Extending the use phase of EEE

POTENTIAL ENVIRONMENTAL BENEFITS OF EXTENDING USE PHASES OF ELECTRICAL AND ELECTRONIC EQUIPMENT AND IMPLICATIONS ON THE WASTE HIERARCHY

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Abstract

The environmental implications of extending the service life of waste electrical and electronic equipment (WEEE) by preparation for re-use after the devices have reached waste status, are a controversly discussed topic. In order to answer the question whether a prolongation of the service life of WEEE poses environmental advantages compared to using new devices, the reviewed relevant literature with regard to benefits of re-using electrical and electronic equipment. The studies covered in this review have been assessed with regard to the impacts of a prolonged lifetime on the impact categories of climate change, abiotic resource depletion and cumulative energy demand as well as with regard to the potential risks of exposure to harmful substances contained in WEEE.

The review has shown that for the majority of cases the environmental benefits prevail and preparation for reuse and reuse itself brings environmental benefits. Prolongation of the service life of devices is associated with higher energy consumption during the extended use phase compared to the use of more energy efficient new equipment. However, taking into consideration the relatively small energy efficiency improvements achievable for EEE to date, this specific disadvantage of reused equipment over new equipment can generally be assumed to be minor compared to the environmental advantages resulting from the avoidance of resource consumption and production of a new device. Regarding the potential risks of exposure to harmful substances contained in WEEE, certain devices (e.g. devices containing CFCs, mercury, cadmium - could be identified which should not be prepared for re-use to avoid substance related risks.

Keywords: Waste electrical and electronic equipment; (preparation for) re-use; waste hierarchy; environmental benefits; extending lifespan

1 Introduction

The prioritisation of the available measures for the prevention and management of waste (five-level waste hierarchy) is determined by Article 4 of the EU Waste Framework Directive 2008/98/EC and its implementation in Germany by section 6 para 1 of the German Circular Economy Act (KrWG):

1.) Prevention,

2.) Preparing for re-use,

3.) Recycling,

4.) Other recovery, e.g. energy recovery; and

5.) Disposal.

The waste hierarchy provides a ranking of waste management measures that is (supposed to be) generally environmentally beneficial (see recital 31 of Waste Framework Directive 2008/98/EC, BMUB 2017, p. 6 f.). This general priority always applies unless a recovery or disposal measure, classified as subordinated, must be considered as having priority or at least equal status in individual cases with regard to protection of people and the environment (see section 6 para 2 of the German Circular Economy, BMUB 2017, p. 6 f.). This may be the case for some waste streams if justified by reasons of environmental protection, technical feasibility and economic viability (see recital 31 Waste Framework Directive 2008/98/EC). Following the waste hierarchy, this implies that waste electrical and electronic equipment (WEEE) should be re-used after undergoing preparing for re-use (and being taken out of waste status) as long as this is environmentally beneficial (and economically feasible). With the legislation such as Directive 2008/98/EC ("Waste Framework Directive") and 2012/19/EU ("WEEE Directive") also EU legislators intended to strengthen the preparing for re-use.

Against this background, in this study, the potential environmental benefit of a service life of electrical and electronic equipment prolonged through re-use or preparing for re-use is analysed. In this regard, a broad literature review of studies assessing prolonged use of EEE has been conducted. The study focuses on the question of whether the first two levels of the waste hierarchy are environmentally preferable to the other stages, or whether derogation from the overall priority order is appropriate for EEE. The work presented in this article is based on work done in a larger project conducted on behalf of the German Environment Agency (Umweltbundesamt – UBA; project title: : "Overall concept for dealing with WEEE with a focus on (preparing for) re-use taking into consideration the priority of the waste hierarchy and the best possible protection of people and the environment in compliance with section 6 of the Circular Economy Act").

For considerations of the (potential) effects on people and the environment, the entire life cycle has to be taken as a basis and, in particular, according to section 6 para 2 of the German Circular Economy Act, the expected emissions, the degree of conservation of natural resources, the energy to be used or gained, as well as the accumulation of pollutants in products, in waste to be recovered or in products derived therefrom must be considered. The technical feasibility, the economic viability and the social impacts shall be taken into account (section 6 para 2 sentence 2 ff. of the German Circular Economy Act). The criterion of the "energy to be used or gained", according to section 6 para 2 of the German Circular Economy Act, does not address an environmental impact category. Instead it has to be considered an auxiliary criterion which can pragmatically (in addition to the consumption of fossil energy resources) also capture the climate impact of measures for the prevention and management of waste.

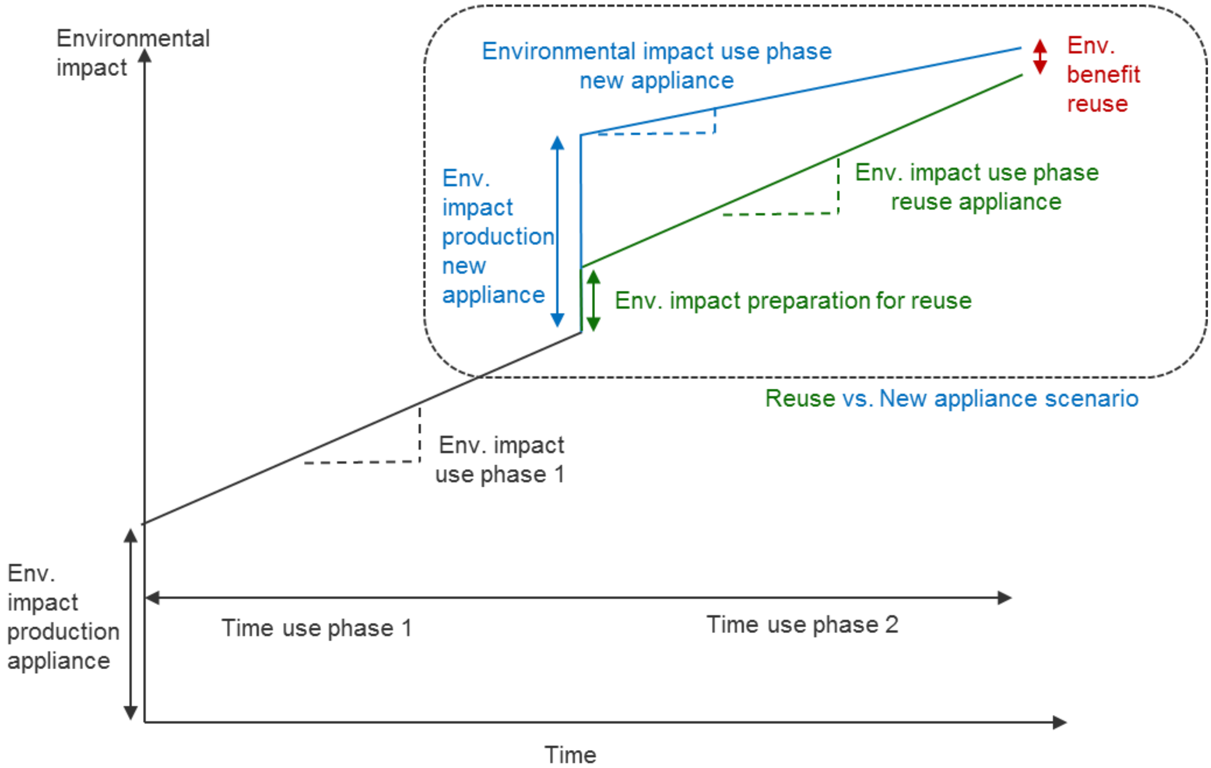
In this regard, 13 studies have been reviewed and systematically analysed. In the review, the focus was on the impact categories of "climate impact", "energy and resource consumption", and subsequently pollutant exposure potentials and aspects of the discharge of pollutants from the equipment pool. Finally, the results have been assessed with regard to the waste hierarchy.

2 Method and approach

A systematic comparative evaluation was carried out in the form of a meta-analysis of studies on the environmental effects of extended service lives for electrical and electronic equipment.

Cooper et al. (2015) reviewed the re-use of products in general. In Figure 1, the relevant life cycle stages of a product to be considered are shown schematically. A distinction is made according to whether, at the end of the use phase of a product, the product is replaced with a new product (with the environmental effects E_{new}) or it is prepared for re-use (with the environmental effects E_{reuse}).

Figure 1: The environmental effect of the substitution of a product with a new product versus prolonged service life due to re-use (Source: by the authors based on Cooper et al. (2015))



Against this background, studies on the environmental effects of an extended service lives for electrical and electronic equipment have been systematically evaluated in the form of a meta-analysis focusing on the impact categories of Global Warming Potential (GWP), Cumulative energy demand (CED), and the use of abiotic mineral resources (abiotic depletion potential elements (ADP el)) without energy resources or alternative indicators related to resource consumption.

GWP, CED and ADP el are the impact categories that are mainly used in the discussion of service life extensions of energy-consuming equipment (Ardente et al. 2012, Ardente and Mathieux 2012a, 2012b, Bakker et al. 2014, Bobba et al. 2015 and 2016, Downes et al. 2011, O'Connell and Fitzpatrick 2013, Prakash et al. 2012, Prakash et al. 2016a, Prakash et al. 2016b, Rüdenauer et al. 2007, Stiftung Warentest 2017, Tecchio et al. 2016, WRAP 2010, WRAP 2011, Zink et al. 2014). In addition, this selection of impact categories reflects the state of research in the field as most publications focus on these categories.

The study considered only electrical and electronic equipment that is either dual-use equipment or equipment for private end user and equipment that is relevant in the context of re-use or preparing for re-use.

To allow drawing conclusions from the studies on the environmental benefits, the data or assumptions on life cycle environmental impacts that underlie the studies needed to be meaningful both in the present and future. Usually, forecasts on the future development of the relevant parameters are used in the studies considered (e.g. on the future development of the energy efficiency of electrical equipment or the proportion of electricity from renewable energy sources). The further into the future the studies predict the influencing factors, the greater the probability of error. In order to address the data uncertainties arising from the forecasts or the forecasting periods, the scope was limited to studies published in 2007 or later.

An extensive literature search in scientific databases and using search engines ultimately identified 13 pertinent publications or groups of publications comprising 23 product analyses, which were evaluated in detail. In only a few of these studies, the research questions were widely congruent with those of this study. However, there have been various studies that deal with the issue of environmentally-optimal service life but do not explicitly address (preparing for) re-use or the environmental impact of (preparing for) the re-use of older electrical equipment compared to new equipment. Other studies compared the environmental relevance of (more elaborately produced) long-life electrical equipment with (less expensive) short-life ones. Others considered whether repairing equipment is more environmentally sensible than disposing of it and buying new equipment. These studies were evaluated and the transferability of the results to the questions of this study are presented.

Table 1 shows the evaluated studies and the equipment types considered in them ("Equipment types" hereinafter means all electrical appliances with a largely identical main function, for example all televisions or all washing machines or all toasters, etc.).

Table 1: Overview of the evaluated studies and the equipment types considered

Study	PC	Printer	Television	Freezer	Dishwasher	Fully automatic coffee machine	Refrigerator	Laptop/Notebook	Mobile phone	Vacuum cleaner	Toaster	Washing machine
Ardente et al. 2012, Ardente / Mathieux 2012a, 2012b												X
Bakker et al. 2014							X	X				
Bobba et al. 2015 and 2016										X		
Downes et al. 2011a and b		X						X	X		X	X
O'Connell / Fitzpatrick 2013												X
Prakash et al. 2012								X				
Prakash et al. 2016a	X											
Prakash et al. 2016b			X					X				X
Rüdenauer et al. 2007				X			X					
Stiftung Warentest 2017						X				X		X
Tecchio et al. 2016					X							X
WRAP 2010, 2011												X
Zink et al. 2014									X			

3 Results

The review of the studies shows clearly (for the considered impact categories) that there is an environmental advantage of prolonged service life in the vast majority of the cases. Especially in the context of the current development of energy efficiency improvements in future equipment (especially large household appliances) and the current and expected energy mix in Germany, it cannot be concluded for any equipment type that the environmental balance of longer use would be negative.

The key findings are described in more detail in the following:

3.1 Environmental relevance of treatment/repair within and outside the waste regime

Various studies have shown that the environmental burden of reprocessing or repairing equipment is low or negligible in comparison to the expense of producing the equipment or the energy/resource consumption in the phase of use (WRAP 2010, Downes et al. 2011a, Downes et al. 2011b). The results can be transferred to (preparing for) re-use of waste electrical and electronic equipment (WEEE).

Differences in the environmental assessment of a prolongation of the service life between re-use outside the waste regime and preparing for re-use in the waste regime could mainly arise from the differences in the transport routes. Information on the differences in transport routes during treatment within or outside the waste regime is not available in most cases. Our review showed that for selected products the main environmental impacts results either from the production phase (e.g. laptops, Prakash et al., 2016a) or the use phase (e.g. refrigerators, Bakker et al., 2014). Transport processes at the end of the use phase appear to be negligible (e.g. Downes et al., 2011a). In this respect, it can be assumed that, with regard to the examined environmental impact categories, it is irrelevant whether the treatment takes place inside or outside the waste regime.

3.2 Environmental advantages of equipment with longer lifetimes compared to equipment with shorter ones

When comparing equipment with long and short lifetimes, long-life equipment has demonstrated environmental benefits in most cases with respect to the impact categories studied. The investigations (e.g. in Downes et al. 2011a) show that despite the increased environmental cost of producing long-life equipment compared to short-life equipment, an overall environmental advantage is observed from a certain service life onwards, and this finding can also be transferred to the scenario in which the service life of equipment is prolonged by reprocessing or repair (i.e., the extra effort is “postponed” from manufacture to reprocessing).

In the case of washing machines, Downes et al. (2011a) show that a long-life machine is environmentally advantageous even if it is reprocessed after six years (replacement of hoses and seals) (Downes et al., 2011a, pp. C71f.). Prakash et al. (2016b) show that the environmental impact of a short-life washing machine is higher in all investigated impact categories than in the average and long-life variants. Despite the increased energy efficiency of new washing machines and the greater manufacturing costs of the long-life equipment, the short-life equipment performs worse in all impact categories studied (Prakash et al., 2016b, p. 245)

For toasters, the environmental impact of the compared long-life and short-life equipment is comparable from the 6th year onwards. From the 11th year, the load of the long-life equipment is lower than of the short-life one. Due to comparatively high maintenance/service costs, the devices are close to each other again from the age of 17, and from the age of 22, devices with a longer service life score consistently better than devices with a shorter service life (Downes et al., 2011a, p. 92.)

Prakash et al. (2016b) show for notebooks that the environmental impact of a short-life notebook is higher than that of the long-life notebook for all environmental indicators studied (Prakash et al., 2016b, p. 254).

For LCD TVs the research has also shown that the environmental impact of a short-life TV is higher than that of the long-life one for all impact categories studied. Sensitivity analyses show that despite the increased energy efficiency of new televisions and greater manufacturing costs of durable equipment, the short-life television performs worse in all impact categories studied (Prakash et al., 2016b, p. 250).

3.3 Comparison of a prolonged service life and premature replacement purchase

In the studies which examine the further use of electrical equipment after reprocessing in comparison to the acquisition of new electrical equipment a differentiated picture emerged. Based on the equipment type, a distinction must be made between older and new equipment and the service life of the reprocessed equipment according to energy efficiency:

For laptops or notebooks as well as mobile phones, it was found in most of the investigated scenarios that further use (if necessary, after reprocessing) is environmentally beneficial until the end of the (technical) lifetime (Downes et al., 2011a, p. C30; C52). For example, Prakash et al. (2012) determined that, for laptops, it is a period of between 6 and 88 years (Prakash et al. 2012, p. 49), until which point a replacement with new equipment brings no environmental advantage. The environmental payback time of six years is only achieved if a new laptop is 70% more energy efficient than the old one. In any case, the environmental payback period is beyond the technical lifetime of notebooks. Similar results are reported by Bakker et al. (2014, p. 13) and Prakash et al. (2016a) for PCs, notebooks and mini PCs.

For washing machines Ardente et al. (2012), Ardente and Mathieux (2012a) and Ardente and Mathieux (2012b) conclude that preparing for re-use and further use is environmentally sensible, provided that certain thresholds for increasing energy efficiency in new equipment and the total service life of reprocessed waste equipment (including life prolongation after preparing for re-use) are not exceeded. It should be noted here that the necessary increase in efficiency is relatively high and the assumption regarding wash cycles (number and temperature) is rather unrealistic, i.e. the importance of the use phase is probably overestimated. Tecchio et al. (2016), WRAP (2010, 2011) and O'Connell and Fitzpatrick (2013) come to similar conclusions. In the study by Tecchio et al. (2016) on the environmental evaluation of (preparing for) re-use of washing machines, high expenditures for preparing for re-use are taken into account (partial replacement of the door seals, suction pumps, heating elements, circuit boards, and circulating pumps). Nevertheless, the study presents positive environmental benefits for preparing for re-use in almost all impact categories and scenarios studied.

In their studies on the environmental evaluation of (preparing for) re-use of dish washing machines Tecchio et al. (2016) they took high expenditures into account for preparing for re-use (partial replacement of the door seals, suction pumps, heating elements, circuit boards, and circulating pumps). The calculations give positive results if the first use phase of the dishwasher was short. However, with a 15% increase in energy efficiency of the replacement equipment compared to the previous one, and a longer first use phase, the GWP also has negative results in the scenario of preparing for re-use with the aforementioned extensive replacement measures. However, the environmental benefit is always positive for the impact category ADP el.

For refrigerators, the results on environmental payback periods show similar results as previously shown for washing machines. Bakker et al. (2014) show different payback periods (or environmentally optimal replacement times) over the observation period, depending on how the energy efficiency of the equipment has improved. In the last period of consideration (from 2011), the environmentally optimal replacement time is after using a refrigerator for 20 years (Bakker et al., 2014, p. 13). Here, too, it was found that the environmentally optimal replacement time would be after the end of the technical life of the refrigerator (Bakker et al., 2014, p. 11).

For vacuum cleaners, Bobba et al. (2015, 2016) conclude that extending the service life through repair is environmentally beneficial as long as certain thresholds are not exceeded in terms of increasing the energy efficiency of new equipment and depending on how long the repaired equipment is then used. An extended service life is, for example, considered environmentally sensible in all scenarios, provided that no increase in the energy efficiency of more than 25% is achieved in the new equipment (Bobba et al., 2016, p. 771).

3.4 Selected overriding factors of influence

When considering the results of the study, it must be remembered that these are based on certain basic assumptions concerning the material composition of the equipment, energy consumption, etc. However, these variables can change over time, and there may also be significant differences in the products of different manufacturers, brands and models that are on the market at the same time. In the literature review some overriding factors have been identified that – independently of the actual type of equipment – influence the environmental impact of an equipment or raise the question whether it makes sense to extend the service life by (preparing for) the re-use of WEEE from environmental point of view.

This relates, among other things, to the share of renewable energies in the electricity mix. The proportion of these energies in the gross electricity consumption has increased significantly in recent years. Changes in the energy mix of a country are therefore important for assessing the environmental potential of a prolonged service life of electrical equipment, as the share of renewable energies decreases the environmental relevance of the use phase with regard to the GWP study parameter (UBA 2017a, UBA 2017b). As a result, the positive environmental impacts of replacing electrical and electronic equipment with more energy-efficient equipment tends to decrease, and other impact categories such as ADP el (resource consumption) or water consumption become more relevant. As a result, the increase of renewable energies in the energy mix consequently means an increasing environmental usefulness or advantage in extending service lives.

For equipment where the use phase accounts for the largest proportion of the total GWP, the environmental benefit of a longer service life also depends heavily on the improvement in the energy efficiency of new equipment compared to the previous one (see Cooper et al., 2015, p. 11). Therefore, when evaluating the study results, it should be borne in mind that the increase in energy efficiency of new equipment usually slows down over the years (e.g., FEA 2016).

The ratio of environmental costs in the production and use phase must also be taken into account for the environmental assessment. Using a “best in class” LCD TV as example, Bakker et al. (2012) questioned the assumption often made in eco-design debates that energy consumption of regularly used electrical and electronic equipment is dominated by the usage phase over its lifetime. They conclude that with the development of much more energy-efficient equipment, there is a pro-rata shift towards the resource recovery and production phases of the equipment, and it is more difficult to determine which phase of lifetime has the proportionately largest energy consumption. This depends, among other things, on the service life (the shorter it is, the greater is the proportion of the production phase in the total energy consumption over the life cycle) and the user’s behaviour.

The influence of the user’s behaviour is also of considerable importance. The life cycle assessments include certain usage patterns that determine, for example, the energy consumption in the phase of usage. For example, during the use phase of WRAP's LCA (2011) on washing machines, 275 washes per year were assumed, each with 5 kg of laundry at 60°C. This is equivalent to almost 4 kg of laundry per day. In the case of less intensive use, for example in single households (In 2015, 41.4% of households in Germany were single-person households (DESTATIS 2017)), the environmental assessment shifts, because the environmental burden of production would have to be weighted relatively more heavily in this case. Accordingly, in a commercial use (i.e. high intensity of use) of, for example, drilling machines, the result would likely be different than in the low intensity use in households. Even with continuously operated types of equipment such as refrigerators, the user behaviour can have an influence, e.g. about the number of door openings and closings per day.

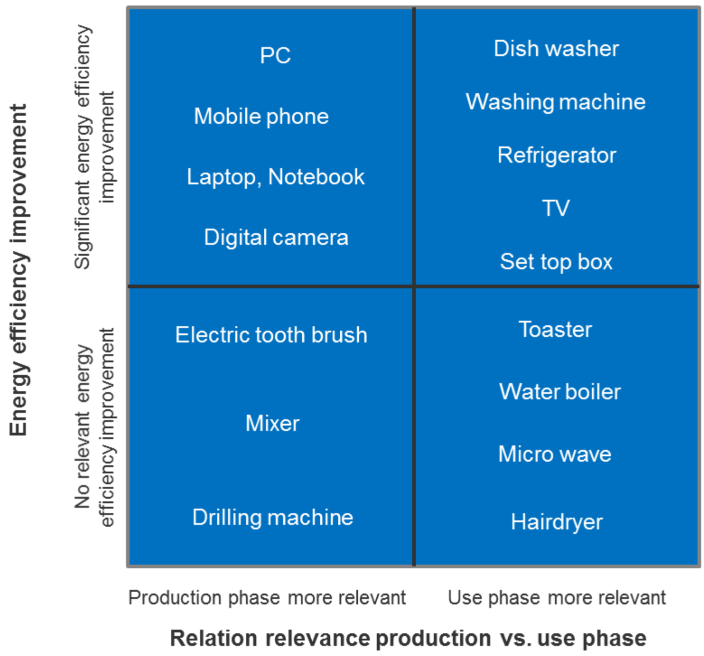
3.5 Transferability of insights to other types of equipment

In the studies evaluated a limited number of types of electrical equipment were examined. For the assessment of the (preparing for) re-use of WEEE the question arises whether the results are transferable to other types of electrical equipment.

The studies evaluated have shown the ratio of environmental costs in the production and use phase and increasing energy efficiency of new equipment compared to previously used ones (often also in connection with technological leaps) as being essential parameters in the categorisation of the different types of electrical equipment. The respective user behaviour or the assigned usage structures (private households are considered here) are relevant for the categorisations.

The results of the literature review, the studies by Böni and Hischier (2016) and Sander (2010a), including the FEA (2016) studies for Switzerland as well as the information provided by ZVEI and the gfk on the sales of large household equipment by energy classes (ZVEI 2016) can all be used as a rough guide in the categorisation of electrical equipment according to Figure 2. The classification of laptops by Böni and Hischier into the category in which the phase of usage is dominant (2016) contradicts the results of other studies evaluated. Perhaps Böni and Hischier underestimated the costs of production in their study like Deng et al. (2011, p. 1205) proved this for the results of the EuP study (IVF 2007). Ciroth and Franze (2011, p. 109ff) also concluded that the production phase of the Ecolabel laptops considered in their study accounts for the largest environmental impact of all impact categories considered.

Figure 2: Matrix of categorisation for electrical equipment



For equipment types with a high relevance in the production phase and low energy efficiency improvements, extending the service life is always practically sensible. For equipment that has high relevance in the production phase, but with a substantial energy efficiency improvement, as well as equipment with high relevance in the use phase but no relevant energy efficiency improvements an increased service life is fundamentally advantageous environmentally-speaking. Only for types of equipment that show significant improvements in energy efficiency over time and for which the usage phase is more relevant than the production phase, it may be environmentally meaningful to replace equipment instead of extending the service life. However, the observations show that there are hardly any actual cases for which this is true. Studies that show an environmental advantage for replacement instead of extension of service life are based solely on assumed framework conditions that are considered to be less realistic.

4 Potential of exposure to pollutants and discharge of pollutants

In addition to the previously considered impact categories which are primarily investigated in association with better use of the resources and the environmental benefits due to this, the issue of pollutants and their discharge plays a central role in the debate on the circular economy.

4.1 Methodology

The subject of the study on pollutant aspects was to determine the differences in the discharge of pollutants between the scenario of a prolonged service life by (preparing for) re-use and subsequent (proper) disposal as WEEE and that without the extension of service life with direct (proper) disposal as WEEE.

Negative consequences in terms of pollution due to extended service life would be conceivable if the current new equipment contained fewer pollutants than the equipment whose service life would be extended by further use (if necessary after preparing for re-use) and the pollutants contained in longer used equipment have, or could have, negative effects in or after the further use phase which do not occur in the case of earlier material or energy recovery or disposal instead of (preparing for) re-use.

On the basis of legal analyses carried out, it was established that material restrictions specified by, for example the RoHS directive 2002/95/EC or 2011/65/EU (or their national transposition in the ElektroStoffV) for products are not relevant for preparing for re-use and therefore regulated/limited material of electrical equipment redeployed in the market would not pose a problem. As a result, it is also possible that re-deployment in the market will prolong the phase-out of substances subject to a substance restriction.

The changes in the pollutant levels between the moment the electrical equipment was placed on the market (first appearance on the market) and today’s new supply of preparing for re-use or in the context of re-use by legal requirements or due to technical developments were examined first. The scope of considerations was limited to 15 years (2002–2017) based on discussions on the marketability of reprocessed equipment.

As of August 2017, the changes that were induced by the RoHS Directives 2002/95/EC and 2011/65/EU and the exemptions from the substance restrictions of the Directives with regard to the levels of pollutants in electrical and electronic equipment were examined. Furthermore, the effects of legal regulations on asbestos (in particular REACH Regulation, German ChemVerbotsV, German GefStoffV) and CFC (in particular the Montreal Protocol, Regulation (EC) No 2037/2000, Regulation (EC) No 1005/2009, German FCKWHalonVerbV) as well as those of the REACH Regulation (EC) No 1907/2006 on other substances were evaluated.

4.2 Results

The legal framework under consideration provided for an effective phase out of pollutants in new electrical and electronic equipment. This applies, in particular, to metals and metal compounds (Hg, Pb, Cd, Cr(VI) and organic pollutants (PBB, PBDE, DEHP, BBP, DBP, DIBP, halogenated hydrocarbons), with exceptions for certain areas of application, such as the exception for the use of Hg in lamps, Pb in picture tubes and Cd in NiCd batteries for certain applications.

Preparing for re-use, and actual re-use, can potentially delay the phase out of these substances in the field of WEEE. However, under the specifications of the disposal of WEEE in Germany, no negative environmental consequences are to be expected from this. It also does not hinder the phase-out of substances, as the pollutants from old equipment are not kept in closed circuits (as is the case, for example, with some plastics such as beverage crates and window profiles). It should only be noted that specific treatment facilities for the treatment of pollutant-containing components (e.g. Hg-containing backlights of flat screens) must be kept for a longer time. However, this is necessary anyway, as the corresponding equipment that did not reach waste status but was used for a long time by one or more owners is expected to be returned at the end of its technical life. As long as technical life time is not extended, there is no difference in the relevant time frames.

Due to the sometimes low level of protection of disposal operations in non-EU countries and the existence of informal disposal routes, consideration should be given as to whether WEEE with restricted use materials should not be re-marketed by the re-use facilities, but instead that such WEEE (in the context of a filtering function of the facilities) should be cleaned of pollutant and recycled or energetically recovered or disposed of. Based on the analysis of the substance prohibition or restriction situation and the quantity-relevant presence in WEEE, this seems to be useful for equipment containing Hg, Cd, Cr(VI), asbestos, and CFC as well as for equipment with leaded glass and lead frits. It should be noted, however, that asbestos and CFC containing equipment may no longer be given to third parties for further use due to legal requirements.

5 Overall assessment in terms of waste hierarchy

The studies examined for the impact categories "climate impact", "energy and resource consumption" and the analysis of the pollutant aspects have not shown any facts that should account for a deviation from the general priority of the waste hierarchy for WEEE in accordance with the criteria of section 6 para 2 of the German Circular Economy Act. A longer service life (due to re-use or preparing for re-use) is in general environmentally beneficial for waste electrical and electronic equipment.

For a few types of equipment mentioned above, however, a deviation from the general priority of the waste hierarchy seems to be appropriate taking into account aspects of pollution, since recycling, energy recovery or disposal are to be seen as preferable options considering the whole life cycle. The goal here would be to selectively dispose of waste equipment that has a particular hazard potential for humans and the environment due to the presence of pollutants.

However, it is not recommended to supplement a pollutant-related negative list with equipment with a specific efficiency category that is particularly inefficient compared to current equipment. As has been shown in the case of the types of equipment in question, a large number of factors influence the assessment with regard to the impact categories of climate impact and resource consumption, which are, in particular, also related to individual usage patterns and alternatively procured new equipment. Generally valid statements, which could reasonably justify a corresponding deviation from the waste hierarchy, are currently not available in the literature analysed.

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