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Chapter from the book *E-Waste in Transition - From Pollution to Resource*

Chapter 7

Increasing the Use of Secondary Plastics in Electrical and Electronic Equipment and Extending Products Lifetime – Instruments and Concepts

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/62778

Abstract

While secondary plastics arising at the manufacturing and processing phases are recycled to the production process in large measure due to its high purity, the market share of secondary plastics remains low and recycling is often dominated by thermal recovery. Energetic recovery of plastics in waste electrical and electronic equipment (WEEE) has been dominating for a long time. At the same time reuse of WEEE is not well developed at EU level; with few exceptions at Member State level.

Against this background we want to discuss in this book chapter several policy instruments that aim to increase the reuse of WEEE as well as the use of secondary plastics in electrical and electronic equipment. Taking the case study of Germany we evaluate instruments theoretical quantity effects and their feasibility. In reality, instruments are often weak and scattered implemented. To identify a policy mix without the risk of creating expensive policies with the potential for inefficient outcomes, we make two complementary conceptual proposes, which first open up perspectives for possible synergies of instruments and second allow an integrated understanding of the regional context in which instruments are implemented. The discussion of the case study of promoting reuse within this framework makes clear, that such an integrated understanding is the basis for any appropriate, targeted and efficient stimulation and bridges the gap between theoretical policy formulation and practically implementation.

Keywords: WEEE, use of secondary plastics, reuse, policy instruments

1. Introduction

Waste electrical and electronic equipment (WEEE) can be considered as one of the most urgent waste management challenges and has raised significant political attention over the last years.

Electrical and electronic products contain substances, which are valuable as well as often also critical (e.g. mass metals: copper, aluminium etc.; precious metals: gold, silver etc.; critical metals: indium, gallium etc.) and pose risks to the environment and human health (e.g. heavy metals: mercury, cadmium etc.; flame retardants: pentabromophenol etc.) [1, 2]. Furthermore WEEE has become one of the fastest growing waste streams. In Europe, therefore it exist high political interest for converting waste into a resource and a proper management of this waste flow. This chapter puts a specific emphasis on plastics contained in WEEE. While secondary plastics accruing at the stages of production and processing are largely redirected to the production process because of their high fraction purity, secondary plastic waste accruing after product use is recovered on a significantly smaller scale. Instead, energetic recovery of plastic waste is still dominant in the Federal Republic of Germany. This is in clear contradiction with the emerging circular economy policy framework where the value of products, materials and resources is maintained in the economy for as long as possible [3]. The life cycle environmental impacts of post-consumer plastics production from mixed, plastics-rich WEEE treatment residues from the perspective of the customers delivering the residues and the customers buying the obtained post-consumer recycled plastics is clearly superior to the alternatives (i.e. municipal solid waste incineration (MSWI) and virgin plastics production) [4].

Directive 2012/19/EU of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE Directive) aims to address this issue by implementing inter alia the principle of the extended producer responsibility and collection, recovery as well as joint recycling/preparing for reuse targets. The achievement of the recovery and recycling/preparing for reuse targets shall be calculated, for each category, by dividing the weight of the WEEE that enters the recovery or recycling/preparing for re-use facility by the weight of all separately collected WEEE for each category (Art. 11, Directive 2012/19/EU).

Accordingly, recovery or recycling/preparing for re-use rates do only consider the recovered mass without looking at the type of waste treatment operation (e.g. no favouring of preparing for reuse because of joint recycling/preparing for reuse target), the recovered material (e.g. no difference if mass metals such as copper or critical metals such as indium, (dissipative used) are recovered) and its quality (e.g. impurity vs. material with high quality). Due to these conceptional gaps, the current system misses significant opportunities of a more circular economy that promises “an opportunity to reinvent our economy, making it more sustainable and competitive” [5].

Figures for recycling/preparing for reuse and recovery performance in 2012 – considering large household appliances (LHA), small household appliances (SHA), IT and telecommunications equipment (ICT) and consumer equipment (CE) – reported by each Member State to Eurostat highlight that all except a few fulfil the targets valid in 2012 (recovery and recycling/preparing for reuse targets according to Directive 2002/96/EC: LHA 80 and 75 %, SHA 70 and 50 %, ICT 75 and 65 %, CE 75 and 65 %) [6]. However, currently only one third of WEEE generated by EU-28 plus Norway and Switzerland are officially reported as collected and proper treated [7].

In Germany, 1.73 million tons of EEE were put on the market in 2010 [8] and around 777,000 tons of EEE were collected [9] – thus the required amount of 4 kg per capita was quite easily exceeded with an average amount of 8,8 kg per capita.

Due to the revised WEEE Directive the collection targets will be significantly increased with 45% (2019: 65%) of the amount put on the market. Against this background collection rates in many of the 1.500 responsible municipalities will have to be increased as well as the often difficult coordination with EPR systems has to be improved [10]. Right now collection rates differ significantly due to different collection systems (bring or pick-up systems, collection intervals etc.) but of course also due to different amounts of discarded products: Especially in the metropolitan regions with smaller households more products are discarded per capita. Until now there is no direct obligation for the municipalities to fulfil the higher targets – they have to be met on the aggregated national level and also against this background new policy instruments will become necessary to set additional incentives for high quality – separate and destruction-free – collection.

Besides the problem of low collection rates, the recycling rates of plastics are very low [11,12], although the legal requirements are met. Accordingly many problems are not solved by the implementation of the WEEE Directive [13]. Plastics are a considerable fraction of WEEE and contributes to the total generation of post-consumer plastic waste in the EU-27, Norway and Switzerland in 2008 at 5% [14], but the presence of brominated flame retardants (BFR) as well as various plastic types and missing incentives (e.g. economic benefits of energy recovery) hampers the recycling of plastics in WEEE [9,11].

Today the in Germany collected amount of WEEE contains around 193,000 tons of plastic, but only 18,000 tons of plastics from WEEE were recycled [9,15]. In Germany, no secondary plastics were used to produce new EEE [9]. But also conserving resources through prolonging products lifetime by reuse is not well developed at EU level, with a few exceptions at Member State level [16]. In Germany, some local initiatives to prepare WEEEfor re-use exist, but a wider application is missing. The joint target for both preparation for re-use and recycling, do not prioritize and promote reuse, since EU Member States might only increase their recycling efforts in order to reach prescribed targets.

Against this background we want to discuss in this book chapter several policy instruments that aim to increase the reuse of WEEE as well as the use of secondary plastics in EEE. Taking the case study of Germany we evaluate instruments theoretical quantity effects and their feasibility. In reality, instruments are often weak and scattered implemented. To identify a policy mix without the risk of creating expensive policies with the potential for inefficient outcomes, we make two complementary conceptual proposes, which first open up perspectives for possible synergies of instruments and second allow an integrated understanding of the regional context in which instruments are implemented. The discussion of the case study of promoting reuse within this framework makes clear, that such an integrated understanding is the basis for any appropriate, targeted and efficient stimulation and bridges the gap between theoretical policy formulation and practically implementation [17].

The chapter is structured as follows: After a brief description of the methodological approach, four specific instruments to increase the circularity of plastics in EEE are described and analysed. This is followed by an assessment of strengths and weaknesses of the instruments as well as conceptual considerations withregard to the formulation of a policy mix. Based on this analysis the chapter ends with conclusions for policy formulation and further research.

2. Approach and methodology

Starting point for this book chapter has been an empirical analysis of central barriers for the gaps between possible potentials for the application of secondary plastics and the currently disappointingly disrupted material loops. Despite a rising trend in prices for primary raw materials (see [18]) and the associated incentives for recycling, the area of plastic waste presents recycling rates far below technical potentials. Amongst other things, this can be traced back to a series of systematic market failures, which result from different economic, informatory, legal and institutional characteristics of waste (e.g. the current competition with energy recovery or insecurities about the actual quality of plastic wastes).

Building upon the analysis of potentials for an increased material recovery of plastics from WEEE and the obstacles identified, the following will outlines measures and instruments that consign the different types of plastics to high-quality recovery and promote their application as secondary raw material.

The objective is, however, to develop integrated sets of measures whose individual elements support each other and altogether aim at the development of a self-supporting innovation dynamic. Against this background, economic, legal and informatory/ institutional instruments have been discussed and tested for their legal feasibility. Clearly no single instrument is capable of addressing the complexity of constraints. Thus it is necessary to develop a policy mix that addresses these different aspects. In the following, the individual instruments have been investigated taking into account the following aspects:

- Description of the general mechanism of action,
- examples for successful implementation,
- specification of the instrument,
- estimation of the effects depending on arrangement and finally the
- feasibility of implementation.

3. Description and analysis of instruments

Based on a first preliminary analysis of available instruments, four approaches have been selected that seem to offer the most relevant potentials with regard to the closure of plastic loops. Nevertheless the analysis also shows the challenges and limitations.

3.1. Plastic-specific recycling targets

Description of mechanism / reference to barriers and motives

Although the existing mass-based requirements in the Directive 2012/19/EU guarantee a recycling of the WEEE product categories, they do not allow a selective control of materials contained in this waste stream.

The Green Paper on a European strategy on plastic waste in the environment describes the unspecific targets for plastics recycling in view of the growing environmental impact of plastics as inadequate EU legal consideration of plastics. Against this background, the European Commission decided, "that it will conduct a wide ranging review of the existing waste legislation and the various targets " [19].

Examples for successful implementations

In Germany, so far material-specific recycling targets are only implemented in the German Packaging Ordinance (for wood, plastics, metals, glass, paper and carton). As a study show, the impact of these differentiated requirements is reflected in technical advancements and efficiencies [20]. International experiences with the implementation of specific recycling targets for plastics exist for example in Belgium: In Belgian law, the implementation of the targets prescribed by the WEEE Directive are not only differentiated by product category, but also material-specific requirements are made. So, in total, the following targets have to be fulfilled (by weight relating to the collected material fraction): plastics 50%, iron / steel 95%, non-ferrous metals 95% (Milieubeleidsovereenkomst betreffende de aanvaardingsplicht voor afgedankte elektrische en elektronische apparatuur (AEEA) C-2009/35519 Art. 10).

Specification of instrument

Ideally, the level of the recycling target should be chosen so that on the one hand the maximum ecological effect is achieved to provide incentives for a high level of material recycling, on the other hand the target have to be feasible for the addressees. Therefore it requires a differentiation between different product categories. When determining material-specific targets for a product the content of this material has to be considered; is this too low, it has an aggravating effect on recycling. Second, the distribution of the material is important, since the more a material is distributed over the product - as opposed to a concentrated form in a single component - the more difficult is the recycling.

Large household appliances (LHA) contain, due to their size and with an average plastic content of 19 % by weight [21], relatively large plastic parts and the presence of brominated flame retardants seems to be less relevant compared to other EEE (1.5% share compared to 60% in ICT devices, see [21]). The definition of a material-specific recycling target based on the experiences in Belgium with 50 % by weight relating to the collected plastic fraction, results by considering the average share of plastics in LHA (19 % by weight) in a target proposal of 9.5 % by weight relating to the product weight. In the course of a target proposal it has to be investigated, to what extent LHAs differ from one to another with regard to their recyclability and it should be considered whether a differentiated target or focusing one product group would be more appropriate. For instance, in practice, only 45% of the plastics contained in refrigerators (2.8 kg with a total plastic content of 6.2 kg) are available in a high purity and are suitable for recycling [22]. Accordingly, it has to be considered to what extent the recyclable fraction is increased by setting a recycling target or whether a limitation actually exists.

Estimation of effects depending on specification

For an estimate of the potential recycled plastic amount the proposed recycling target of 50 % by weight relating to the plastic fraction (according to the targets in Belgium) / 9.5 % by weight relating to the average weight per product is used. It is assumed that this is a conservative estimate because the target-setting in Belgium relates to all EEE, which in principle have a worse starting position for a material recycling compared to LHA alone. Based on this, the potential recycled plastic amount in Germany can be calculated to 23,750 tons. By comparison, the actual recycled plastic amount of all EEE in Germany is so far only about 18,000 tons (see chapter 1).

Concluding evaluation

The introduction of plastic-specific targets for the recycling of WEEE would allow a selective control of material flows, while giving investment security for the recycling industry. Plastic-specific recycling targets would therefore clearly lead to an increase of secondary plastics supply. The extent of the use of secondary plastics, however, depends on the quality of recovered materials and ultimately determines the actual environmental impacts [14].

However, by the binding material-specific recycling targets a critical mass could be achieved that makes it economically possible for the producers within the producer responsibility to invest in a recycling-friendly product design. Flanking instruments could be specific requirements in the eco-design directive to limit the use of a variety of different types of plastics.

The feasibility of the instrument is generally considered as high, since the legal framework and the recycling infrastructure is given as well as the integration of the plastic-specific recycling targets would be possible from a legal perspective. The administrative barriers are characterized rather by the actual selection of the focus (different product compositions of WEEE do not allow an universal target for all WEEE), as through the establishment of the level of the recycling target itself (in the case of a suitable focus). The level of the recycling target could be modified continually by a self-learning target-model. Basically, when introducing such an instrument it is worth considering taking account of other materials by specific targets.

3.2. Minimum recyclate quota in the electronics sector

Description of mechanism / reference to barriers and motives

The classic approach towards waste management activities has always been the establishment of mandatory recycling targets – regulating the treatment of waste and avoiding environmentally harmful disposal. Although mass-based product-specific or waste stream-specific targets ensure material recycling of these two categories, they do not allow a targeted control of materials contained in the product. Against this background a mandatory recyclate quota could be introduced especially for plastics. With the specification of minimum recyclate quota for plastic-containing products, the demand would rise significantly for high-quality secondary raw materials and thus provide incentives to capture a greater share of separated plastic wastes (i.e. in the sense of high-quality recycling) which will be recycled and not utilized for thermal recovery.

Examples for successful implementations

Experiences with minimum recyclate quotas have already been made in particular for the case of packaging in the 1980's as it became clear that the recycling sector needs to be supported. After the emergence of different scandals concerning the dispose of waste in California, Oregon and Wisconsin, different regulations on recyclate quotas had been introduced in the U.S., while each of these instruments had a different result [23]. In Oregon the recycling law does only apply if the recyclate quota for plastics drops below 25%. In fact, the recyclate quota has always exceeded this value through mandatory deposit-refund schemes, meaning that the law was never actually applied. In Wisconsin, the inclusion of plastic waste from production was allowed by the law. According to general assessments, this has undermined any effect on the actual management of plastic waste.

The by far most stringent regulation has been applied in California and has received a lot of criticism for its bureaucratic burdens and the associated administrative costs and monitoring problems. The adoption of this law however has led to a significant stabilization, especially in the market for HDPE product waste [24]. The Rigid Plastic Packaging Container Law (RPPC) was fundamentally revised in 2012, manufacturers or marketers of plastic packaging must confirm complying with a minimum recyclate quota that is being controlled by a sample system [25]. The scope has been expanded significantly over beverage packaging. Simultaneously, manufacturers may comply with the law via design changes (-10% material input or minimum use of 5 times), a 45% recycling rate, or through a 25% share of secondary resources. Similar regulations are, for example, currently planned in Europe under Guidance of the European Packaging Directive [26].

Specification of instrument

The specification of the instrument is challenging because specific content quotas for plastics in specific products would have to be defined: On the one hand, the quota must be set sufficiently high to trigger actual effects on product design and the management of plastic waste. On the other hand, it must be technically achievable without impeding the final quality of the products. Against this background, the Japanese Top-Runner approach could be used: In this case the best available quota on the market today would be used as minimum threshold value for a certain time period like three or five years (see relevant considerations to a resource based Top-Runner approach in the research project “Material Efficiency and Resource Conservation (MaRess)” [27]). Thus, the technical feasibility of the quota would already be proven. At the same time, the possibility of strategic monopolization approaches needs to be taken into account since products with recycled material of up to 100% exist in the market (as opposed to energy efficiency without an upper limit). Considering similar examples e.g. in the construction sector, a minimum recyclate quota of 30% seems appropriate for all plastic-based components. This quota has also been mentioned in a BioIS study and termed as a realistic target for PVC [28].

Within the “MaRess” project the instrument of minimum recyclate quotas has been examined for ICT products and in particular contained critical metals. It has been proven that the Ecodesign Directive could provide the legal foundation for such an instrument.

Estimation of effects depending on specification

The introduction of minimum recyclate quotas would allow direct control of the use of secondary raw materials and thus mechanical recycling. Instead of defining technological standards, this approach would be based on market consideration how these standards can be met at the lowest cost level. Electronic products offer good conditions for the introduction of a recyclate quota because many of the employed components are used in the „non-visible range“ meaning that the frequently cited problems of colour fidelity of secondary plastics only play a minor role (i.e. [29].

Concluding evaluation

Despite the potential benefits, the actual implementation faces severe challenges: The proof on the utilization of secondary plastics for certain products without the cooperation of all relevant actors will hardly be realized. This will require a comprehensive monitoring of complex international material flows and the certification of recycling processes. It is also obvious that the proposed changes in production processes require not only a national but also an EU-wide approach.

From an ecologic standpoint, it should also be taken into account that plastics might be replaced by raw materials with probably higher resource consumptions along their entire life cycle just to avoid complying with the quota. As long as such an integrated view over the "resource footprint" is missing, manufacturers could start using secondary raw materials of inferior quality that would affect the life cycle of products causing even a higher consumption of primary resources.

3.3. Mandatory deposit for small electric and electronic devices

Description of mechanism / reference to barriers and motives

The instrument of a mandatory deposit aims to lead back products after use into a controlled system for reuse or recycling. A deposit is charged when selling the product (in addition to the purchase price), which will be paid back upon return of the product again. This results in an economic incentive for the purchaser to return products.

Deposit schemes on selected plastic-containing products can firstly lead to an increase of the collection rate and, secondly, to a more homogenous collection in comparison to a collection of a variety of plastics-containing products with many different types of plastic. Consequently, the supply of economically recyclable fractions can be depending on the amount of the deposit significantly increased and thus incentives for the recycling of plastics are set.

According to the German Advisory Council on the Environment deposit shemes are in particular for mobile phones and computers, owing to their wide use (100 households own 57.8 laptops and 160.9 mobile phones), an effective tool for a high-quality collection of the products [30]. Also in the public consultation on the Green Paper on a European strategy on plastic waste in the environment the majority of interviewees considered a deposit shemes as meaningful. However, the estimates also show that general statements about the effectiveness of a mandatory deposit are not possible and must be investigated specifically: "Any proposals in this area should be mindful of the differing situation across the member states and also they must be considered by specific product sector / application" [31].

Examples for successful implementations

In Germany, a mandatory deposit scheme exists for beverage packaging and automotive batteries. Also in the USA – in 11 states - a deposit scheme for batteries is established [32]. Up to the introduction of the WEEE Directive in 2005 (general obligation to take back products) in Austria and Italy a deposit was charged on several EEE. In Austria, for instance, 10 schillings were collected on lamps and 1,000 schillings on refrigerators. After abolition of the deposit scheme in Austria only one-fifth of the outstanding amounts of deposits was picked up (even without the return of the products possible). At the end of the year 2008 (abolition 2005) still 39 million euros were managed by the foundation [33]. Obviously, the deposit was too low and has been lost from the consciousness of consumers due to the long-term capital commitment.

Specification of instrument

Against the background of the experience in Austria it is reasonable to focus those EEE that have a relatively short useful life (presence of the deposit in the minds of consumers). For instance, mobile phones, which have an enormously low collection rate, contain a number of valuable raw materials and have a relatively short useful life with an average of 2 years [34].

Basically, the deposit amount has to be addressed to the consumer. Fehling 2010 (cited in [35]) is proposing to undertake retailers to collect the deposit. The return should be possible at all retailers, regardless at which retailer the products were purchased (possibly with deposit tokens). By means of a clearinghouse raised deposits could be managed.

[36] have identified three key criteria that must be considered when determining the level of deposit: social criteria (effort for the consumer e.g. temporally, spacial), ecologic criteria (raw material consumption, types and amount of hazardous substances) and economic criteria (expected price development of raw materials, raw materials values, static lifetime of raw materials, possibilities of deposit-fraud). For instance, the green political party in Germany "Alliance '90/The Greens" propose a deposit of 10 euros [37], the German Advisory Council on the Environment propose up to 100 euros deposit for mobile phones [30]. Obviously, so far, it is not sufficient investigated, which level of deposit is appropriate.

Estimation of effects depending on specification

An investigation by Germany's digital association (BITKOM) has revealed that 86 million unused mobile phones are stored in German households [38]. Assuming that with a deposit amount of 10 to 100 euros 50 to 90% of these mobile phones are collected, 43 to 77 million mobile phones could be additionally collected and made available for reuse and recycling (at this level once; afterwards such storage at best no longer take place and a continuous return establish). However, it is still unclear which deposit amount on mobile phones induces its corresponding steering effect, while the related efforts (administratively e.g. clearinghouse, at an individual level e.g. capital commitment) are in proportion to the benefits.

The actual effects of a mandatory deposit for mobile phones on their recycling practices are also not clearly foreseeable. Due to the complex material composition of EEE and its short innovation cycles, even a product-specific collection allows only to draw conclusions on a higher recycling rate in total, but not a recycling of specific materials such as plastics. However, in principle, it is assumable that the starting position for a comprehensive recycling will improve, the higher the collection quantities are.

Overall, in terms of the economic and environmental effects of a mandatory deposit on mobile phones, it remains an enormous need for research.

Concluding evaluation

The concrete implementation of the instrument can be assessed – particularly with regard to the bureaucratic and infrastructural efforts – as problematic. For mobile phones an administrative structure has to be built up. Moreover, it is still completely unclear, which level of deposit and involved capital commitment is reasonable and what economic and ecological effects are actually to be expected from a mandatory deposit on small EEE.

3.4. Obligatory ecodesign standards for reuse and repair-ability

Description of mechanism / reference to barriers and motives

The instrument of mandatory eco-design standards for reuse and repair of selected products encourage producers to take the future repair and reuse of a product into account when designing the product by considering issues like whether it can be easily dismantled and reassembled, and whether it is set up in such a way that faults can be easily identified. Producers put than only such products on the market that do not prevent the reuse of whole products or its components and their repair.

Examples for successful implementations

So far almost no experience with standards on reuse and repair exist, but the instrument has been very successfully used in the energy efficiency sector. In the course of the Ecodesign Directive (2009/125/EC) mandatory ecodesign standards for energy-related products are introduced to reduce the energy consumption and other negative environmental impacts of products. Although the Ecodesign Directive cover a wide range of environmental aspects such as energy, water and other resource consumption, most of the "Implementing Measures" (which are set for every product group separately and have to be fulfilled by the industries) focused so far primarily on parameters to energy efficiency during the use phase [39]. In this respect, an analysis and assessment of impacts of the implementation of the Ecodesign Directive on GHG emissions in the EU until the year 2020 shows „that the GHG emissions can be reduced by 211 to 265 Mio. t CO2eq. compared to business as usual (BAU) development" [40], if all implementing measures are in place (Status: June 2010). One of the most famous implementing measures within the Ecodesign Directive is the regulation on household lamps, leading to the phase out of incandescent light between 2009 and 2012 [41]. According to [42] the Directive has the potential to be also a powerful policy instrument for resource efficiency and the circular economy such as it is for improving energy efficiency.

Specification of instrument

The implementation of mandatory ecodesign standards for reuse and repair through the existing European Ecodesign Directive is proposed by several studies [39,43,44]. Especially the feasibility – since the Directive is already in place - is one reason for using the Directive for promoting reuse and repair on an European level [45]. But [46] argue for instance that the agreement procedure of the implementing measures takes too long in order not to be technically outdated. In average the procedure takes 55 month; but the innovation cycle of EEE is often shorter. In addition the data quality is poor, since manufactures are not obliged to provide specific technical or economic information of their products. Also market surveillance is inefficient, because of too few employees, insufficient budget, inadequate surveillance infrastructure and sanctions. Insufficient cooperation of Member States as well as within industry and the absence of standardised measure methods are further reasons for the inefficient market surveillance. These issues have to be considered in specifying the instrument.

Furthermore, appropriate parameters are required that could be used to practical measure the reuse-ability and repair-ability. According to [47] determining technical criteria for the assessment of the reuse-ability of EEE are the kind and variety of parts and materials used, suitability for disassembly, cleaning and testing. In [43] within a JRC project have proposed a threshold for the time for disassembly of products components under a standardized procedure. Further parameters can be for instance a limited number of bolds, the avoidance of glue or welding of parts and the availability of spare parts.

Estimation of effects depending on specification

As result the durability of products will be extended through repair and reuse and therewith the life cycle of products can be managed in an environmentally friendly and cost-effective way. Since it is estimated that more than 80 % of all product-related environmental impacts are determined in the design phase [48], relevant resource saving potentials can be covered with the implementation of this instrument. However, so far, almost no experience with standards on reuse and repair and knowledge about its effects exist.

Concluding evaluation

Implementing mandatory eco-design standards for reuse and repair of EEE through the existing European Ecodesign Directive can be a promising approach, but possibly, as described above, not the most effective, if no flanking measures are implemented.

Moreover, the throw-away culture in which a quick turnover of (often cheap) goods and low acceptance of reused products (e.g. social stigma arising, trust regarding quality and safety) have become deeply routed become a barrier on the consumer side. Thus may lead to low demand for even eco-designed products. For instance, according to a 2011 Eurobarometer survey the most common reasons for not buying second-hand products were related to concerns about product quality and usability (58 % of mentions) [49]. However, some best practice examples (e.g. Kringloop in Flandern, Revital in Austria) verify the fact that repair and reuse can be practiced successfully with a strong support of reuse activities [50]. In this respect the linking of mandatory product ecodesign standards with a strong support of reuse activities will contribute towards a greater cost-effectiveness of repair, but also awareness and demand for repair and reuse and therewith promote reuse, leading to circularity according to the waste hierarchy.

4. Building a policy mix: from theory to practice

4.1. Preliminary assessment of impacts and feasibility

Looking at the different instruments it becomes clear that there is no lack of ideas, the key challenge is obviously the implementation phase. The following table provides a general overview over the investigated instruments and the evaluations of quantity effects (+++ high quantity effects) and their feasibility (+++ generally high feasibility) carried out in the process. There is a clear trade-off between these two analytical dimensions: Instruments with potentially high quantitative effects often seem rather unrealistic to implement. Feasible instruments on the other hand let expect so low effects that the transaction costs of policy developments maybe equal or higher, preventing e.g. the change of regulatory frameworks.

	Case Study: Germany	
Instrument	Quantity effect	Feasibility
1. Plastictype-specific target for large household appliances	++	++
2. Minimum recyclate quota in the electronics sector	++	+
3. Mandatory deposit for small electric and electronic devices	+(only plastics), +++(additional consideration of all materials)	+
5. Obligatory ecodesign standards for reuse and repair-ability	+	+++

Table 1. Assessment of the selected instruments, Source: Own illustration

4.2. Bundling the instruments into core strategies

The analysis of the various instruments clearly shows that the complex technical, economic, regulatory and informational barriers can not be overcome by a single instrument if an increased use of secondary plastics in closed material loops is intended. In fact, a long-term process adjusting various central levers is required to achieve this goal. Against this background specific instruments could be integrated into three core strategies aiming at a continuous improvement. The integration of the individual instruments that all aim to close plastic loops linked to electronic products to these three core strategies highlight the need for coordinated action and thus provides a glimpse into possible synergies.

Core strategy 1: "Push"

The first core strategy aims at increasing the collection rate of separated plastic waste according to type, which then becomes available for the mechanical recycling. An increase of these quantities may be regarded as a necessary condition for an increased use of secondary raw materials but as previously shown, this alone will not result in a higher use of secondary raw materials under the given conditions. Nevertheless, this push-strategy may lead to economies of scale, that increase incentives for the use of secondary plastic at lower unit costs. Deposit schemes have proven to be an extremely effective instrument for this strategy.

Core strategy 2: "Pull"

The second core strategy is focused on increasing the demand for secondary plastics. The theoretically available potential for secondary plastics exceeds the demand by far. Obviously, economic incentives of switching to secondary plastics are not yet significant enough for most plastic types and uses. The instrumental approach of a mandatory recyclate quota here presented is therefore intended to either lower prices of secondary plastics or strengthen the public sector as its major consumer.

Core strategy 3: "Market development"

In addition to the more traditional approaches of increasing supply and demand of mechanical recycling ("push" and "pull"), the need of a third strategy, which relies on a continuous market development, becomes clear. With regard to the recycling of plastic waste, the need and effectiveness of such measures was for instance, identified by the OECD: "Encouraging ever-higher recycling rates in an imperfect market may impose very high social welfare costs. In such cases it may be far less costly to address the imperfection within the market than to try and bring about increased recycling rates through increasingly ambitious recycling programmes.“ [51].

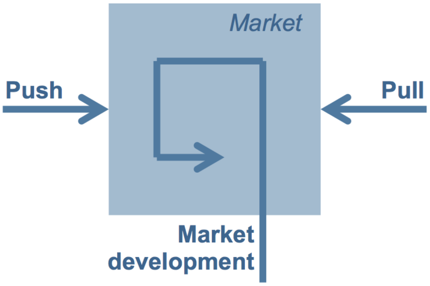

Figure 1. Core strategies towards increasing the use of secondary raw materials, Source: Own illustration

The following above illustrates the necessary interplay of the three core strategies and their different approaches. A successful policy mix must include specific instruments aiming at both the demand and supply side. Additionally, the framework conditions must be strengthened enabling the efficient exchange between the two market sides.

4.3. An analytical framework for an integrated understanding of material flows, the underlying socio-technical system and environmental effects

In order to avoid the implementation of single instruments with inefficient outcomes, it is necessary to base instruments on an integrated understanding of material flows, the underlying socio-technical system and environmental effects. For this purpose in the following an analytical framework for the integrated understanding of this institutional-ecological nexus taking the example of reusing WEEE is developed. It is possible to apply this framework to any other waste treatment operation or waste fraction.

The framework is based on the socio-ecological research perspective and considers the material and structural dimension of reuse: Environmental benefits of reuse depend not only on the product (and its production), but also to a large degree on consumption patterns (e.g. displacement of new product, additional consumption), the use phase (e.g. usage time) as well as collection (e.g. destructive) and repair practice (e.g. availability of adequate tools, knowledge). Regulatory frameworks, incentives structures and policy approaches influence these production, consumption and end-of-life activities. In consequence, resource consumption depends on technical, but also social aspects like the institutional context, in which the waste is generated and managed. This makes clear that it is not sufficient to look for “one size fits all” approaches when aiming to promote re-use with an appropriate mix of policy instruments.

According to [52] socio-technical regimes can be described as “the whole complex of scientific knowledge, engineering practices, production process, technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology”. Drawing on [53], these socio-technical regimes exist of stabilised trajectories and share regulative rules (e.g. laws), normative rules (e.g. behavioural norms) and cognitive rules (e.g. problem definitions) that coordinate action. These rules “enter in decisions and actions, because actors are embedded in regulatory structures and social networks” [53].

Following this a systematic identification of relevant influencing factors and their interdependencies is required to achieve a comprehensive understanding of the institutional-ecological nexus of reuse. For this purpose the framework was developed considering the product/material flow alongside the supply chain from the first to the second user (including the collection of products, the checking, cleaning, repairing and testing of products, and the sale of the products). Three types of influencing factors were defined: product-technical factors (material dimension), product-flow-related factors (material dimension) and context factors (structural dimension). The interplay of these factors result in incentive structures, which coordinate action and bring product/material flows along specific pathways. A context-specific resource consumption results.

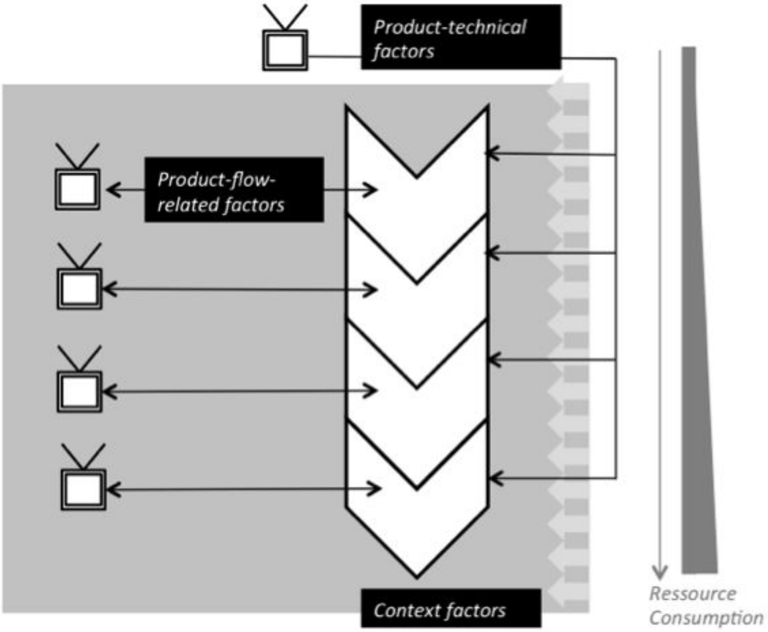

Figure 2. Analytical framework for an integrated understanding of material flows, the underlying socio-technical system and environmental effects – example of reusing WEEE, Source: Own illustration

For a comprehensive understanding the concept differs between the following types of factors:

- **Product-technical factors (material dimension)** concern a specific character of a product such as the product size. These factors are considered to be rather technical and are detached from e.g. waste infrastructure or user behaviour and are comparable for one product no matter in which region the product is used or waste generated.
- **Product-flow-related factors(material dimension)** relate to aspects, which result from the practice of users, collectors, repairmen etc. (e.g. condition of product) and can be studied by tracing the handling of a given product throughout the whole chain. These factors are dependent from the specific waste management context.
- **Context factors (structural dimension)** such as infrastructure, political or economic aspects, cover all context-specific factors, from which – together with the influence factors of the material dimension – incentive structures results, which coordinate action.

The influencing factors interact and thus multiply or mutually reinforce one another. A promising approach to analyse the structures would be therefore the acquisition of actors along the supply chain and expert knowledge – a suitable starting point to gain transparency on complex regime characters.

5. Conclusions

Based on the considerations towards the development of a policy mix to increase the use of secondary raw materials, it can be noted that on the one hand a number of potential approaches can be identified and on the other hand none of the instruments identified is able to address the multiple barriers to the desired extent single-handedly. In this respect, the need for a coordinated, long-term approach becomes apparent.

The described push, pull and market development strategies can be viewed as the basic structure to develop the identified technical potential for systematically boosting the closure of plastic material loops. At the same time, the increased use of secondary raw materials requires a functioning market process for which the right framework conditions must be set without enforcement. Secondary plastics still lack economic competitiveness in many areas for various reasons, therefore processes may be initiated which will only be reflected in the form of higher market share in the medium term.

The developed framework to base instruments on an integrated understanding of material flows, the underlying socio-technical system and environmental effects highlights the institutional-ecological nexus – the waste regime, in which the waste is generated, forms the way in which the waste is managed by the actors and therewith the environmental effects. The technological waste management perspective is shifted to a version, in which social aspects are no exogenous factors, but elementary parts of the system [54]. Analytical approaches to increase the transparency in these systems can be seen as a crucial element for transformation towards a circular economy that avoid the implementation of single instruments with inefficient outcomes.

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