. It can be clearly recognised that engine capacity classes > 1.5 L represent a good 80% of German passenger car production. Recent figures on the development of German production can be taken from Table 4.6.

Figure 4.6 Production in Germany according to engine capacity classes in 1999 [VDA 1999]

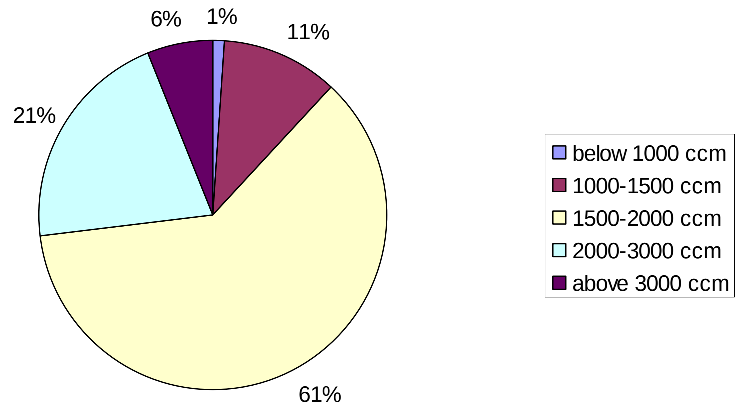


Table 4.6 Development of German production according to engine capacity

Passenger cars	Production units intended for sale			
	2003	**2004**	**1st Quarter 2005**	**1st Quarter 2004**
With petrol engine and more than 1 L capacity	3,383,651	3,287,689	774,099	850,372
With diesel engine and more than 1.5 L capacity	2,142,796	2,400,538	630,638	573,637
With diesel engine, all capacities	:	2,485,728	677,834	626,066
Total	:	5,773,417	1,451,933	1,476,438

Source: Federal Statistical Office, press release of 6th September 2005

Economic relationships:

Vehicle manufacturing in general:

Export and import:

- In all, products with a value of €146.3 billion were exported and automotive products with a value of €65.5 billion imported. Passenger cars dominate exports in terms of the number of units (see Table 4.7).
- 80.6% of imports arrive from the EU 25, 83.7% from Europe as a whole, 6.0% from Japan and 5.9% from the USA.
- Foreign markets have gained importance for the domestic automobile industry. Whereas around half of all produced passenger cars were exported in the mid-nineteen-nineties, today (2004) it is 71%. The most important sales regions for German manufacturers are their European neighbours (see Table 4.8).

Table 4.7 Export according to vehicle type (2004):

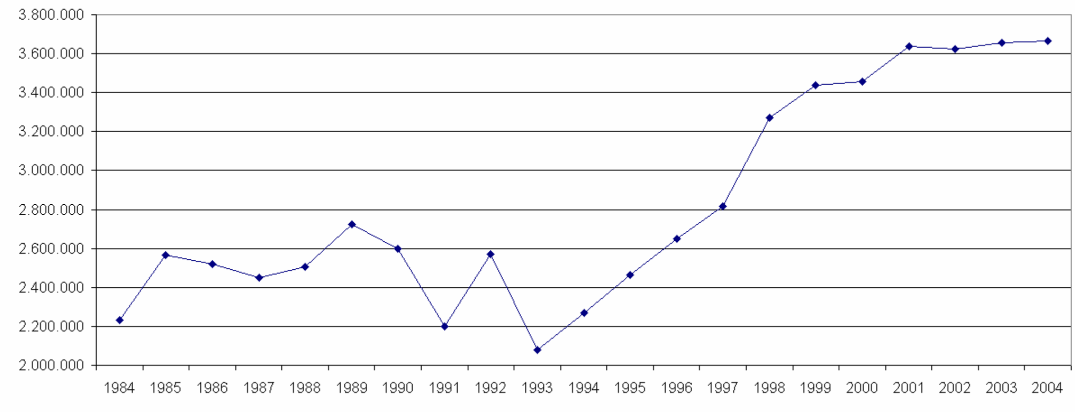
	Absolute	In %
Passenger cars	3 666 524	93.4%
Commercial vehicles	257 526	6.6%
Including:		
Lorries up to 6 t gross perm. weight	145 242	3.7%
Lorries over to 6 t gross perm. weight	104 838	2.7%
Busses	7 446	0.2%
Total vehicles	3 924 050	100%

Table 4.8 Export of passenger cars and commercial vehicles according to export regions/countries

	Passenger car exports from Germany according to consuming countries 2004		Commercial vehicle exports from Germany according to consuming countries 2004	
	Absolute	In %	Absolute	In %
Europe in total	2,666,889	72.7%	220,372	85.6%
Western Europe	2,363,406	64.5%	179,269	69.6%
Including				
France	306,464	8.4%	29,267	11.4%
Great Britain	623,114	17%	44,420	17.3%
Eastern Europe	303,483	8.3%	41,103	16%
Africa	50,997	1.4%	8,552	3.3%
America	618,387	16.9%	4,392	1.7%
Asia in total	275,987	7.5%	21,044	8.2%
Australia and Oceania	51,576	1.4%	3,118	1.2%
Total export	3,666,524	100%	257,526	100%

It can be seen from Figure 4.7 below that the car export figures for the automotive industry have considerably increased over the last ten years and have been above the three million mark since the end of the nineteen-nineties [VDA 2005].

Figure 4.7 Development of export figures for German passenger cars



<u>Ecological indicators: Data relating to environmental criteria:</u>

1.) Vehicle manufacturing in general

- The proportion of German industry's total energy consumption utilised in vehicle manufacturing in 1998 was 24.1%. [Select committee 2001]
- Road vehicle manufacturing in Germany represents 30% of steel consumption [Stahl 2005] and 33% of aluminium consumption [IPAI 2000].

2.) Passenger car production

- The specific characteristics of the passenger car as consumer goods are the diversity of the materials specially developed for the automotive sector and the large number of individual components from which a passenger car is built. It has the highest recycling rate compared to other produced goods [VW 2000].
- In the last 25 years the average unladen weight of a new passenger car has nevertheless increased from 900 kg to 1,120 kg (due to improved comfort and safety packages and more powerful engines). Simultaneously, however, the proportion by weight of relatively lightweight materials such as plastics and aluminium has increased [Jochem 2004].
- For example, the eighty heaviest individual components represent only half of the vehicle weight of the Golf A4 [VW 2000]. This underlines the complexity of passenger cars as produced goods. It is obvious that decisive weight reductions can only be achieved by the development of numerous component alternatives.
- Average values for the year 2000 are given for a passenger car of vehicle class M1 (the major contingent of passenger cars belongs in this class) in [Jochem 2004]:

Steel:	approx. 59%
Aluminium:	approx. 8%
Plastics:	approx. 14%
Elastomers/rest:	approx. 14%
Other non-ferrous metals:	approx. 5%

While the steel component has continuously fallen since 1975 (from 75%), the aluminium (1975: 3%) and plastics (1975: 6%) components have increased.

Some important life cycle assessment data concerning production of passenger cars (including upstream chains) are given in Table 4.9 below for two separate sources. It should be noted that the data refer to very different vehicle models and, in part, to differing criteria (carbon dioxide equivalent or carbon dioxide, sulphur dioxide equivalent or sulphur dioxide). They nevertheless provide a good first impression of the ecological relevance of passenger car production.

Table 4.9 Life cycle assessment of a Mercedes-Benz and a VW Golf [MB 2005], [VW 2000]

Model	**Mercedes Benz (S-Class, S 350 model)**	**VW Golf A4 manufacture**
Primary energy demand for manufacture	Approx. 105 MJ/kg	Approx. 84 MJ/kg
Greenhouse potential	CO_2 equivalent: CO_2 equivalent 6.54 kg/kg	Carbon dioxide: 4.23 kg/kg
Acidification potential	SO_2 equivalent SO_2 equivalent 0.0317 kg /kg	Sulphur dioxide: 0.015 kg/kg

4.1.3.2 Dynamics and trends

In passenger car production in particular the raw material and energy requirement can be reduced by means of material-saving design. Weight reductions can be achieved by material-saving design of the component and by appropriate selection of materials. For steel, for example, this can be achieved by tailor-made sheets of different thicknesses, high-strength steels, high-pressure hydro-formed components and laser-welded sections, as well as by material substitution, in particular by aluminium and plastics.

4.1.3.3 Potentials

In a planning study the weight of the body in white was reduced by 25% relative to an average middle-class limousine. Compared to current vehicle components it was possible to save:

- up to 27% for various door design concepts (tailored blanks),
- up to 32% for bonnets,
- up to 29% for boot lids,
- up to 26% for tailgates.
- Using the Lotus Unique system, weight savings of 34% and cost savings of 22% were achieved on the chassis.

Assuming a weight reduction of 15%-25% by 2030, energy savings in manufacturing alone result in approx. 30–50 PJ. However, these figures must be contrasted to other efficiency effects [Select Committee 2001]. The savings potentials in terms of material selection and design measures are summarised for a number of studies in [Altmann 2002] (see Table 4.10). It is clear that the technical potential may total up to 40% with regard to the conventional (i.e. usual today) vehicle weight.

Table 4.10 Comparison of weights of passenger car assemblies by conventional and optimised (PNGV) models

Assembly	Conventional	PNGV* vehicle	Saving
Bodywork	514 kg	257 kg	50%
Drive system	499 kg	249 kg	50%
Chassis	394 kg	354 kg	10%
Others	62 kg	28 kg	55%
Total	1,470 kg	889 kg	40%

***: PNGV - Partnership for a New Generation of Vehicles**

As a rough estimate, 1 kg of steel can be replaced by 0.6 kg of aluminium in a passenger car. By employing magnesium in the bodywork it is even possible to save as much as 50% weight compared to classical vehicle models [Jochem 2004]. However, it should be noted that substitution of steel is often associated with a substantially higher energy demand in production. For example, the energy demand associated with the production of primary aluminium (secondary aluminium) is around 10 times greater (2 times greater). This, however, must be contrasted with the considerable energy savings during the use phase resulting from reduced fuel consumption ([Jochem 2004] goes into detail on this).

A substantial part of the environmental effects in the vehicle manufacturing sector in particular do not occur during the manufacturing process, but during the use phase. Only 15%-20% of the primary energy involved in the total life-cycles, for example, is used to manufacture a passenger car. [VW 2000]; [MB 2005] As these studies demonstrate, it is difficult to make any absolute statements on the ecological advantages of any given material or design. On the contrary, individual cases must generally be considered [LIRECAR 2004], [Jochem 2004].

The energy intensity involved in vehicle manufacturing is governed by the material intensity per vehicle and the material selection. Efficiency increases in this sector are therefore achieved by stagnation or reduction in the weight of the vehicles, because this is associated with a corresponding fuel reduction.

A rough estimate of the effects of material reduction can be had by multiplying the specific energy demand taken from LCA data (95 MJ/kg, average taken from Mercedes Benz and Golf data, see above), the specific material reduction (PNGV) of approx. 580 kg/car (40%) and the number of passenger cars produced in Germany (approx. 5.8 million units). Using these optimistic assumptions results in a material reduction of approx. 3.4 Mt/a and an annual energy saving for passenger car production of 318 PJ (minus approx. 40% compared to original value).[13] An additional large fuel saving in the use phase of the passenger car is associated with this energy saving in the manufacturing chain. If, on the other hand, a considerably lower weight reduction after LIRECAR [LIRECAR 2002] is assumed, the saving is reduced by approximately half. The savings outlined for passenger car manufacturing may be lower if simple, less energy-intensive materials (e.g. steel) are substituted for by energy-intensive materials (e.g. primary aluminium).

A further route is given by optimised recovery of scrap cars within the scope of the end-of-life ordinance. Here, the options should be examined for their energy efficiency and certain procedures be abandoned in favour of efficient overall concepts. For example, VW calculates a CO_2 relief of approx. 280 kg per passenger car for its optimised method (VWSicon) for segregating and recovering the light shredder fraction within the scope of end-of-life recycling. Assuming that approx. 1 million passenger cars are disposed of as end-of-life cars in Germany, this results in a relief potential of approx. 280,000 t of CO_2 [VW 2005].

4.1.3.4 Options for action

Vehicle manufacturing is a central branch of German industry. It employs numerous primary materials and dominates the use of energy-intensive materials such as steel (approx. 30%) and aluminium (approx. 33%). Vehicle weight is therefore highly relevant, not only with regard to the materials used, but also via the influence of vehicle weight on fuel consumption. In addition to the quantity of the used material, the quality of the material determines the savings that can be achieved. On the one hand, attention must be paid that lightweight construction materials (aluminium, magnesium) do not negate the successes of weight reduction (reduction in fuel

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13 This reduction potential corresponds approximately to 18 Mt/a CO_2 equivalent, i.e. 1.8% of total German emissions for 2002 (without additional substantial savings from reduced fuel consumption).

consumption) by their energy-intensive production. On the other hand, the quality of the residual materials is a governing factor for the future recycling regime and determines their fitness for use. The reduction of undesirable constituents (e.g. heavy metals, see end-of-life ordinance) and substances in vehicles and the corresponding treatment of the fractions originating in end-of-life vehicles require discussion here.

Overall, the principle option for action consists of the continued research, development and implementation of vehicle designs that contribute to the reduction of vehicle weights. The framework for this (promotion of pure and applied research) must correspondingly be optimally planned. In addition, appropriate recovery concepts must be adopted to close the substance cycles. While the passenger car sector is quite correctly handled with priority by the legislature, attention is drawn here to the fact that no detailed arrangements are in place for the lorry sector. There is also a lack of information on the fate and disposal of lorries. It is important that these information gaps be closed.

4.1.4 Synopsis of passenger car consumption in Germany

4.1.4.1 Facts and figures

"Passenger car consumption" describes the purchase and use of passenger cars by households in Germany. Passenger cars in this sense comprise vehicles with petrol or diesel engines or other types of drive (natural gas, electric) registered for private passenger transport. This includes mobile homes. Passenger cars may be bought as new or used passenger cars. Once the registration has expired they are considered end-of-life vehicles.

Households obtain new passenger cars from domestic and foreign production. In addition, passenger cars are purchased as used passenger cars from other households and from commercial owners (trade between households and commerce, included here). Moreover, used passenger cars are also imported in small numbers and exported in substantial quantities. End-of-life vehicles are disposed of accordingly. Overall, a "grey" export of used passenger cars occurs that is not adequately recorded in the foreign trade statistics due to exemption thresholds.

<u>Economic indicators:</u>

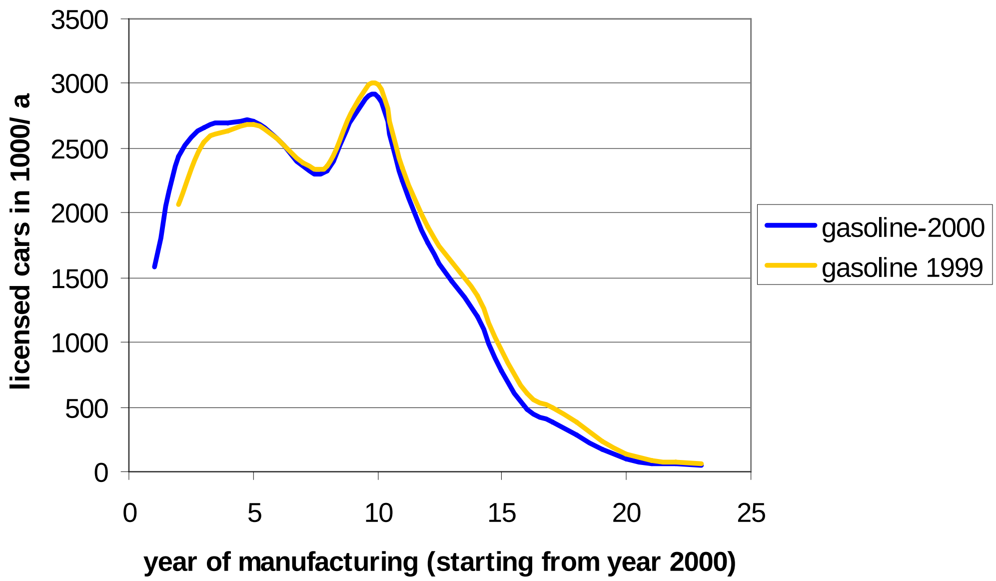
The supply of households with passenger cars is surveyed by the SOEP monitor [SOEP 2004 (*Socio-Economic Panel*)] and records an increase in supply in West Germany from 67% in 1985 to 72% in 1992 and 76% in 2004. In East Germany household provision was 49% in 1991, increasing to 70% in 1998 and 72% in 2004. The supply of households with passenger cars has therefore almost equalised between the old and the New Federal States. It should be noted that the number of households has increased significantly.

In 2004 the households:

1. Bought approx. 1.6 million new passenger cars (petrol) and 0.48 million new passenger cars (diesel).
2. Bought approx. 0.71 million used passenger cars (approx. 1-5 years old) from imports and from commerce.
3. Sold or disposed of to commerce or export approx. 1.55 million used passenger cars and end-of-life cars.

Overall, the passenger car stock in households is accumulating (see Figure 4.8). It has increased for passenger cars (petrol) from 33.62 million in 1999 to 34.41 million passenger cars in 2000. An increase in stock from 4.3 million to 4.65 million passenger cars was recorded for passenger cars (diesel) for the same period.

Figure 4.8 Store accumulation, passenger car consumption (German household passenger cars)



If passenger cars are subdivided into capacity classes and their manufacture, import, registration (households & commerce) and registration by households (passenger car consumption) investigated, the distribution shown in Table 4.11 is revealed:

Table 4.11 Manufacture, import, registration and consumption of passenger cars (petrol and diesel) according to engine capacity classes in units

Class (capacity)	Produced in Germany	Imported	Registered in Germany	Passenger car consumption	Proportion passenger car cons./prod.
< 1.5 L	679,072	735,883	985,273	650,318	96%
1.5-2.0 L	3,185,638	936,143	1,843,442	919,539	29%
2.0-2.5 L	845,503	159,221	631,870	373,578	44%
> 2.5 L	609,196	160,180	253,817	114,469	19%
Total	5,319,409	1,991,427	3,714,402	2,057,904	39%

The table shows the various patterns in production and use. While the proportion of passenger cars with engine capacity <1.5 L is low in production, registration exceeds production by approx. 50%. The proportion of passenger car consumption to production is approx. 96%. Imports dominate in this class.

In the engine capacity class between 1.5 and 2 L registration corresponds to approx. 58% of production. New purchases by households, in contrast, are only 29%. Disproportionately high domestic production can be recognised here. The effect of initial purchase by commerce and subsequent resale to households is strongly pronounced for this class.

In the two capacity classes above 2 L domestic production dominates supply. New purchases by households have fallen to approx. 19% of domestic production for passenger cars above 2.5 litres.

Economic relationships:

Fuels, spare parts and other operating substances are required to maintain passenger car consumption. Additionally, attention is drawn to the foreign trade relationships arising from the export of used passenger cars and end-of-life cars. This leads to lower accumulation of end-of-life cars to be disposed of than would be expected from the stock without export (see below).

Ecological indicators: Data relating to environmental criteria:

Passenger car operation is associated with high fuel consumption. Fuel consumption is also governed by passenger car stock, average annual kilometrage and average consumption. Passenger car stock (here: households and commerce) has increased from 36.7 to 44.3 million between 1991 and 2001. Average kilometrage has decreased during the same period from approx. 13,500 km (1991) to 11,500 km (2001). This means that the overall kilometrage has increased from approx. 496 billion km (1991) to 511 billion km (2001).

Average fleet consumption fell simultaneously from 9.5 L/100 km (~29.75 mpg) in 1991 to 8.8 L/100 km (~32.1 mpg) in 2001 for passenger cars with a petrol engine. Consumption for diesel passenger cars changed from 7.7 (~36.7) to 7.3 l/100 km (~38.7 mpg) between 1991 and 2001. Thus, overall petrol consumption fell from 39.6 billion litres to 35.6 billion litres. In contrast, the increasing proportion of diesel passenger cars resulted in diesel fuel consumption increasing from 6.1 to 7.7 billion litres [DIW 2002].

4.1.4.2 Dynamics and trends

The material equipment level of passenger cars has changed considerably over the past 25 years. For example, the average unladen weight of a new passenger car has increased from 900 kg to 1,120 kg. This is due to improved comfort and safety packages and more powerful engines. This increase was dampened by a greater weight proportion of lighter materials (in particular with regard to alternative materials) such as plastics and aluminium. Because the unladen weight of passenger car consumption has increased considerably over the last few decades, newly purchased passenger cars display a greater average weight. The reason for this is a higher equipment level (electronics, air conditioning, safety). This trend has over-compensated the weight savings affected by new materials (aluminium, plastics, etc.). A wide field for action can be opened here by reversing this trend and making passenger cars lighter and thus less material-intensive.

Approximately 2 million passenger cars are removed from stock and exported as used passenger cars or disposed of as end-of-life cars. The exports recorded in the statistics shows a volume for 2000 of 505,054 passenger cars. Disposal figures in Germany are estimated at approx. 0.8 to 1.2 million units. The rest must be classified as "grey market" export.

4.1.4.3 Potentials

Beside fuel consumption (not the central object of this investigation), material equipment level and disposal potentials can be identified. The same potentials exist in principle for passenger car consumption as were described in the previous chapter. However, it should be noted here that the vehicles owned in Germany by private households generally have smaller engines and smaller unladen weights. The corresponding estimates of potentials must therefore be lower. In addition, it should be noted that passenger cars kept by German households, in particular those with small engine capacities, increasingly originate from foreign production. This means that Germany must rely on international cooperation in order to activate manufacturing potentials (material selection, etc.). Overall, however, the continuous increase in the per capita supply of passenger cars remains one of the main driving forces for sales and therefore for the accumulation of an important material store in the technosphere.

4.1.4.4 Options for action

Please refer to the previous "vehicle manufacturing" chapter for the principal options for action.

As a specific option for action with regard to passenger car consumption, it should be noted that the statistics and the information available on the fate of used and end-of-life cars exhibit considerable gaps, and that timely measures are necessary for better disposal planning.

4.1.5 Important existing regulations

The regulation density in vehicle manufacturing and disposal (partially a question of passenger car consumption) is very high and also stretches as far as the product manufacturing sector in particular (EU type approval directive, ELV directive). The principal regulations are anchored in European legislation. Some initial concrete attempts at regulating substance cycles have been made (specification of recovery quotas, prohibition of the use of certain substances). The automobile associations have adopted a voluntary commitment for the passenger car consumption sector with the goal of decreasing fuel consumption in the passenger car fleet, as well as a commitment to identify fuel consumption. However, both previous "regulations" are not sufficient to decisively reduce consumption. According to the EU Commission, measures "must obviously" be taken to achieve the target of 120 g/km CO_2 by 2010.[14]

4.1.5.1 Greenhouse Gas and Emissions Trading Act (TEHG)

The following plant forming part of the investigated material flow system is subject to the TEHG with regard to CO_2:

- Plant for the dry distillation of bituminous coal or lignite (coking plant).
- Plant for calcining, smelting or sintering iron ores.
- Plant for manufacturing or smelting pig iron or crude steel including continuous casting, also inasmuch as concentrates or secondary raw materials are employed, with a smelting capacity of 2.5 tonnes or greater per hour, also inasmuch as employed in integrated smelting works.

The TEHG does not incorporate the passenger car branch.

4.1.5.2 Landfill Ordinance[15] and Technical Directive on Waste[16]

When disposing of steel industry waste such as fly ashes or blast furnace gas sludge, the Landfill Ordinance (DepV) and the Technical Directive on Waste must be adhered to. The Technical Directive on Waste deals with the treatment of waste requiring special supervision (storage, chemo-physical and biological treatment and

[14] Communication from the Commission to the Council and the European Parliament, Implementation of the Community Strategy for Reduction of the CO_2 Emissions from Cars: Fifth Annual Communication on the Effectiveness of the Strategy, Brussels, 22.06.2005, COM(2005) 269 final.

[15] Ordinance on Landfill and Long-Term Storage (Landfill Ordinance – DepV) of 24th July 2002, Federal Law Gazette pg. 2807; last amended on 12th August 2004, Federal Law Gazette pg. 2190.

[16] Second General Administrative Provision to the Waste Act (Technical Directive on Waste) of 12th March 1991, Joint Ministerial Gazette, pg. 139.

incineration, as well as the requirements for surface and subsurface deposition). It is supplemented by the Landfill Ordinance, which regulates, among other things, the construction and operation of waste disposal sites and ensures correct allocation of wastes to the individual waste disposal site classes by means of defined assignment values. Among other things, the Landfill Ordinance applies to waste disposal sites intended for waste requiring special supervision (hazardous). Waste disposal sites of classes 0 and III must adhere to the specifications for geological barriers, base liners and capping systems based on the Technical Directive on Waste. The disposal of waste requiring special supervision in landraise is only permitted as of Class III and the assignment criteria for Class III waste disposal sites given in Annex 3 of the Landfill Ordinance must be adhered to. So-called old waste disposal sites (waste disposal sites still in the deposition phase on 01.08.2002) may apply for a limited permit until 15th July 2009 in accordance with the transitional regulations in Article 14, Section 2 of the Landfill Ordinance.

Steel production wastes are also affected by the Landfill Ordinance regulations concerning waste requiring special supervision. For example, from 15.07.2009, accumulated blast furnace gas sludges, which are classified as waste requiring special supervision, may only be deposited in Class III landfill if they adhere to the specifications in Annex 3 of the Landfill Ordinance.

4.1.5.3 Voluntary commitment of sintering plant operators (VDEh)

The sintering plant operators (VDEh) have amalgamated to form a working group with the title "Reduction of dioxin emissions from sintering plants". They are working together to find a technical solution on a pilot plant in order to achieve the 0.1 ng I-TEQ/Nm³ dioxin target demanded by the authorities.

4.1.5.4 EU type approval directive for passenger cars

The EU regulates specifications for the recyclability of passenger cars with EU type approval directive 2005/64/EC.[17] The directive instructs that new passenger cars not complying with the stricter EU recycling provisions may not be brought into circulation from the end of this decade. Small series of less than 500 vehicles per year in any EU country are exempt from the new recycling regulations. If they do not adhere to the recycling and reuse regulations, EU countries must refuse to register, sell and market new vehicles 54 months after the directive comes into force. Only vehicles with valid type approval may be introduced to the market. They must be at least 85 mass percent reusable and/or recyclable and at least 95 mass percent reusable and/or recoverable. The manufacturers must provide the authorities with all

[17] Directive of the European Parliament and the Council of 26th October 2005 on the Type Approval of Motor Vehicles with Regard to their Reusability, Recyclability and Recoverability and Amending Council Directive 70/156/EEC, Official Journal No. L 310 of 25.11.2005, pg. 10.

necessary technical information on the materials used and on their quantities in order to allow them to examine their calculations.

4.1.5.5 End-of-Life Vehicles Ordinance[18]

The End-of-Life Vehicles Ordinance implements the EU End-of-Life Vehicles Directive of September 2000 in German law.

The End-of-Life Vehicles Ordinance includes vehicles of classes[19]:

- M1 (passenger transport with up to 8 seats) and
- N1 (freight transport up to 3.5 t).

Vehicles that transport more than 8 passengers, such as busses, and freight vehicles, such as lorries of more than 3.5 t, for example, are exempt from the End-of-Life Vehicles Ordinance.[20] The First Ordinance for Amendment of the End-of-Life Vehicles Ordinance[21] states that in future, special purpose vehicles over 3.5 t gross permissible weight will be subject to the End-of-Life Vehicles Ordinance.[22] This means that vehicles of Class M1 are subject to the End-of-Life Vehicles Ordinance even when they are built on base vehicles not within Classes M1 and N1. This affects mobile homes, in particular.

According to the ordinance manufacturers, importers and the disposal industry must jointly ensure that from 2006 at least 85% of the average weight of an end-of-life vehicle can be recovered and at least 80% recovered as feedstock or reused. These recovery targets are increased to 95% (recovery) and 85% (feedstock recovery, reuse) from 2015.

As of 2006, dismantling companies must subject at least 10 weight percent of accepted end-of-life vehicles to feedstock recovery. From this time, shredder plant must recover at least 5 weight percent of shredder residues (primarily the light shredder fraction) relative to end-of-life vehicles input. As of 2015 this quota

[18] Ordinance on the Transfer, Collection and Environmentally Sound Disposal of End-of-Life Vehicles, of 4th July 1997, Federal Law Gazette I 1997, pg. 1666; revised by notification of 21.06.2002, Federal Law Gazette I, pg. 2214; last amended on 25.11.2003 I, pg. 2304.

[19] In its meeting of 25th May 2005, the German cabinet decided to amend the End-of-Life Vehicles Ordinance, among other things, see previous footnote. In future, special purpose vehicles over 3.5 tonnes gross permissible weight are subject to the regulations given in the Ordinance.

[20] The End-of-Life Vehicles Ordinance results from problems with mass wastes from vehicles with a shorter life than lorries and busses and with greater volumes of hazardous substances. It should be considered whether or not the "market" (market value and scrap price) for lorries and busses contributes to a resource-conserving market control mechanism.

[21] Cf. the First Ordinance for Amendment of the End-of-Life Vehicles Ordinance in the version specified by the cabinet decision of 20th December 2005.

[22] See: http://www.bmu.de/pressemitteilungen/pressemitteilungen_ab_22112005/pm/36448.php.

increases further by 15 weight percent, whereby 5 weight percent must be subject to feedstock recovery.

Since 1st July 2003 it is forbidden to offer for sale vehicles and components containing the heavy metals cadmium, mercury, lead and hexavalent chromium. Exceptions are specified in Annex II of the End-of-Life Vehicles Directive, which must be adopted directly. The existing environmental standards for the treatment and recovery of end-of-life vehicles by approved companies are correspondingly improved by the EU specifications. These are substantiated in the Annex to the End-of-Life Vehicles Ordinance. This gives details of requirements for acceptance and return of end-of-life vehicles, on the correct and hazard-free recovery of end-of-life vehicles and the remaining bodies, as well as on the correct and hazard-free disposal of the accumulated wastes. These specifications only apply to accepting/returning stations and dismantling companies dealing with "end-of-life vehicles" in the context of the End-of-Life Vehicles Ordinance. Specifications concerning the dismantling of batteries, operating fluids, etc., need therefore only be fulfilled for end-of-life vehicles in the context of the End-of-Life Vehicles Ordinance (No. 3.2.2 End-of-Life Vehicles Ordinance Annex).

Beside this, any dismantling company operators concerned with other end-of-life vehicles (busses, lorries) must also adhere to general environmental regulations with regard to the company location (planning permission, liability to notify to Article 67 Federal Immission Control Act) such as the Closed Cycle and Waste Management Policy/Waste Act (*KrW-/AbfG*), the Federal Immission Control Act (*BImSchG*) and the Water Resources Management Act.

4.1.5.6 Electrical and Electronic Equipment Act[23]

The Electrical and Electronic Equipment Act does not apply to the passenger car consumption sector. The electrical and electronic equipment covered by the Electrical and Electronic Equipment Act are named in the catalogue in Article 2, Section 1 (e.g. monitoring and controlling instruments). However, the law should not be applied if the equipment in Article 2, Section 1 form part of other equipment that is not covered by the scope of the Electrical and Electronic Equipment Act. This applies to control instruments fitted into passenger cars, for example.

4.1.5.7 Battery Ordinance[24]

The Battery Ordinance (*BattV*) implements the EU Battery Directive. According to Article 3 of the Battery Ordinance batteries may only be placed on the market if it is

[23] Act Governing the Sale, Return and Environmentally Sound Disposal of Electrical and Electronic Equipment (Electrical and Electronic Equipment Act - *ElektroG*) of 16th March 2005, Federal Law Gazette, pg. 762.

[24] Ordinance on the Return and Disposal of Used Batteries and Accumulators (Battery Ordinance - BattV) of 2nd July, 2001, Federal Law Gazette pg. 1486; amended on 9th September 2004, Federal Law Gazette pg. 2331.

certain that the end-consumer can return them, even if they contain no hazardous substances in the context of the Battery Ordinance. Accordingly, manufacturers and sellers of batteries and accumulators must develop a return system in accordance with Articles 4 and 5 of the Battery Ordinance. The majority of battery manufacturers now participate in a joint national battery return system (GRS), organised as a foundation. The GRS can recover a large proportion of the returned batteries. According to Article 13 of the Battery Ordinance certain batteries containing hazardous substances may not be placed on the market.

4.1.5.8 Waste Disposal Ordinance[25]

The Waste Disposal Ordinance (*AbfAblV*) is intended to avoid climate-damaging emissions and landfill leachate containing hazardous substances, in order to guarantee the environmental compatibility of municipal waste. In order to achieve this objective it specifies, among other things, where which thermally or mechanically/biologically treated wastes may be deposited (landfill input criteria). According to the Waste Disposal Ordinance the disposal of untreated waste in municipal landfill must cease by 31.05.2005 (Article 6, Section 2, No. 1 Waste Disposal Ordinance). This also aims to prohibit the previous practice of disposing of untreated shredder residues in municipal landfill as of 1st June 2005.

4.1.5.9 Voluntary commitment of the European automotive industry

According to the voluntary commitment of the Association of European Automobile Manufacturers (ACEA)[26] fleet consumption will be reduced to below 140 grams of CO_2 per kilometre by 2008, which corresponds to ~42 mpg.[27] In addition, it was announced to the EU that the option of a further reduction to 120 g CO_2/km by 2012 would be examined (corresponds to ~48 mpg). A voluntary commitment for the Kyoto phase 2008 to 2012 does not yet exist.

Distance-to-target monitoring is carried out by ACEA jointly with the Commission (Article 1, Section 5 Commission Recommendation 1999/125/EC). Appropriate sanctions for non-adherence do not yet exist. However, the Commission has announced that it will present a legislation proposal on CO_2 emissions by passenger cars if the emission targets in the voluntary commitment are not achieved by 2008.

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25 Ordinance on Environmentally Compatible Storage of Waste from Human Settlements (*Abfallablagerungsverordnung - AbfAblV*) of 20th February 2001, Federal Law Gazette pg. 305; last amended on 24th July 2002, Federal Law Gazette pg. 2820.

26 Commission recommendation of 5th February 1999 on the reduction of CO_2 emissions from passenger cars (promulgated under reference number K(1999) 107).

27 The members of the Association of European Automobile Manufacturers (ACEA) should jointly achieve a CO_2 emission target of 140 g/km by 2008 for the average new passenger car (Class M1 according to the definition in Annex I of Council Directive 70/156/EEC) sold within the community, primarily by the introduction of new technologies and the resulting changes in the market, measured against Commission Directive 93/116/EU (4).

According to the ACEA monitoring report for 2002 the average specific emission of the new car fleet in the EU is 165 g/km (for petrol passenger cars 172 g/km; for diesel vehicles 155 g/km).[28] A 164 g/km average specific emission for the new car fleet of was achieved in the EU for the calendar year 2003.[29] The Commission comes to the conclusion that measures "must obviously" be taken to achieve the target of 120 g/km by 2010. In the view of the Commission, implementation of Directive 1999/94[30] on the provision of consumer information regarding fuel economy and CO_2 emissions data has not been very effective. At the same time the Commission points out that ACEA and JAMA (Japanese Automobile Manufacturers Association) see no economical means of achieving the target of 120 g CO_2/km by 2012 using technical measures.[31]

4.1.5.10 Passenger car energy consumption labelling (*PKW-EnVKV*)[32]

The Passenger Car Energy Consumption Labelling Ordinance is aimed at ensuring that consumers are provided with information on fuel consumption and CO_2 emissions by means of signs on the vehicle, notices in the sales room, a guide and marketing materials when buying new passenger cars. The Passenger Car Energy Consumption Labelling Ordinance came into force in Germany on 1st October 2004 and implements a corresponding 1999 EU Directive (known as the CO_2 Labelling Directive) on the provision of consumer information on fuel consumption and CO_2 emissions of passenger cars.

4.1.5.11 Waste Oil Ordinance[33]

The Waste Oil Ordinance (*AltölV*) implements the EU Waste Oil Directive. The aim of the Waste Oil Ordinance is to facilitate the reuse of as much waste oil as possible. Article 2 of the Waste Oil Ordinance therefore gives priority to reprocessing. It is possible to extract base oil by feedstock recovery from waste oils,

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28 Monitoring of ACEA's Commitment on CO_2 Emission Reductions from Passenger Cars (2002), Final Report from 05.09.2003. Joint Report of the European Automobile Manufacturers Association and the Commission Services, see: http://www.acea.be.

29 Communication from the Commission to the Council and the European Parliament, Implementation of the Community Strategy for Reduction of the CO_2 Emissions from Cars: Fifth Annual Communication on the Effectiveness of the Strategy, Brussels, 22.06.2005, COM(2005) 269 final.

30 Directive 1999/94/EC of the European Parliament and the Council of 13th December 1999 on the Provision of Consumer Information on Fuel Consumption and CO_2 Emissions when Marketing New Passenger Cars, Official Journal No. L 12 of 18.01.2000, pg.16.

31 Commission communication, COM (2005) 269.

32 Ordinance on Consumer Information on Fuel Consumption and CO_2 Emissions for New Passenger Cars of 28th May 2004, Federal Law Gazette I 2004, 1037.

33 Waste Oil Ordinance (*AltölV*) of 16th April 2002, Federal Law Gazette pg. 1368.

thus acquiring the source product for lubricants. Oils that are also PCBs in the context of the PCB Waste Ordinance (*PCB-AbfallV*) are exempt from the scope of the Waste Oil Ordinance because these oils must be disposed of in accordance with the PCB Waste Ordinance.

4.1.6 Synopsis of options for action for this material flow system

In order to further utilise the considerable potentials for reducing environmental impacts the following options for action can be particularly emphasised for the iron ore-steel-vehicle manufacture-car consumption material flow system following the project investigations:

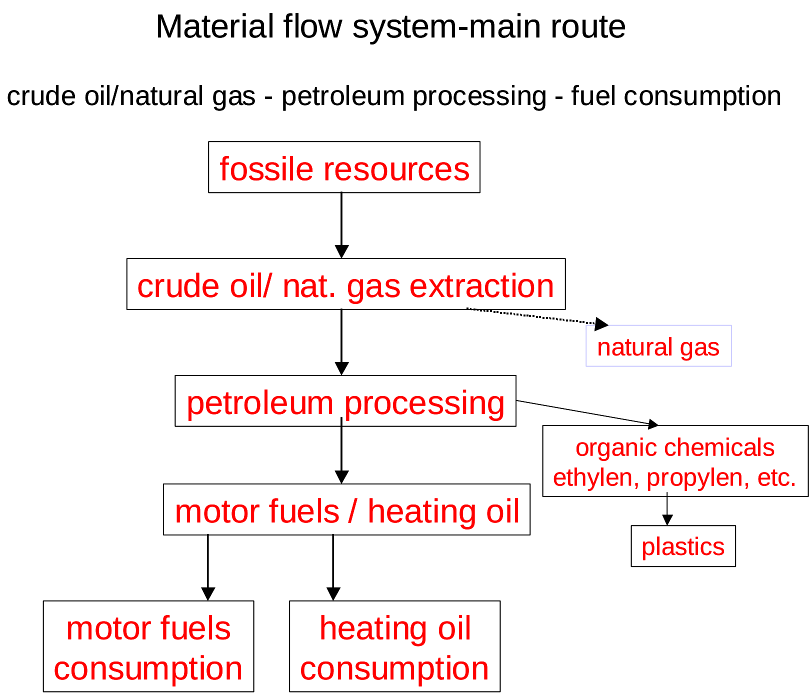
- Measures for increasing mid- to long-term scrap utilisation in the German steel industry from the diverse material stores in the technosphere (end-of-life vehicles, infrastructure, permanently unused building) and increasing the proportion utilised in the electrosteel route. This includes a detailed survey of the material stores and improved estimates of their mobilisation times and mobilisation options.
- Efforts to recover steel manufacturing waste flows previously sent to landfill (creation of recovery capacities, disposal restrictions) such as blast furnace gas sludge.
- Promoting measures for noticeable weight savings in vehicle manufacturing taking upstream chain efforts into due consideration (particularly energy-intensive materials, etc.).

4.2 Crude oil/natural gas-petroleum processing-fuel consumption

4.2.1 Material flow system synopsis: Main route

The crude oil/natural gas-petroleum processing-fuel consumption material flow system (see Figure 4.9) comprises two key sectors of the German economy, including petroleum processing and the important lateral industry of plastics manufacturing. They will be dealt with in the following sections.

Figure 4.9 Material flow system – Main route: Crude oil/natural gas-petroleum processing-fuel consumption



4.2.2 Synopsis of petroleum processing in Germany

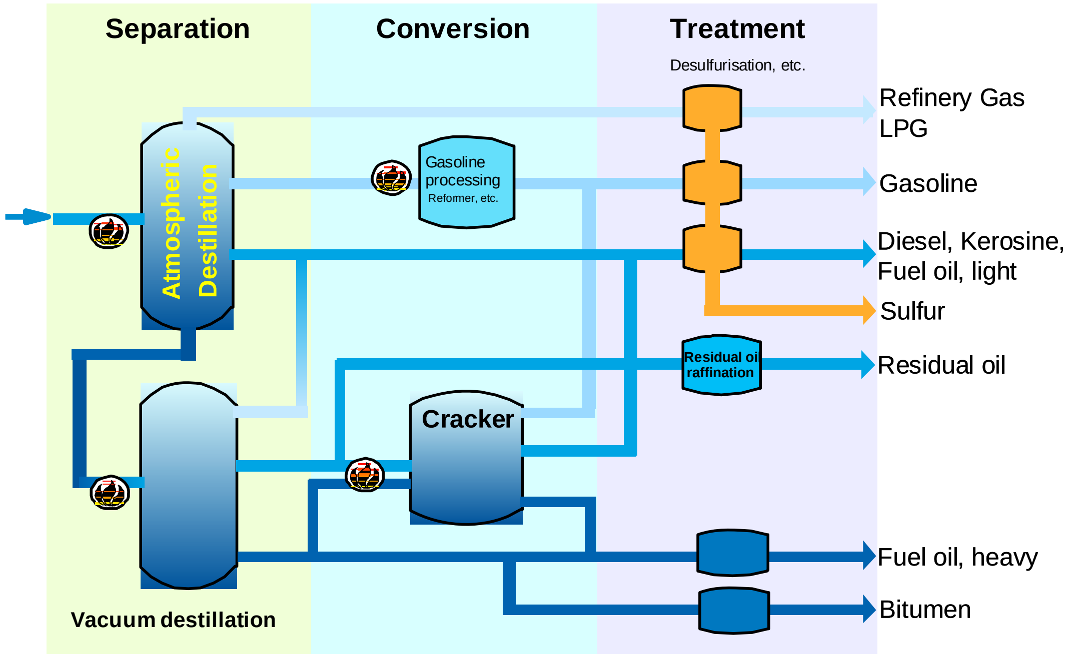
4.2.2.1 Facts and figures

The "petroleum processing industry" comprises the sector that produces motor and heating fuels and a variety of other products such as lubricants and bitumen, as well as feedstock for the petrochemical industry. The petroleum processing industry produces the mineral oil-based fuels for petrol and diesel engines, fuel oils for household and industry and naphtha for the petrochemical and plastics industries by refining, cracking and constituent admixing.

According to the BMWA the turnover in 2003 of the mineral oil sector including taxes was 78.5 billion euros. The crude oil input in 2004 totalled 110 Mt. The number of employees is around 20,000. In 2004 the sector achieved a record result of 19 euros per tonne of mineral oil product.

Input consists almost completely of crude oil. Crude oil is a mixture of short, long, branched, non-branched, aliphatic and aromatic components, primarily consisting of hydrocarbon compounds. Minor elements include sulphur, nitrogen, oxygen and various heavy metals. The quality of the crude oil varies greatly depending on origin. The initial quality exercises a great influence on the product yields and processing effort. The "lighter", low-sulphur oils, such as those extracted from the North Sea fields, are highly prized. Heavy oils require considerably greater effort by cracking and desulphurisation, for example, for a roughly similar product yield.

Figure 4.10 Schematic diagram of a refinery

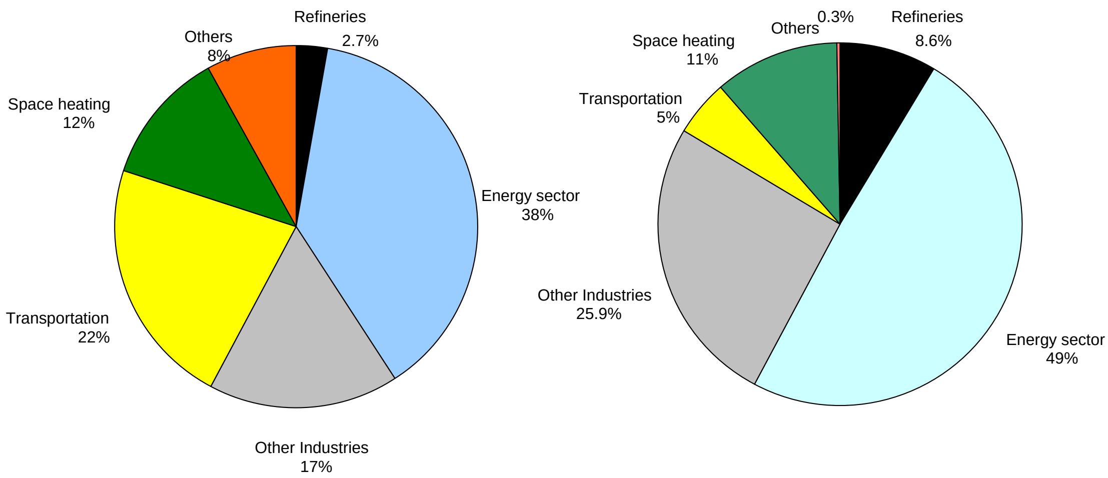


Some refineries buy intermediate products from other refineries. Feedstock of other origins is increasingly utilised as additives for finishing fuels. These are petrochemical substances such as MTBE or, increasingly, components such as the so-called GTLs (gas to liquid) or biogenic substances (rape seed diesel). This development can also lead to a tendency to "degradation" of the crude oil qualities to be accepted because the synthetic components allow a more targeted formulation of the oil properties.

The mineral oil extraction sector can be delineated in the production chain upstream of the petroleum processing industry. Demarcation downstream is possible with regard to petrochemicals where, however, transitions are often flexible because, among other things, upstream products such as aromatics (benzene, toluene, xylenes) are often refined to order, or synthetic products such as MTBE produced at the refinery. Petroleum processing is interwoven with extraction and is operated by companies within the concern structure. Price formation for refinery crude oil purchases in Germany is almost exclusively determined by the crude oil spot market in Rotterdam. The mineral oil concerns themselves market motor and heating fuels with the end consumer in mind, with the exception of petrol station leaseholders and medium-sized fuel oil dealers. Naphtha is sold as a product to the petrochemical industry – which is in part in the hands of the mineral oil concerns or forms joint ventures with chemicals companies.

The basic structure of the buildings in the majority of refineries in Germany is up to 40 years old. In previous decades progress in specific energy consumption and emissions has been attained by renewal, refurbishment and retrofitting. Nevertheless, considerable discrepancies exist between improved existing plant and completely new ones (Leuna 2000, in part PCK Schwedt). According to the mineral oil products inventory analysis (*Sachbilanz Mineralölprodukte*) [Patyk 2001], the specific CO_2 output in 1999 for 1 TJ of mineral oil product averaged 5.56 t. Depending on the exact type of product, this value may be anywhere between 8.5 t (petrol) and 2.65 t (naphtha). Figure 4.11 shows the proportion of petroleum processing emissions to total emissions in Germany [Fehrenbach 2004]. It can be seen that the refineries produce 5% of CO_2 emissions and approx. 12% of the SO_2 emissions of the whole industrial sector. The refineries also contribute to NOx emissions by way of their process heating systems. VOC emissions are also produced by tanks, handling and numerous diffuse sources. However, in both cases the contribution to total emissions in Germany is substantially lower than for CO_2 and SO_2.

Figure 4.11 Percentage contributions of CO_2 and SO_2 emissions of refineries in Germany compared to other sectors [Fehrenbach 2004]



CO_2 emissions according to sectors

SO_2 emissions according to sectors

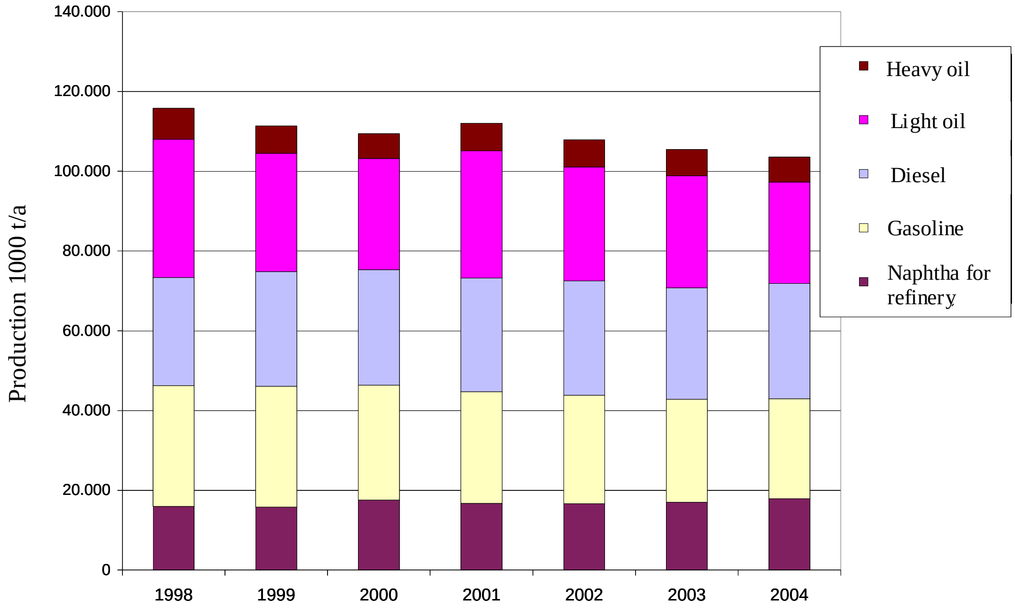
Beside airborne emissions, refineries also cause waste water emissions. Nitrogen compounds in particular play an important role here.

4.2.2.2 Dynamics and trends

The principal products continue to be petrol and diesel fuels and light fuel oil. As Figure 4.12 shows, sales of petrol and light fuel oil have continuously fallen over the last seven years, while diesel sales have remained relatively constant at around 28 Mt/a, and have even tended to increase slightly.

Sales of naphtha (straight run petrol) to the petrochemical and therefore also to the plastics industry displayed a tendency to increase from around 16 to 18 Mt.

Figure 4.12 Development of product output of the mineral oil industry [MWV 2004]



The trend to higher proportions of diesel fuels and naphtha is expected to continue over the next few years. Motor and heating fuels are the outstanding mass energy goods of the industrial society. Naphtha represents the central primary substance in the petrochemical and plastics industry and will remain so as long as mineral oil is available as a raw material.

The most recent measures for sulphur reduction in motor and heating fuels, for example, can be considered particularly successful. The emissions at the plants themselves have increased slightly, the total emissions, however, are considerably less thanks to the reductions in the product.

4.2.2.3 Potentials

At 320 PJ/a, the mineral oil industry sector accounts for slightly more than 2% of Germany's total energy consumption (consumption and processing losses, not product feedstock). Between 2 and 3% of greenhouse gas emissions is assumed, increasing to as much as around 9% for SO_2 emissions.

Many of the core elements of the plant engineering base in Germany originate in the nineteen-sixties. Individual components have been successively renewed, allowing some optimisation. Nevertheless, the theoretically achievable potentials for increasing efficiency and reducing emissions are not exhausted by far. The greatest potential for saving energy and thus reducing CO_2 emissions is given by the process heating and boiler systems. Together, they account for around 70% of total refinery energy consumption. Older plant displays thermal efficiencies ranging between 80 and 85%. Using new technologies with optimised heat control, values up to 93% are possible. This is already implemented on a few new systems. Roughly, a reduction in total energy consumption of around 5 to 10 percentage points (minus 16–32 PJ/a)[34] can be theoretically achieved in this way. Further reductions can be accomplished by coupled generation of electricity and steam, for example. [BAT Mineral Oil 2003].

Potentials are currently far higher for SO_2 reductions. Complete renewal of refinery plant would not be absolutely necessary for this; instead, retrofitting of the appropriate flue gas scrubbing systems or further reductions of heavy fuel oils as a refinery fuel would suffice. While the large coal-fired power stations were able to exhibit substantial reductions during the nineties due to national implementation of the 13th German Federal Immission Protection Ordinance (*BImSchV*), the refinery heating systems, being either older systems, systems often of smaller capacity (below 50 MW or 50 to 300 MW) or special systems (catalytic cracker, Claus plant), are generally not affected by stricter thresholds.

In some cases SO_2 emissions could be reduced by up to 90% by adopting an end of pipe solution, common in power stations. If this is extrapolated for the complete industrial plant base a reduction of 50% (approx. 25,000 t/a) could be realised. This amounts to around 5% of the total SO_2 emissions for Germany. This objective can be further supported by reducing the use of sulphur-rich heavy fuel oil as a fuel. Many of the core elements of the plant engineering base are comparatively old and have not exhausted the theoretically possible potentials for efficiency improvements and emission reductions by far. During the last 5 to 10 years innovations have preferably been invested in these downstream stages based on the demands placed on product quality (sulphur-free fuels, aromatic content).

[34] This corresponds to approx. 1.2 to 2.4 Mt/a CO_2 equivalent.

In principle it can be noted that the existing plant base exhaust their capacities in terms of energy efficiency in order to minimise their own product losses - and thus costs. New plants, in contrast, display a far greater efficiency potential.

4.2.2.4 Options for action

Options for action in the petroleum processing sector consists primarily of reductions in the substantial sulphur dioxide emissions by implementing end-of-pipe solutions as already used in power stations. Additional options for action exist in terms of energy-related modernisation of the mainly older plant, oriented to the standards of the more efficient new plant.

4.2.3 Synopsis of plastics production and consumption in Germany

4.2.3.1 Facts and figures

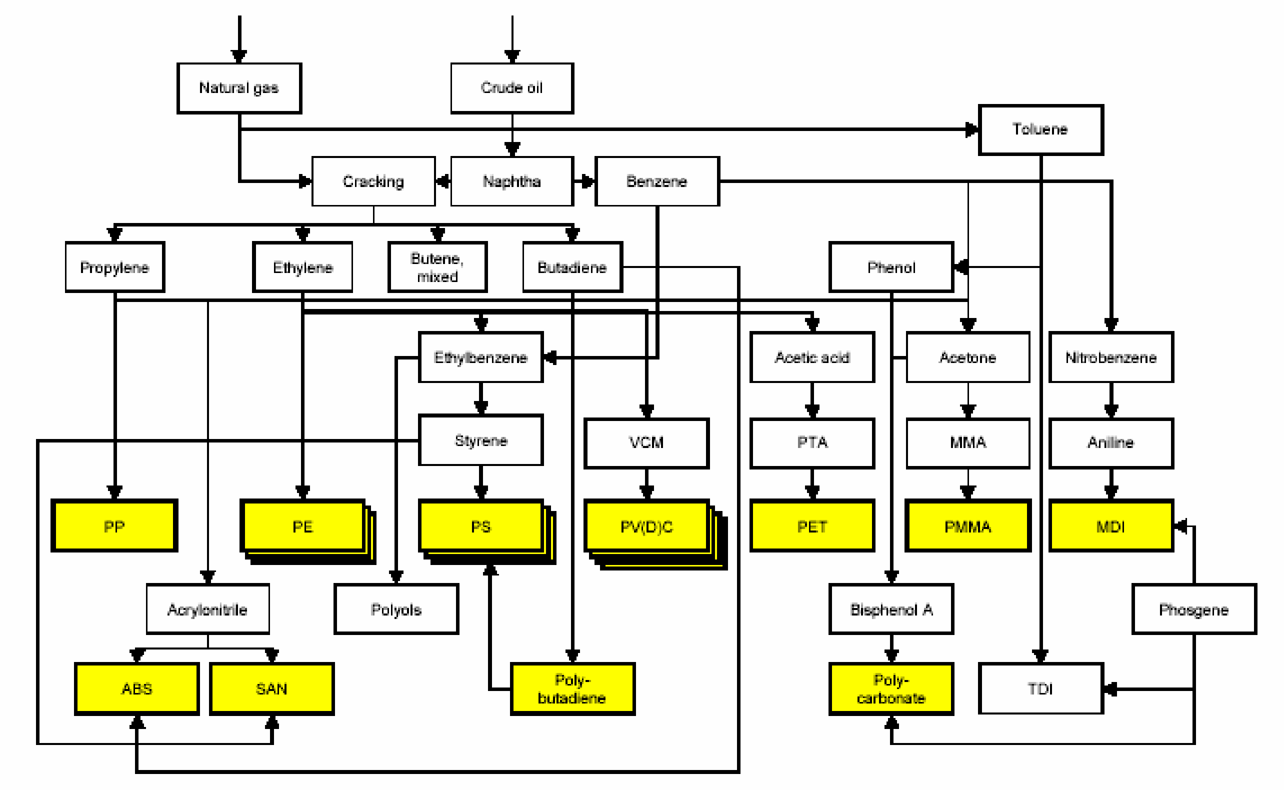
One of the main products of the refinery sector - naphtha - represents the most important raw material for the production of plastics. The composition of the crude oil can vary greatly, depending on origin; the naphtha fraction may vary between 5-15%. Table 4.12 below shows the composition of a crude oil from Kuwait. Beside naphtha, natural gas is also utilised as a raw material for plastics production, particularly in the U.S.A., but also in northern Europe.

Table 4.12 Fractions from refining crude oil after [Ecoinvent 2004]

Fraction	Boiling range [°C]	Mass fraction
Gases	<15°	2%
Petroleum (fuel)	15° - 95°	6%
Naphtha	95° - 175°	12%
Kerosene	175° - 232°	9%
Light oils/diesel	232° - 343°	17%
Heavy oil and paraffins	343° - 525°	24%
Bitumen (residues)	>525°	30%

Naphtha is further processed in the cracking process. The principal monomer building blocks for plastics are acquired here (see Figure 4.13).

Figure 4.13 Plastics production tree, starting from natural gas and crude oil, after [Ecoinvent 2004]



In Table 4.13 the main average fractions as products of the cracking process are listed for 17 of the 50 western European crackers (1999). Based on the primary materials produced, the different kinds of plastic are essentially won by different polymerisation processes.

Table 4.13 Production output of European cracking plant Source: [Plastics Europe 2005] (eco-profile ethylene)

Product	Output/Mt	%
Ethylene	7.78	42.1
Propylene	3.63	19.6
Butenes (mixed)	1.52	8.2
Butadiene	0.98	5.3
Hydrogen	0.22	1.2
Pyrolysis gasoline	4.37	23.6
Total	18.5	100.0

The importance of plastics has increased over the past few decades both in Germany and worldwide. Around 80% of plastics produced today are thermoplastics. Thermoplastics harden upon cooling or soften upon warming without altering their chemical structure. This means that they can change shape without limitation. Duroplasts differ to thermoplastics in that they harden by means of a chemical cross-linking reaction and are chemically degraded upon heating. In addition, plastics are generally categorised in the following groups:

- Commodity plastics: polyvinylchloride (PVC), polyethylene (HDPE: high density, LDPE: low density, LLDPE very low density), isostatic polypropylene (PP), standard polystyrene (PS)
- Engineering plastics: polyethylene terephthalate (PET), polybutylene terephthalate (PBT), polyamide (PA) (aliphatic, amorphous, aromatic), poly-carbonate (PC), polyoxymethylene (POM), polymethylmethacrylate (PMMA), modified polystyrenes such as styrene acrylonitrile (SAN) and acrylonitrile-butadiene-styrene (ABS)
- High-performance plastics: liquid crystalline polymers (LCPs), polyetheretherketone (PEEK), various polysulfones, polyimides, etc.
- Functional or specialty plastics

The plastics industry can be subdivided into the plastics production, plastics processing and plastics recycling sectors.

Plastics producers: are raw material producers who market their plastics products as moulding materials (e.g. powder, granulate, paste feedstock) to the processing industry.

Plastics processors: process the primary goods (or recyclates) of the plastics producers to products for use in various sectors of the economy such as packaging, building, vehicles, etc.

Plastics recyclers: obtain waste plastics and process them either to intermediate products for further recycling (agglomerate, ground stock, re-granulate) or process the waste plastics directly to final products.

The following facts and figures on the current situation in Germany must be emphasised [VKE/Plastics Europe 2005]

- German production (2004): total plastics 17.5 Mt (+4.2% on the previous year) (corresponds to 7.8% of worldwide production and 33% of western European production)
- Technical thermoplastics approx. 1 Mt
- PUR approx. 1 Mt

- Plastics for non-materials uses such as polymers for manufacturing adhesives, paints, glues, resins and fibres, approx. 6 Mt
- Main component for producing commodity plastics approx. 8 Mt
- Plastics consumption in Germany (2004) [Plastics Europe 2005]: taking export (11.79 Mt) and import movements (6.97 Mt) into due consideration, domestic consumption amounts to 12.68 Mt
- Main areas of application are packaging and building (see below for fields of use)
- Employment 2004 [Plastics Europe 2005]: the number of employees in the plastics industry decreased slightly during the period 1995 to 2003. In 2004 a total of 378,000 persons were employed in the plastics industry sector (1995 around 420,000), 52,000 in plastics production, 280,000 in plastics processing and 46,000 in mechanical engineering. Table 4.14 shows a summary of the principal producers in Germany, together with their products.

Table 4.14 Main plastics producers in Germany Source: [VKE/Plastics Europe 2005]

Main Plastics Producers in Germany 2003

	PE-LD/ LLD	PE-HD/ MD	PP	PS	EPS	PVC	ABS, ASA, SAN	PMMA	PA	PET	Sonst. Thermoplaste	PUR	Sonstige Kunststoffe
Atofina									x				
Bakelite													x
Barlo								x					
Basell	x	x	x										
BASF				x	x		x		x		x	x	
Bayer							x		x		x	x	
Borealis		x	x										
Degussa								x	x		x		
Deutsche BP	x	x		x	x								
Domo									x				
Dow	x		x	x	x					x		x	
DuPont									x		x		
Dyneon											x		
EMS-Chemie									x				
EVC						x							
EXXON Mobil											x		
Kosa									x	x			
Kraton									x		x		
Polimeri	x												
Raschig													x
Resolution													x
Rütgers											x		
Sabic	x	x	x										
Solvin						x			x				
Ticona											x		
Vestolit						x							
Vinnolit						x							

Wi-Daten 01-2005

PlasticsEurope
Der Verband der Kunststofferzeuger

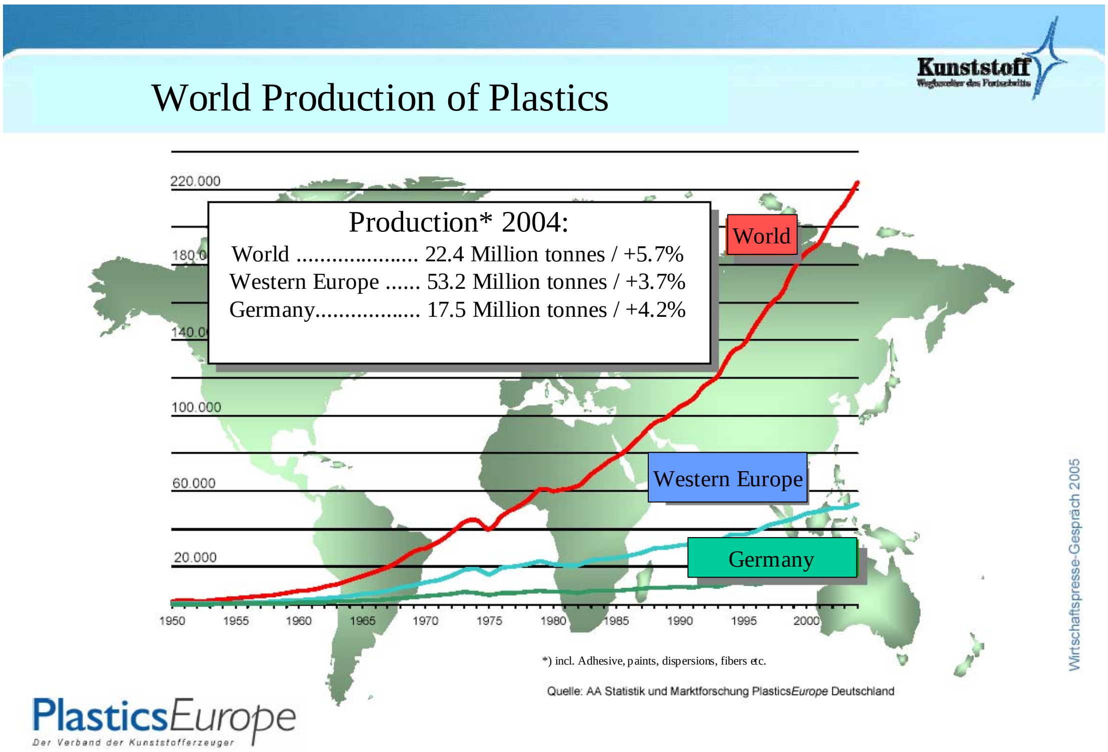
24

Source: PlasticsEurope Deutschland, WG Statistics and Market Research

4.2.3.2 Dynamics and trends

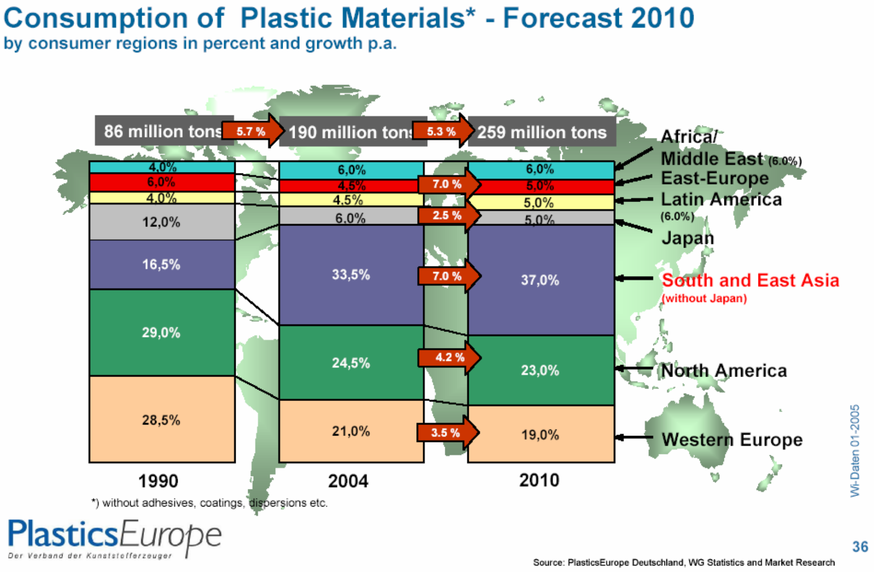
The following information is important in order to understand historical developments: The German and worldwide production of plastics has increased continuously since 1950 (see Figure 4.14). In terms of volume, worldwide plastics production has overtaken steel production. In Germany, materials were largely affected by this increase in past years; the export surplus also increased. The production increase was therefore mainly based on higher foreign demand.

Figure 4.14 Plastics production: worldwide, Western Europe and Germany [Plastics Europe 2004]



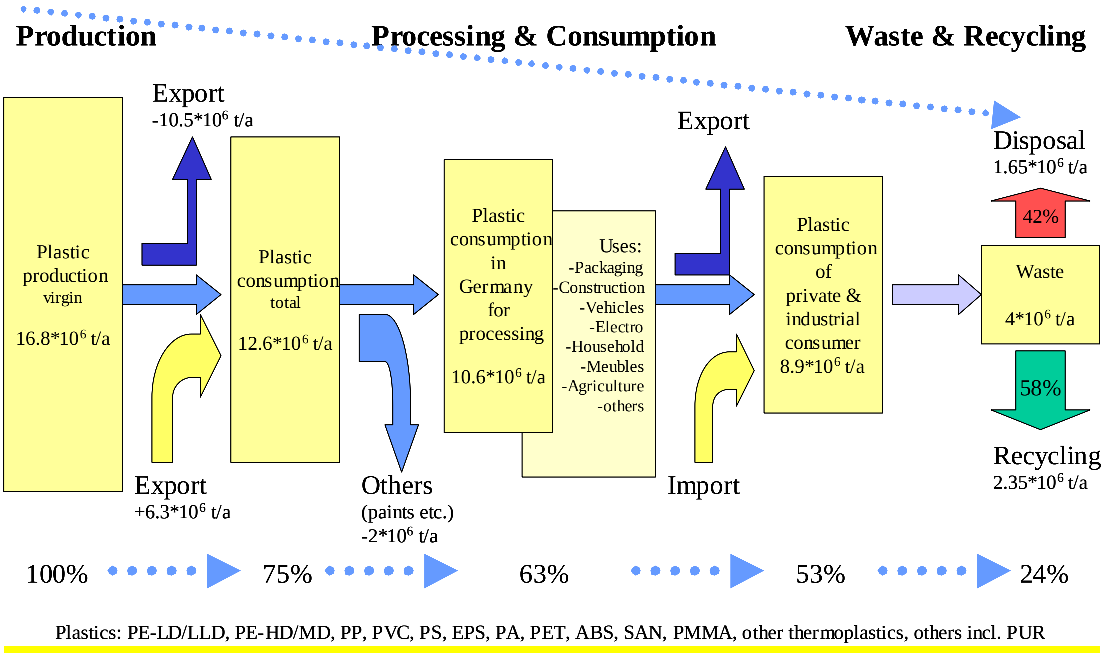
In terms of the development forecast (see Figure 4.15), increasing German plastics production is also expected for the future, especially considering the expected further increase in worldwide plastics consumption.

Figure 4.15 Plastics consumption in 1990, 2004 and a forecast for 2010 [VKE/Plastics Europe 2005]



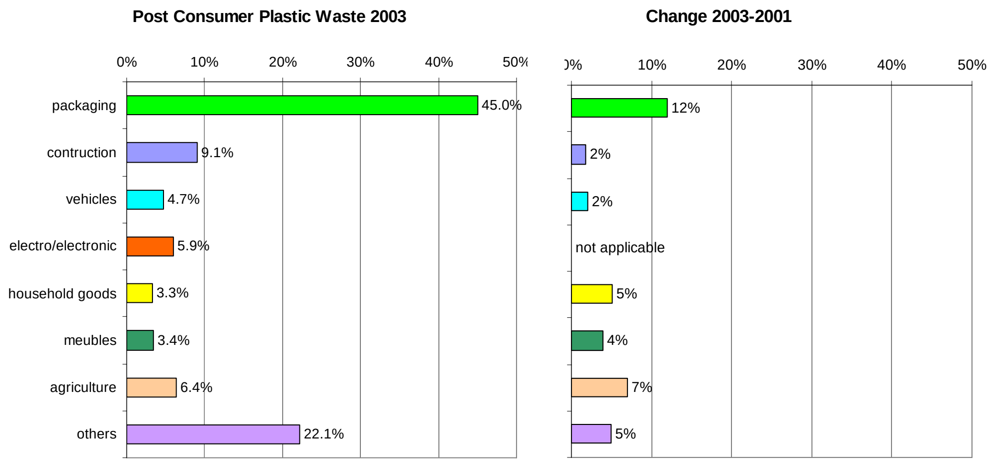
With regard to the current situation in terms of waste plastics and plastics recycling, waste accumulation of around 4 Mt in 2003 resulted from polymer production of 16.8 Mt. Consumption for manufacturing plastics products was 10.6 Mt and an import- and export-adjusted domestic consumption was 8.9 Mt. 58.4% of the 4 Mt waste accumulation was recycled and 41.6% was disposed of (see Figure 4.16).

Figure 4.16 Schematic substance flow for production, processing and consumption as well as waste and recovery [consultic 2004]



Plastics waste is primarily post-consumer waste (approx. 3.1 Mt or 77.8%; around 55% of this from private households and 45% from commercial end consumers); 0.9 Mt are production and processing waste (20% plastics processors and 2.2% producers). The recovery rate for post-consumer waste is 49.6%, in the production and processing wastes sector almost 90%. The origin of the post-consumer waste is shown in Figure 4.17 for 2003 according to sectors and the changes compared to 2001 shown in percent.

Figure 4.17 Origin of post-consumer wastes [consultic 2004]



Waste disposal:

The 2.34 Mt of plastic waste recycled in 2003 was mainly utilised for feedstock recovery (1.75 Mt), 1.35 Mt as direct materials and 0.4 Mt as raw materials (see Figure 4.18). The remaining 0.59 Mt were utilised for energy purposes (approx. 64% via waste incinerator and waste-fired cogeneration plant, the remaining roughly 36% in heating systems, primarily in cement and power stations, some after preparation and sorting). Around 53% of the 1.67 Mt of plastic waste disposed of in 2003 were sent to landfill, the remainder to waste incinerators.

Historical development:

The total volume of plastic waste has increased (from 1994 until 2003 by a total of 43% or 3.6% annually), where the increase was caused almost entirely by post-consumer waste. Production and processing waste, in contrast, has only marginally increased despite greater production volume. This is due to optimised production processes and improved domestic recycling by the processors. The recovered volume has also increased considerably (by 67%), while the volume disposed of only increased by about 19%.

Figure 4.18 Plastic waste and recovery volumes [consultic 2004]

10 years Overview

	1994	1997	1999	2001	2003
	10^3 t/a	10^3 t/a	10^3 t/a	10^3 t/a	10^3 t/a
Waste total	2800	3240	3570	3850	4005
- post consumer	1950	2285	2610	2930	3115
- post industrial	850	955	960	920	890
Recycling	1400	1850	2090	2250	2340
- mechanical	1250	1270	1360	1405	1350
- feedstock	50	380	330	295	400
- energy	100*	200	400	550	590
Disposal	1400	1390	1480	1600	1665

* estimates

Development forecast:

Due to the expected increase in production volume an increase in waste volume is also expected for the future. Since the implementation of the Waste Disposal Ordinance, direct landfill of the wastes is no longer an option. A proportional increase in the recovered quantities should be expected, corresponding to the increased disposal costs. Increased separate collection and recovery of plastic waste from the post-consumer sector is also expected as a result of the Electrical and Electronic Equipment Act (*ElektroG*) and the End-of-Life Vehicles Ordinance.

Economic relevance:

The plastics industry accounted for 6.4% of the nationwide industrial production of 1,071 billion euros in 2004 [Plastics Europe 2005].

Import and export:

Germany currently provides 7.8% of worldwide plastics production and is therefore one of the main producer nations (North America 26%, Asia (excluding Japan) 29%, Japan 6.5%, Benelux 5%, France 3%, eastern Europe 5,5%, Africa + Middle East 5.5%). Germany is an important net exporter of plastics.

Plastics usage in Germany in 2003 is shown according to sectors in the following two Figures 4.19 and 4.20.

Figure 4.19 Plastics usage in Germany according to sectors in 2003 [Plastics Europe 2004]

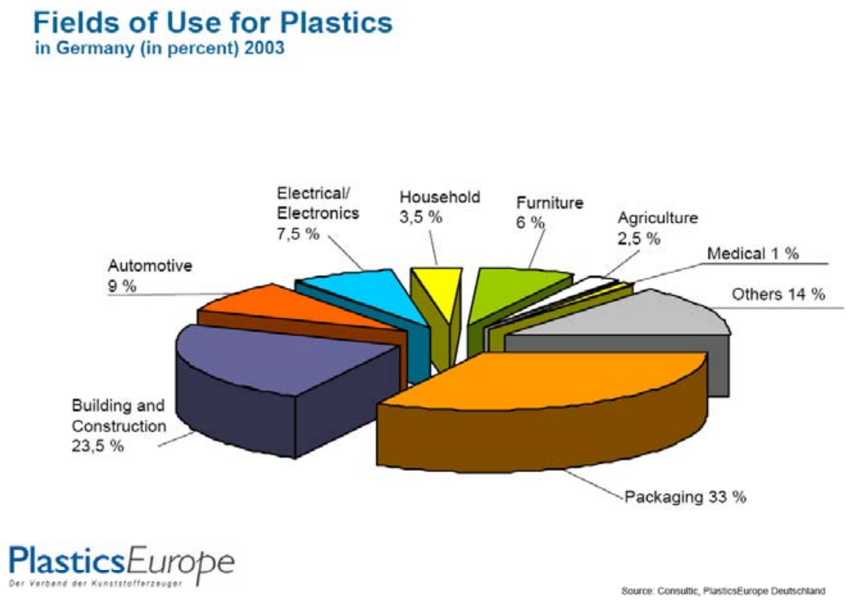
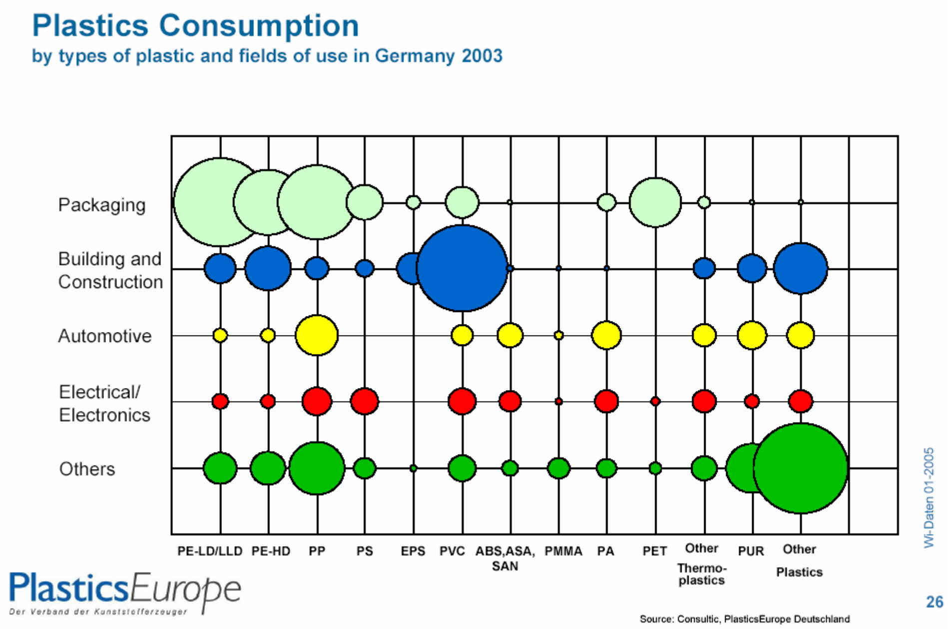


Figure 4.20 Plastics usage in Germany according to types of plastic and sectors in 2003 [VKE/Plastics Europe 2005]



Ecological indicators: Data relating to environmental criteria:

In the plastics production process chain, beginning with crude oil exploration and processing in the refinery, the refining and cracking processes represent the most environmentally relevant process steps. The resulting environmental effects are dependent on the allocation method of the naphtha raw material and the products of the cracking process. A variety of techniques are employed for polymerisation of the different types of plastics. Of these, the high pressure polymerisation of LDPE is very energy intensive (see Table 4.15).

Table 4.15 Environmental effects of plastics production

	Greenhouse Gases	Acidification	CED-total	CED-fossile	Mineral resources	Metals
Emission Factors Production						
	kg CO2-Eq/kg	kg SO2-Eq/kg	MJ/kg	MJ/kg	kg/kg	kg/kg
Ethylen	1.35	0.0039	66.0	65.8	0.00091	8.36E-07
Propylen	1.39	0.0039	67.4	67.2	0.00069	8.25E-07
HDPE granule	1.86	0.0064	76.7	75.9	0.00067	5.04E-06
LDPE granule	2.03	0.0077	78.1	76.8	0.00135	1.90E-05
PET amorph	3.20	0.0154	80.8	80.2	0.00244	2.15E-06
Total Emissionen of German Production 2004						
	Mt CO2-Eq/a	Mt SO2-Eq/a	TJ/a	TJ/a	Mt/a	Mt/a
Ethylen	2,618	7.47	127,969	127,665	1.758	0.002
Propylen	2,493	7.05	121,283	120,994	1.241	0.001
HDPE granule	2,480	8.51	102,030	100,901	0.890	0.007
LDPE granule	3,268	12.47	125,706	123,571	2.178	0.031
PET amorph	1,374	6.61	34,723	34,491	1.051	0.001

The environmental impact of waste disposal is minor compared to that of production. A net relief is generally achieved for recovery. Principle expenditure lies in the energy requirement for sorting and processing to re-granulate or to moulding plastics. As far as recycling to re-granulate takes place, the substitution potential is between 70% and 100% compared to primary materials, depending on purity, quality and field of application.

4.2.3.3 Potentials

With a production volume of 17.5 Mt in 2004 (7.8% of the world market) and a current annual rate of increase of 4.2%, the German plastics industry plays a vital role in terms of economic sectors. In addition, increasing production volume is assumed for the future. Simultaneously, as a buyer of naphtha, the plastics industry is one of the mineral oil industry's most important customers. Large ecological potentials exist on the production side of the plastics sector primarily in the upstream petroleum processing industry (see above). With regard to the actual plastic products, the immediate and future development of further substantial recycling potentials (up to 80% of accumulated volume; preliminary estimate of the Öko-Institut) represents one of the central challenges. In 2003, the recovered proportion (mechanical, feedstock and energy recovery) of plastics was a mere 58.4% relative to the accumulated volume. It should be emphasised here that in 2003 the 8.9 Mt consumed domestically considerably exceeded the total plastic waste of around 4 Mt in the same year. This means that plastics can also be stored in the technosphere (in buildings, vehicles, furniture, electronics products, etc.) and that a considerable increase in volume must therefore be expected in the future, leading to increasing recovery potentials. Consequently, an increase in the recovery proportion to 80% relative to today's waste volume will easily lead to 1 Mt/a of additional recovered plastics; however, in a long-term projection (long-term substantial storage development, which in turn must one day lead to a considerable increase in waste volume) this means up to 5 Mt/a of additional recovered volume.

4.2.3.4 Options for action

The central option for action for future years is to considerably increase the recovery volume for plastics in real terms. The recycling course pursued here (mechanical recycling or energy recovery) depends on the individual plastics, their fields of application, the logistics in place or subsequently put into practice and not least on suitable customers. The mobilisation and recycling of plastics from mid- to long-life applications with the greatest ecological benefits (see section on residential buildings) is a future-oriented task and is also supported by a series of critical legislative regulations (prohibition of disposal of the respective untreated waste since June 2005) and their consequences (enhanced attractiveness of material segregation and recycling by making disposal more expensive). The attentive treatment of problem substances occurring in parts of the volume of waste plastics (e.g. heavy metals), and their environmentally compatible segregation and discharge from the materials cycles, are of particular importance for optimal recycling success.

4.2.4 Important existing regulations

When discussing important existing regulations, specifications primarily addressing questions of plant immission and emission control and those addressing product specifications should be differentiated. The installations for distilling or refining or other processing of crude oil or petroleum products in mineral oil or lubricant refineries are subject to the Greenhouse Gas and Emissions Trading Act. The chemical industry has adopted numerous voluntary commitments; however, some are so specific that no synergy effects for the substance flows considered here result.

Fuel quality specifications (to DIN) exist for all current common automobile fuels (petrol, diesel, biodiesel, liquefied gas and natural gas). Certain pollutants are regulated by prohibitions and minimum content specifications for these fuels (lead, chlorine and bromide compounds, sulphur). Emission control regulations apply to natural gas consumption.

4.2.4.1 Greenhouse Gas and Emissions Trading Act (TEHG)[35]

The following plant forming part of the material flow system is subject to the TEHG with regard to CO_2:

- Installations for distilling or refining or other processing of crude oil or crude oil products in mineral oil or lubricant refineries.

4.2.4.2 Federal Immission Control Act (13th Federal Immission Control Ordinance, 17th Federal Immission Control Ordinance, Technical Instructions on Air Quality Control 2002)

The Federal Immission Control Act[36], in particular the 13th Federal Immission Control Ordinance[37] and - if waste is incinerated – the 17th Federal Immission Control Ordinance[38], must be taken into consideration for the approval of large combustion plant (both as large combustion plant in refinery power stations and for process firing). The aim of the 13th Federal Immission Control Ordinance is to limit pollutant emissions to the air with regard to the erection, quality and operation of combustion and gas turbine plant, as well as gas turbine plant for driving machines with a net furnace heat input of 50 megawatts[39] or more for firing solid, liquid or gaseous fuels. Universal requirements (also known as a "bell") are particularly problematic when approving large combustion plant. In combustion plant using mixed fuels in a refinery, in which distillation and conversion residues are utilised for internal plant consumption, the combustion plant permissible emission threshold value of the regularly depends on the fuels employed (see Article 8, Section 3, Clause 1 of the 13th Federal Immission Control Ordinance). In divergence to this regulation the approving authority may, on request, also approve a daily average emission threshold for these plant of 600 mg/m³ and of 1,200 mg/m³ for the half

[35] Act on the Trade with Entitlements for the Emission of Greenhouse Gases (Greenhouse Gas Emissions Trading Act - TEHG) of 8th July, 2004, Federal Law Gazette I pg. 1578; last amended by Section 2 of the Act on 22nd September, 2005, Federal Law Gazette I, No. 61, pg. 2826.

[36] Act on the Prevention of Harmful Effects on the Environment Caused by Air Pollution, Noise, Vibration and Similar Phenomena (Federal Immission Control Act – *BImSchG*) of 26th September, 2002, Federal Law Gazette I pg. 3830; last amended by Section 1 of the Act on 25th June, 2005, Federal Law Gazette I, No. 39, pg. 1865.

[37] Thirteenth Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on Large Combustion and Gas Turbine Plant – 13th BImSchV) of 20th July, 2004, Federal Law Gazette I, pg. 1717; last amended on 15th November, 2004, Federal Law Gazette I, pg. 2847.

[38] Seventeenth Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on Incineration and Co-Incineration of Waste – 17th BImSchV) of 14th August, 2003, Federal Law Gazette pg. 1633.

[39] Plant with less than 50 MW furnace net heat input are covered by the regulations in the Technical Instructions on Air Quality Control 2002 (*TA-Luft*). Neither the 13th Federal Immission Control Ordinance nor the Technical Instructions on Air Quality Control contain special regulation for gas turbines with downstream auxiliary-fired waste heat recovery boilers.

hour average, with regard to sulphur dioxide and sulphur trioxide, given as sulphur dioxide and measured as a mean value weighted in terms of the exhaust flow rates of all process heating plant, regardless of the fuel used.

Large combustion plant co-incinerating waste is covered entirely by the 17th Federal Immission Control Ordinance. The ordinance applies to the erection, quality and operation of this plant if, for example, these fire solid, liquid or gaseous wastes enclosed in containers or solid, liquid or gaseous substances generated during the pyrolysis or gasification of wastes.

4.2.4.3 Chemicals Act (*ChemG*) and Chemicals Prohibition Ordinance (*ChemVerbotsV*)

In order to protect humans and the environment against the damaging effects of hazardous substances and as a precautionary measure, the Federal Government may enact manufacturing, distribution and application prohibitions and restrictions, and establish manufacturing or application process prohibitions and restrictions (Article 17, Section 1, Nos. 1 to 3, Chemicals Act - *ChemG*[40]). The Chemicals Prohibition Ordinance is such an ordinance in accordance with Article 17, Section 1, Chemicals Act. Article 1 of the Chemicals Prohibition Ordinance identifies prohibitions and exceptions for marketing certain substances and preparations, and substances, preparations and products which may release or contain aforementioned certain substances and preparations. The respective substances or preparations are listed, divided into sections, in the annex to the Chemicals Prohibition Ordinance:

- Column 1 contains the substances and preparations.
- Column 2 contains the prohibitions for these substances and preparations.
- Column 3 contains the exceptions to the prohibitions.

4.2.4.4 Voluntary commitments of the chemical industry[41]

The voluntary commitments of the chemical industry are numerous and are listed below. However, some are so specific that they cannot all be described in detail:

- **Climate protection**

In its 1996 voluntary commitment declaration the chemical industry pledged to reduce energy-related CO_2 emissions and specific energy consumption by 30% respectively for the period 1990 to 2005. According to information available from the VCI (*Verband der Chemischen Industrie* – Chemical Industry Association), the chemical industry had already achieved the aims of the voluntary commitment due to the exceptional measures implemented by its member companies.

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40 Act on Protection against Hazardous Substances (Chemicals Act - *ChemG*), in the version published on 20.06.2002, Federal Law Gazette I pg. 2076.

41 A list of all the chemical industry's voluntary commitments can be found at www.vci.de.

In its new November 2000 voluntary commitment declaration the chemical industry pledges:

- To reduce those greenhouse gases relevant to the chemical industry stipulated in the Kyoto protocol (energy-related CO_2 emissions and N_2O) by 45-50% in CO_2 equivalent for the period 1990 to 2012. This corresponds to an absolute reduction of 91.2 Mt CO_2 equivalent in 1990 to 50 to 46 Mt CO_2 equivalent in 2012.
- To also further improve energy efficiency. To reduce specific energy consumption for the same period by 35-40%.
- To present, during the extended period, the *Rheinisch-Westfälischen-Institut für Wirtschaftsforschung* (RWI Essen Research Institute) an annual report on the development of specific energy consumption, energy-related CO_2 emissions and nitrous oxide (N_2O) emissions.

- **Voluntary commitment – Voluntary identification of plastic products**

A voluntary identification system for packaging materials is introduced in accordance with Directive 94/62 by decision 97/129/EC of the Commission on the identification system for packaging materials.[42] The Commission decision envisages the identification of packaging materials using letters and numbers. Use of this identification is initially voluntary, but may be made obligatory at a later date.

- **Voluntary commitment of the PVC industry**

A pan-European PVC industry voluntary commitment has existed since 2000. The PVC industry voluntary commitment on sustainable development is a 10-year programme comprising a half-way evaluation of targets in 2005 and the definition of new targets in 2010, taking technical advances and EU expansion into due consideration. An additional component of the programme is a strict monitoring process with regard to its implementation in the shape of certified annual reports. Sorting/segregation of PVC waste in the post-consumer sector poses problems. The commitment makes the following stipulations:

- Adhering to the ECVM Charta with regard to emission thresholds in PVC production.
- Planning for complete substitution of lead stabilisers by 2015 in addition to the substitution of cadmium stabilisers applicable since March 2001.

[42] Decision 97/129/EC of the Commission of 28th January 1997 establishing an identification system for packaging materials pursuant to European Parliament and Council Directive 94/62/EC on packaging and packaging waste, Official Journal No. L50 of 20.02.1997, pg. 28.

- The recovery of 200,000 tonnes of "post-use PVC waste" in 2010. This target applies in addition to the recovery quantities declared in 1999 for "post-use waste" and any recovery of "post-use waste" in accordance with the implementation requirements of the EU directives on packaging waste, end-of-life cars and end-of-life electrical and electronic equipment for the post-1999 period.
- Recovery of 50% of the collectable PVC waste originating from window frames, pipes, fittings and roofing sheets as of 2005 and from floor coverings as of 2008.
- A research and development programme aiming at new recovery and reclamation technologies including feedstock recovery and solvent-based technologies.
- Partnership with the communities within the "Association of Communes and Regions for Recycling (ACRR)" with the aim of promoting both best practice and local pilot schemes in the recovery field.

4.2.4.5 Electrical and Electronic Equipment Act

The Electrical and Electronic Equipment Act shall be discussed here, because electrical and electronic equipment contain a large proportion of plastics. A minimum quota for the separate collection of end-of-life equipment is specified by the Act Governing the Sale, Return and Environmentally Sound Disposal of Electrical and Electronic Equipment (Electrical and Electronic Equipment Act - *ElektroG*)[43]. It is aimed to separately collect an average of at least four kilograms of end-of-life equipment per capita and year from private households by 31st December 2006.

Recovery quotas for end-of-life equipment are specified in Article 12 depending on the equipment categories. For example, at least 80 percent of the average weight of the respective equipment must be recovered from end-of-life equipment of categories 1 and 10 and the proportion of recycling and feedstock recovery from components, materials and substances at least 75 percent of the average weight of the respective equipment. The Act does not contain special regulations for recycling plastics. Selective treatment with regard to hazard mitigation of materials and components from end-of-life electrical and electronic equipment is regulated in Annex III. For example, plastics containing brominated flame retardants must be removed from end-of-life equipment.

[43] Of 16th March 2005, Federal Law Gazette, pg. 762.

4.2.4.6 Commercial Waste Ordinance[44]

The principal aim of the Commercial Waste Ordinance, which focuses on regulating the recovery and disposal of commercial municipal waste and building and demolition waste, is the segregation of waste fractions in order to achieve higher feedstock or energy recovery. Plastics represent one of the most important waste fractions. Further information on the Commercial Waste Ordinance can be found in the legal regulations for the material flow system "Mineral resources-cement-concrete-residential building".

4.2.4.7 Packaging Ordinance[45]

The Packaging Ordinance prescribes a minimum target of 22.5 material weight percent for feedstock recovery of plastics from packaging waste by 31.12.2008. Further information on the Packaging Ordinance can be found in the legal regulations for the material flow system "Biomass-forestry-paper and furniture consumption".

4.2.4.8 Fuel consumption

4.2.4.8.1 Petrol Lead Act[46]

The Petrol Lead Act prohibits the marketing of petrol with a specified lead compound content and other metal compound additives used in place of lead.

4.2.4.8.2 3rd Federal Immission Control Ordinance[47]

The 3rd Federal Immission Control Ordinance contains stipulations for the sulphur content of light and heavy fuel oil used as a fuel and for diesel fuel for operating diesel engines. Light fuel oil and gas oil were previously only allowed to be commercially provided to others for marine transport purposes or in the course of economic activities if the sulphur compound content, calculated as sulphur, did not exceed 0.20 mass percent. 0.10 mass percent may not be exceeded as of 1st January 2008 (Article 3, Section 1, 3rd Federal Immission Control Ordinance).

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[44] Ordinance on the Management of Municipal Wastes of Commercial Origin and Certain Building and Demolition Wastes (Commercial Waste Ordinance – *GewAbfV*) of 19th June 2002, Federal Law Gazette I pg. 1938, last amended by Section 2 of the Act on 25th July 2005, Federal Law Gazette I, No. 46, pg. 2252.

[45] Ordinance on the Prevention and Recovery of Packaging Waste (Packaging Ordinance - *VerpackV*) of 21st August 1998, Federal Law Gazette I pg. 2379; last amended by Section 1 of the Act on 24th September, 2005, Federal Law Gazette I, No. 29, pg. 1407.

[46] Act for Reduction of Air Pollution by Lead Compounds in Petrol for Motor Vehicle Engines (Petrol Lead Act – *BzBlG*) of 5th August 1971 (Federal Law Gazette I pg. 2795), last amended on 25th November 2003 (Federal Law Gazette I pg. 2308).

[47] Third Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on Sulphur Content of Certain Liquid Vehicle and Heating Fuels – 3rd *BImSchV*) of 24th June 2002, Federal Law Gazette I pg. 2243.

Since 1st January 2003, heavy fuel oil may only be provided to others commercially or in the course of economic activities if the sulphur compound content, calculated as sulphur, does not exceed 1.00 mass percent. When using heavy fuel oil in industrial combustion plant a higher sulphur content may be allowed if the fuel oil may be used in such combustion plant in compliance with the requirements of the Ordinance on Large Combustion Plant or the First General Administrative Regulation to the Federal Immission Control Act (Technical Instructions on Air Quality Control) and is intended exclusively for this purpose (Article 3, Section 1, 3rd Federal Immission Control Ordinance). Since 1st January 2005, diesel fuel may only be provided to others commercially or in the course of economic activities if the sulphur compound content, calculated as sulphur, does not exceed 50 mg/kg (Article 3, Section 3, 3rd Federal Immission Control Ordinance).

4.2.4.8.3 Marine fuels

Threshold values for air pollutants are specified in Annex VI of the international MARPOL convention for the prevention of pollution from ships; Germany has ratified Annex VI of this international convention. It includes NOx standards for marine engines and monitoring areas for SOx emissions (Baltic Sea, North Sea and the English Channel). EU Directive 2005/33/EC[48] has been in force since August 2005. Among other things, it prescribes that member states restrict the threshold for the sulphur content of marine diesel for passenger ships to 1.5% by 11.08.2006.

4.2.4.8.4 10th Federal Immission Control Ordinance[49]

The 10th Federal Immission Control Ordinance prescribes the requirements for petrol, diesel, bio-diesel, liquefied gas and natural gas in order for them to be sold to consumers. The fuels must satisfy certain DIN specifications for this purpose. As of 01.01.2009 the sulphur content of petrol and diesel may not exceed 10 mg/kg.

4.2.4.8.5 19th Federal Immission Control Ordinance[50]

The 19th Federal Immission Control Ordinance applies to fuels for operating motor vehicles and for chlorine and bromide compounds used as additives to fuels for operating motor vehicles. It stipulates that fuels may only be marketed commercially or in the course of economic activities if they do not contain any chlorine or bromide compounds as additives.

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[48] Directive 2005/33/EC of the European Parliament and of the Council of 6th July 2005 amending Directive 1999/32/EC as regards the sulphur content of marine fuels, Official Journal No. L 191 of 22.07.2005 pg. 59.

[49] Tenth Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on the Nature and the Identification of Quality of Fuels – 10th *BImSchV*) of 24th June, 2004, Federal Law Gazette I pg. 1342).

[50] Nineteenth Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on Chlorine and Bromide Compounds as Fuel Additives – 19th *BImSchV*) of 17th January 1992, Federal Law Gazette I pg. 75).

4.2.4.8.6 20th Federal Immission Control Ordinance[51]

The 20th Federal Immission Control Ordinance aims to limit the emissions of volatile organic compounds when handling and storing petrol. Among other things, it contains regulations for the construction and operation of large fuel depots (throughput of 25,000 t), such as vapour recovery systems for reclaiming petrol from vapours or an installation for energy recovery from vapours, in particular in a gas engine.

4.2.4.8.7 21st Federal Immission Control Ordinance[52]

The 21st Federal Immission Control Ordinance applies to the erection, the nature and the operation of petrol stations, inasmuch as the fuel tanks of motor vehicles are filled with petrol and the petrol stations do not require a permit in accordance with Article 4 of the Federal Immission Control Act. The aim of this regulation is to erect and operate petrol stations such that when filling vehicles with petrol the fuel vapours displaced from the vehicle tank are collected and delivered to the petrol station storage tank using a vapour recovery system according to current best practice. In order to check for failures in the vapour recovery system, the mineral oil industry association (*Mineralölwirtschaftsverband e.V.*) has regulated, in a voluntary commitment, the introduction of a "quick tester" at petrol stations since 2000, as well as documentation of the defect remedy.

4.2.4.8.8 Combustion Ordinance and 1st Federal Immission Control Ordinance (stipulations for fuel oil)

The Ordinance on Combustion Plant, Heat and Fuel Supply Plant (Combustion Ordinance - *FeuV*)[53] regulates stipulations concerning the storage of fuel oil. Beside this, the 1st Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on Small and Medium-Sized Combustion Plant – *1st BImSchV*) also contains immission control regulations. This states that in small combustion plant in the context of the 1st Federal Immission Control Ordinance only extra light fuel oil to DIN 51603-1, Issue March 1998, may be used.

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51 Twentieth Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on the Limitation of Emissions of Volatile Organic Compounds when Handling and Storing Petrol – 20th *BlmSchV*) of 27th May 1998 (Federal Law Gazette I pg. 1174), last amended on 24th June 2002 (Federal Law Gazette I pg. 2249).

52 Twenty-first Ordinance for the Implementation of the Federal Immission Control Act (Ordinance on the Limitation of Hydrocarbon Emissions when Filling Motor Vehicles – 21st *BImSchV*) of 7th October 2003 (Federal Law Gazette I pg. 1730); last amended on 6th May 2002 (Federal Law Gazette I pg. 1566).

53 Of 6th March 1998, Law and Ordinance Gazette pg. 112, amended on 19th July 2005, Law and Ordinance Gazette pg. 310.

4.2.5 Synopsis of options for action for this material flow system

In order to further utilise the considerable potentials for reducing environmental impacts the following recommendations can be particularly emphasised for the crude oil/natural gas-petroleum processing-fuel consumption material flow system following the project investigations:

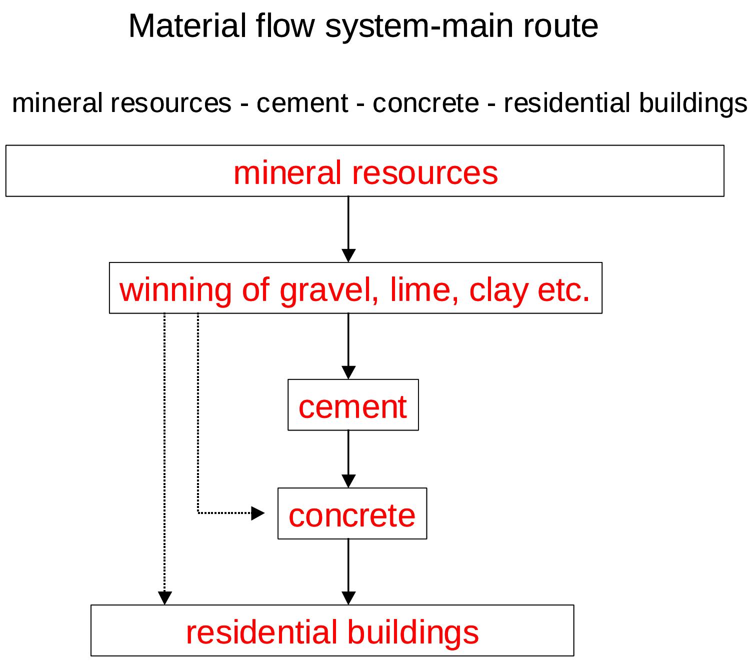
- The rehabilitation in terms of energy-efficiency of the predominantly aging plant base in German refineries (reference standard: energy efficiency achieved in new plant).
- Reduction of the still considerable sulphur dioxide emissions in German refineries by strict implementation of end-of-pipe solutions as already used in power stations.
- A considerable increase in real terms in the recovery volume for plastics represents an important option for action for future years. The mobilisation and recovery of plastics from mid- to long-life applications with the greatest ecological benefits should assume a central role here (greater and continuously increasing store build-up in the technosphere). The legal framework offers a sound foundation; however, measures are required to optimise separate collection during the dismantling of buildings and, where necessary, to remove sub-flows contaminated by pollutants (e.g. heavy metals) from the material cycles.

4.3 Mineral resources-cement-concrete-residential buildings

4.3.1 Material flow system synopsis: Main route

On the production side, the mineral resources-cement-concrete-housing material flow system (see Figure 4.21) comprises as its core element the important primary production of cement and the principal customer directly associated with this, the concrete industry. On the demand side, the housing sector continues to assume a leading role despite the fall in new building activity since the mid nineteen-nineties. The housing sector continues to be extremely relevant for the products of other industrial sectors such as the plastics industry, the glass industry, the brick industry, etc.

Figure 4.21 Material flow system – Main route: Mineral resources-cement-concrete-residential buildings



4.3.2 Synopsis of the cement industry in Germany

4.3.2.1 Facts and figures

The German cement industry – as in all industrial nations – is one of the key primary industries in the primary production sector and, together with the concrete industry, the most important buyer of mineral raw materials. It is therefore only right that Germany's cement production is thoroughly discussed below. Information on the concrete industry, the cement industry's largest customer by far, is provided in the following section.

In the cement industry's own words they are characterised by the following qualities (www.bdzement.de): *"The cement industry is very capital intensive. Investment projects therefore only pay for themselves in the long-term and can only be realised if the supply of raw materials is guaranteed. The cement industry is location-bound, that is it is bound to raw material deposits in the immediate vicinity of the plant and sells its products primarily in regional markets, due to the high transport cost intensity. Production close to the consumer is not only associated with economic advantages, but also with ecological advantages (avoiding transport). The cement industry is raw material- and energy-intensive. Conservation of resources and increasing efficiency are therefore important fields of action for the companies involved for simple economical reasons."*

In 2004, 23 companies produced around 32 Mt cement in 59 operations in Germany [BDZ 2005]. The German Federal Cement Industry Association (*Bundesverband der Deutschen Zementindustrie e.V.*) (*BDZ*) emphasises that the cement industry has continuously invested in Germany in past years, despite the poor economic situation in the building industry and growing internationalisation. The branch points out that between 1995 and 2003 the gross investment in plant totalled 2.1 billion euros – for an average annual turnover of 2.4 billion euros. They also emphasise that around 20% of new investment is accounted for by environmental protection measures (www.bdzement.de). In 2001, the number of employees in the German cement industry was approx. 11,000 at an annual turnover (excluding VAT) of 2.41 billion euros.

49% of cement production goes to the ready-mixed concrete industry. Further buyers include manufacturers of prefab concrete components at 25%. Finally, sales of sacked cement also play a role at 10% [VDZ 2005a]. In 2001 approximately 36% of cement in Germany was utilised for civil engineering purposes, 35% on housing and 28% in non-housing building. The German cement industry is closely intertwined with the concrete industry. The Concrete Information Centre (*Informationszentrum Beton GmbH*) (IZB) is a subsidiary of the German Federal Cement Industry Association (BDZ). The BDZ, in turn, is a member of the European Cement Manufacturer's Association (CEMBUREAU).

The principal material input in cement manufacturing is finely ground Portland cement clinker mixed with calcium sulphate (natural gypsum, anhydrite or FGD gypsum); cement may also include granulated slag, fly ash, natural Pozzolana (for example Trass), oil shale firing residues or limestone as primary constituents [VDZ 2005a]. The raw material mix for cement clinker is heated to sintering temperature at around 1,450°C in a rotary kiln (in Germany today primarily dry in rotary kilns with a cyclone pre-heater, only a few ovens have grate pre-heaters). The roasted clinker is then ground to cement in cement mills adding calcium sulphate and any further main constituents required. Because cement is a transport-cost-intensive mass ware it is delivered almost entirely to local markets. The raw material input in the cement industry is shown in detail in Table 4.16.

Table 4.16 Raw material input for the German cement industry in 2004 [VDZ 2005a]

Group	Raw material	Input 2004 in 1000 t
Ca	Limestone/marl/chalk	41,045
Ca	Lime sludge from drinking water and effluent treatment, slaked lime, foamed concrete granulate, calcium fluoride	101
Si	Sand	1,334
Si	Waste foundry sand	151
Si-Al	Clay	1,298
Si-Al	Bentonite/kaolinite	49
Si-Al	Coal treatment residues	3
Fe	Iron ore	134
Fe	Other input substances from the iron and steel industry such as roasted pyrites, impure ore, iron oxide/fly ash mix, steelworks dust, rolling mill scale	93
Si-Al-Ca	Granulated slag	5,110
Si-Al-Ca	Fly ash	378
Si-Al-Ca	Oil shale	164
Si-Al-Ca	Trass	34
Si-Al-Ca	Others, such as paper residues, combustion ashes, mineral residues, oil-contaminated soils	170
S	Natural gypsum	569
S	Natural anhydrite	541
S	FGD gypsum	428
Al	Input substances from the metals industry such as treatment residues from salt slags, aluminium hydroxide	60
Total		**51,662**

Raw material input per tonne of cement (total production 2004: 32 Mt cement) is therefore 1.61 t. However, around 6.5 Mt of the raw materials used (12.6% of raw material input) are secondary raw materials from a variety of sources. Around 14.2 Mt of raw material-related CO_2 emissions were released in 2004.

The building industry already utilises 100% of available fly ash (approx. 4 Mt/a) The fly ash is either mixed with other cement types in the cement plant or used as an additive in concrete plant. The recovery of granulated slag is also important. This blast furnace slag is traditionally employed in the cement industry: (see table above:

> 5 Mt 2004), the primary energy saving in the German cement industry by using granulated slag is estimated to be around 7% [ISI 2004].

The proportion of the energy production factor for the German cement industry is 26% of gross added value, providing a strong incentive for energy savings (www.bdzement.de). The specific fuel energy input in the German cement industry was 2.943 kJ/kg of cement in 2004; the electrical energy input for the same year was 101.8 kWh/t of cement. In 2004, 0.675 t of CO_2 emissions were recorded per tonne of cement (0.162 t thermal-related, 0.070 t electrical-related, 0.443 t raw material-related), 60% of the total CO_2 emissions of the cement industry were raw material-related [BDZ 2005)]; this is a special property of this branch.

4.3.2.2 Dynamics and trends

Table 4.17 summarises the most recent trends with regard to production, sales, export and import for the German cement industry.

Table 4.17 Production, sales and export for the German cement industry in 2004 [BDZ 2005], [VDZ 2005b]

	2002 (1,000 t)	2003 (1,000 t)	2004 (1,000 t)
Clinker production	23,954	25,233	26,281
Cement sales (incl. clinker export)	31,247	33,410	33,439
Domestic sales	27,377	28,747	27,497
Export incl. clinker	3,870	4,663	5,942
Cement import	1,544	1,184	1,347
Domestic consumption	28,921	29,931	28,844

The following figures were reported for domestic sales in previous years: 1999: 33,776 Mt, 2000: 31,985 Mt, 2001: 28,034 Mt (www.bdzement.de). It can be seen that following the downturn between 1999 and 2001 the domestic sales for 2004 have remained remarkably stable considering the poor economic situation in the building industry.

Domestic consumption[54] (not to be confused with domestic sales or domestic shipping) fell from 41.2 Mt to 31.1 Mt between 1994 and 2001 (further downturn by 2004 to 28.8 Mt). Imports fell in the same period from 6.9 Mt to 2.3 Mt (see table above: further downturn in imports by 2004). It can be concluded that the German cement industry has asserted itself on the market despite considerably lower domestic consumption (downturn in the economic situation in the housing building

[54] Domestic consumption = domestic shipping and domestic sales + import

industry, etc.) (cf. data on clinker production and cement sales incl. clinker export). In this context, the volume of cement imported to Germany has fallen drastically over the past years on the one hand, while on the other hand exports from Germany have been forced.

The specific electricity consumption for cement production in Germany shows an increase (1970 approx. 92 kWh/t cement) until the mid-nineteen eighties to around 110 kWh/t cement. The reasons for this are higher product requirements and greater technical environmental protection efforts. In the following years a decrease to 101.8 kWh/t cement was noted up to 2004 due to innovations such as improved grinding technology.

The specific fuel input in the German cement industry has been halved between 1950 and today (only minor changes since the beginning of the nineteen nineties). An outstanding trend in past years was the use of secondary fuels. Their use more than quadrupled within the space of ten years. Table 4.18 shows the proportions of fuel inputs in the German cement industry for the years 1994 and 2004.

Table 4.18 Fuel input in the German cement industry for 1994 and 2004, after [VDZ 1996], [VDZ 2005b]

Fuel	% in 1994	% in 2004
Anthracite	48.4	16.4
Lignite	31.6	33.3
Petroleum coke	1.9	4.0
Fuel oil heavy/extra light	0.5	2.9
Natural gas and other gases	5.6	0.5
Other fossil fuels	1.9	0.7
Secondary fuels	10.1	42.2

The total fuel input for 1994 was 103.0 million GJ/a and 95.3 million GJ/a in 2004.

Essentially, the development of cement production is directly related to the economic situation in the building industry. A noteworthy increase in production in the German cement industry is not expected in the mid- to long-term (until around 2025). Considering that plant investment in this branch is long-term in nature and cement is required as a key building material in all sectors of the building industry (and is therefore not entirely subject to fluctuations in some areas such as housing), stagnation with regard to the production magnitude is expected, but not a dramatic fall in production. No considerable relocation in production capacity is expected because the proximity to raw material deposits and regional markets are exceptionally important.

The cement industry will continue to be of central importance in the future as a primary sink for diverse secondary raw materials and secondary fuels.

4.3.2.3 Potentials

The specific energy input and the associated CO_2 emissions were and are important topics for the German cement industry as an important energy-intensive primary sector. The voluntary commitment of the German cement industry (9th Nov. 2000) envisages a 28% reduction in energy-related (fuel- and electricity-related) specific CO_2 emissions by the 2008/2012 period relative to 1990. In addition, the emission trading system has been installed since 01.01.2005: this affects all companies in Germany producing clinker (note: excluding electricity-related CO_2 emissions but including geogenic = raw material-related emissions).

Regardless of the fact that technical limits to further measures for reducing the specific fuel input and the specific input of electrical energy can be foreseen[55], the 28% reduction target for CO_2 (approx. 2 Mt/a CO_2) defined in the voluntary commitment declaration may be adopted as a potential. An important role is ascribed to the future volume of secondary fuels of biogenic origin (waste wood, etc.). It must be emphasised that due to the great importance of this sector, emission reductions of only a few percentage points will represent an important contribution to the national climate protection targets.

Another important cement industry potential is the required retrofitting of older plant with regard to the emissions of nitrogen oxides. With regard to the current threshold value of 500 mg NO_2/m^3 defined in the Technical Instructions on Air Quality Control the branch itself says: *"..in 2004 the emissions of some plant exceeded the emission values envisaged today in the Technical Instructions on Air Quality Control for cement works. The operating permits for these works are based on higher NOx thresholds. Some of these plants are now closed, or will be in the next few years, others will be retrofitted with NOx reduction systems."* (BDZ 2005). The work on the BAT at the European level specifies emission concentrations of 200 to 500 mg NOx/m^3 (as NO_2) for nitrogen oxides. In this respect attention is drawn not least to SNCR technology (selective non-catalytic reduction) [BAT Cement 2001]. In 2004, 32 systems were operating with SNCR technology. A cautious estimate reveals a possible reduction potential of 10% to 20% for nitrous oxide emissions (relative to 2004) from retrofitting old plant in Germany (i.e. minus 4,000 to 8,000 t/a)[56].

4.3.2.4 Options for action

One option for action is the timely retrofitting of old plant to meet modern reduction system standards with regard to nitrous oxide emissions. Appropriate technical

55 *Cf*. [BAT Cement 2001]: The use of electrical energy in the EU: 90–130 kWh/t cement (compare to current value of 101 kWh/t in Germany).

56 This reduction potential corresponds to approx. 0.25 to 0.5% of total German emissions.

solutions (SNCR technology) are available for this purpose and are underpinned by the European BAT process [BAT Cement 2001]. Moreover, an important option for action is represented by further increasing energy efficiency and additionally forcing the use of suitable secondary fuels (also see Chapter 6 on further investigation requirements with regard to the cement industry).

4.3.3 Synopsis of the concrete industry in Germany

4.3.3.1 Facts and figures

The two primary product groups of the concrete industry are prefab concrete components and ready-mixed concrete. Table 4.19 shows a summary of products for 1997 [ISI 2004]:

Table 4.19 Product groups in the concrete industry

Product group	Production in Mt	Production in Mm³
Lightweight concrete masonry bricks	1.28	0.80
Normal concrete masonry bricks	16.40	7.10
Structural prefab components	4.25	1.85
Other prefab components	4.89	2.13
Garages and other prefab components	1.30	0.57
Wall sections	2.75	1.20
Roofing slabs	5.83	2.53
Roofing tiles	3.30	1.43
Preformed chimney sections	0.40	0.17
Prefab components for horticulture and landscaping	1.45	0.63
Paving slabs and paving stones	21.50	9.34
Concrete pipes	3.45	1.50
Ready-mixed concrete	112.60	49.00
Total	**179.40**	**78.25**

Production of concrete and concrete products follows the economic situation in the building industry. Around 80 Mm³ of concrete products are produced in Germany annually. After [ISI 2004], significant trends in structural and civil engineering which would lead to massive material substitutions cannot be discerned. Concrete is represented in all sectors of the building industry. However, it is represented most strongly in housing in the ceilings and lintels field. In the non-housing sector (primarily office and similar buildings) concrete contributes highly to load-bearing walls, i.e. concrete dominates in non-housing buildings, in contrast to classical wall materials such as brick, etc. Ready-mixed concrete for in-situ concrete purposes accounts for around 60% of concrete products. Prefab concrete components, paving stones and concrete masonry bricks account for around 10% each.

Principal material inputs for concrete production include cement, aggregates, water, concrete admixtures (cement ersatz, pigments, etc.) and concrete additives. The final strength of the concrete is controlled by the quantity and quality of the cement. Typically, the cement content of concrete is 280–350 kg/m^3 of compacted concrete. For outdoor reinforced concrete components to DIN 1045, this must be at least 300 kg/m^3. The inert aggregates serve as fillers and influence the physical characteristics of the hardened concrete. Generally, sand and gravel are used as aggregates, whereby defined sieving curves must be adhered to depending on the specific application. Sand is the material of choice for the fine 0/2 mm fractions, while the coarser 2/4, 4/8 and larger fractions are covered by gravel. Concrete additives (50g/kg of cement max.) are used to control the wet concrete consistency, the curing speed and other concrete properties. [ISI 2004]

4.3.3.2 Dynamics and trends

Similar to cement production, future concrete production can only be estimated. It follows the economic cycles of the building industry. Stagnation of the annual production level at around 80 Mm^3 is the most probably scenario in the mid- to long-term.

An important question from the point of view of resource conservation is that of the future development of the volume of demolished concrete. This plays an important role as a recovery material from building wastes. Using the data of the Working Group for Building Industry Sponsors of Closed Cycle and Waste Management Policy [KWTB 2001], the Fraunhofer Institute for Systems Technology and Innovation Research (ISI) estimates a total accumulation of 30 Mt of demolished concrete for 1998 (incl. concrete slabs from excavated roads). A whole series of classical recovery routes exist for demolished concrete [Kohler et al. 2001]:

Unstabilised RC aggregate mixes[57]

- Base courses below asphalt road surfaces,
- base courses below concrete road surfaces,
- frostproof courses below paving,
- crushed stone base courses below paving,
- ballast material for paving,
- Fill material for embankments, ramps and other earthworks.

Hydraulically stabilised RC concrete

- Hydraulically stabilised base courses below paving,
- additive for blinding layers below foundations,

[57] RC = abbreviation for recycled construction materials

- additive for rear retaining concrete for kerbs, paving and gutter sets,
- additive for blinding concrete in cavity filling.

According to model analyses carried out by Görg [Görg 2002], the demolished concrete volume, excluding excavated roads, will increase sharply based on 12 Mt in 1994, developing over time to approx. 90 Mt by 2020. The model uses a statistical distribution of building lifetimes. The model analysis is based on the simple assumption that the considerable quantities of concrete emplaced during the years of the German *economic miracle* are removed from the technosphere by the demolition of buildings in accordance with a defined mean lifetime and are thus made accessible to recycling. However, the monitoring reports of the Working Group for Building Industry Sponsors of Closed Cycle and Waste Management Policy [KWTB 2001, KWTB 2003] cannot yet confirm such a trend. The total volume of demolition waste shows practically no increase (note: demolished concrete forms only a part of this).

According to estimates by the Öko-Institut based on their own work [Öko-Institut 2004b], the actual lifetime of buildings is generally underestimated. This applies all the more if real market mechanisms are not taken into consideration (see Chapter on housing consumption below); i.e. the motivation for demolition is particularly strong if new building is planned for the area involved. In the case of sluggish or non-existent demand (vacant office real estate far exceeds 10% in some towns and cities), decades of vacancy can increase the "lifetime" of a building considerably before demolition. The projected wave of demolished concrete must therefore be viewed with caution, at least before 2020. Nevertheless, it is thanks to Görg that discussion has been drawn to the technosphere store (in this case in particular to the important structural engineering concrete fraction). When and at what rate of increase the immense volumes of emplaced concrete material will become available to recycling remains unclear.

4.3.3.3 Potentials

The classical recovery routes for concrete in the civil engineering sector have already been followed for years. Around 70% of accumulated discarded building materials were previously recovered [KWTB 2003]. Demolished concrete is one of the more easily recoverable fractions. Additional potentials for conserving mineral raw materials by recycling concrete are expected on the one hand from future increases in volume (also see the section on housing consumption) and, on the other hand, by forcing relatively new options for high-quality concrete recycling in structural engineering.

This young, innovative development is the reuse of suitable and suitably prepared broken concrete as a concrete aggregate, replacing gravel aggregate from natural deposits [Öko-Institut 2004b, ISI 2004]. In 1996, 1.6 Mt of recycled concrete was already being used as aggregate. [Bundesverband Baustoffe, 2000]. Some known examples are the *Hundertwasserhaus* in Darmstadt (*Waldspirale*) and an office building owned by *Bauverein AG* (also in Darmstadt). A new guideline was published by the German Committee for Reinforced Concrete (*Deutscher Ausschuss für Stahlbeton*) with the title "Concrete with Recycled Aggregate" (*Beton mit rezykliertem Zuschlag*) in 1998. The use of recycled aggregate in concrete is permissible to a limited extent (e.g. concrete grit and crushed concrete sand > 2 mm in indoor components up to B25 quality) and under certain circumstances: one requirement is that "the origin of the waste concrete is known and that an expert has classified the aggregate material without a doubt in a safe alkali sensitivity class".

Based on the guideline, a study by Schmidt Consult Heidelberg assumes a technical absorption potential for recycled concrete as an aggregate in the concrete industry of 26 Mt and an actual use in 2010 of 16 Mt max. [Bundesverband Baustoffe, 2000]. If the lower of the two values is assumed and adopted for in ratio of approximate total annual concrete production in Germany (approx. 80 Mm^3, i.e. approx. 180 Mt), the raw material (gravel) savings potential can be estimated at around 10%. Fraunhofer [ISI 2004] calculate primary energy savings of 13.57 MJ/t for breaking and recovering broken concrete as opposed to sending to landfill (balance of additional effort for breaking concrete and credit for the use of concrete rebar in an electric furnace).

The demolition of larger buildings with a greater proportion of reinforced concrete is of primary interest for high-quality concrete recycling (few incompatible substances such as gypsum, mortar, etc.). The stock of non-housing buildings chiefly represents an immense material store (see Chapter: Non-housing buildings excursus).

4.3.3.4 Options for action

The promotion of high-quality recycling of demolished concrete is a specific option for action in the concrete industry sector. It can be achieved by the selective demolition of residential and, above all, non-residential buildings. Important elements include the exemplary function for public building projects using recycled concrete, eradication of restraints and measures for avoiding contamination of concrete recyclates by incompatible and hazardous substances during demolition, e.g. gypsum, mineral fibres, etc. (see chapter on housing consumption) and promotion of the required logistics[58]. Precise information on the mid- to long-term concrete quantities accumulating in the technosphere is also required (see chapter on housing consumption or the non-housing buildings excursus).

[58] In Büttelborn near Darmstadt a ready-mixed concrete producer has built a concrete mixing plant directly neighbouring a building waste treatment plant. The qualitatively best fractions from the building waste treatment plant can thus be utilised directly on site as a concrete aggregate without additional transport effort.

4.3.4 Synopsis of housing consumption in Germany

4.3.4.1 Facts and figures

Despite a drastic decline in the volume of housing built in past years (see below), it continues to be an outstanding economical sector in Germany with an estimated volume of 41.36 billion euros in 2004. It thus continues to considerably surpass the non-housing sector, with estimated total costs in Germany of 25.68 billion euros in 2004.[59]

The Federal Statistical Office[60] provides the following important definitions for the housing sector: *Residential buildings are represented by buildings that serve residential purposes over at least half of their area (measured against the total usable area). Holiday, summer and weekend houses with a minimum of 50 m² living area are also included. The living area of housing (in accordance with the 2nd Calculation Ordinance) is the sum of allowable floor areas of the rooms belonging exclusively to the housing. The living units are differentiated into flats and other living units. A flat consists of one or more rooms, allowing the management of a household, always including a kitchen or a room with a fixed cooking facility installed. Other living units are all other living units without kitchen or cooking area. These primarily include individual or communicating rooms in residential homes for permanent dwelling of the home residents."*

However, the proportion of other living units in the total new living units under construction was only 1.57% in 2004 and therefore plays only a minor role. Housing in non-residential buildings represents a "grey area". They are separately listed in building activity statistics (proportion of new housing building in Germany in 2004: A mere 1.70%). Flats in residential and non-residential buildings are recorded together in housing stock statistics. Not included in stock statistics are flats in residential homes.

With regard to economic interactions, it should be noted that imports only play a certain role in terms of some building materials (and energy carriers for their production); nevertheless, well above 90% of building materials are from domestic, and often regional, sources (sand, gravel). Due to their low specific value (per tonne) transport costs play a relatively large role, making the transport of bulk building materials over long distances (with the possible exception of inland waterways) generally economically unattractive. Important upstream sectors include the cement, concrete and brick industries (and therefore the extraction of non-metals in general), the steel, wood and plastics industries and many other sectors of the economy.

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[59] The respective figures include construction measures on existing buildings (leading to new flats or expansion of the floor area) and value added tax.

[60] Federal Statistical Office, Technical Series 5, No. 1, Building activity and housing (*Bautätigkeit und Wohnungen*), annual.

The housing sector is equally well investigated in terms of its relevance to material and energy flows. The following selected facts and figures are taken from the paper "Sustainable Construction and Housing in Germany" (*Nachhaltiges Bauen und Wohnen in Deutschland*)[61] and are based on the year 2000. Regardless of the fact that merely heating this housing stock is the origin of a substantial proportion of the national greenhouse gas emissions (180 Mt CO_2 including upstream chains, approx. 97% domestic emissions), the housing sector is without a doubt of immense importance from an ecological perspective in terms of resource utilisation, the emission of greenhouse gases for new buildings, maintenance and a number of other criteria. Around 33 Mt of CO_2 emissions were calculated for new housing building alone for 2000, together with maintenance/modernisation. The most important contributions are primarily associated with the production of bulk building materials such as cement/concrete, bricks, sand-lime bricks, foamed concrete, steel, etc. The estimated mineral raw material requirement for housing building and maintenance for 2000 is around 150 Mt (excluding additional requirements for the necessary infrastructure such as residential roads).

This contrasts with around 33 Mt of housing sector[62] building waste in the same year; of this, only around 5 Mt were from demolition, but 28 Mt from maintenance and modernisation, etc. [63] This means that in 2000 the ratio of material input to material output for the housing sector was around 5 to 1. Finally, at this point, it is worth mentioning the important contribution of approx. 31 ha/d (net housing building land and sealed traffic area) of the housing sector to land utilisation. [Öko-Institut 2004b]

The multitude of problematic substances are much more difficult to quantify. Regardless of the fact that many have been prohibited for years in new applications, they remain in the building stock and will continue to present problems for building material cycles. The Select Committee on "Protection of Humans and the Environment" [Enquete 1998] discussed these problematic substances in the building material cycle in 1998. The following problem areas were mentioned as examples:

- arsenic (mixed building waste),
- asbestos (asbestos cement, asbestos dust, sprayed asbestos, materials containing asbestos),

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61 *Cf.* [Öko-Institut 2004b]. In this paper for the Federal Environment Agency the building and living needs area was intensively investigated with regard to possible future developments in material flows.

62 The data are in a suitable relationship to literature figures of 50 Mt/a (1998 figures) for total building waste accumulation (incl. non-housing buildings) [van Norden 2002].

63 Building waste from new building activities was not included in this calculation. In building practice – in particular in small-scale housing – building material waste accrued in new building is partially disposed of together with other site waste.

- cadmium (mixed building waste),
- chlorine (organic compounds),
- chromium (chromate) (cement),
- lindane (waste wood),
- polychlorinated biphenyls (PCBs), (jointing compounds/durable elastic sealing compounds,
- pentachlorphenol (PCP) (waste wood, structural protection).

As previously mentioned, quantification is difficult in this sector and the available data only rudimentary in nature. The following figures are taken from a 1999 Federal Environment Agency publication, providing a glimpse of the dimension of the problem [UBA 1999]. For example, PVC input in the building sector in 1997 was around 883,000 t. According to Federal Environment Agency estimates, more than 5,000 t of cadmium were used as stabilisers in the last 15 years (pre-1999); principally for windows, shutters and other hard PVC sections for use on exteriors. The typical cadmium content is given as between 0.5 and 2.5 g/kg. Furthermore, the same paper explains that lead equalling a total of 100,000 t to 300,000 t is stored in the technosphere (different figures are given by VKE and LGA Bavaria). The main fields of application for lead stabilisers in PVC include tubing, window sections, building sections and cable sheathing compounds. The typical lead content of PVC products lies between 0.5 and 3 mass percent. [UBA 1999]

Even if the data given here do not affect only the housing sector it must still be assumed that, due to the very long lifetime of the buildings, a considerable inventory of problematic substances continues to exist in the housing stock material store.

4.3.4.2 Dynamics and trends

It is clear from the following table that the housing stock in the Old Federal States (OFS) (adjusted for loss = demolition + redesignation) increased between 1994 and 2004 from 28.41 million units to 31.65 million units. This corresponds to an increase of 11.4% or 3.24 million units. The living area increased in the same period from 2.47 billion m^2 to 2.81 billion m^2, corresponding to an increase of 13.85% [StBA 1994-2004a].

Table 4.20 Housing and living area in OFS housing stock from 1994 to 2004

Housing stock OFS (31.Dec)		
year	Housing [10^6]	Living Area [10^9 m^2]
1994	28.41	2.47
1995	28.90	2.51
1996	29.30	2.55
1997	29.69	2.59
1998	30.05	2.63
1999	30.41	2.66
2000	30.73	2.70
2001	30.99	2.73
2002	31.21	2.76
2003	31.43	2.78
2004	31.65	2.81

In the New Federal States (NFS) the number of flats increased by 0.752 million units or 10.8% between 1994 and 2004. Living area increased in the same period by 74.40 Mm^2 or 15.4% [StBA 1994-2004a].

Table 4.21 Housing and living area in NFS housing stock from 1994 to 2004

Housing stock NFS (31.Dec)		
year	Housing [10^6]	Living Area [10^9 m^2]
1994	6.96	0.48
1995	7.06	0.49
1996	7.19	0.50
1997	7.36	0.52
1998	7.48	0.53
1999	7.58	0.54
2000	7.65	0.55
2001	7.70	0.55
2002	7.71	0.55
2003	7.71	0.56
2004	7.71	0.56

Overall, the housing stock in Germany increased between 1994 and 2004 by 3.99 million units (net) or 11.3%. Living area increased in the same period by 416.04 Mm^2 or 14.1%. The greater percentage increase in living area (the unit living area is more relevant for estimating or calculating material flows) compared to the number of flats is due to the fact that newly built housing (higher proportion of 1-2 family houses, etc.) is, on average, considerably larger than that being demolished [StBA 1994-2004a].

Table 4.22 Housing and living area in united German housing stock from 1994 to 2004

Housing stock Germany (31.Dec)		
year	Housing [10^6]	Living Area [10^9 m^2]
1994	35.37	2.95
1995	35.95	3.01
1996	36.49	3.05
1997	37.05	3.11
1998	37.53	3.15
1999	37.98	3.20
2000	38.38	3.25
2001	38.68	3.28
2002	38.92	3.31
2003	39.14	3.34
2004	39.36	3.37

It is clear from the following table that completed new housing fell from 505,179 units to 226,267 units between 1994 and 2003 due to the saturation of many regional markets. The slight increase to 238,290 units in 2004 should not be interpreted as an upward change in the trend. However, it is often assumed that the bottom has almost been reached in terms of housing building activity. The 53% decline in completed housing between 1994 and 2004 was considerably greater than the 38% decrease in the creation of new living area. This is because the decline in completions disproportionately affected the smaller (on average) flats in larger blocks of flats [StBA 1994-2004b].

Table 4.23 Housing and living area in OFS new housing from 1994 to 2004

New Housing OFS (31.Dec)		
year	Housing [1000]	Living Area [10^6 m^2]
1994	505	46.4
1995	499	44.9
1996	416	38.6
1997	400	39.0
1998	372	38.0
1999	370	39.3
2000	337	37.3
2001	268	30.8
2002	241	28.3
2003	226	27.0
2004	238	28.8
inclusive construction at existing buildings		

New housing in the NFS was characterised in the nineteen-nineties by a rapid increase in annual figures until 1997. This was followed by a dramatic downturn until 2004 due to strong market saturation tendencies, demographic developments and the associated strong increase in vacant housing (see below). The decline in annual housing figures between 1997 and 2004 was around 78%, while the decline in annually completed living area for the same period was 68%! This can also be explained by the substantially disproportionate decline in completed blocks of flats [StBA 1994-2004b].

Table 4.24 Housing and living area in NFS new housing from 1994 to 2004

New Housing NFS (31.Dec)		
year	Housing [1000]	Living Area [10^6 m^2]
1994	67.7	6.2
1995	104.2	9.1
1996	143.4	11.9
1997	177.8	14.5
1998	128.4	11.3
1999	102.9	9.7
2000	86.3	8.5
2001	58.3	6.1
2002	49.0	5.3
2003	41.8	4.7
2004	39.7	4.7
inclusive construction at existing buildings		

The following table lists new housing in united Germany. A decline of 54% can be seen between the peak in 1995 (602,757) and 2004 (278,008). The decline in annual new living area for the same period is 32% [StBA 1994-2004b].

Table 4.25 Housing and living area in united German new housing from 1994 to 2004

New Housing Germany (31.Dec)		
year	Housing [1000]	Living Area [10^6 m^2]
1994	572.9	52.7
1995	602.8	54.0
1996	559.5	50.5
1997	578.2	53.5
1998	500.7	49.3
1999	472.6	49.0
2000	423.0	45.8
2001	326.2	36.9
2002	289.6	33.7
2003	268.1	31.8
2004	278.0	33.5
inclusive construction at existing buildings		

The dynamics of housing demolition is highly interesting from a resources perspective because it releases considerable material flows from the technosphere. These have the potential to at least partially reduce the utilisation of new resources by means of recycling. It is clear from the following table that both the overall housing losses (including redesignation) and housing demolition have been extremely stable in the OFS between 1994 and 2004. A clear trend cannot be seen [StBA 1994-2004b].

Table 4.26 Housing and living area demolition in the OFS from 1994 to 2004

Housing & living area demolition OFS				
	Housing		Living area	
year	overall housing losses*	from which demolition**	overall housing losses** [1000 m^2]	from which demolition in [m^2 per housing]
1994	15368	14043	1221	87
1995	15029	13632	1185	87
1996	14120	12710	1069	84
1997	14950	13360	1132	85
1998	14955	13449	1139	85
1999	14540	13265	1086	82
2000	14979	13631	1156	85
2001	15132	13604	1123	83
2002	16256	14765	1171	79
2003	14607	13504	1128	84
2004	16812	15479	1258	81
	* including partial buildings			
	** own calculation based on data from Statistisches Bundesamt			

In contrast to the OFS, development was more dynamic in the NFS between 1994 and 2004. An almost uninterrupted increase in figures was recorded both for demolition of housing and of living area. The crucial acceleration occurred post-

2000, after the "Vacancy Commission" (Pfeiffer 2000) presented its report for the NFS and the Federal Government started the "Eastern Urban Regeneration Programme", which supports the professional demolition of excessive housing stock by means of bonuses. This crucial effect can also be recognised in the change in age distribution of losses. For example, only 3.2% of losses in the NFS in 1994 were attributable to housing built post-1970. In 2004, 62.5% of total losses in the NFS were in the post-1970 building class. The focal point of demolition work in the prefabricated panel blocks of flats can be clearly recognised here. They were erected in the GDR (German Democratic Republic – former East Germany) in great numbers. This also explains the large drop in the average value of living space per demolished flat in the NFS between 1994 and 2004 [StBA 1994-2004b].

Table 4.27 Housing and living area demolition in the NFS from 1994 to 2004

Housing & living area demolition NFS				
	Housing		Living area	
year	overall housing losses*	from which demolition**	overall housing losses** [1000 m^2]	from which demolition in [m^2 per housing]
1994	6984	5377	405	75
1995	6904	5727	416	73
1996	7923	6993	496	71
1997	7846	6949	484	70
1998	10130	8828	566	64
1999	10309	9123	602	66
2000	9985	8803	586	67
2001	17133	16025	1005	63
2002	33934	32993	1946	59
2003	41658	40695	2463	61
2004	43234	42452	2534	60
	* including partial buildings			
	** own calculation based on data from Statistisches Bundesamt			

The figures for housing losses and demolition given in the following table reflect developments for Germany as a whole. As described above, the dynamic developments from 2000 occur primarily in the NFS, and are subject to substantial conscious influence by the state [StBA 1994-2004b].

Table 4.28 Housing and living area demolition in Germany from 1994 to 2004

Housing & living area demolition Germany				
	Housing		Living area	
year	overall housing losses*	from which demolition**	overall housing losses** [1000 m^2]	from which demolition in [m^2 per housing]
1994	22352	19420	1626	84
1995	21933	19359	1601	83
1996	22043	19704	1565	79
1997	22796	20309	1617	80
1998	25085	22277	1705	77
1999	24849	22389	1687	75
2000	24964	22434	1742	78
2001	32265	29630	2128	72
2002	50190	47758	3117	65
2003	56265	54199	3591	66
2004	60046	57931	3792	65
	* including partial buildings			
	** own calculation based on data from Statistisches Bundesamt			

Future resource conservation potentials lie primarily in the very large stock (material store) of German housing[64]: this was around 10.5 billion t in 2000. Of this, around 9.6 billion t are mineral building materials (concrete, brick, sand-lime plasters, mortar, etc.), around 220 Mt are wood, almost 100 Mt are metals (the majority of steel, copper wire and copper piping, etc. are not taken into consideration in this figure) and 6.8 Mt are insulating materials. According to Öko-Institut scenarios using the BASiS-2 model, the housing stock material store will continue to grow drastically until 2025 by more than 19% to 12.6 billion t. For new buildings this scenario is based on a BBR housing projection. As of 2006 the scenario assumes demolition figures for Germany of 110,000 flats/a. This is more than twice as much as the previous value for 2004. Nevertheless, even in 2025 the material input in the building stock will be around twice as high as the material output from demolition. That is, the ratio changes between 2000 (5:1) and 2025 (2:1) considerably. A "steady state" is not expected for the foreseeable future.

The insulating materials in stock will increase disproportionately because this building materials group will greatly increase in importance due to improved thermal standards (Energy Saving Ordinance (*EnEv 2002*)) and the subsequent insulation of housing stock. According to conservative scenarios around 725 Mm^3 of additional insulating materials, with a total weight in the magnitude of more than 20 Mt, will become part of the housing stock by 2025. This will have important implications for waste management during subsequent refurbishment or demolition of the buildings. The problems involved with insulating materials containing artificial mineral fibres (AMF) with a high carcinogenity index, i.e. insulating materials that do not conform to the KI 40-KMF standard, in widespread use until 2000, are highly relevant in this

64 The figures given for the materials in the housing stock were calculated using the BASiS-2 model. [Öko-Institut 2004b]

context. This may represent a high risk potential in the case of unsuitable demolition methods (wrecking ball, etc.) employed for building decommissioning in the next few decades.

In this context, it is particularly relevant that the housing stock will continue to grow considerably, despite substantially increased demolition figures relative to the reference year 2000: notwithstanding high vacancy rates in places and stagnating population. The Federal Statistical Office figures given above for housing stock up until 2004 also show continuous growth in housing and living area and thus in the "housing stock" material store.[65]

Vacant housing in Germany has increased considerably during the last 10 to 12 years. This mainly, although not entirely, affects the NFS. The causes of regionally very different levels of vacancy are numerous: economic decline and associated migration of the young and mobile population, general demographic developments (aging population in many regions), but also in part comparatively high new building rates in the region contribute to increased levels of vacancy. The level of vacancy in many towns in the NFS was not increased by migration to the OFS only, but also by a building boom – promoted in part by an owner-occupier subsidy – of 1-2 family houses in the directly neighbouring regions.

It must be mentioned here that the housing industry generally considers a 3% vacancy rate in the entire housing stock to be necessary. This unoccupied reserve eases house-moving, modernisations and large renovation tasks [StBA 2000]. The level of vacancy has now risen considerably above the 3% mark. According to [StBA 2000] the vacant proportion in the OFS grew between 1993 and 1998 from 804,100 flats (2.9%) to 1,795,200 flats (6.0%), i.e. the proportion has doubled within 5 years. Annual new building figures decreased in subsequent years, but the housing stock balance remains clearly positive. However, at the same time it should be noted that, for demographic and other reasons (single senior citizen households, singles, etc.), the average size of a household (persons/household) continues to fall and that therefore the number of households increases even with a stagnating population. The 1998 figure of 6.0% becomes all the more explosive in nature due to the fact that it only represents an average value for the OFS. Regions suffering from housing shortages (e.g. Munich), or with dynamic population, household and economic developments, such as parts of Baden-Württemberg, for example, are in stark contrast to regions such as many of the Ruhr area towns, which are suffering from problems such as structural changes, unemployment, migration and an overaging population. Many of these problems are yet to be overcome.

Vacant housing in the NFS has assumed dramatic proportions. From 1993 it increased from 417,500 flats (6.2%), to 456,300 flats in 1995 (6.8%) and to 917,600 (13.2%) in 1998. Since then the increase in vacant housing has slowed, but without

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[65] Note: the Federal Statistical Office figures are clearly differentiated to Federal State level and reveal interesting details!

a reversal of the trend. The Institute of Ecological and Regional Development (*Institut für ökologische Raumentwicklung - IÖR*) gives a current magnitude of 1,100,000 unoccupied flats for the NFS [IÖR 2005]. Following the work of a Federal-State Commission under the leadership of the Federal Ministry of Transport, Building and Housing (*Bundesministerium für Verkehr, Bau- und Wohnungswesen - BMVBW*) [Pfeiffer 2000] a targeted demolition programme known as the "Eastern Urban Regeneration Programme" was initiated primarily for the NFS. This was aimed at safeguarding the housing associations in the NFS against financial collapse, not least by the physical removal of several hundred thousand unoccupied flats, and generally helping to stabilise the housing market in the NFS. Comprehensive urban refurbishment is closely associated with these both objectives and the demolition work. The first effects of this programme are obvious from the demolition figures for the NFS since 2000.

A comparable programme, the "Western Urban Regeneration Programme", exists in the OFS, but is considerably lower key due to the different proportion of the problem. In its publication "Urban Regeneration and Vacant Housing from an Ecological Perspective" (*Stadtumbau und Leerstandsentwicklung aus ökologischer Sicht*) [IÖR 2005], the IÖR emphasises the relationship between vacant housing and raw material intensity. On the one hand, the enormous volume of vacant housing can lead to unnecessary energy consumption due to the indirect heating of empty flats (or background heating to avoid structural damage such as burst pipes, etc.). On the other hand, the raw materials required for building houses are not optimally utilised. If, in extreme cases, new housing is built in the vicinity – without utilising unoccupied housing, for example by the conversion/pooling of unoccupied housing – this further negatively influences raw material productivity.

"In residential areas, vacant housing leads to a waste of building materials. If buildings, pipe and cable systems, and roads are not utilised according to their design capabilities, the raw material intensity per m² of used living area increases. Residential areas with low urban densities are particularly sensitive to this effect." [IÖR 2005]

In summary, it can be said of the dynamics and trends in the housing sector that, without decisive changes, the demand for raw materials and energy will continue to be very large. In addition, the housing stock material store will continue to grow substantially. The dynamics must be viewed both in relation to the close links to other problematic environmental fields (land utilisation, etc.) and to the very close links to the social and economic aspect (social and economic challenges of increases in vacant housing, etc.). Overall, annual new housing will probably tend to stagnate, demolition will tend to increase slightly and the housing stock will generally increase considerably. In addition, a gradual mid- to long-term increase in building waste is expected, which may tend to present problems from incompatible substances (e.g. plastics containing heavy metals).

4.3.4.3 Potentials

Without question considerable mid- and long-term potentials exist for reducing environmental impacts in the housing sector in Germany. On the one hand, these include the new buildings sector and the provision of housing with heating energy. On the other hand, the importance of the continuously growing housing stock material store as a supply of secondary raw materials should be given considerably more attention. Ultimately, future efficiency gains in production processes can only be achieved by the increased use of secondary raw materials (e.g. concrete, steel) if the corresponding material store in the technosphere can be activated. The housing stock represents an important fraction of this material store.

The following results were acquired from the calculation of potentials using the BASiS-2 model and represent the difference between the reference scenario and a sustainable scenario between 2000 and 2025. The assumptions adopted for the scenario were carefully coordinated with an expert advisory panel beforehand (representatives of Federal and State ministries, science and environmental associations, etc.). All technical measures assumed (e.g. new-build passive houses, post-insulation of stock, etc.) are already established on the market today.[66] It should be emphasised that, according to the sustainability scenario, the pro capita living area will continue to increase considerably (to 46.8 m^2 in 2025 in contrast to 39.8 m^2 in 2000). This is due, among other things, to demographic developments (reduction in the size of households = persons per household) and the increasingly divergent regional housing markets. The following housing sector potentials can be emphasised:

- reduction of CO_2 emissions by 52% (approx. 110 Mt/a)[67] by 2025 (relative to 2000),
- reduction of the utilisation of mineral raw materials by 150 Mt/a (2000) to around 70 Mt by 2025 (buildings only),
- reduction in land consumption for residential and linked traffic areas from 31 ha/d to 5 ha/d by 2025 despite a distinct increase in living area,
- increased use of the otherwise unused material store (from increased vacant housing),
- minimisation of the release of problematic substances (e.g. heavy metals, artificial mineral fibres: AMF[68]) when converting and demolishing.

[66] The details of the assumptions made for the scenario can be found in [Öko-Institut 2004b].

[67] This reduction potential corresponds to approx. 13% of total German emissions.

4.3.4.4 Options for action

The following housing sector options for action can be presented for resource conservation and to avoid the release of problematic substances:

- increased upgrading of the housing stock (extension of building lifetimes and reduction of the substantial building stock heating energy requirement), pooling of housing, restrictions to new-build volume to actual requirement,
- forced exploitation of inner-city development potentials (e.g. derelict land), suitable density increases,
- identification of permanently vacant housing and mobilisation of materials by targeted and selective demolition,
- environmentally compatible disposal of problematic substances in increased quantities from demolition or quantities from demolition which will tend to increase in the future, dealing with the "insulating material mountain", ejection of problematic and incompatible substances from the material cycles and their safe and hazard-free disposal.[69]

Upgrading the building stock was and is an important object of federal (e.g. the programme provided by the *Kreditanstalt für Wiederaufbau*), state and municipal policy. The option involving targeted demolition of permanently vacant housing has been addressed in the NFS in particular by the "Eastern Urban Regeneration Programme", but also in the OFS by the "Western Urban Regeneration Programme". Ultimately, however, the (financial) boundaries of such state activities should not be underestimated.

A further essential and central option can be seen in the forcing and qualitative improvement of selective demolition. Optimised material segregation should be ensured at the demolition stage for the – even if slowly – increasing future demolition volume, because the numerous problematic substances in the noticeably

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68 According to information from the Federal Environment Agency, this problem relates to AMF products installed before May 2000. These are now reaching waste management by way of refurbishment and demolition work. New applications in terms of manufacturing, use and marketing are sufficiently prohibited by chemicals legislation. Violations against this cannot be avoided by further legislation. Attention should therefore be directed towards the reduction in stock taking place currently and over coming years. The decision by the upper house of the German parliament (Bundesrat) was originally made in 1999. However, it was not published and therefore did not come into force until May 2000. Before 2000, the largest absolute market share was taken up by carcinogenic AMFs and only a small proportion by so-called CI 40 AMF. Insulating materials distributed today, on the other hand, adhere to both WHO and CI 40 criteria and display no sign of "excessive carcinogenity".

69 These problems are heightened by the fact that the illegal installation of non-approved insulating materials cannot be completely ruled out, even post-2000. Moreover, in the case of demolition and refurbishment work the installation date (generally long ago) of the insulating materials in unknown or, at best, uncertain.

greater quantity of building materials could significantly disturb or even completely hinder recycling (gypsum, insulating materials, etc.). The potentials of the housing stock material store can only be optimally realised in future by improved demolition practices.

4.3.5 German non-residential buildings excursus

Non-residential buildings were not the subject of this Öko-Institut and IFEU-Institut project. Nevertheless, due to the future importance of this sector for a sustainable substance flow and resources policy the non-housing building sector will be briefly discussed here. It should first be noted that building activity (new-build, losses, etc.) is recorded annually by the Federal Statistical Office [StBA 1994-2004b], but not the development of stock, as is the case for housing. In addition, information density for the materials used in the various types of non-residential buildings is much lower. The information deficits with regard to non-residential buildings should be addressed in the near future for the following reasons.

- Non-residential buildings often possess a greater proportion of material fractions of interest to the recycling industry (steel, aluminium, copper, concrete, etc.),
- the lifetime (at least the term of occupancy) is shorter than for residential buildings,
- the stock material store should also increase considerably in the case of non-residential buildings.

The final point can be concluded from currently available data. The non-residential buildings material stock in Germany will probably increase further. In absolute figures, the loss of non-residential buildings in 2004, at 9,889,000 m^2, was considerably higher than for housing (4,336,000 m^2), in terms of living area and effective floor area. But at around 24,269,000 m^2, completed non-residential buildings exceed losses by a factor of approx. 2.5. This is remarkable considering the fact that competition in Germany is increasingly fierce, e.g. in the office building sector. Newly erected office blocks are leading to high vacancy rates in the nineteen-sixties and seventies building classes in many towns. "Greenfield" DIY stores and shopping centres compete with inner city shopping areas, etc.

Because a factor of 2.5:1 in the non-housing buildings sector is inconceivable in Germany in the long-term, due to the deficient markets, increased demolition is probable for the non-housing buildings sector in the future, or should at least be forced by policy.[70]

[70] The non-sustainable alternative would be a further increase in vacancies with incalculable social (ghost inner cities) and economical consequences (underutilised urban infrastructure, dramatic fall in office and shop rentals, etc.).

In order to be optimally prepared for the materials flows expected in the future from the non-housing buildings sub-sector of the technosphere, and to properly accompany their necessary activation, a considerably improved database is required for the sector. This includes both detailed information on the current building stock and sound expert assessments of the temporal dynamics and the extent of activation by demolition. Last but not least, the restraints acting on the sustainable activation of important secondary material cycles should be identified and proposals developed to overcome them.

4.3.6 Important existing regulations

At the European level, efforts are being made to focus more sharply on the recycling of certain waste fractions. The 6th EU Environment Action Programme (EAP), for example, includes promotion of recycling of building and demolition waste as one of its main objectives. The EU Commission presented its concept for the further development of waste prevention and disposal on 21.12.2005 under the title "A Thematic Strategy on the Prevention and Recycling of Waste".[71] This thematic strategy is one of seven environmental strategies envisaged in the 6th EAP and is based on existing legal regulations and comprehensive consultations with those involved. The primary objectives of current EU waste policy (waste prevention and promotion of reuse, recycling and recovery to mitigate environmental impacts) continue to apply and are supported by the strategy. The long-term objective is to develop the EU to a society with a closed cycle and waste management policy, which aims to both prevent waste and utilise waste as a resource. In order to achieve this objective, modernisation of the existing legal framework is proposed (introduction of life-cycle analyses in the political process; clarification, simplification and tightening of EU waste legislation). Here, the strategy recommends a combination of measures:

- renewed pressure for complete implementation of existing legal regulations,
- simplification and modernisation of existing legal regulations,
- introduction of the concept of the life-cycle in waste policy.

Production (of building products) and consumption (principal accumulations of building waste for housing) must also be differentiated within the material flow system in order to identify the most important regulations at the national level. Individual voluntary commitments and DIN standards are chiefly of note in the manufacturing sector. In the consumption sector (housing), the Commercial Waste Ordinance (*GewAbfV*) and the 1996 voluntary commitment declaration of the ARGE Working Group for Building Industry Sponsors of Closed Cycle and Waste Management Policy (KWTB) in particular influence the material flows.

[71] COM (2005) 666 final.

4.3.6.1 Manufacturing sector: Important regulations for cement and concrete production

4.3.6.1.1 Greenhouse Gas and Emissions Trading Act[72]

In accordance with the Greenhouse Gas and Emissions Trading Act (*TEHG*) which took effect last year, the release of greenhouse gases (e.g. CO_2, see Article 3, Section 2, *TEHG* for a complete list of greenhouse gases) as the result of an activity in the context of the *TEHG* requires an emission permit. The production of cement clinker in plant with a production capacity of more than 500 t/d in rotary kilns and more than 50 t/d in other kilns is regarded as an activity in the context of the *TEHG*. The cement production sector therefore requires an emission authorisation (certificate). This certificate signifies that the volume of emissions from cement clinker production is regulated by the state.

4.3.6.1.2 Waste Incineration Plant Ordinance (17th *BImSchV*)[73]

The 17th Federal Immission Control Ordinance is the governing authority for cement clinker and cement production plant, because fossil fuels or suitable wastes are utilised as secondary fuels to make these products. As co-incineration substances they are subject to immission control monitoring. This has the particular consequence that emission thresholds must be adhered to for cement production, as specified by the 17th Federal Immission Control Ordinance (Article 5a, Section 2, Annex II, No. II.1 of the 17th Federal Immission Control Ordinance).

4.3.6.1.3 Voluntary commitment of the German cement industry with regard to reduction of CO_2 emissions

In 1995 the German cement industry was a signatory to the "Declaration of German Industry on Climate Care" under the auspices of the Federation of German Industry (*Bundesverband der Deutschen Industrie e.V.*). In 1996 - after discussions with the Federal Government - the German cement industry, together with other associations involved in this branch, put a figure on its obligation, stating that specific fuel energy consumption should be decreased by 20% between 1987 and 2005. This corresponds to a reduction in specific fuel energy input for cement production of 3,510 kJ/kg of cement in 1987 to 2,800 kJ/kg of cement in 2005. The major proportion of this reduction is achieved by increased use of cements with several main constituents.

For the first time, the 1997 Kyoto Protocol defined quantitative international reduction obligations for the signatory states. These commitments are based on the reference year 1990 and a target period between 2008 and 2012. It is against this backdrop that German industry extended and updated their voluntary commitment in

[72] Act of 08.07.2004, Federal Law Gazette pg. 1578.

[73] Ordinance of 23.11.1990, Federal Law Gazette pg. 2545; republished on 14.08.2003, Federal Official Gazette pg. 1633.

October 2000 after negotiations with the Federal Government. German industry has now agreed to reduce their specific CO_2 emissions by 28% between 1990 and 2005 and to reduce greenhouse gas emissions by 35% by 2012. In this written agreement the individual associations have also agreed to update their commitments by the end of 2000.

The German cement industry is now also ready to reduce their specific energy-related CO_2 emissions relative to the reference year 1990 by 28% by 2008/2012.

4.3.6.1.4 DIN Standard 1045 for concrete production[74]

From a judicial point of view DIN standards do not represent directly binding legal regulations, but are merely recommendations (Federal Supreme Court, Building Law (*BauR*) 1994, 531). Nor are the recommendations compiled and published by the legislature, but from a private committee (Civil Engineering Standards Committee at the Deutsche Institut für Normung). Nevertheless, the regulations published in DIN standards represent rules that mirror current and recognised best practice and which therefore substantiate undefined legal concepts. This provides the DIN standards with the authority necessary for civil law standards (e.g. soundness of a building) and for the validation of building regulations. Because the DIN Standards also recommend further standards for producing building products (e.g. concrete or cement) and therefore influence the composition and use of individual substances, they are relevant as originating technical regulations, which initiate a given substance flow.

The DIN 1045 series "Concrete, reinforced and pre-stressed concrete structures" consists of four parts:

- Design and construction (DIN 1045-1)
- Concrete; Specification, properties, production and conformity (DIN 1045-2)
- Execution of structures (DIN 1045-3)
- Additional rules for the production and conformity control of prefabricated elements (DIN 1045-4)

The DIN standard contains all explanations, encompassing the technical sector from production to use of the concrete. These explanations comprise topics such as the composition, quality control, and delivery and processing of the concrete. It has subsequently been edited and adapted to European standards. In particular, the recommendations of European standard EN 206-1 were incorporated in DIN 1045. For example, there are now extended regulations for the use of feedstock for concrete and improved demarcation of the responsibilities of producers and users of concrete. The explanations given in DIN 1045-2 govern the production and use of recycled concrete. It lists the additives that may be used for the production of concrete (for example bituminous coal fly ash and silicates).

[74] Dated 06/2002, Ministerial Gazette of Lower Saxony 2004, pgs. 193, 194.

In addition, the German Committee for Reinforced Concrete has compiled a guideline as a supplement to DIN 1045 recommending the use of recyclates for concrete production. The guideline "for regulation of the utilisation of treated demolition materials for the production of concrete to DIN 1045" contains explanations allowing the use of recyclates for the production of high-quality concrete. Production was previously only allowed by way of individual permits (e.g. the administration building of the *Umweltstiftung* (Environmental Foundation) in Osnabrück or the Hundertwasser House in Darmstadt).

4.3.6.2 Consumption sector: Housing

4.3.6.2.1 Voluntary commitment of the ARGE Working Group for Building Industry Sponsors of Closed Cycle and Waste Management Policy

A Voluntary commitment of the Working Group for Building Industry Sponsors of Closed Cycle and Waste Management Policy (*ARGE KWTB*) was agreed upon with the Federal Environment Ministry in 1996 and aims to serve the "environmentally compatible recovery of building waste". The main objective of the agreement is the promotion of closed cycle and waste management policy and on-site recycling as well as halving the volume sent to landfill by 2005. In detail, the associations amalgamated in the ARGE KWTB agree to reduce disposal of recoverable building waste to half of the volume relative to 1995. The voluntary commitment declaration is valid up to and including 2005.

4.3.6.2.2 Commercial Waste Ordinance[75] and LAGA implementation notes[76] to Commercial Waste Ordinance

This ordinance mainly regulates the recovery and disposal of commercial municipal waste, and construction and demolition waste. The structure employed by the ordinance accordingly follows two routes; the system of principles applying to commercial municipal waste is also adopted for the explicitly emphasised building and demolition waste listed using a separate system. The building and demolition waste, in turn, is differentiated into discrete and mixed waste fractions.

The principal aim of the Commercial Waste Ordinance (*GewAbfV*) is the segregation of waste fractions (four fractions for building and demolition waste: metallic waste, glass, plastics and concrete) in order achieve greater feedstock or energy recovery.

Particular attention should be paid to two aspects: the approach employed by the ordinance with regard to recovery quotas, and the special regulations for building and demolition waste. The recovery quotas apply to the recovery of waste in pre-treatment plant. However, not all accumulated (and recoverable) waste arrives here;

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[75] Ordinance on the Management of Municipal Wastes of Commercial Origin and Certain Construction and Demolition Wastes of 19.06.2002, Federal Law Gazette pg. 1938.

[76] Implementation notes of the Working Group of the Federal States on Waste (LAGA) to the Commercial Waste Ordinance, passed on 26.03.2003.

consequently, the question arises whether the recovery quota as an instrument actually develops its full effect. The period between the accumulation of the waste (demolition of a house) until transport to a pre-treatment plant, that is, the period in which the selection, segregation and collection of recyclable waste takes place, is generally defined by the KWTB voluntary commitment declaration. In this regard the question also arises whether the Commercial Waste Ordinance only achieves the effect intended by the legislator by means of an additional timely voluntary commitment declaration. Previously, the building industry has fulfilled the recycling quotas imposed by the voluntary commitment declaration. Accordingly, the instrument is functioning, legislative regulations (to be integrated in the Commercial Waste Ordinance) are currently not absolutely necessary.

On the other hand, the specifications already given for building and demolition waste in the Commercial Waste Ordinance must be studied in more detail. For example, the list of building materials (e.g. plastics, glass, concrete) does not include such things as insulating materials or high-quality building materials (concrete from structural engineering). However, there are reservations for insulating materials due to heavy soiling because recovery of soiled (usually mixed with other building materials) insulating materials is only possible with restrictions. In practice, the problem of mixing occurs for insulating materials in particular. Insulating materials are therefore explicitly mentioned as mixed waste in the LAGA implementation notes. Due to the failure to list these materials in the Commercial Waste Ordinance, however, the limited existing potential for the recovery of insulating materials during demolition is not exhausted. Wood, in turn, does not come under the regime of the Commercial Waste Ordinance, but is covered by the Waste Wood Ordinance[77] (*AltholzV*); this divides wood waste from the building sector into several waste wood categories (see Annex III of the Waste Wood Ordinance). The requirements placed on treatment prior to reuse then depend on the category.

The LAGA implementation notes previously mentioned put into concrete terms the principal regulations contained in the Commercial Waste Ordinance. In parts they contain information which could not be included in the Ordinance for fear of bloating the text or because it represents background information only. It is explained that the four main waste fractions metal, glass, plastics and concrete primarily accumulate for the following measures:

- new-build (in particular structural engineering),
- refurbishment, modernisation and renovation,
- demolition, where individual components or building materials are removed separately (selective demolition).

[77] Ordinance of 15.08.02, Federal Law Gazette pg. 3302.

In the case of demolition, the LAGA points out that selective demolition may be obligatory depending on the Federal state involved. However, regulations involving Federal state laws have not yet been identified.

Beside this, the implementation notes also address mixed waste and briefly describe the situation surrounding the origin and types of accumulating waste mixtures in order to clarify fields of action for the executive agency. This shows that mixed building and demolition waste primarily occurs where no selective demolition is practiced. In most cases, these types of waste consist of mineral building waste fractions and, in addition, bitumen mixtures, insulating materials or gypsum-based building materials.

4.3.7 Synopsis of options for action for this material flow system

In order to further utilise the considerable potentials for decreasing environmental impacts the following points can be particularly emphasised for the mineral resources-cement-concrete-housing material flow system following the project investigations:

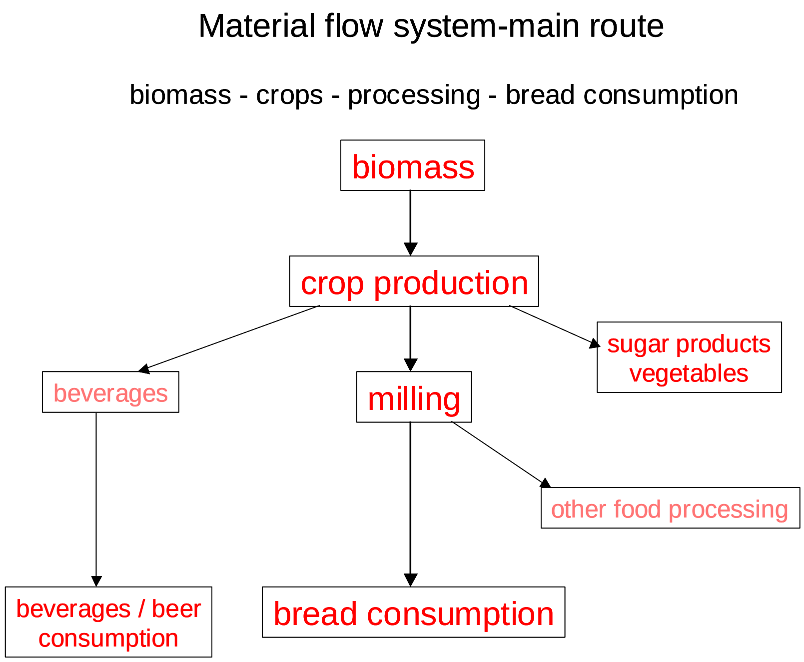
- Further improvements in the energy efficiency of the plant base and the utilisation of secondary fuels are relevant to the cement production sector (achieving the voluntary commitment, i.e. reduction of the specific CO_2 emissions by 28% between 1990 and 2008-2012).
- Timely retrofitting of old plant to modern reduction system standards with regard to nitrous oxide emissions is still emphasised for the cement industry sector. Further investigations are recommended with regard to output of trace elements.
- In the concrete production sector the promotion of high-quality recycling of demolished concrete by the public authorities is very important. Strict measures for optimisation of the selective demolition of buildings and logistical measures are crucial here.
- Increased upgrading of the housing stock is a central sustainability task for the coming decades. The Federal Government's agreements take this into due consideration and should be strictly put into practice.
- A comprehensive identification of vacancies and the targeted mobilisation of materials by targeted demolition represents and eminently important task for the near future.
- The environmentally compatible disposal of problematic substances in volumes that will tend to increase in the future is one of the principal challenges to environmental policy. In order to avoid risks and contamination of important large-scale secondary material flows, optimisation of material segregation during the demolition phase is essential.

4.4 Biomass-crop production

4.4.1 Material flow system synopsis: Principal route

The material flow system shown in Figure 4.22 comprises, on the supplier side, that section of agriculture responsible for the supply of vegetable-based foodstuffs. The production of meats and other products of animal origin (milk, etc.) are considered in more detail in Section 4.5.

Figure 4.22 Material flow system – Principal route: Biomass-crops processing-bread consumption



4.4.2 Synopsis of crop production in Germany

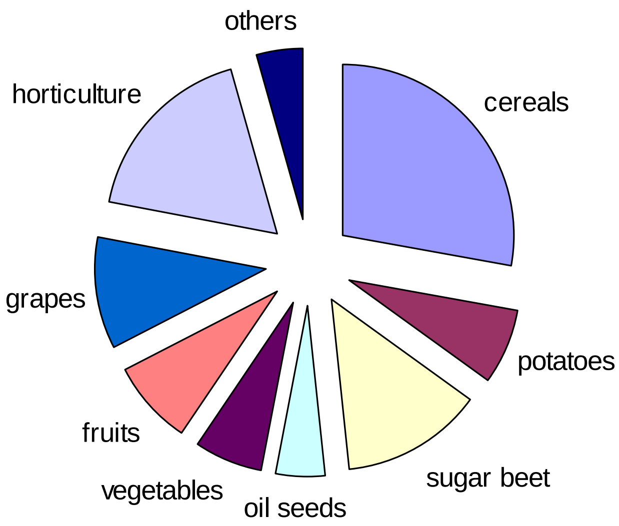
4.4.2.1 Facts and figures

The "crop production" substance flow considers that part of agriculture concerned with the production of vegetable foodstuffs and fodder. The most important crop products include cereals, potatoes, legumes, sugar beet and oil seeds. There are also special products such as trees from nurseries and horticultural products (flowers, etc.), fruit, tobacco, hops and wine, which will, however, not be considered further here. In addition, mixed grazing stock farming, that is the use of pastures (grass, hay) and fodder cultivation, are not included.

Economic indicators: Primarily turnover and employment:

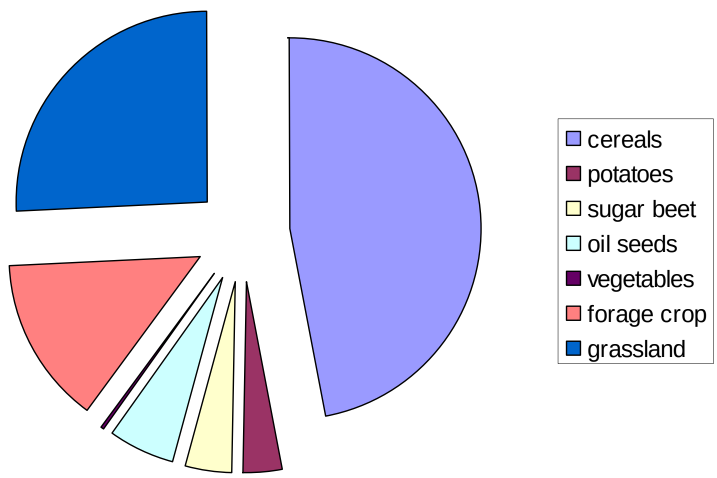
The production value of crop production in 2000 totalled approx. €18 billion. The greatest contribution (see Figure 4.23) was provided by cereals and horticulture/flowers including tree nursery products [Agrar 2005].

Figure 4.23 Percentage production values of crop products



The distribution of crop areas, in contrast (see Figure 4.24), indicates the dominance of cereal cultures, followed by forage crops and green pastures. The final items are not incorporated in the production value, however, as they are used internally for livestock farming.

Figure 4.24 Percentage of crop production products to farmed area

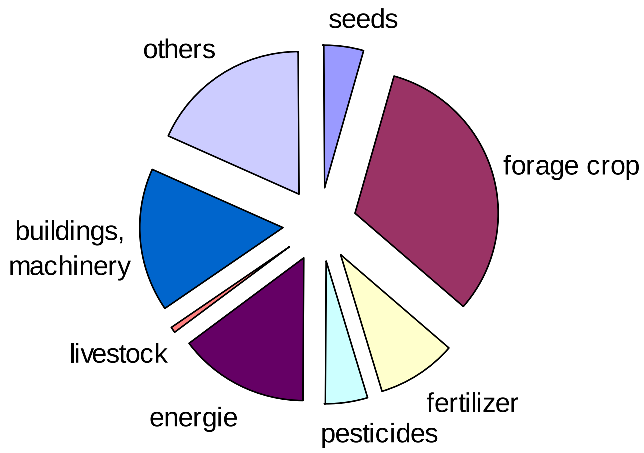


A total of approx. 600,000 agricultural operations are listed, employing a total workforce of 1.2 million. With the exception of proprietors and their families, the requirement for "non-family" workforce fell dramatically in the nineteen-nineties from approx. 400,000 to 150,000. This drop is attributed almost entirely to the New Federal States.

Economic relationships:

Agriculture receives advance services and products from other sectors of the economy to a total of €16 billion. The greatest proportion (see Figure 4.25) consists of fodder and the maintenance of buildings and machines [Agrar 2005].

Figure 4.25 Proportion of other economic sectors in advance services and products



Ecological indicators: Data relating to environmental criteria:

A set of environmental indicators is being compiled within the OECD and the EU, which will model the state of the environment and the environmental impact of agriculture [Agrar 2001]. The indicators will model the following 11 topics (preliminary):

1. socio-cultural aspects (land-use changes, population growth),
2. operational management (management nutrients, irrigation, pesticides),
3. nutrient application,
4. pesticide consumption,
5. water consumption,
6. land-use changes (fallow, sealed),
7. soil quality,
8. greenhouse gases,
9. biological diversity,
10. natural and near-natural areas,
11. landscape (typification & evaluation).

Cultivated areas store and emit carbon and nitrogen. In comparison to this, increased nitrous oxide and methane are emitted due to the input of fertilisers and working of agricultural land. Soil cultivation was responsible for 40 Mt/a of CO_2 and 0.1 Mt/a of N_2O emissions in 2004. Diffuse sources such as the transport (leaching) of soil constituents result in approx. 50% of the pollution of aquatic systems by nitrates, phosphates and heavy metals. [Böhm 2000] It is not possible to unequivocally allocate crop production and livestock farming to the total emissions from agriculture. The use of mineral fertilisers is stable at a high level. However, a reduction of 50% was noted for phosphates between 1991 and 1995 [Agrar 2005].

4.4.2.2 Dynamics and trends

In conventional agricultural systems, the yield per unit area has increased continuously. The OECD/FAO forecast comes to the conclusion that the increases in yield are not yet complete even in Western Europe. For example, a continuous increase of approx. 1% per annum is assumed. The reasons for this increase include the introduction of high-yield crops and improved processing technologies. The specific hectare yield is also increased by low-yields sites being removed from production. The trend is reduced by increased ecological farming, acting in opposition to improvements in yield.

If such an increase in yield is assumed, areas will be vacated in the future which will be available for nature conservation purposes or other biomass utilisation purposes (renewable natural resources, fuels). An increase of 0.5 Mha (1995) in the area of biomass utilised for energy applications to approx. 1 Mha in 2004 can be observed. It is assumed that this trend will be supported by further increases in oil and gas prices. A decreasing trend in greenhouse gas emissions can be observed. Emissions fell by 16% between 1990 and 2000.

4.4.2.3 Potentials

The environmentally relevant potentials resulting from the restructuring of EU agricultural policy (CAP) have not yet been clarified. Because subsidies ("green box") are coupled to ecological operational management, an improved ecological framework may be expected as a result. The increase in agricultural yield and the associated release of agricultural land for foodstuffs production can only be roughly estimated. According to Fritsche [Fritsche 2004], this may involve up to approx. 30% of the area by 2030 (corresponding to approx. 5.73 Mha released). This release of land can influence practically all the ecological effects of agriculture, whether e-missions, nutrient balance or biodiversity. Which effects can be reduced and to what extent depends on the follow-up use of the released areas.

4.4.2.4 Options for action

The follow-up use of the released areas should be closely accompanied. Various uses are possible for these areas. Their respective suitability for ecological farming or extensification, energy crop cultivation or the cultivation of renewable natural resources (for feedstock use), as well as nature conservation areas, must be examined and weighed against each other. The accompaniment should be carried out in close coordination with the expected changes in EU agricultural policy. In connection with the structural changes in livestock farming, special attention should be paid to the regional distribution of manure (see next chapter).

4.4.3 Important existing regulations

With regard to the biomass material flow systems, attention is also drawn to the sixth European Environment Action Programme. This is because one of the aims of the 6^{th} EAP is to protect the soil from erosion and pollution. In order to achieve this aim the Commission published a Communication[78], sketching the way for the development of a soil conservation strategy. This strategy is one of the seven thematic strategies of the 6^{th} EAP, previously mentioned in connection with the strategy on waste prevention and recycling.

Once the individual components of the soil conservation strategy lead to legislative changes, they will encroach in particular upon national regulations relating to agricultural soil use. Inasmuch as they are relevant, these regulations will therefore be discussed here (Fertiliser Ordinance, Sewage Sludge Ordinance, Biowaste Ordinance). The common element of these regulations is that they influence the amount of pollutant entering the soil, particularly by means of threshold values.

4.4.3.1 European soil conservation strategy

The EU Commission aims to present its soil conservation strategy in 2006. The 2002 Commission Communication presents the principal hazards to soil in the EU: erosion, reduction of organic substance, soil contamination, sealing (caused by building houses, roads and other infrastructure), soil compaction (as a result of the use of heavy machinery, overgrazing and sporting activities), reduction of the biological diversity of the soil, salinisation (excessive accumulation of soluble salts of sodium, magnesium and calcium in the soil) as well as floods and landslides. Some processes have intensified over past decades, leading to considerable economic consequences and substantial costs for remediation of the endangered soils.

The strategy should be supported by the principles of responsibility, prudence and environmental liability and build on the following elements: existing environmental initiatives, improved incorporation of soil conservation in other fields of politics, soil monitoring and the development of new measures based on the monitoring results.

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[78] Commission Communication of 16.04.2002, Com (2002) 179 final.

4.4.3.2 EU Common Agricultural Policy

The Common Agricultural Policy (CAP) aspires to promote ecological agriculture, the conservation of terraced cultures, the safe application of pesticides, the use of certified composts, forestry, reforestation and other measures relevant to soil conservation. With the CAP reform, the Commission aims to increase the subsidies available for the development of rural areas and soil conservation. As far as soil monitoring is concerned, the Commission is considering regulations for a common soil hazards information and monitoring system. This monitoring will form the basis for future legislative initiatives favouring soil conservation and for adapting and examining the appropriate policies.

4.4.3.3 Fertiliser Ordinance[79] and Fertilising Ordinance[80] (based on the Fertiliser Act[81])

Agriculturally used land emits carbon and nitrogen, among other things. Fertiliser input from working these areas emits additional quantities of methane and nitrous oxide, for example. The background to the fertiliser legislation is to increase agricultural yield while simultaneously protecting soil fertility and the health of both humans and livestock. The Fertiliser Act divides the substances added to the soil into fertilisers, manure, secondary raw material fertilisers, biofertilisers, growth media and biopesticides. The Act specifies that fertilisers especially may only be marketed commercially if they correspond to the fertiliser types approved by the Fertiliser Ordinance (*DüngemittelVO*). In addition, the Fertiliser Act forms the basis for the Fertilising Ordinance (*DüV*), which regulates the demands placed on good practice and the reduction of risks presented by certain substance when applying fertilisers.

The ordinance builds on the classifications used in the Fertiliser Act and regulates in detail the demands placed on the substances named in the Fertiliser Act. Here, the legislator primarily aims at influencing the composition of the fertilisers (they are divided into fertiliser types on this basis) and on other substances not declared as fertilisers. For example, no organic feedstock or mineral residues other than those named in the Fertiliser Ordinance may be employed. Additionally, the threshold values which the fertilisers and non-fertilisers, and their respective feedstock substances, must adhere to are also specified.

Regulations referring to the application of the fertilisers are specified in the Fertilising Ordinance. For example, the fertiliser requirement should be correctly identified before applying large quantities of nutrients (nitrogen, phosphate). Identification of the fertiliser requirement must be oriented on the anticipated nutrient

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[79] Ordinance of 26.11.03, Federal Law Gazette I pg. 2373; amended by ordinance on 03.11.2004, Federal Law Gazette pg. 2767.

[80] Ordinance of 10.01.06, Federal Law Gazette pg. 30.

[81] Act of 15.11.77, Federal Law Gazette pg. 2134.

requirement and the nutrient supply. On the one hand, the Fertilising Ordinance regulates restrictions in the application of fertilisers where a hazard of excessive impact to the soil exists. These restrictions include volume restrictions and temporal restrictions on fertiliser application, as well as the specification of identification obligations. On the other hand, application prohibitions are dictated by the ordinance, beside application restrictions. This especially links to existing limitations, regulated in Table 1 of Annex 2 of the Fertiliser Ordinance. Ultimately, the Fertilising Ordinance thus represents a legal instrument, intended to avoid over-fertilisation and to reduce the impacts of certain substances.

4.4.3.4 Sewage Sludge Ordinance[82]

The Sewage Sludge Ordinance (*AbfKlärV*) controls the requirements by which sewage sludge from waste water treatment plants may be applied to agricultural or gardening soils. Here, too, the uppermost principle is that application may not impair public welfare. Because these sludges contain heavy metals, they must be investigated for their nickel, chromium, cadmium, copper, mercury and zinc content before application to the soil. As soon as the threshold values specified in the Sewage Sludge Ordinance are exceeded, the legal consequence is application prohibition. The soil concerned must be examined with regard to pH and the amount of bioavailable phosphate, sodium and magnesium before applying the sewage sludge. The suitability of the soil for application is then given by the target pH value.

Sewage sludge application represents a soil impact not directly originating from agriculture because the impacting substances are of a different origin (private households, commerce) and are introduced to the material flow system from outside. Regardless of this, the substances introduced by sludge application enter the soil and should be included in the overall considerations.

4.4.3.5 Biowaste Ordinance[83]

The Biowaste Ordinance (*BioAbfV*) was introduced to ensure the correct and safe recovery of biological waste (of animal or vegetable origin) in the agricultural sector. It controls the requirements for the application of biowaste (waste of animal or vegetable origin for recovery) to agricultural soils. The prior treatment of these wastes is obligatory. At the same time, precise information on pre-treatment must be provided. With regard to the pollutant precautionary instrument, parallels are drawn to the Sewage Sludge Ordinance. The Biowaste Ordinance also specifies heavy metal thresholds, which may not be exceeded if the biowaste is to be applied to agricultural land. A soil analysis for heavy metals and pH must be carried out before applying biowaste, similar to that for the application of sewage sludge. If a valid soil

[82] Ordinance of 15.04.92, Federal Law Gazette I pg. 912; last amended by ordinance of 26.11.2003, Federal Law Gazette pg. 2373.

[83] Ordinance of 21.09.98, Federal Law Gazette I pg. 2955; last amended by ordinance of 26.11.2003, Federal Law Gazette pg. 2373.

analysis in the context of the Sewage Sludge Ordinance is available for an application area, this may also be referred to for the application of biowaste (Article 9, Section 2, pg. 3, BioAbfV).

It is characteristic of the agricultural raw materials cycles that biowaste is subsequently applied to the soil as a fertiliser. The biotic waste thus replaces the fertiliser, but not the other resources necessary for crop production, such as water. The fertilisers that are otherwise produced industrially, but which, in turn, assume a certain raw material input, are saved. This raw material input would become unnecessary in particular the relatively high energy costs for the production of certain feedstock substances (e.g. nitrogen).

4.4.4 Synopsis of options for action for this material flow system

In order to further utilise the considerable potentials for decreasing environmental impacts the following point[84] can be particularly emphasised for the biomass-crop production material flow system following the project investigations:

- Proactive strategies for future use (nature conservation areas, ecological farming, energy crop cultivation, etc.) should be developed for the considerable areas being released by agricultural productivity increases in coming years.

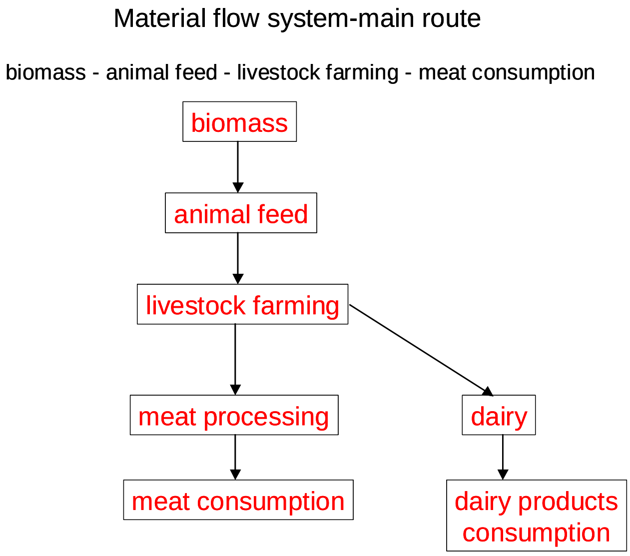
[84] Further important options for action relating to the agricultural complex can be found in Chapter 4.5.4 on the biomass-animal feed-livestock farming-meat consumption material flow system.

4.5 Biomass-livestock farming

4.5.1 Material flow system synopsis: Principal route

This material flow system (see Figure 4.26) considers that part of agriculture concerned with farming and raising livestock (meat production, dairy products).

Figure 4.26 Material flow system – Principal route: Biomass-animal feed-livestock farming-meat consumption



4.5.2 Synopsis of livestock farming in Germany

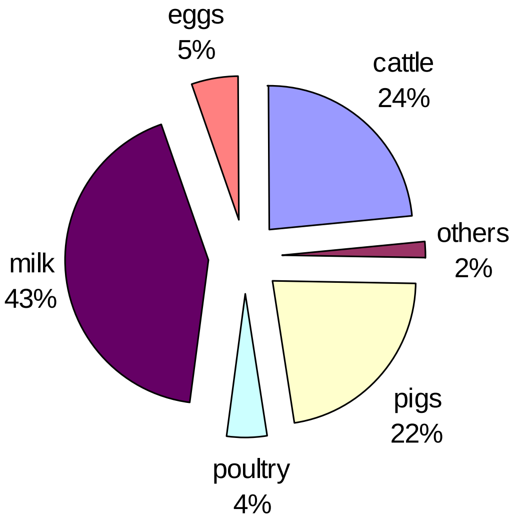
4.5.2.1 Facts and figures

Livestock farming includes cattle farming (dairy cattle, cattle farming, cattle fattening), pig and poultry farming. This sector also covers sheep and goat farming, as well as horses and donkeys. The final two sectors will not be dealt with due to their low relevance to Germany. The sector comprises the actual farming and mixed grazing stock, i.e. the use of pastures (grass, hay) and fodder cultivation.

<u>Economic indicators: Primarily turnover and employment:</u>

The production value of animal products in 2000 totalled approx. €19 billion and remained practically constant throughout the nineteen-nineties [Agrar 2005]. The largest contribution was made by milk and cattle farming. Pig farming, and eggs and poultry continue to be important (see Figure 4.17).

Figure 4.27 Production value of animal products



Livestock farming comprises a total of approx. 16 million cattle and calves (including 5.3 million dairy cattle), 26 million pigs (including weaners), as well as 38.7 million laying hens and approx. 41 million broilers including geese and ducks. Most dairy cattle operations are in the size class 10-20 ha (33,000), but larger operations are active at 20-30 ha (27,100) or 30-50 ha (27,400). Only 17,700 operations are listed at 50 ha or larger. The area covered by pig fattening operations, in contrast, is considerably smaller. Most operations are in the size class below 2 ha (3,900). 80% of all operations cover an area of less than 20 ha.

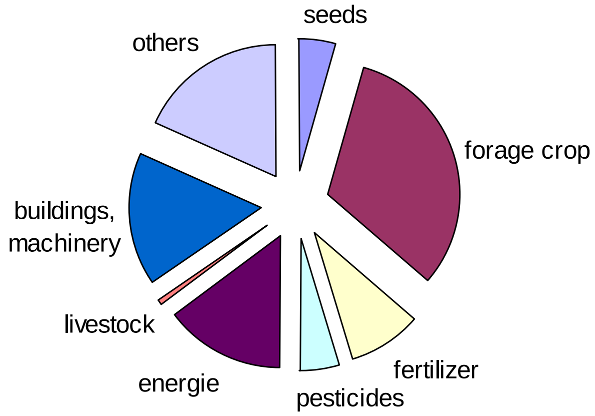
In all, 25% of operations are classified as dairy cattle operations, but only 2.5% as pig operations. The clear majority of operations are located in western Germany. However, the distribution of cattle numbers is almost equal. In the New Federal States cattle farming is concentrated in large operations.

Whilst the majority of operations (75%) farm permanent pastures, the proportion of permanent pasture in the total area is approx. 30%. A total of approx. 600,000 agricultural operations are listed, employing a total workforce of 1.2 million. With the exception of proprietors and their families the requirement for "non-family" workforce fell dramatically in the nineteen-nineties from approx. 400,000 to 150,000. This drop is attributed almost entirely to the New Federal States.

Economic relationships:

Agriculture receives advance services and products from other sectors of the economy (see Figure 4.28) to a total of €16 billion. The greatest proportion consists of fodder and the maintenance of buildings and machines.

Figure 4.28 Advance services and products for agriculture [Agrar 2005]



Ecological indicators: Data relating to environmental criteria:

Currently, the use of agricultural land as a source of fodder for traditional cattle and dairy operations is not normal practice. Here, the use of pasture land and the cultivation of forage crops should be given particular consideration. In addition, agricultural land is required for the application of manure. Manure (liquid manure and similar) is a waste product of livestock farming. Manure may be applied to agricultural land after storage or utilisation for biogas production and substitutes for conventional fertilisers.

Livestock farming causes direct emissions of methane and nitrous oxide, in particular in cattle and dairy farming. The emissions from livestock farming amount to 1.28 Mt/a of methane, as well as 1.3 Mt/a of methane and 9.8 Mt CO_2 equivalent/a of nitrous oxide from manure management. [NIR 2005]

Additionally, approx. 590 kt/a of ammonia emissions were recorded in 2002, originating primarily from livestock farming. The emissions from factory farming, in particular, represent an additional local problem here. Diffuse sources such as the transport (leaching) of soil constituents leads to approx. 50% of the pollution to aquatic systems by nitrates, phosphates and heavy metals. An unequivocal allocation of livestock farming emissions to total agricultural emissions is not possible.

4.5.2.2 Dynamics and trends

From the point of view of conventional livestock farming, efficiency is determined by the use of fodder. This includes, for example, increasing the milk production per milk cow, or the meat production. The increase is accompanied by high-quality fodder (soya) and fodder supplements (proteins, phosphates). Here, forage grasses and imported fodder substitute for fodder from permanent pasture (hay).

Greenhouse gas emissions were reduced considerably between 1990 and 2002. Methane emissions, for example, were reduced from 3.24 Mt/a in 1990 to 2.6 Mt/a.

Nitrous oxide emissions also fell from 14.4 Mt CO_2 equiv./a in 1990 to 9.8 Mt CO_2 equiv./a in 2002. Production of biogas by fermentation of manure (liquid manure) has increased substantially. The main sources are up to 70% cattle, 22% pigs and 8% poultry.

4.5.2.3 Potentials

A reduction in the use of pasture is expected due to the displacement of fodder production to higher protein fodder. Overall, the release of 0.46 Mha in 2010 and 1.1 Mha in 2030 is estimated. If further land consumption is taken into consideration (settlements, infrastructure, commerce), as well as the implementation of existing nature conservation targets, the total additional pasture available will be 0.3 Mha in 2010 and 0.86 Mha in 2030 [Fritsche 2004]. In addition, the factory farming associated with this will lead to locally concentrated accumulation of manure. Simultaneously, the nutrient cycle will be interrupted by the loss of local fodder cultivation.

Biogas production is another growing sector. It presents a total potential of 80-90 PJ/a. Its most notable side effect is the reduction of ammonia. Overall, reduced emissions may be expected by increasing the quality of manure management. EU regulations are the driving force here (cross compliance), which bind compensation payments to proper management (good practice). The national target for ammonia emissions within the framework of the UNECE/EU Directive envisages a reduction from 590 kt/a to 500 kt/a by 2010. This will be achieved by means of integrated measures [Agrar 2005].

According to Eurich-Menden [Eurich-Menden 2004], 457 kt/a of emissions can be allocated to livestock farming. Cattle farming causes 52% of total emissions and pig farming 22%. In his examination of various liquid manure application management systems he comes to the conclusion that by making certain changes a reduction in ammonia emissions of 20 to 30% (approx. 90,000 to 140,000 t/a)[85] can be achieved. The optimum time for the application of liquid manure and immediate working-in represent the most economical methods. The Federal Government, in its sustainability strategy, is also aiming for a reduction in excess nitrogen on agricultural land from 114 to 80 kg/ha by 2010 (based on 1996-2000) [Federal Government 2002]. This corresponds to an annual reduction of around 650,000 t of nitrogen.

According to the Federal Government's agricultural policy report the reduction target for greenhouse gas emissions for the entire agricultural sector (crop production and livestock farming) is a drop from 81 Mt/a in 2002 to 79 Mt/a in 2010 [Agrar 2005].

[85] This reduction potential corresponds to 15 to 24% of the total national ammonia emissions.

4.5.2.4 Options for action

The specialisation in dairy cattle farming has been identified as the central field of action for the future. There is a tendency for traditional dairy farming, consisting of dairy cattle farming and crop production (pastures), to be replaced by specialised operations concentrating solely on dairy cattle farming. Intensive monitoring is required in order to recognise developing errors early in the manure cycle. One option for action in this sector is improvement of the regional distribution of liquid manure, in order to minimise local peaks and the associated environmental problems on agricultural land. In addition, optimised application and management of the liquid manure (time and type of working-in) is highly relevant to the reduction of ammonia emissions. This is associated with the release of pastures. Concepts need to be developed to adapt these areas to meaningful uses, or for redesignation. Finally, the reduction of fertiliser use is a central tool for achieving the required reduction of excess nitrogen on agricultural land.

4.5.3 Important existing regulations

In livestock farming the soil, and therefore soil use, also plays a vital role in material flow considerations. This is because the available agricultural land is also utilised as a source of fodder (pasture, cultivation of forage crops, application of manure such as liquid manure, slurry or stable manure). For this reason, regulations that demonstrate the aforementioned relevance to agricultural soil use are primarily of interest here, similar to crop production. Attention is therefore drawn to the information given in the European soil conservation strategy, as well as to the national regulations of the Fertiliser, Fertilising, Sewage Sludge and Biowaste Ordinances in Chapter 4.4.

4.5.4 Synopsis of options for action for this material flow system

In order to further utilise the considerable potentials for decreasing environmental impacts the following recommendations can be particularly emphasised for the biomass-livestock farming material flow system following the project investigations:

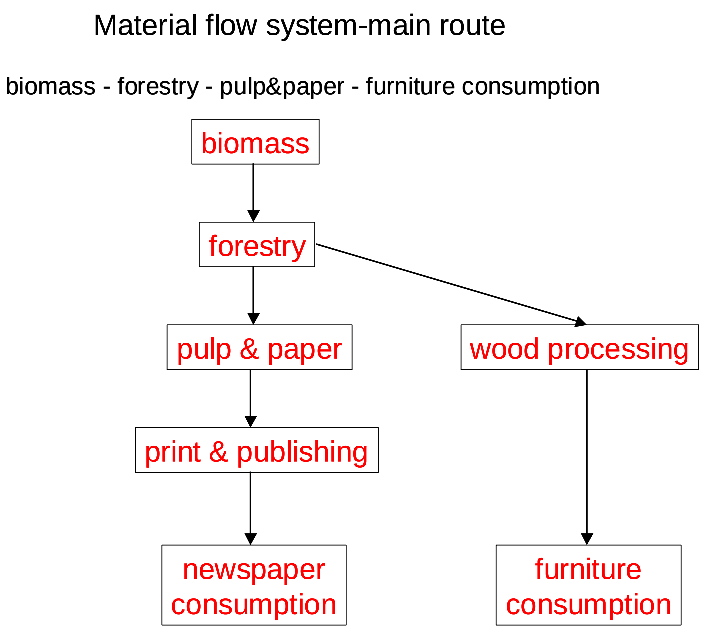
- Errors developing in the manure cycle (increased nitrogen import from imported high-performance fodder) must be countered by specialising in dairy cattle farming and displacing traditional dairy farming consisting of dairy cattle farming and crop production (pasture). A consistent reduction in the use of fertilisers and optimisation of application in order to reduce excess nitrogen plays a central roll. In this context, improved regional distribution of accumulated manure (liquid manure) is also important.
- Improved application and management of liquid manure as a decisive module for reducing emissions (greenhouse gases, ammonia) must be demanded and promoted with some emphasis.

4.6 Biomass-forestry-paper-furniture consumption

4.6.1 Material flow system synopsis: Principal route

The third material flow system with biotic character is based on the sustainable raw material wood and comprises the production and consumption of paper and furniture (see Figure 4.29).

Figure 4.29 Material flow system principal route: Biomass-forestry-paper-furniture consumption



4.6.2 Synopsis of paper production and consumption in Germany

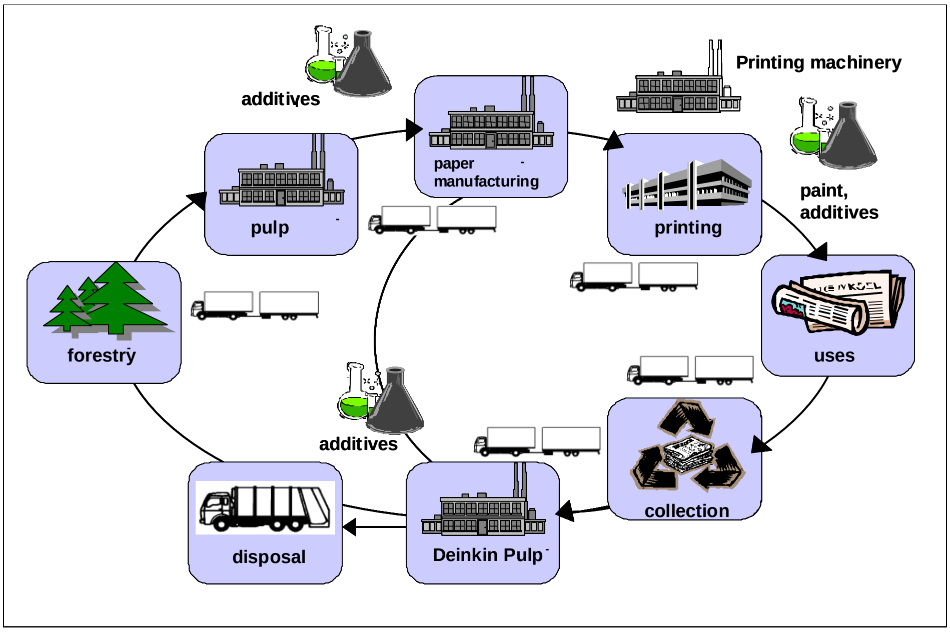
4.6.2.1 Facts and figures

The "paper production and consumption" substance flow (see Figure 4.30) comprises the sector including the production of paper raw materials such as lignin, pulp and waste paper, as well as the consumer paper products and cardboards produced from them. Considered as a whole the paper industry begins with the extraction of the paper raw materials lignin, pulp and waste paper (deinking pulp) from the raw materials wood and collected waste paper (textile raw materials are not involved). Mineral raw materials such as lime and kaolin are required as filler and coating materials. Paper, cardboard and paperboard are produced from the above raw materials, principally for use in printing, packaging and hygiene products. The paper industry is divided structurally into the production of mass market products and the production of specialised products. This has retained medium-sized structures in Germany alongside large production units.

In Germany the raw material wood originates principally from forest thinning and saw mill residues. The main products from these are lignin and sulphite pulp. In the Nordic countries forestry is practiced on a large scale for the production of pulp. A new pulp plant for sulphate pulp went into operation several years ago in Germany. The majority of the sulphate pulp processed in Germany, however, is imported from northern Europe and America.

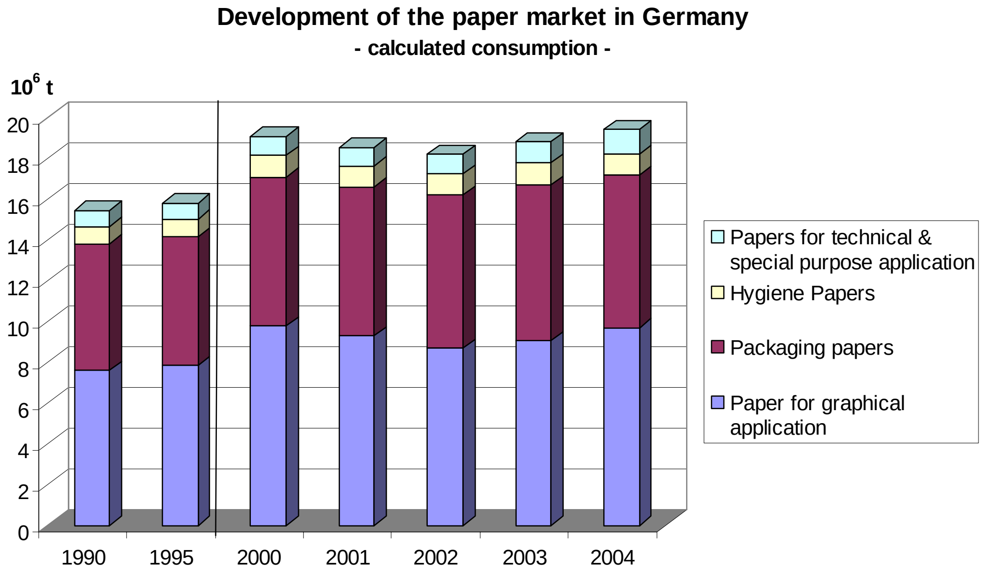
Waste paper is very important in Germany as a paper raw material and more than half of the fibre material utilised in the German paper industry is extracted from waste paper. Base papers produced in Germany for cardboard on the one hand and newsprint on the other are made entirely from waste paper.

Figure 4.30 Paper substance flow (simplified representation)



Papers for graphical applications, such as newspapers, magazines, catalogues, and office and administration papers, dominate production and consumption of consumer products. Packaging papers, cardboard and paperboard are almost as widespread. They are used as packaging and corrugated paperboards, machine board, millboard, packaging paper and labelling paper. Hygiene papers comprise toilette paper, paper towels, cloths, etc. Finally, there is the paper and paperboard sector covering technical and special-purpose uses (e.g. wallpapers, etc.). The production, consumption and disposal of paper raw materials and papers, cardboards and paperboards represents a closed substance flow with relatively minor links to other sectors. Figure 4.31 shows the development of the paper market in Germany from 1990 until 2004 [VDP 2005].

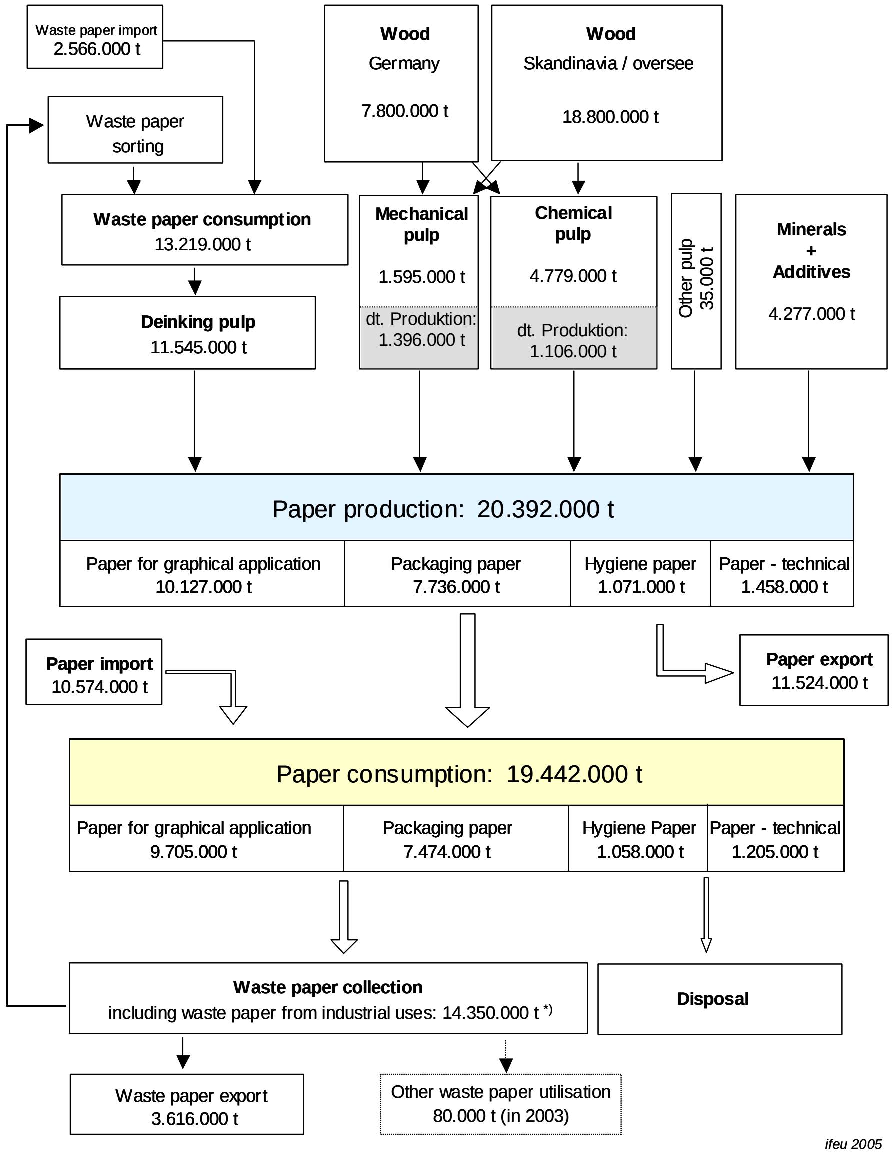
Figure 4.31 German paper market from 1990 until 2004



A representation of the substance flows involved in the paper market for 2004 can be seen in Figure 4.32 below. This representation is based on figures and information available from the Association of German Paper Factories' (*VDP - Verband Deutscher Papierfabriken*) [VDP 2005]. The substance flow illustration clearly demonstrates that, at 20.4 Mt, Germany is an important paper producer and consumes almost as much paper – 19.4 Mt – as it produces. Export and import links to other countries are nevertheless huge. Only 2.5 Mt of primary lignin and pulp are produced in Germany, while almost 4 Mt of primary raw materials are imported, mainly from northern Europe and overseas (USA, Canada, etc.).

This also emphasises the high level that the utilisation of waste paper has achieved in Germany. 14.5 Mt of collected waste paper lead to 13.2 Mt of waste paper consumption in the paper industry. If the use of waste paper (after subtracting production losses from waste paper consumption) is put in relation to the amount of fibre used, the proportion of waste paper is 64%. With exports of 11.5 Mt and imports of 10.6 Mt, the link to finished paper products is also very large relative to consumption.

Figure 4.32 Paper production substance flow, schematic



*) estimation for 2004

Economic indicators: Primarily turnover and employment:

According to the *Papier Kompass 2005* published by the Association of German Paper Factories, turnover in the German pulp and paper industry in 2004 was 12.6 billion euros. This corresponds to about 0.9% of the turnover of the industry as a whole. In all, around 45,000 people were employed in the paper and pulp industry in 2004.

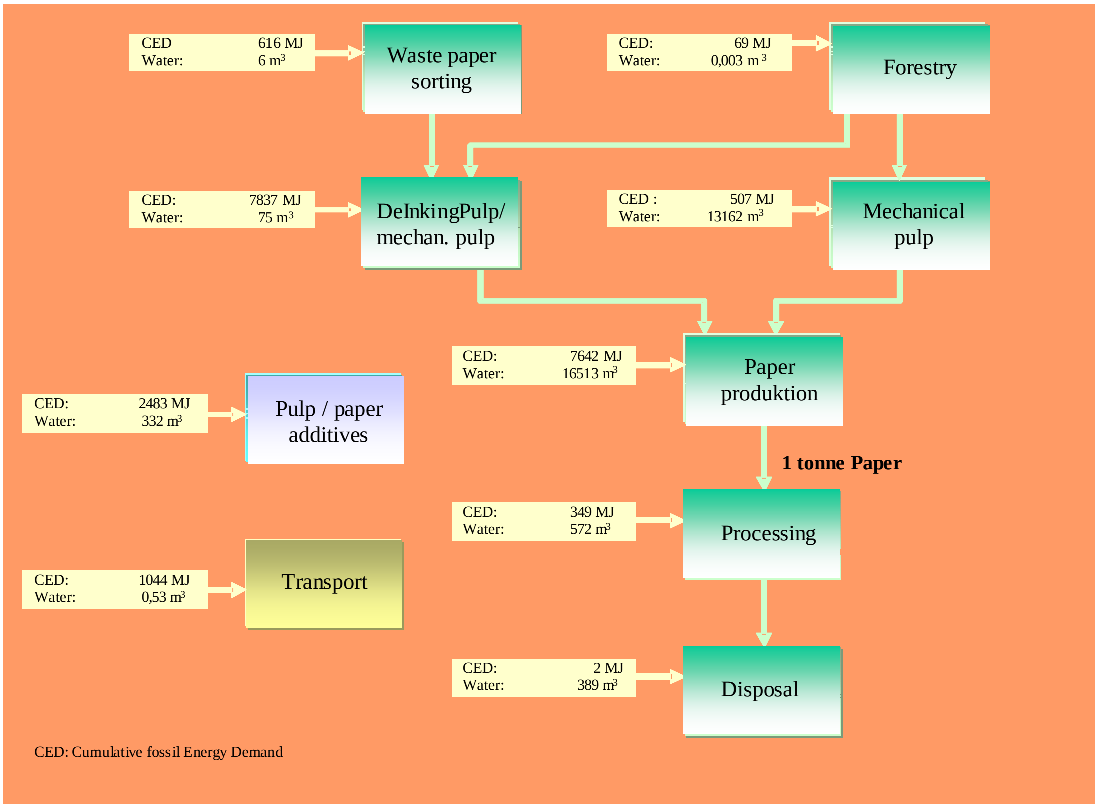
Economic relationships:

The pulp and paper industry is now dominated by only a few companies operating worldwide. In Europe these companies are mainly from the Nordic region (e.g. Stora-Enso, SCA, Assi Domän, Norske Skog, etc.). The Nordic paper concerns have all bought out large German paper companies. A German national paper industry exists only in the small- to medium-sized enterprise range. The mass market products are almost exclusively produced by multinational concerns, while the special-purpose papers are produced and marketed by smaller companies. Almost all large paper companies in the Nordic countries are also the owners of large areas of forest or have long-term contracts with forest owners organised in cooperatives in Norway, Sweden and Finland. These companies are increasingly present in the neighbouring countries to the east, predominantly in Russia. Because the large paper companies have also invested in the production of paper products from waste paper – mainly in Germany – economically motivated confrontation between the use of primary and secondary raw materials (waste paper) is no longer a factor.

Ecological indicators: Data relating to environmental criteria:

In the past, paper production severely damaged the environment, in some cases very visibly. The release of organic chlorine compounds from chlorine bleach via the waste water from the pulp factories led to sharp criticism of the paper production industry. The high water and energy demand for production and the wood consumption for fresh fibre papers was also criticised and occasionally still is. The principal contributions are represented using the example of the cumulative energy demand and water consumption for the production of one tonne of printing paper (average) (see Figure 4.33).

Figure 4.33 Cumulative fossil energy demand (CED) and water consumption for the production of one tonne of printing paper



4.6.2.2 Dynamics and trends

With regard to energy consumption it was possible to reap the benefits of high energy conservation potentials in Europe. Water consumption was also reduced substantially by cycle management measures. Organic chlorine emissions in Europe were reduced drastically by abandoning elementary chlorine (ECF – elementary chlorine free), but also by the conversion from pulp bleach to completely chlorine-free (TCF – total chlorine free) methods during the nineteen-nineties. As far as is currently known, waste water from ECF bleach and that from TCF bleach cannot be measurably differentiated in terms of their problem potential, as long as the process steps "extended cooking", "oxygen delignification" and "biological waste water treatment" are implemented in line with current best practice. The case is different for production sites in Asia and in America, for example. Often, they are not operated to current best practice and continue to be associated with some severe environmental impacts. [IFP 2002], [IFEU 2003]

Nevertheless, energy consumption for the production of lignin in particular may be considered high, because grinding wood is very energy-intensive. Beside this, the waste water emissions for lignin production, pulp production and waste paper treatment must be considered, because a reduction here in the quantity of waste water here may be accompanied by an increase in pollutant concentration.

Bleaching without chlorine represents current best practice for lignin production and waste paper treatment. Bleaching is carried out with the aid of peroxides. However, this requires the addition of chelating agents. These, in turn, may represent a problem for waste water treatment in sewage treatment plants. At the beginning of the nineteen-nineties, ecotoxicologically highly effective chelating agents were mainly employed, which have now been replaced by less harmful compounds.

4.6.2.3 Potentials

The innovation potential in the paper industry, an old and highly traditional industry, is generally regarded as exhausted, both in Germany and in northern Europe. Alternative processes for pulp and paper production have been proposed and tested in pilot schemes, but could not establish themselves for a number of reasons (handling of hazardous substances, quality problems, displacement of environmental problems, etc.). Processes that further reduce waste water, and even operate in a completely closed cycle, do exist, but must be regarded as very cost-intensive by international comparison. They have previously been restricted to sites for which the operating permit placed the highest demands on groundwater protection.

When considering the technical potentials and the technology employed, particularly outside of Europe, special attention should be paid to whether the imported pulp (approx. 4.8 Mt in 2004) and paper (approx. 10.6 Mt in 2004) was produced using environmental standards generally acceptable and usual for Europe.

In Germany at least, the waste paper utilisation rate is high, but can only be kept at this level by adequate utilisation of primary fibres. Energy-intensive papers produced from wood should be further replaced by waste paper. A quantitative estimate of potential is barely possible, however, because of the need to take quality aspects and customer's wishes into consideration.

Sectors in which innovation potentials may still come into play to improve the environmental situation in particular include:

- Wood origin and type of forest management. Wood, and thus silviculture, representing a central source of raw materials, should be given more consideration in terms of the quality of land use (biodiversity, nature conservation certification). This is especially the case in eastern European, but also in far eastern countries.
- Use of chemicals, water consumption/impact on waste water. Attention should be paid to the use of chemicals and their fate (emissions to water and possible residues in product). Information from REACH may be of great importance in this regard.

- Energy conservation. The energy consumption of individual paper types, especially TMP, is comparatively high and requires a high-quality energy type in the form of mechanical energy. Further reductions by means of improved processing methods and further replacement by waste paper are indicated here.
- Waste and recyclability. The rate of waste paper use in Germany is regarded as exhausted for some product groups. The aim is to stabilise use at the high level already achieved. New aids and printing inks should not impair recyclability.

In terms of numbers, German forestry has access to sufficient resources to cover a higher demand for pulp works. The industrial wood required is accumulated during the forest thinning that is occasionally required. However, there is currently no demand from the pulp industry, nor do the prices for industrial wood cover the costs of German forestry.

4.6.2.4 Options for action

No meaningful reduction potentials can be made out for paper and pulp production in Germany and northern Europe in terms of important environmental parameters. This does not apply to paper and pulp production outside of Europe. Because no direct options exist for intervention, this can only be influenced by consumer behaviour.

It is possible to produce and use products made from waste paper with considerably lower energy consumption and associated emissions. However, due to the high recycling ratio on the one hand and the desired product quality (e.g. tear strength, whiteness) on the other, replacement of paper containing wood by waste paper has now reached a threshold and can only be increased further if accepted by commercial customers and consumers.

Input of waste paper is approx. 12 Mt, contrasting with cumulative production and consumption figures of 18 Mt and 18.5 Mt respectively for all paper types (2002 figures). Particular attention must be paid to retaining these high quotas. Any use of water-soluble printing inks and other feedstock and consumables in the paper chain could impair recycling capability and thus reduce waste paper utilisation. Increased interest in the whiteness of a paper may also work to suppress the use of waste paper or lead to increased bleaching of products containing waste paper, which in turn is associated with increased environmental impacts.

On top of this there are a number individual topics such as emission of chelating agents or other very specific pollutants in waste water from paper production, which should be addressed within the scope of a substance flow policy. However, these cannot be easily quantitatively and qualitatively evaluated and require more detailed investigation in each case.

In the paper production sector the origin of the actual wood raw material plays a primary role. The quantity of paper used in Germany roughly corresponds to 50 Mt of fresh wood mass. This makes the paper industry an important user of wood raw material. The type of management employed in German forests and, more importantly, in the forests where the wood used in German paper originates, is an environmentally relevant topic which can only be quantified with some difficulty. Here, attention should be paid to wood from certified forests, e.g. using the FSC label (although there are also FSC labels for wood originating from plantations). Increasing the proportion of wood from certified sources represents an important potential (conservation of biodiversity, etc.) for the future.[86]

Collectively, the options for action in the paper sector involve mainly the consumer side, for both commercial customers and the end user, at least at the present time[87]. A targeted demand policy would be in a position to considerably strengthen the recognised positive environmental developments such as near-natural wood management, high waste paper input and low-emission production. It is possible to further develop the German *Blue Angel* environmental label, which plays a vital role in maintaining the use of recycled fibres, in accordance with the above data concerning fresh fibres. By taking the requirements of the FSC label with regard to fresh fibres into consideration, the *Blue Angel* would play an important role for paper from both primary and secondary fibres.[88]

4.6.3 Synopsis of furniture consumption in Germany

4.6.3.1 Facts and figures

The principal production processes for producing furniture from wood include drying, cutting and planing, assembling, painting or polishing wood. Adhesives, both soluble and polymers (hot melt), are used for assembling upholstered furniture. A further characteristic is the extensive surface treatment employing stainers, dyeing agents and polishes.

<u>Economic indicators:</u>

The furniture branch is one of the medium-sized branches in Germany, with approx. 170,000 employees (see Figures 4.34, 4.35 and 4.36). [Sietz 2001] However, it may be regionally more important (e.g. in the Black Forest region or East Westphalia).

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86 Problems were encountered here in the sawing mills: Paper production makes extensive use of sawing waste, which allegedly cannot yet be separated into FSC or other certification systems. FSC has therefore revised its Chain of Custody.

87 Sales of recycled paper (e.g. in the hygiene industry, but also for school exercise books) can be further enhanced in this manner.

88 Details and the opportunity for clear communication of an appropriate enhancement to the Blue Angel first require detailed and careful coordination with the specialists involved at the UBA.

[Sietz 2001] At approx. 15%, the foreign turnover component of the German furniture branch is low.

Figure 4.34 Turnover of the German furniture industry in million Euro [Sietz 2001]

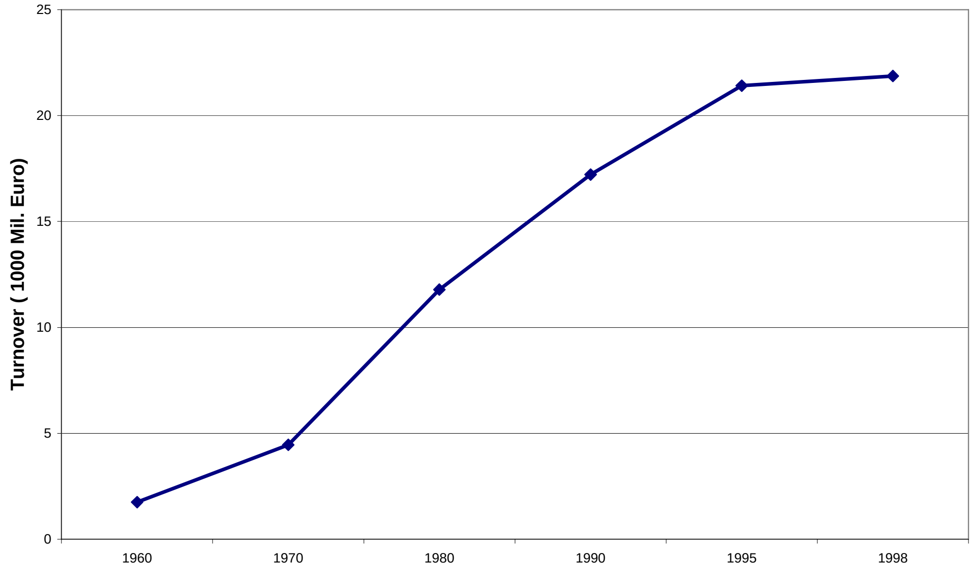


Figure 4.35 Employees in the German furniture industry [Sietz 2001]

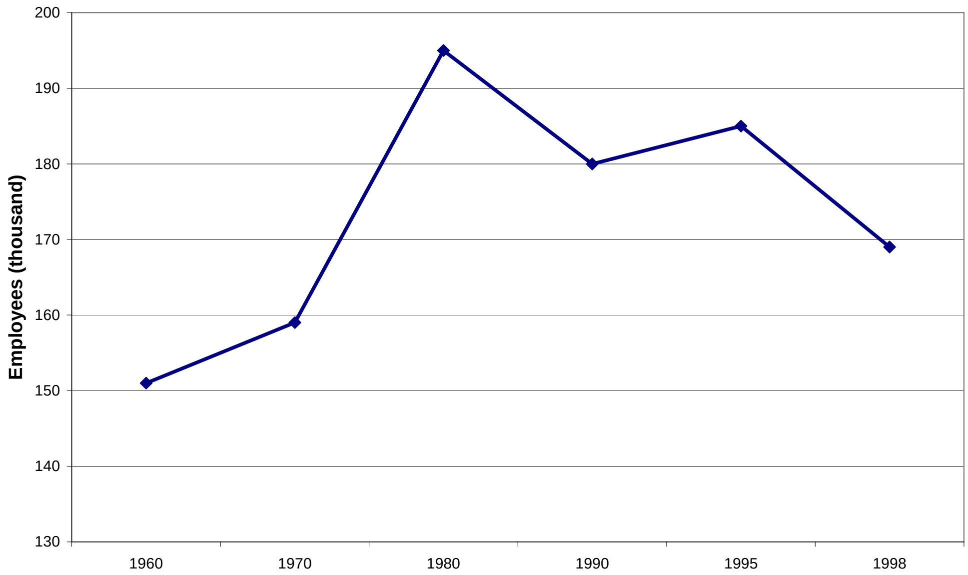
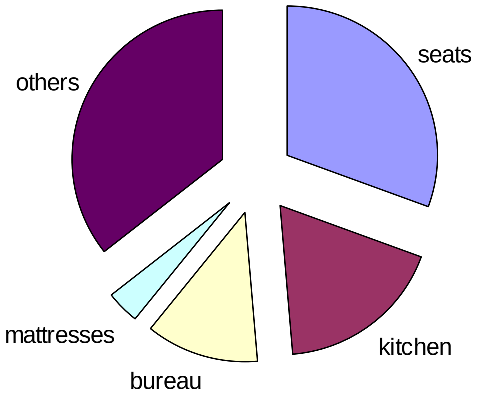


Figure 4.36 Turnover of the German furniture industry according to product groups [Sietz 2001]



In 2004, every German citizen invested an average of €360 in furniture. This represents the first per capita increase in expenditure since 2000. This makes Germany, together with Austria and Sweden, European leaders in expenditure for furniture consumption. Imports increased by 48% between 1992-1999. The most important import regions are Eastern Europe (€2.1 billion), Italy (€1.6 billion) and Denmark: (€0.6 billion).

<u>Economic relationships:</u>

The consumption of semi-finished wood products in the German furniture industry is shown in Table 4.29 according to wood products. [Mantau 2005] The furniture industry is an important buyer of panels and veneers.

Table 4.29 Wood consumption of the German furniture industry

	Absolute in Mm³	**% of wood consumption in furniture sector**	**% of all semi-finished wood products of other fields of application**
Sawn timber	2.362	20.6	10.3
Veneer and plywood	0.440	3.8	35.9
Panels	8.647	75.5	74.3
Total	11.449	100.0	32.0

Of the semi-finished products used, 66.4% remain stored in wooden furniture products and 33.6% accumulate as waste [Mantau 2005] and must be disposed of. The input corresponds to 6.47 Mt/a of air-dried wood. Accordingly, 4.3 Mt/a (air-dried) remain in the furniture.

<u>Ecological indicators: Data relating to environmental criteria:</u>

Table 4.30 shows examples of material composition. It shows the various principal materials used, their input and processing losses.

Table 4.30 Example of material input and output for upholstered furniture [Sietz 2001]

	COR company Conseta model		**COR company Barca model**		**Gepade* company combio⁺ model**		**Gepade company Troja model**	
	Input	Output finished furniture	Input	Output finished furniture	Input	Output finished furniture	Input	Output finished furniture
Electrical energy	16.26 kWh	-	21.77 kWh	-	13.75 kWh	-	6.69 kWh	-
Energy consumption for pre-production of wooden products	25.24 kWh	-	11.14 kWh	-	11.9 kWh	-	15.12 kWh	-
Wood materials	54.30 kg	37.18 kg	31.40 kg	29.78 kg	46.21 kg	30.43 kg	18.1 kg	24.9 kg
Foam rubbers	20.85 kg	20.85 kg	17.34 kg	17.34 kg	5.7 kg	4.56 kg	6.0 kg	6.0 kg
Fabric	9.55 kg	7.21 kg	8.90 kg	6.68 kg	12.43 kg	8.56 kg	8.99 kg	6.55 kg
Steel	2.64 kg	2.64 kg	0.41 kg	0.41 kg	0.67 kg	0.67 kg	4.6 kg	4.6 kg
Plastics PE	1.31 kg	1.31 kg	0.06 kg	0.06 kg				
Adhesive	0.31 kg	0.31 kg	0.05 kg	0.05 kg	0.1 kg	0.1 kg	0.2 kg	0.2 kg
Lacquers and other aids			1.50 kg	0.75 kg	0.2 kg	0.15 kg		
Plastic films	0.90 kg	0.90 kg	1.67 kg	1.67 kg	0.13 kg	0.13 kg	0.13 kg	0.13 kg
Aluminium			0.07 kg	0.07 kg				
Down feathers							2.0 kg	2.0 kg
Paperboard							3.08 kg	2.8 kg

The current composition of discarded furniture is given in Table 4.31. At 60%, wood represents the main constituent.

Table 4.31 Furniture waste fractions [UEA 2005]

Wood	60.0%
Metal	11.9%
Plastics	5.9%
Fittings	5.4%
PU foams	4.0%
Fabrics/textiles	3.4%
Glass	2.0%
Rubber	0.7%
Others	6.7%

The average design life of furniture is approx. 10-12 years. It is estimated that 2.3 Mt/a of furniture are discarded in Germany. This corresponds to approx. 6% of residual waste. [UEA 2005] The furniture consumption sector is not exceptionally important in terms of material flows and the associated environmental impacts. Currently, 9.6 Mm^3 of finished wood (corresponding to 6.5 Mt of air-dried wood) are used for furniture production in Germany. By weight, 66.4% remains stored in wooden furniture products, the remaining 33.6% are residual substances. Further materials such as metals also occur. The EU annual waste figures include 4.6 Mt of wood, 0.9 Mt of metal, 0.45 Mt of plastics and a further 0.3 Mt of PUR foams forming the principal fractions from waste furniture.

4.6.3.2 Dynamics and trends

Germany, together with Italy, is the largest furniture producer in the EU. While the employment figures in Germany are falling, they are climbing in the new member states. In addition, import has increased rapidly since 1998, accounting for 15% of value but 24% of volume in the EU in 2003. The main export country is China.

Because furniture is made from high-quality wood, there is an interest both in recycling and in utilising the waste wood. An empirical survey of furniture producers revealed that 7% of producers already accept furniture returns and 12% are seriously considering this or are planning for it in the mid-term: overall, however, returned furniture plays a minor role only. [Mantau 2005] A study in the German state of Saxony-Anhalt showed that of the furniture found in bulky waste, 42% were free-standing cabinets/kitchen furniture, 32% upholstered furniture and 26% frame furniture (generally tables and chairs without upholstery). [WKI 2003]

4.6.3.3 Potentials

In principle, potentials for decreasing environmental impacts can be achieved at the design stage by reducing the materials used and by substitution of especially harmful materials (solvents, adhesives) with less environmentally harmful ones. Furthermore, a reduction in the environmental impacts of long-life furniture consumer goods can be achieved in particular by further extending the design life. Quality furniture, for example, can achieve a design life of more than 25 years. It is possible to derive from the relatively inexact surveys that households in Germany buy considerably more furniture (approx. 7.1 Mt/a at 60% wood) than they dispose of (2.3 Mt/a). In all, these calculations result in a total store of approx. 4.8 Mt/a.

The furniture industry is a large wood consumer, especially high-quality woods. The furniture industry is therefore in a position to send signals to forestry by purchasing certified wood and thus to support sustainable forestry.

4.6.3.4 Options for action

Options for action lead in two directions for furniture products. On the one hand, furniture consists of the renewable raw material wood, which can be supplied from certified stock. On the other hand, stringent demands must be placed on the surface treatment and joint technology in terms of the chemicals employed (e.g. solvents, adhesives). Both processes can be supported by a quality seal. The furniture industry is active at the European level in this context.

The figures allow an estimate of the annual increase of approx. 3 to 5 Mt in the store of furniture for the housing and office building sector in Germany alone. This estimate agrees well with the living area in Germany. This continues to increase and in the end represents the receptacle for furniture in the technosphere (together with associated areas). This also indicates an increasing mid- to long-term potential represented by the "waste furniture" material store in the context of a sustainable resources conservation policy. The option for action must be sought in improved material segregation and subsequent recycling (feedstock or energy recovery from waste wood, metal and plastics recycling, etc.) of waste furniture. Some regional administrations already segregate bulky waste (and thus waste furniture) to a large extent as a result of the legislative framework (Technical Directive on Waste, etc.) and the high disposal costs. Nationwide segregation represents one option for action allowing even better recycling of the secondary raw materials potential from waste furniture, which will continue to increase in the future.

4.6.4 Important existing regulations

Material flow-related regulations in the form of feedstock recovery quotas are only found for paper, cardboard and wood (see Packaging Ordinance) in this material flow system. Other regulations relevant to this material flow (Waste Wood Ordinance, Biowaste Ordinance) aim to control hazards to humans, the environment or wildlife, but contain no material flow-relevant starting points. A voluntary commitment with regard to the material flow system has been put in place by the "Working Group on Printing Papers" for the return and recovery of used printing paper only.

4.6.4.1 Greenhouse Gas and Emissions Trading Act (*TEHG*)

The following plant in the material flow system is subject to the *TEHG* with regard to CO_2:

- plant for the extraction of pulp from wood, straw and similar fibre substances,
- plant for the production of paper, cardboard or paperboard with a production capacity of more than 20 tonnes per day.

4.6.4.2 Commercial Waste Ordinance[89]

The principal aim of the Commercial Waste Ordinance, which focuses on regulating the recovery and disposal of commercial municipal waste, is the segregation of waste fractions in order to achieve higher feedstock or energy recovery. Paper and paperboard, glass, plastics and metals, but not wood, belong to the groups with high feedstock and energy recovery targets. They must be separately collected in accordance with the Commercial Waste Ordinance. For example, the producers and owners of commercial municipal waste may, in accordance with Article 4, Commercial Waste Ordinance, include wood in commercial municipal waste mixes intended for pre-treatment: Further information on the Commercial Waste Ordinance can be found in the legal regulations for the "non-metals-cement-concrete-housing consumption" material flow system.

4.6.4.3 Waste Wood Ordinance[90]

The Waste Wood Ordinance states that waste wood is divided into various categories. Waste wood classified as hazardous waste is placed in the highest category, "A IV", due to its pollutant content. According to the Waste Wood Ordinance, neither feedstock recovery (Article 4, Section 3, *KrW-/AbfG*) nor energy recovery (Article 4, Section 4, *KrW-/AbfG*) take priority, because wood, as a renewable raw material, displays no clear advantages or disadvantages for one or the other recovery method. The waste owner has a choice between feedstock and energy recovery. With regard to energy recovery, however, further requirements must also be fulfilled in terms of the calorific value, combustion efficiency, produced heat and the resulting waste (Article 6, Section 2, *KrW-/AbfG*). Waste wood of category "A IV" may only be subject to feedstock recovery in order to extract synthesis gas for further chemical utilisation, or to produce activated charcoal (Article 3, Section 1, in association with Annex I, Waste Wood Ordinance). Waste wood not subject to recovery must be supplied to a thermal treatment plant for disposal (Article 9, Waste Wood Ordinance). Combustion, pyrolysis and gasification plant are all acceptable.

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[89] Ordinance on the Management of Municipal Waste of Commercial Origin and Certain Construction and Demolition Wastes (*Gewerbeabfallverordnung – GewAbfV*) of 19 June 2002, Federal Law Gazette I pg. 1938; last amended by Clause 2 of the Act on 25th Julye, 2005, Federal Law Gazette I, No. 46, pg. 2252.

[90] Ordinance on the Management of Waste Wood (Waste Wood Ordinance – *AltholzV*) of 15th August 2002, Federal Law Gazette pg. 3302.

4.6.4.4 Packaging Ordinance[91]

The Packaging Ordinance provides regulations for all packaging distributed in the scope of the Closed Substance Cycle Waste Management Act regardless of the materials they are made of (Article 2 Packaging Ordinance).

The following general Packaging Ordinance specifications for the production and sale of packaging must be adhered to (Article 12, Packaging Ordinance):

- The packaging volume and mass must be kept to the minimum required for the necessary safety and hygiene of the packaged product and adequate for acceptance by the consumer.
- Reuse or recovery must be possible and the environmental impacts of the recovery and disposal of packaging waste must be reduced to a minimum.
- Harmful and hazardous substances and materials in emissions, ash or leachate must be reduced to a minimum when disposing of packaging or packaging components.

Following a lengthy discussion of the revision of the 1994 packaging and packaging waste directive, its amendment came into force in February 2004 with Directive 2004/12/EC[92]. The amendments were implemented in Germany in January 2006. The directive places heightened demands and target quotas on the recovery of packaging waste. The minimum feedstock recovery from packaging waste in the member states, for example, is increased from 25% to 55%. This quota must be achieved by the end of 2008. Prevention of packaging waste is given priority in the directive's regulation system. Other main principles include the reuse of packaging, feedstock recovery and other forms of recovery of packaging waste, as well as the reduction of waste resulting from these measures. This resulting waste must then be ultimately disposed of. In order to realise the recovery target, quotas are specified in Clause 6 for the recovery of packaging waste. They were increased up to 2008. The establishment of a return, collecting and recovery system is also planned. Waste requiring special supervision occurs within the packaging waste sector primarily through contamination of the packaging by the waste requiring special supervision transported within it. The governing factor for the reduction of waste flows is not, therefore, the quotas for recovery of packaging waste, but the disposal costs for packaging requiring disposal and which can no longer be recycled.

The amended Directive 2004/12/EC prescribes the following minimum targets for feedstock recovery of individual substance groups:

[91] Ordinance on the Avoidance and Recovery of Packaging Waste(Packaging Ordinance - *VerpackV*) dated 21st August 1998, Federal Law Gazette I, pg. 2379, last amended by Federal Law Gazette I of 6th January 2006, pg. 2.

[92] Directive 2004/12/EC of the European Parliament and of the Council of 11.02.2004 amending Directive 94/62/EC as regards packaging and packaging waste, Official Journal No. L 47/26 of 18.02.2004.

Table 4.32 Minimum targets for feedstock recovery from packaging waste of individual substance groups by 31.12.2008

Material	Weight percentage
Paper and cardboard	60%
Wood	15%

A labelling obligation for packaging material is not included in the Packaging Ordinance. Article 14 states that packaging can be labelled using the numbers and abbreviations provided in Annex IV in order to identify the materials used.

4.6.4.5 Biowaste Ordinance[93]

Biowaste in the context of the Biowaste Ordinance is waste of animal or vegetable origin for recovery which can be decomposed by microorganisms, soil organisms or enzymes; this especially includes the waste types named in Annex 1 No. 1; soil material that does not include large proportions of biowaste is not biowaste; vegetable remains accumulating on forestry or agricultural land and which remain on this land is not biowaste;

Annex I of the ordinance lists the biowaste considered suitable in principle to be utilised on land areas, as well as that suitable in principle as mineral aggregates. Biowaste from forestry is named in Annex I of the ordinance as bark, wood and wood remains. They have the Waste Catalogue Ordinance key 02 01 07. After suitable cutting in the course of composting, bark, natural wood or natural wood remains may also be added to other biowaste to be applied to permanent pastures.

The Biowaste Ordinance includes obligatory demands on the quality of treatment of biowaste. These are listed in Annex I of the Biowaste Ordinance. The Biowaste Ordinance restricts and prohibits the application of biowaste to arable land in commercial farming. It prescribes that biowaste must be subject to treatment before application, ensuring that any hazards from pathogens to human or animal health are avoided. The ordinance does not apply to application on household and kitchen gardens and allotments, landscaped areas or areas under recultivation measures. Personal use on agricultural holdings and in gardening and landscaping operations is also exempt from the requirements of the Biowaste Ordinance.

4.6.4.6 Voluntary commitment of the Working Group on Printing Papers for the Return and Recovery of Used Printing Paper (AGRAPA)

The 1994 voluntary commitment (renewed in 2001) contains the following arrangements:

[93] Ordinance on the Utilisation of Biowastes on Land used for Agricultural, Silvicultural and Horticultural Purposes of 21st September 1998, Federal Law Gazette I 1998, 2955; last amended on 26.11.2003, Federal Law Gazette I, 2373.

- An obligatory quota for the feedstock recovery of waste printing papers of 80% +/- 3%.
- Use of recycling-friendly fibre substances, paper production aids and fillers.
- Promotion of sales of paper including recycled paper by way of expansion and diversification of supply.
- Support of research and development of recycling-friendly material combinations, consumer products and production processes.
- Consultation with public waste disposal agencies with regard to cost-effective and assured quality waste paper collection.

4.6.4.7 Furniture consumption

Used furniture discarded by private households is classified as municipal waste. A compulsory supply obligation with regard to public waste disposal agencies exists for municipal waste from private households (Article 13, Section 1, *KrW-/AbfG*) and for waste for disposal from other origins, e.g. commercial waste where it is not disposed of in other plants. The public waste disposal agencies regularly provide bulky waste collections for this purpose and collect the bulky waste of the suppliers under obligation.

The Waste Wood Ordinance prescribes a recovery-related obligation for separate collection (Article 9 Waste Wood Ordinance), linked to the legal requirements of the *KrW-/AbfG* specifying that recovery takes priority over disposal. However, strict segregation of individual fractions is not required for furniture, i.e. not even for wood.

4.6.5 Synopsis of options for action for this material flow system

In order to further utilise the considerable potentials for decreasing environmental impacts the following recommendations can be particularly emphasised for the forest-paper-furniture consumption material flow system following the project investigations:

- The importance of the raw material wood for paper production (approximately 50 Mt/a of fresh wood mass) should be emphasised. Wood with the FSC label from certified stock should therefore be increasingly promoted for use in the paper industry (and furniture industry).
- The continuously growing furniture sector material store should be optimally utilised in future. Potentials for decreasing environmental impacts in terms of high-quality feedstock and energy recovery remain to be utilised. This can be achieved by improved collection and material segregation after the lifetime of the products.

5 Synopsis of potentials and options for action

By way of the procedure selected for this project employing the dual perspectives of "sectors and produced goods" and "consumer goods" for the prequalification of particularly relevant material flows, it was possible to rapidly and efficiently identify relevant materials (see Section 3). The subsequent detailed investigation of the selected items in the context of their material flow systems reveals considerable additional potentials for resource conservation, emissions and waste reductions, greenhouse gas reductions and for addressing risks (e.g. pollutants contained within the substantial material stores associated with building stocks). Important options for action in terms of the individual material flow systems (e.g. iron ore-steel-vehicle manufacture-car consumption) can be found at the end of the subsections in Chapter 4.

Table 5.1 summarises the most important potentials and options for action. The information is described in more detail and derived in Chapter 4 of this final report. Further data, details and referenced sources can be found there. The potentials described serve primarily to give an idea of the magnitude of the potentials and the respective focus (e.g. sulphur dioxide emissions). These are, on the one hand, generally only purely technical potentials, i.e. they generally represent maximum target values for the period in question. On the other hand, validation of some of the estimated potentials and the options for action require more detailed investigations of the selected foci (see Chapter 6).

Table 5.1 Overview of potentials and options for action

Sector	Potential	Option for action
Steel production	**Reduction in primary energy consumption: 17 or 27% respectively (128 or 204 PJ/a corresponds to approx. 10–15 Mt/a CO_2 equivalent) between 2000 and 2030,** lower and upper scenarios respectively (increase in proportion of electrosteel from 28.7% to 33% or 45%)	Energy savings arising from innovations in electrosteel and oxygen steel production, additional increase in the proportion of electrosteel production by forcing scrap collecting and recycling (dismantling of buildings, etc.)
Steel production	**Avoidance of landfill for up to 350,000 t/a of blast furnace gas sludge**, in particular, recycling of iron, lead and zinc components.	Creation of suitable and sufficient recycling capacities for blast furnace gas sludges.
Vehicle manufacturing	**Reduction of vehicle weight: up to 40% (approx. 3.4 Mt/a**); **thereby reducing primary energy consumption: up to 40% (318 PJ/a corresponds to approx. 18 Mt/a CO_2 equivalent),** additional savings of considerable amounts of greenhouse gases.	Advanced R&D of lightweight components and vehicle designs as well as appropriate implementation.
Mineral oil industry	**Reduction in total energy consumption: approx. 5–10% (16–32 PJ/a corresponds to approx. 1.2–2.4 Mt/a CO_2 equivalent)**	Comprehensive refurbishment of the numerous old systems.
Mineral oil industry	**Reduction of sulphur dioxide emissions: approx. 50% (approx. 25,000 t/a)**	Systems refurbishment based on power station desulphurisation.
Plastics industry	**Increase in recycling of plastic waste from 58.4% to 80% (at least 1 Mt/a, dynamically increasing in the long-term to additional 5 Mt/a)**, base year 2003: long-term until 2020, incl. energy recovery.	Increase in recycling quotas, in particular from intermediate- to long-life products (vehicles, electronics, construction applications): landfill minimisation, improved collection, etc.
Cement industry	**Reduction in specific CO_2 emissions: 28% (approx. 2 Mt/a)** between 1990 and 2008-2012 in accordance with voluntary commitment.	Implementation of the voluntary commitment by further optimisation of energy efficiency (grinding technology, etc.) and increased use of secondary fuels of biogenic origin.
Cement industry	**Reduction of NOx emissions: 10–20% (approx. 4,000–8,000 t/a)** in the mid-term compared to 2004	Equipping the remaining old systems with SNCR technology (selective non-catalytic reduction)

Concrete production	**Natural resource conservation: up to 10% (up to 16 Mt/a)** from around 2010	Promotion and stronger establishment of concrete recycling in high-quality applications (aggregates for new concrete)
Residential buildings	**Reduction in CO_2 emissions: approx. 52% (approx. 110 Mt/a)** between 2000 and 2025	Forced remediation of the often suboptimal housing stock in terms of energy efficiency (principal option)
Residential buildings	**Reduction in the requirement for mineral resources: approx. 50% (approx. 80 Mt/a)** between 2000 and 2025.	Extension of building lifetime by comprehensive refurbishment, pooling of apartments, lowering of unoccupied conditions and thus a restriction of new building volume to meet requirements, forced selective demolition of unused buildings.
Residential buildings	**Reduction in land utilisation: from 31 ha/d to 5 ha/d,** net housing and development land.	Forced exploitation of inner development potentials (e.g. derelict land), suitable density increases.
Residential buildings	**Minimisation of the release of problematic substances (e.g. heavy metals, mineral fibres) during conversions and demolition.**	Forcing and qualitative improvement in selective demolition and separate collection and recycling, removal of problematic and incompatible substances from the material cycles and their safe and hazardless disposal.
Agriculture, livestock farming	**Reduction in excess nitrogen: by 30% (approx. 650,000 t/a; from 114 to 80 kg/ha)** by 2010 based on 1996-2000.	Reduction in fertiliser use and optimisation of its application.
Livestock farming	**Reduction in ammonia emissions: 20–30% (approx. 90,000 to 140,000 t/a)**	Optimisation of liquid animal manure application management (primarily time and method of application).
Paper production	**Substantial increase in the use of wood from certified forests and (consumer side) increasing use of environmentally friendly paper,** important contribution to biodiversity.	Increased use of wood from near-natural cultivation (FSC certificate) and further development and propagation of the Blue Angel for paper.
Furniture consumption	**Optimised feedstock recycling and energy recovery of waste furniture** resource potential grows in future due to store build-up in the technosphere (precise information and data require detailed investigations).	Forced segregation primarily of metals (feedstock recycling) and wood (feedstock recycling or energy recovery in high efficiency systems) from bulky waste.

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6 Further investigation requirements and relevant data gaps

This project allowed particularly relevant material flows and their associated production processes, produced goods and consumer goods to be identified in a timely and efficient manner with the aid of a material flow approach. This establishment of priorities represents an important requirement for the development of the circular economy towards a sustainable substance flow and resources policy in Germany. Because it was only intended to use existing data and sources in this six-month project, collection of our own source data (e.g. by interviews with specialists, expert workshops, etc.) is reserved for further detailed investigations. On the one hand, the results of the project demonstrate the need for more detailed investigations with regard to the development of the important potentials illustrated here. On the other hand, a number of relevant data and information gaps capable of being closed in the short-term (i.e. in the next one to two years) were identified.

6.1 Investigation requirements for development of relevant potentials

In general, the work has demonstrated that, in the context of resource conservation and energy saving, it will be possible in future to access large potentials in a number of sectors from the growing material stores in the technosphere. Generally speaking, it would be an interesting exercise to examine existing regulations, including those of a general nature, e.g. in tax legislation, to discover whether any regulations exist that create broad positive (e.g. lorry tolls) or negative effects (e.g. high burden of taxation for the factor work in contrast to the factor resources) on sustainable materials management, together with expert estimates of the extent for each case.

6.1.1 Iron ore-steel-vehicle manufacture-car consumption material flow system

Detailed investigations are important for the steel industry in terms of defining the necessary conditions for promoting a sustainable increase in energy efficiency and the conservation of resources by improving scrap utilisation (electrosteel route). This will assist in exploiting the large potential for reducing environmental impacts (*cf.* Chapter 4). Broad and detailed identification of potentials covering all – primarily intermediate- to long-life – applications (scrap vehicles, residential buildings, non-residential buildings, rail infrastructure, machines, etc.) would therefore be very important to the steel industry in order to arrive at more detailed scenarios and projections for developing the scrap potential. This information, equally vital to both publicly- and privately-owned businesses, in turn represents an essential precondition in terms of substantiating the necessary framework conditions for an optimal increase of secondary raw material utilisation in the future.

In vehicle manufacturing, the investigation of previous and expected future effects caused by the development and use of weight-saving components (fuel savings) represents a task with long-term relevance. Opposing effects (increase in vehicle weight due to larger, more powerful cars and new "extras", occasionally serving other purposes (e.g. increasing safety)), must be taken into consideration. Life-cycle analyses suited, among other things, to early recognition of counterproductive developments (e.g. use of components extremely energy-intensive in their manufacture) should be employed. In the scrap vehicles sector the results of recycling quota monitoring (spring 2006) should be evaluated at short notice and developments closely followed with regard to the progress made in recycling methods for treatment of the light shredder fraction (e.g. VWSicon).

6.1.2 Crude oil/natural gas-petroleum processing-fuel consumption material flow system

Detailed investigations are necessary for this material flow system primarily on the production processes side in terms of the technical possibilities and measures suited to considerably reducing sulphur dioxide emissions from mineral oil processing. With regard to forcing plastics recycling mainly from intermediate- (e.g. electronics) and long-life applications (structural and civil engineering, vehicles, etc.), precise knowledge of the plastics inventory in the material store is required – similar to steel. Beside information on quantities, questions regarding the inventory of problematic substances (e.g. heavy metals) and optimum selective demolition are at the forefront (*cf*. remarks on investigation requirements for residential buildings)

6.1.3 Mineral resources-cement-concrete-residential buildings material flow system

A detailed overview of current technical options and measures suited to considerably reducing dust and nitrous oxide emissions (refurbishment of old plants, etc.) are of interest to the cement industry for the purpose of defining detailed investigations.[94] An important area of research would be an explicit investigation of the current ecological condition of the German cement industry. This is against the backdrop of the BAT (Dec. 2001) and the voluntary commitment of the German cement industry, as well as in terms of the development of further potentials. Beside measures for reducing both energy consumption and CO_2 emissions (maximising the potential for secondary fuels, among other things), detailed investigations should be placed at the focal point of a status report aimed at minimising the discharge of trace elements (influence of the spectrum of fuels or secondary fuels, etc.).

In particular, an investigation of suitable measures and initiatives for significant improvements to building demolition practice is required, because the current

[94] The Federal Environment Agency already plans to carry out appropriate investigations with regard to the topics addressed with reference to the cement industry.

framework is insufficient. Not least because of numerous problematic substances (e.g. asbestos, heavy metals) and incompatible substances (e.g. gypsum in concrete recycling, insulation materials manufactured from fibres, etc.) contained in the material store, which in practice make successful high-quality recycling more difficult or even hinder it completely, a means of optimal material segregation by selective demolition should be sought. This should adopt an ecological perspective, taking practical aspects (effort, costs, minimum limits, etc.) into due consideration. In terms of results, an appropriate investigation should be open and unbiased, comprising all imaginable categories of measures (adaptation of legal regulations, communication measures, voluntary measures such as voluntary commitments entered into by various associations, etc.) with regard to their efficiency and practicality for future access to potentials.

In addition, an investigation of existing restraints, including the specification of concrete proposals to overcome them, will prove extremely relevant in the future in terms of options for improved activation of the material store from permanently unused buildings (permanently unoccupied office buildings, factory buildings, residential blocks of flats, etc.). In this context it is important not to forget the extensive complex of subsidies and the tax framework. In terms of resource conservation effects, the current counterproductive arrangement of land transfer tax can be named as an important example.[95]

6.1.4 Biomass-plant processing-bread consumption and biomass-animal feed-livestock farming-meat consumption material flow systems

Within the agricultural sector, the primary requirement is for extensive investigations of the question of which way the land expected to be freed up within the next twenty years as a result of agricultural productivity increases can be optimally dealt with in the context of sustainability (e.g. areas given over to nature conservation, for biomass feedstock or energy applications). Additionally, it is important to investigate how, by what means and with what prospect of success the continued high agricultural ammonia emissions can be substantially reduced. These investigations should comprise a wide spectrum of possible options (e.g. technical emission reduction in factory farming, type and means of liquid animal manure application, etc.).

[95] In the NFS the creation of open spaces and traffic areas dominates due to the subsidisation of demolition: 2004: OFS total: Demolition of 1,324,000 m^2 of housing and utility space, including 237,000 m^2 (17.9%) for the creation of traffic areas and open spaces, the rest for new-build of housing and non-housing buildings; NFS: 2004 total: 2,713,000 m^2, including 1,754,000 m^2 (65%) for the creation of traffic areas and open spaces, the rest for new-build of housing and non-housing buildings.

6.1.5 Biomass-forestry-paper-furniture consumption material flow system

An investigation of the best or most efficient practice in Germany would be suitable with regard to improved utilisation of the potentials arising from the waste furniture material store. A discussion of best practice strategies is interesting (e.g. optimal collection and recycling results for metal components, wood components, etc.) because waste furniture is generally disposed of or recovered by means of bulky waste collections or in municipal building yards and the practical details differ here from one regional administration to another. Subsequent nationwide communication of suitable information on exemplary recycling strategies for waste furniture/bulky waste is also relevant in view of insufficient regional disposal or recovery capacities (key word: interim storage).

6.2 Closing important data gaps

In conjunction with the subject of data gaps, the material store contained in non-residential buildings is highly interesting from a resources perspective (high proportions of metals, concrete, etc.). Here – in contrast to residential buildings – there is considerably less knowledge about the quantities of pure materials and their possible mobilisation periods and rates. It is therefore recommended to close these important data gaps by means of a detailed investigation (see Chapter 4.3.5 "German non-residential buildings excursus").

Considerable data gaps were also determined in relation to the electric and electronic products sectors and their associated resource potentials. Here, too, a substantially higher level of knowledge would be desirable in order to estimate the potentials and options for action. Due to the special complexity and dynamics within this sector (rapid changes in models and the technological properties of products, the variety of some "exotic" but important metals from a resources perspective, etc.) the investigation effort here – subject to the necessary detailed description – is considered more extensive compared to that required for closing the data gaps mentioned above with regard to non-residential buildings.

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Annex 3: Synopsis of data particularly relevant to prequalification

Produced goods	Greenhouse gases	Acidification	Total CED	Fossil CED	Raw material - mineral	Raw material - metallic	Raw material - biotic
	1000 t CO2 equivalent	*1000 t SO2 equivalent*	*TJ*	*TJ*	*1000 t*	*1000 t*	*1000 t*
Pig iron/crude steel products	60,678	190	808,263	693,046	14,336	40,666	0
Pipes	5,746	33	102,796	96,581	2,056	4,534	0
Manufacture of basic iron and steel	8,882	52	172,239	162,311	2,962	7,412	0
Vehicle manufacturing	84,187	385	1,484,548	1,445,855	13,832	40,289	0
Coking plant/mineral oil	71,852	483	838,526	829,739	1,377	1,012	0
Crude oil/natural gas	1,966	2	0	0	248	78	0
Plastic goods	10,272	37	408,237	402,503	5	2	0
Chemical fibre fabrics	471	2	11,911	11,831	0	0	0
Rubber goods	3,545	13	101,211	97,860	156	22	0
Non-metals union	5,052	26	75,581	70,483	445,718	15	0
Natural stone	61	0	833	809	5,053	0	0
Cement/lime/gypsum	46,715	81	236,361	228,721	76,153	26	0
Concrete products	32,192	67	184,657	178,467	190,203	46	0
Bricks and other construction ceramics	2,967	7	40,643	30,330	20,240	6	0
Agriculture	7,996	38	56,364	50,496	811	10	0

Grinding and peeling mills	3,213	15	26,977	25,801	299	7	7,725
Other foodstuffs industry	21,531	88	235,023	234,656	745	38	99,800
Fruit/vegetables/oils/fats	19,541	66	300,366	280,915	338	53	17,340
Drinks manufacturing	10,131	26	139,223	133,491	382	25	7,004
Livestock farming	66,215	505	353,226	336,347	4,016	164	201,346
Meat processing	37,883	471	259,302	243,901	4,983	49	75,377
Milk processing	28,991	220	157,735	150,221	1,745	72	87,275
Forestry	738	5	8,954	8,666	159	2	27,985
Wood industry	7,352	35	300,152	191,063	256	49	46,181
Paper industry	22,534	37	402,693	330,646	604	62	26,325
Publishers and printing	9,864	16	176,272	144,735	265	27	11,523
Furniture	639	4	23,234	21,668	5	1	802
Coal mining, peat extraction	2,758	7	23,895	23,859	36	12	0
Non-ferrous metals	11,930	62	162,303	113,349	595	4,877	0
Glass	2,670	14	52,380	45,956	2,829	16	1
Ceramics	176	0	2,406	1,795	1,198	0	0
Other mineral products	2,011	11	91,488	90,980	15,119	23	0

Data compilation: Öko-Institut, IFEU-Institut Heidelberg

Consumer goods	Greenhouse gases	Acidification	Total CED	Fossil CED	Raw material - mineral	Raw material - metallic	Raw material - biotic
	1000 t CO2-equivalent	*1000 t SO2 equivalent*	*TJ*	*TJ*	*1000 t*	*1000 t*	*1000 t*
Motor vehicles	18,232	83	321,501	313,121	2,996	8,725	0
Passenger car fuels	36,160	243	421,995	417,572	693	509	0
Fuel oil	11,749	85	128,821	126,243	375	204	0
Gas	9,262	22	121,400	119,711	458	232	0
Housing	35,300	99	295,450	273,505	150,000	2,349	4,600
Household maintenance	648	3	25,417	16,322	29	4	5,194
Bread	13,925	43	171,242	163,916	681	38	14,975
Vegetables	1,292	7	8,959	8,936	225	2	16,131
Beverages	13,716	47	210,667	197,082	236	37	12,111
Product containing sugar	12,547	103	67,441	67,162	3,878	0	23,123
Beer	1,873	5	25,738	24,678	71	5	1,295
Fruit	2,741	23	34,897	34,840	74	7	4,908
Meat products	22,944	318	129,704	121,748	3,388	25	51,880
Dairy products	15,235	122	56,758	55,464	1,522	15	56,751
Furniture	3,366	23	122,430	114,175	28	6	4,226
Newspapers	4,333	7	77,430	63,577	116	12	5,062
Solid fuels	2,821	6	26,788	26,476	33	5	0
Garden products	476	1	2,885	2,773	3,817	1	0
Commodities	7,769	28	183,889	174,078	850	1,785	0

Data compilation: Öko-Institut, IFEU-Institut Heidelberg