MEG equivalents and the SVHC Score: assessment of problematic substances in software and digital services

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Abstract: A wide range of chemicals are used in the manufacture and use of electronic devices. For most applications, alternatives for problematic substances are now available that have better properties. For the assessment of sustainability in the ICT sector, it is therefore important to know to what extent problematic chemicals are used. In the ECO:DIGIT project, we developed the indicator TOX for this purpose, which complements the method of life cycle assessment. The indicator TOX consists of a single value, the MEG equivalents. This is the total quantity of problematic substances, weighted according to their hazardousness. Monoethylene glycol (MEG) is used as the reference substance for the aggregation. The method of weigthing and aggregating of amounts of problematic substances using MEG equivalents described here can be used for all hazardous substances, not only in the electronics sector.
In addition, the SVHC score shows how much is known about the concentrations a particularly problematic group of chemicals in a device, the so called SVHC ('Substances of Very High Concern').

***Keywords*—**Digital infrastructures; Digital services; MEG equivalents, Indicator TOX, SVHC Score, REACH, LCA, Environmental impacts; Hazardous substances; REACH, ECO :DIGIT

I. Introduction

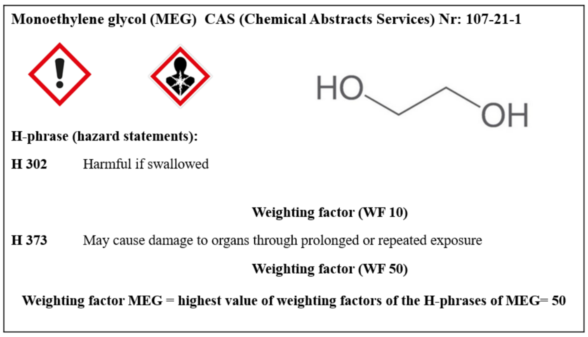
In recent years, numerous research studies have been conducted to assess the environmental impacts associated with digital infrastructures [1-6] and services [7, 8].

The purpose of a life cycle assessment (LCA) is to highlight all relevant environmental issues of a digital service. In the public debate, the environmental impact category of climate change is most prominent, followed by primary energy consumption, water consumption and abiotic resource depletion potential (ADP). The toxicity impacts associated with the numerous chemicals involved in manufacturing processes and product use phases have so far been insufficiently investigated due to methodological constraints and limited data availability. The mining and processing of raw materials are responsible for large material streams, destruction of ecosystems and depletion of toxic waste material. European countries fail to achieve the EU recycling rate of waste electric and electronic equipment year after year. In order to reduce the environmental impacts of raw material extraction and of waste electric and electronic equipment, circularity aspects need to be reflected in the LCA methodology. A circularity indicator should not be restricted to allocate the use of recycled material input streams and second life benefits, but should rather focus on the recyclability of the devices.

A major obstacle to recycling is the presence of problematic substances in waste streams. But problematic substances are not only relevant at the end-of-life of electronic devices. The production of ICT hardware already requires many hazardous substances for which serious risk management measures to prevent damage to workers' health are necessary. Electronic devices can contain very different amounts of problematic substances, e.g. brominated flame retardants in the plastic parts. In addition, chemicals with adverse effects on the environment are required for the provision of digital services e.g., cooling agents in data centers. There are often several options that would make it possible to reduce the environmental impact of a service. To this end, it is important that the corresponding impacts are visible and quantified.

We therefore propose broadening the scope of an analysis of the environmental impact of digital infrastructures and services and going beyond energy consumption and CO2 emissions. In addition, the use and presence of hazardous substances should also be recorded and evaluated. This requires a weighting of hazardous substances and an aggregation of their quantities. The internationally so-called "hazard statements" (H phrases) can be used for the weighting of substances. They characterize the potential of a substance to cause adverse effects. The organic chemical monoethylene glycol (MEG) has been chosen as a reference substance. This makes it possible to express the quantity of substances contained in a product in kilograms of MEG-equivalents (kg MEG-equivalents). The principles of this approach are also shown in the figure below.

Figure 1: Weigthing and aggregation of Amounts of problematic substances : Monoethylene glycol as reference substance.



One group of particularly hazardous chemicals are the "substances of very high concern" (SVHC). In addition to indicating the quantity of hazardous substances (in kg MEG equivalents), the SVHC score developed by us can be used to record how much is known about these substances in an electronic device and also in a digital supply chain. This information can help to optimise not only the use of hazardous substances, but also recyclability through design selection and purchasing requirements.

The following sections present an approach to assess problematic substances from the research project "Enabling green COmputing and DIGItal Transformation" (ECO:DIGIT) [33]. Compared to the LCA, it is characterised by additional elements: the pollutant balance with MEG equivalents in the TOX indicator and the SVHC score.

The assessment methodology used in the ECO:DIGIT project combines the life cycle assessment with the TOX indicator and the SVHC score. In this way, it can provide information that supports the transition towards a more circular digital infrastructure [34, 35].

The research project ECO:DIGIT is funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) on the basis of a decision by the German Bundestag. The aim of the ECO:DIGIT project is to develop an objective measurement methodology and implement it in a universally applicable test bench. The measurement methodology will record the energy and resource consumption of decentralized digital solutions. The project has not yet been completed, and the project results will continue to contribute to the discussion on methodological issues and practical implementation.

II. METHODOLOGICAL APPROACH

A. *LCA and the indicator TOX*

The LCA guides environmental scientists and sustainability professionals in making well-founded statements on the environmental impact of products and services. Digital services can also be analyzed using life cycle assessments.

The three levels of environmental impacts associated with the interaction of ICTs and the natural environment are generally defined as first, second, and third order effects [9]. This paper deals with the first order effects i.e., the negative direct effects associated with the production, use, and disposal of ICT products as part of a digital service. The second and third order effects are not the subject of this work.

The emphasis of the indicator TOX described in the following is the assessment of the use and presence of problematic chemicals. addresses hazardous substances in the workplace, hazardous substances in ICT hardware, the state of knowledge about a specific group of hazardous substances (SVHC, substances of very high concern) and problematic substances in the use phase of ICT. In all areas of use or presence of problematic substances, the quantities of several substances can be summed up and expressed as MEG equivalents. In addition to the TOX indicator, the SVHC score is used to record and evaluate the level of knowledge about the presence of substances of very high concern in electronic devices.

The target group for the described method are LCA practitioners seeking a comprehensive understanding and quantification of the environmental impacts associated with the provision of digital services. The additional elements proposed in chapter II.C. can also be used to assess and compare individual digital products and services in terms of the use and presence of problematic substances. This would raise awareness of these issues and support decisions for safer and more sustainable chemicals.

B. *Assessment of environmental impacts following the life cycle assessment approach*

The Life Cycle Assessment (LCA) approach is a recognized, scientifically based method for assessing the environmental impact of products and services, considering all life cycle stages and various impact categories. This provides a comprehensive, holistic overview of the particularly high impacts (hotspots) associated with a product or service and avoids compromises between different life cycle phases and impact categories. ISO 14040/44 [31, 32] provides the framework and guidelines of a life cycle assessment. ICT-specific methodologies in the context of a life cycle assessment are e.g. the GHG Protocol ICT Sector Guidance (2017) [10]; ITU-T L.1410 / ETSI ES 203 199 [11, 12], ADEME methodological standard for the environmental assessment of digital services [13].

For each digital infrastructure device used by the digital service, the environmental impact can be determined using established LCA methods. As part of the ECO:DIGIT project, fundamental environmental impact categories have been assessed: Global Warming Potential (GWP), Abiotic Resource Depletion Potential (ADP), Water Use (WU), the Cumulative Energy Demand (CED) of digital infrastructures and the total quantity of Waste Electrical and Electronic Equipment (WEEE) in kilograms. Additionally, the new indicator TOX has been used to address specifically the presence and use of problematic substances in the digital supply chain. This complements the LCA approach.

C. *The Assessment of problematic substances within the digital supply chain*

The main objective of the LCA approach is to assess the environmental impacts of products and services, considering all life cycle stages and various impact categories. In the context of chemicals, one significant environmental impact category is their toxicity potential. Within the LCA community, the USEtox® model [30], endorsed by UNEP's Life Cycle Initiative, is a scientifically recognized method for characterizing the human and ecotoxicological impacts of chemicals. USEtox® evaluates the environmental consequences between contaminant emissions released and their impact on ecosystems and human health based on fate, exposure and effect parameters.

The indicator TOX described in the next sections gives additional information on hazardous substances compared to the LCA approach with USEtox.

The indicator TOX does not focus on environmental impacts like USEtox. It evaluates the problematic substances used, regardless of whether they are ultimately released into the environment or not. Why? Digital services can widely vary in the amounts of problematic substances used or contained in the digital devices. The presence of these substances can cause problematic exposures of humans and the environment as well as problematic contaminations of material flows. Therefore, it is an important objective of product design and process design to reduce the use of problematic substances and to reduce the concentrations of such substances in products.

Results from the assessment of emissions in LCA do not allow a direct comparison of products and services regarding the use and the content of problematic substances. Therefore, in the following we propose the indicator TOX. It accounts for the use and content of problematic substances - based on information from an analysis of the substances used or contained in a specific life cycle stage. It consists of three modules.

In contrast to the LCA approach, the three modules of the indicator TOX are not concerned with the assessment of emissions. They are used to assess and illustrate the extent to which problematic substances are connected with a digital supply chain, a digital service or a specific hardware component.

The three elements of the indicator TOX use the same reference substance to be able to aggregate figures on the amount of problematic substances. The reference substance is the organic substance monoethylene glycol (MEG). Therefore, the results of the aggregations in the indicator TOX are expressed as kilogram MEG equivalents. Results from these elements can be aggregated into one number.

The indicator TOX was developed for the first time as a generally usable approach for assessing the use of chemicals, which can be applied in various product areas. So-called MEG equivalents are used as a parameter for balancing. It was used for pollutant balancing in the construction sector [18, 19, 20]. Within the ECO:DIGIT Project, it is applied for the first time to chemicals used in digital supply chains.

In the following sections, we describe the three areas where problematic substances can occur within the digital supply chain and approaches to assess and aggregate the substances:

- Hazardous substances in workplaces in the production of ICT hardware (section III.1);
- Hazardous substances in ICT hardware (section III.2);
- problematic substances in the use phase of ICT (section III.3).

Results from these additional three assessment elements can be aggregated into a TOX indicator that relates specifically to the three areas listed above. It is possible to extend this approach to other topics related to problematic substances in the digital supply chain.

A large number of chemicals is relevant in the areas described below. In order to aggregate the quantities of chemicals used or contained in a product, monoethylene glycol (MEG) is used as a reference substance. This approach is explained in the following section (III.1). For substances classified as hazardous, the required weighting factors are derived based on hazard phrases (H phrases) of the substances. These hazard phrases do not cover the Global Warming Potential (GWP) of substances e.g., of fluorinated gases (used as cooling agents). For such chemicals without H phrases, weighting factors can be derived based on other properties of the chemicals, e.g. their GWPs. This is described in section III.3.

In addition to the indicator TOX, we recommend to characterize individual hardware components regarding the level of information about Substances of Very high Concern (SVHC). These are the most hazardous substances and they are listed on the REACH Candidate list. There are specific notification and information obligations in Europe for the substances of Very High Concern. They also apply to devices imported into Europe.

The **SVHC Score,** developed in the ECO:DIGIT project, shows whether or not information on these substances is available for a hardware component. Products with such information contribute to more transparency about these substances and to substitution with less problematic ones. Therefore, the SVHC Score informs about the state of knowledge on these substances for a given product and to rank products based on this score. The SVHC score is described in Chapter IV.

In the following sections we describe the three elements of the indicator TOX (Chapter III) and the SVHC Score (Chapter IV).

III. The indicator TOX and its elements

The indicator TOX consists of three elements with a focus on the use and presence of problematic substances.

1) Element 1: Hazardous substances at working places in the production of ICT hardware

A large number of hazardous substances is required for the production of ICT hardware. Inventories of these chemicals were analyzed e.g. by Kim et al. [14] and Yoon et al. [15]. More than four hundred chemical products were used in semiconductor manufacturing plants in annual amounts of more than 40,000 t per plant [14].

If these hazardous substances are used without appropriate protection measures, they cause severe damage to workers' health and problematic emissions into the environment [4]. Cases of miscarriage and stillbirths have been documented among women working in semiconductor producing factories in the Philippines [16]. Damage to workers' health is one of the major problems in the production of ICT hardware.

Information on the chemical identity and the exact quantity of hazardous substances used in the manufacture of a specific electronic device is scarce. Examples for the amounts of chemicals required for the manufacture of wafer (thin silicon wafer for semiconductor production) are shown in Table 1 (Note: this example has been chosen to explain the approach. More recent life cycle assessment data sets can have other values. This is of no importance for the description of the MEG equivalent approach).

TABLE 1 Examples of chemicals used for the production of wafer, weigthing factors and MEG equivalents. (Unit: gramm MEG-equivalents per cm^2 wafer)

Substance	Amount		Weighting Human Health	MEG equivalents	
Sulfuric acid	6	g/cm^2	100	12	g
Hydrogen peroxide	2	g/cm^2	100	4	g
Hydrogene fluoride	0.5	g/cm^2	1,000	10	g
Phosphorous acid	2.7	g/cm^2	100	5.4	g
2-Propanol	2.3	g/cm^2	50	2.3	g
Ammonium hydroxide	0.89	g/cm^2	100	1.78	g

Source: column 1, 2 [16]; column 3, 4 own calculation, based on [18, 19]

For the safe use of chemicals, detailed information on their hazardous properties and the related risk management measures is essential. Under the Global Harmonised System (GHS) for the classification of chemicals, hazard phrases (H phrases) are used to characterize the potential of a chemical to cause adverse effects to humans and the environment. In addition, these H phrases allow the classification of chemicals according to the severity of their adverse effects [17]. In order to compare substances according to their hazardous potential, monoethylene glycol (MEG) can be used as a reference substance. This allows the quantity of hazardous substances to be expressed in MEG equivalents. The use of information from the classification of chemicals for the comparison of substances and their weighting is a common element in several approaches to the assessment of chemicals [21, 22]. Hazardous statements are a central element in the risk management of problematic substances. They are therefore known and publicly available for tens of thousands of chemicals [23]. If the hazard phrase of a substance is known, the toxicity weighting factor can be determined. Table 2 shows examples for H phrases and their weighting factors. A complete list of H-phrases and associated effect factors is shown in Appendix 1 at the end of this article.

TABLE 2: EXAMPLES FOR H PHRASES, MEANING AND WEIGHTING FACTORS

Source: [17, 18, 19]

H phrase	meaning	Weighting factors
H 300	Fatal if swallowed	1,000
H 301	Toxic if swallowed	100
H 302	Harmful if swallowed	10
H 304	May be fatal if swallowed and enters airways	1,000
H 310	Fatal in contact with skin	1,000
H 311	Toxic in contact with skin	100
H 312	Harmful in contact with skin	10
H 350	May cause cancer	50,000
H 400	Very toxic to aquatic life	1,000
H 410	Very toxic to aquatic life with long-lasting effects	50,000
H 411	Toxic to aquatic life with long-lasting effects	1,000
H413	May cause long lasting harmful effects to aquatic life.	50

The weighting factor for the reference substance monoethylene glycol is 50. The quantities of a given substance are expressed in kilograms of MEG equivalents. This indication is calculated according to the following equation (1):

$$\text{MEG}_{\text{equivalents}}(\text{amount}_{\text{substance i}}) = \text{amount}_{\text{substance i}} \cdot \frac{\text{weighting factor}_{\text{substance i}}}{\text{weighting factor}_{\text{monoethylene glycol}}} = \text{amount}_{\text{substance i}} \cdot \frac{\text{weighting factor}_{\text{substance i}}}{50}$$

The MEG equivalents approach allows data on the amount of hazardous chemicals used to be summarized in a single figure. In Table 1, the weighting factors and MEG equivalents for the substances used to produce 1 cm^2 wafer are given in column 3 and 4. In order to raise awareness of problematic substances in ICT production, the weighted amount of substances used should be part of the characterization and comparison of the sustainability impacts of ICT products and services.

This sub-indicator can be extended, if more information is available on specific groups of problematic substances in the workplace, e.g. for per- and polyfluorinated alkyl substances (PFAS) and for sulfur hexafluoride (SF_6), For future assessments of the sustainability of electronic devices and services, the identity and quantity of PFAS used should be an important element.

*2) **Element 2: Hazardous substances contained in ICT hardware***

Of the numerous chemicals used in the manufacture of ICT, some remain in the product itself. Examples include flame retardants, anti-dripping reagents and softeners in the plastics used in electronic devices [23]. In order to achieve a desired functionality (e.g., the flexibility of a material), a variety of chemicals and designs are usually available. The chemicals can differ greatly not only in their physical and chemical properties, but also in their toxicity to humans and the environment.

For some of these groups, chemicals legislation already bans very problematic substances (e.g., RoHS restriction of PBDEs, Stockholm Convention on polybrominated biphenyls). In addition, far reaching restrictions are planned for the coming years e.g., for brominated flame retardants [24] and PVC [25].

Requirements to avoid several groups of problematic additives are a common element in the award criteria of many important voluntary environmental labels for electronic devices. Examples include the European Ecolabel, the TCO label and the German Blue Angle. Voluntary commitments to avoid such substances are part of the environmental reports of ICT manufacturers [26].

ICT hardware can vary greatly in their content of such hazardous substances. Therefore, the recording and evaluation of the content of these substances should be part of the sustainability assessment of electronic devices and services.

Information on the content of hazardous substances for a specific electronic device can be obtained from various sources. Bills of materials are available for some products. If such data is missing, generic values for the concentration of problematic substances in materials can be used for an initial assessment. Table 3 shows average concentrations of flame retardants and problematic metals in plastic parts in waste electronic equipment [27].

TABLE 3: CONCENTRATIONS OF FLAME RETARDANTS AND METALS IN PLASTICS OF WASTE FROM ELECTRONIC DEVICES

Flame retardants	Concentration	
TBBPA	1,700	mg/kg
DecaBB	14	mg/kg
TBP	50	mg/kg
BTBPE	360	mg/kg
DBDPE	1,100	mg/kg
DDC-CO	66	mg/kg

Metals	Concentration	
Antimony	1,400	mg/kg
Cadmium	36	mg/kg
Lead	1,400	mg/kg
Mercury	0.3	mg/kg
Nickel	270	mg/kg

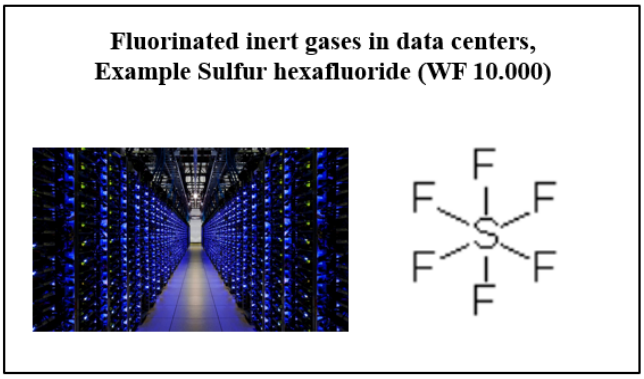
Source [26]

If more precise information is available, the generic values can be replaced by device-specific values. Problematic organic and inorganic compounds in an electronic device can be summarized using Bisphenol A and lead as reference substances. Other substances can be compared with these reference substances according to their hazardous properties. If additional information on the content of certain problematic substances in an electronic device is available, these can be characterized according to their toxicity and added to the equivalents described above. The information required for this step is the concentrations of the substances and their H phrases. A weighting factor can be derived for each substance with H phrases in the manner described above. It then makes it possible to express the amount of a substance used in MEG equivalents. The procedure for this is described above in section III.1.

*3) **Element 3: Problematic substances in the use phase of the digital infrastructure***

Chemicals are used at several points in the digital supply chain to provide digital services. Examples include cleaning agents for monitors, cooling agents in data centers and fluorinated greenhouse gases such as SF_6 in switchgear (see figure 2). These chemicals contribute to the environmental impact of a digital service.

FIGURE 2: FLUORINATED SHIELDING GASES IN SWITCHGEAR, EXAMPLE SF6.



In the case of data centers, these chemicals are purchased by the operators of the data centers or by specialized companies that are contracted to maintain, the cooling systems or switchgears, for example. In both cases, the quantity and technical specifications of the chemical products (substances or mixtures) are known. The safety data sheets of the chemical products provide information on the hazardous substances involved and their concentrations (at least in concentration ranges). This makes it possible to count the amounts used and to aggregate them using weighting factors that reflect the toxicity of the chemicals.

The general approach is the same for different types of chemicals (e.g., cleaning agents and cooling agents). To facilitate the comparison, function-specific reference substances can be selected. This is illustrated below for cooling agents used in data centers.

As part of a research project on key performance indicators for the ecological assessment of data centers, the amounts of cooling agents required in several datacenters were determined [7]. In a data center with a cooling capacity of 60 kW, a total amount of 24 kg cooling was used, with an average annual loss of 4%. Cooling agents, differ greatly in their global warming potential.

In the example, the substance R 134a has been used as cooling agent. It is one of the most frequently used cooling agents. It was chosen as a reference substance to compare data centers in terms of their consumption of cooling agents. The amount which is lost annually (4% of 24 kg) corresponds to 0.96 kg of R134a equivalents.

We have chosen R 134a as a reference substance to communicate the coolant consumption of data centers, based on their GWP value in relation to the GWP of R134a. This is not double counting of GWP impacts because in most cases the impact category of climate change is dominated by fossil fuels in the electricity production and cooling agents are being neglected there.

In addition, the amount of coolant used can also be specified in kilograms of MEG equivalents. There are no hazard statements (H-phrases) in the CLP Regulation for the possible effects of a substance on the climate. Therefore, for such substances without H-phrases, no weighting can be made on the basis of H-phrases. However, the TOX weighting factors can be derived directly from the global warming potential of the substance. The weighting factors have values between 0 and 10,000. For substances with a GWP up to 10,000, the TOX weighting factor is equal to the GWP. For substances with a GWP above 10,000, the TOX weighting factor is set to 10,000. (This is the upper limit of the weighting factor for effects that require the emission of a significant amount of a substance. For substances with chronic effects even at very low concentrations, the TOX weighting factor can have a value of 50,000).

In order to calculate the MEG equivalents, the same equation is used as already described in section III.1.

In the example above, R134a has a GWP of 1,446 and a weighting factor of the same value. Therefore, the amount of losses of R 134a (16 kg) calculated above (for 1 MW cooling capacity) corresponds to 16 kg * 1,446 / 50 = 463 kg MEG equivalents. These equivalents – which come from one year's worth of coolant losses – can be attributed to the data center's digital services.

IV. THE SVHC SCORE

The SVHC Score shows the level of information on the occurrence of a particular group of substances in appliances. This group is not all hazardous substances, but the "substances of very high concern" (SVHC).

Information on hazardous substances in ICT hardware is generally difficult to obtain. There is no obligation for manufacturers to provide information on all hazardous substances in e.g., process chemicals used in manufacturing, within the supply chains. Substances of very high concern (SVHC) are an exception. There are special communication obligations here.

Substances of very high concern can cause irreversible damage to human health or the environment. Such substances are identified by the European authorities. The list of Substances of Very High Concern as defined in REACH Art. 58 is published by the European Chemicals Agency (ECHA). This list is known as the REACH Candidate List [28].

The inclusion of a substance in the Candidate List triggers legal obligations for importers, manufacturers and suppliers of an article containing such a substance in a concentration of above 0.1% (by weight). In the case of products consisting of several parts, the indication of concentration refers to the individual sub-products. Suppliers of such an article must provide sufficient information to the purchasers of the article to enable safe use of the article. In this case, the recipients are industrial or professional users and distributors. As a minimum, the name of the substance must be provided.

Consumers may request similar information. The supplier of the article must provide this information free of charge within 45 days. In addition, manufacturers and importers must report articles containing SVHCs (above 0.1%) in the SCIP - Substances of Concern in articles as such or in Complex Objects (Products) - Database [29]. This obligation is part of the European Waste Framework Directive. The SCIP database is publicly accessible and allows searches for articles from all sectors, including ICT.

The following figure shows an example of a data set from the SCIP database. The figure shows the SVHCs contained in a specific desktop PC.

FIGURE 3: SUBSTANCES OF VERY HIGH CONCERN (SVHC) IN A DESKTOP PC. EXAMPLE OF THE INFORMATION IN THE SCIP DATABASE.

OVERVIEW

For the safe use instruction of the article go to: **Safe use instruction**

CANDIDATE LIST SUBSTANCES

Substance name(s)	Reason for inclusion
2-methyl-1-(4-methylthiophenyl)-2-morpholinopropan-1-one	Toxic for reproduction (Article 57c)
1,3,5-Tris(oxiran-2-ylmethyl)-1,3,5-triazinane-2,4,6-trione (TGIC)	Mutagenic (Article 57b)
Lead titanium trioxide	Toxic for reproduction (Article 57c)
Lead titanium zirconium oxide	Toxic for reproduction (Article 57c)
Hexahydromethylphthalic anhydride	Respiratory sensitising properties (Article 57(f) - human health)
1, 2-dimethoxyethane; ethylene glycol dimethyl ether (EGDME)	Toxic for reproduction (Article 57c)
Diboron trioxide	Toxic for reproduction (Article 57c)

Source: ECHA 2024

The legal obligations set out in Article 33 of REACH can be used to systematically request or obtain information on the content of SVHCs in individual hardware components. This information is important in order to

- encourage the substitution of such substances with less problematic substances, if possible;
- increase knowledge about the presence or absence of these substances in articles and in waste streams originating from these articles; and
- reduce impacts on humans and the environment due to the presence of these substances in the life cycle of ICT hardware and associated material flows.

Elements of a digital supply chain with sufficient information about the presence of SVHCs should be prioritized over elements lacking this information.

Within the TOX indicator, the so-called "SVHC score" shows the level of knowledge about SVHC in a given hardware component. It can have values from 1 to 5. The following figure shows the SVHC score and presents the meaning of its values in keywords:

FIGURE 4: THE SVHC SCORE AND THE MEANING OF ITS VALUES.

-**The SVHC Score**-

- **SVHC Score 5**: No information, no activity
- **SVHC Score 4**: Information requested
- **SVHC Score 3**: Information retrieved
- **SVHC Score 2**: SVHC identified (substances)
- **SVHC Score 1**: : SVHC content clarified (name, concentration, location)

Supply chain, 4 elements: SVHC Score = sum (SVHC Score (El. 1-4)) / 4.

The lower the score, the more is known about the SVHC content in an electronic device. The scores have the following meaning:

- **SVHC Score 5**: No information, no activity. It is not known in the analysis whether the device contains SVHCs in concentrations above 0.1%. It has not yet been looked up in the SCIP database. No inquiry has yet been made to the supplier of the article.
- **SVHC Score 4**: Information requested. Information on the SVHC content in the product has been requested from the supplier.
- **SVHC Score 3**: Information found. Information on the SVHC content for the assessed product was found in the SCIP database or the manufacturer of this product has provided the information.
- **SVHC Score 2**: SVHC identified (names of SVHC). The names and CAS numbers of the SVHC contained in the product (above 0.1%) are known.
- **SVHC Score 1**: SVHC content specified or none found. Content clarified (name, concentration, location). This (best) score is awarded if additional information on the SVHC is available. This includes more detailed information on the concentration (not only that the concentration is above 0.1%) and on the materials or components in which the SVHC are contained. The SVHC score 1 is also awarded if the information is available that no SVHC above 0.1% are contained in the device.

For a digital infrastructure with n platforms, its SVHC score is calculated as the average value of the SVHC scores of the participating platforms (equation 2).:

$$\mathrm{SVHC}_{\text{digital infrastructure}} = \frac{1}{n} \cdot \sum_{i=1}^{n} \mathrm{SVHC}(\mathrm{platform}_i)$$

The information required for this assessment of a particular electronic device can be collected in two ways: Direct contact with the supplier of the device (the supplier must provide this information within 45 days) or search for the specific product the ECHA's SCIP database.

V. Conclusions and Outlook

The combination of the LCA method with the indicator TOX and the SVHC Score leads to a more complete picture of the environmental impact of products and services. MEG equivalents, which are based on the hazard statements of chemicals, make it possible to weight and aggregate the quantities of chemicals used or present in digital devices. In addition, the SVHC score shows the extent to which information on the content of substances of very high concern is available. This information is important because it encourages the substitution of these substances and increases the transparency of particularly critical substances in material flows.

The methods developed in the ECO:DIGIT project are intended to make the environmental impacts of various software applications comparable. However, the indicator TOX and the SVHC Score can be used also in other sectors to better assess and predict the environmental impact of products and to optimize them in terms of their environmental impact.

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Annex I: H-phrases and associated weighting factors (WF)		
H phrase	**Meaning**	**Weighting Factor**
H300	Fatal if swallowed	1000
H301	Toxic if swallowed	100
H302	Harmful if swallowed	10
H303	May be harmful if swallowed	5
H304	May be fatal if swallowed and enters airways	1000
H305	May be harmful if swallowed and enters airways	5
H310	Fatal in contact with skin	1000
H311	Toxic in contact with skin	100
H312	Harmful in contact with skin	10
H313	May be harmful in contact with skin	5
H314	Causes severe skin burns and eye damage	100
H315	Causes skin irritation	5
H316	Causes mild skin irritation	1
H317	May cause an allergic skin reaction	500
H318	Causes serious eye damage	100
H319	Causes serious eye irritation	50
H320	Causes eye irritation	5
H330	Fatal if inhaled	1000
H331	Toxic if inhaled	100
H332	Harmful if inhaled	10
H333	May be harmful if inhaled	5
H334	May cause allergy or asthma symptoms or breathing difficulties if inhaled	500
H335	May cause respiratory irritation	5
H336	May cause drowsiness or dizziness	5
H340	May cause genetic defects	50000
H341	Suspected of causing genetic defects	100
H350	May cause cancer	50000
H351	Suspected of causing cancer	100
H360	May damage fertility or the unborn child	1000
H361	Suspected of damaging fertility or the unborn child	50
H361d	Suspected of damaging the unborn child	50
H361f	Suspected of damaging fertility	50
H362	May cause harm to breast-fed children	100
H370	Causes damage to organs	1000
H371	May cause damage to organs	100
H372	Causes damage to organs through prolonged or repeated exposure	500
H373	May cause damage to organs through prolonged or repeated exposure	50
Environmental hazards		
H400	Very toxic to aquatic life	1000
H401	Toxic to aquatic life	100
H402	Harmful to aquatic life	50
H410	Very toxic to aquatic life with long-lasting effects	50000
H411	Toxic to aquatic life with long-lasting effects	1000
H412	Harmful to aquatic life with long-lasting effects	100

H413	May cause long-lasting harmful effects to aquatic life	50
H420	Harms public health and the environment by destroying ozone in the upper atmosphere	10000