How to unlock potentials of preparation for reuse: barriers and action recommendations

Sandra Köhler

Abstract: This paper reports on success factors and action recommendations for preparation for reuse (PfR) of Waste Electrical and Electronic Equipment (WEEE). Relevant actors along the value chain of PfR are identified. Based on semi-structured interviews, the market attractiveness for PfR operators is evaluated from a German perspective. The results show deficits in access to viable products, barriers to market entry and remarketing of reused goods, intense competition for reused goods, and impeding interdependencies with the primary market. Second, a literature review is conducted to derive action recommendations that address the barriers to reuse. The action recommendations are distinguished by the type of instrument into the categories information (six measures), legal framework (eight measures), organizational structure (seven measures), and process change (five measures). Each measure is assigned to the relevant actors and the effect towards improving the market attractiveness for PfR. Based on the number of references in literature, the main success factors for PfR are derived. Those are value-conserving logistics, public relations work, the introduction of an umbrella brand, and cooperation between collection points and repair or sales platforms. This structured overview serves as a guide for decision-makers as to which recommendations for action should be given priority and implemented.

Keywords: barriers preparation for reuse, success factors, action recommendations, reuse of electrical and electronic equipment, WEEE.

Potentiale der Vorbereitung zur Wiederverwendung erschließen: Barrieren und Handlungsempfehlungen

Zusammenfassung: Dieser Artikel behandelt Erfolgsfaktoren und Handlungsempfehlungen für die Vorbereitung zur Wiederverwendung (VzW) von Elektro- und Elektronikaltgeräten (EAG). Es werden relevante Akteure entlang der Wertschöpfungskette der VzW identifiziert. Basierend auf halbstrukturierten Interviews wird die Marktattraktivität für Akteure der VzW aus deutscher Sicht bewertet. Die Ergebnisse zeigen Defizite beim Zugang zu geeigneten Produkten, Hemmnisse für den Markteintritt und die Wiedervermarktung von VzW-Gütern, einen intensiven Wettbewerb um VzW-Güter und hinderliche Interdependenzen mit dem Primärmarkt. Zweitens wird eine Literaturanalyse durchgeführt, um Handlungsempfehlungen abzuleiten, die sich mit den Hindernissen für die Wiederverwendung befassen. Die Handlungsempfehlungen werden nach der Art des Instruments in die Kategorien Information (sechs Maßnahmen), rechtliche Rahmenbedingungen (acht Maßnahmen), Organisationsstruktur (sieben Maßnahmen) und Prozessänderung (fünf Maßnahmen) unterschieden. Jede Maßnahme wird den relevanten Akteuren und der Wirkung zur

Verbesserung der Marktattraktivität für die VzW zugeordnet. Basierend auf der Anzahl der Literaturhinweise werden die wichtigsten Erfolgsfaktoren für VzW abgeleitet. Diese sind die werterhaltende Logistik, die Öffentlichkeitsarbeit, die Einführung einer Dachmarke und die Kooperation zwischen Sammelstellen und Reparatur- oder Verkaufsplattformen. Diese strukturierte Übersicht dient als Orientierungshilfe für Entscheidungsträger, welche Handlungsempfehlungen priorisiert und umgesetzt werden sollten.

Stichworte: Barrieren der Vorbereitung zur Wiederverwendung, Erfolgsfaktoren, Handlungsempfehlungen, Wiederverwendung von Elektro- und Elektronikgeräten, WEEE.

1 Introduction

The European waste hierarchy gives waste prevention the highest priority. Preparation for reuse (PfR) constitutes the second priority, followed by recycling, other recovery, and disposal. It yields social, environmental, and economic benefits (Boldoczki et al., 2020; X. M. González et al., 2017; O'Connell et al., 2012; Pini et al., 2019). PfR is preferable to recycling because the value is conserved, and therefore resource is maximized (Kalmykova et al., 2018). This is especially relevant for products with resource-intensive upstream processing, such as Waste Electrical and Electronic Equipment (WEEE) (Braungart et al., 2007). In the EU, 8.4 kg of WEEE per inhabitant is collected annually (Eurostat, 2020b). Of the collected WEEE, 97.8 % are recycled. However, a case study from Belgium shows that only 32 % of the materials are recycled towards high-end applications whereas 68 % is lost in low-end applications, landfill or incineration (De Meester et al., 2019; Eurostat, 2020a). This shows that for recycling of WEEE not only highly energy intensive recycling processes are required, but also a considerable share of primary resources is not recoverable. Therefore, it is of high interest to increase the share of PfR for this specific waste stream.

Various management practices for WEEE can be observed within Europe (Ongondo et al., 2011). The success of PfR varies greatly, even among countries with an identical legal basis concerning reuse operations (Johnson et al., 2015). In Europe, the Directive on Waste Electrical and Electronic Equipment (Directive 2012/19/EU) regulates WEEE collection. It establishes the concept of extended producer responsibility (ERP) for WEEE. ERP puts the responsibility for the financing of collection, recycling, and end-of-life disposal on producers. However, incentives initiated by ERP mainly focus on material recycling and are rarely involved in PfR operations (Kunz et al., 2018; Zacho et al., 2018). In Germany, the Law on Closed Cycle Management and Waste (*Kreislaufwirtschaftsgesetz*, KrWG) enforces the waste management hierarchy on a national level. The handling of WEEE is additionally regulated by the Electrical and Electronic Equipment Act (ElektroG). The act governs sales, return, and environmentally sound disposal of WEEE and implements ERP. Consumers are obliged to collect WEEE separately from household waste. They can discard WEEE at municipal collection points, public depot containers or via pick-up systems operated by municipal disposal services. They can also return WEEE to the distributors upon sale of a new piece of equipment or via take-back systems offered by producers or resellers of electrical and electronic equipment. A representative survey, conducted by the German Environment Agency (*Umweltbundesamt*, UBA), identifies municipal collection points as the main disposal route, with a share of 37 % of the respondents using this return option (Schmiedel et al., 2018). A recent case study on the potentials of PfR states

that 113.114 t of WEEE arise annually at Bavarian collection points alone, of which up to 87 % are theoretically viable for reuse (Messmann et al., 2019). The preeminence of collection points compared to other disposal routes is also observed in Denmark (Parajuly & Wenzel, 2017) and England (Curran et al., 2007; WRAP, 2011). Charitable institutions handle the major part of municipally collected waste processed for PfR but the overall amount of goods undergoing recovery operations for remarketing is minimal (Sander et al., 2013; Schomerus et al., 2014). Johnson et al. (2015) and Queiruga and Queiruga-Dios (2015) identify a strong need for a distinct reuse quota. While already 93 % of collected WEEE is recycled in Germany, the share of WEEE being prepared for reuse is below 2 %, despite its higher priority within the waste hierarchy (Eurostat, 2020a). In 2017 the European commission re-investigated the possible setting of separate targets for WEEE to be prepared for reuse but concluded that it is unfeasible at the current stage due to insufficient knowledge about quantities of WEEE that could be prepared for reuse in the EU and requirements for reverse logistics (European Commission, 2017). In literature, several approaches exist to fill the lack of data about potentials for PfR (Bovea et al., 2016; Curran et al., 2007; Messmann et al., 2019; Parajuly and Wenzel, 2017; WRAP, 2012). All studies agree that a considerable reuse potential exists, and therefore, the implementation of a binding PfR target for WEEE can be expected in the future. Spain took a pioneering role among Europe as the first country to implement a binding PfR target for large EEE (3 %) and small IT and telecommunication equipment (4 %) (Ministerio de Agricultura alimentaciòn y medio Ambiente, 2015). Several organizations such as ComputerAid, RREUSE, ACR+, and the European Environmental Bureau support a PfR target of 5 % as suggested by the European Parliament (Esenduran et al., 2016). With the current share of PfR of WEEE of less than 2 % it is necessary to take action and follow an effective strategy to promote PfR.

As part of a research project by the Bavarian State Ministry of the Environment and Consumer Protection, this study sets out to consolidate findings of previous studies on success factors and barriers of PfR. In literature, it is agreed that actions need to be taken to increase the share of PfR, but a structured review of action recommendations and best practice examples is missing. Therefore, in this study a literature review on action recommendations is conducted. To be able to put the identified recommendations into context, barriers of PfR are assessed as well. The aim is first to gather primary data concerning barriers to the implementation of PfR and then derive action recommendations from literature that address these barriers. In the following semi-structured interviews and a structured literature review are conducted in order to answer the following research questions:

What are success factors for PfR in Germany and Europe?

RQ1. What are the barriers to preparation for reuse in Germany?
RQ2. What action recommendations can be identified in literature and how can they be classified and prioritized?

A complete process of PfR contains the components identification, recovery, and re-provision on the market (Sander et al., 2019). Before a good can be re-provided on the market, it is required to undergo recovery operations. These operations comprise examination, cleaning, and repairing (KrWG § 3). Barriers that currently hinder preparation for reuse

and restrict access to sufficient volumes of reusable goods are legal hurdles (CIWM, 2016; Cole et al., 2019; European Commission, 2015; J. G. González, 2013; Johnson et al., 2015; Kissling et al., 2013; Löhle et al., 2016; Ongondo et al., 2011; Sander et al., 2013), a lack of consumer awareness and information (CIWM, 2016; Cole et al., 2019; European Commission, 2015; Löhle et al., 2016; Neitsch et al., 2010; Sander et al., 2013), missing cross-sector engagement and organizational structures (CIWM, 2016; Johnson et al., 2015; Löhle et al., 2016; Neitsch et al., 2010; Sander et al., 2013; Spitzbart et al., 2009) as well as insufficient infrastructure (Broehl-Kerner et al., 2012; European Commission, 2015; Neitsch et al., 2010; Sander et al., 2013).

To structure action recommendations within the (reversed) supply chain, potential actors need to be known. A stakeholder analysis is performed based on the concept of Mayers (2005) and Hostmann et al. (2005), which classifies stakeholders according to their influence and involvement. Figure 1 shows the flow of influence and the exchange of information among the different stakeholders as the results of expert discussions within the project steering board. As discussed above, waste management is strictly regulated by European and national legislation. The legislator influences all subjacent levels (Gollakota et al., 2020). Public authorities implement the legal framework on the subsequent level. On the third level, commercial and non-commercial actors can be distinguished. A study of the German Federal Environmental Agency identifies manufacturers and repair facilities as commercial actors of the supply chain municipal disposal and social-charitable institutions as non-commercial ones (Schomerus et al., 2014). Associations, such as the German used Electronic Appliances Register (EAR foundation), function as mediators between all levels.

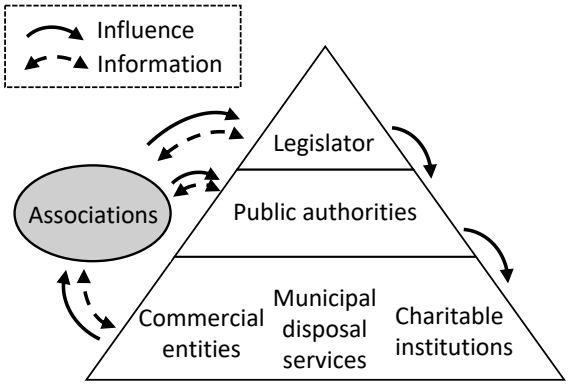


Figure 1: Actors of PfR operations classified by influence and involvement. The top-level represents the greatest area of influence; the width represents the level of involvement in PfR processes.

2 Method

The study's structure is illustrated in Figure 2. The research approach follows seven subsequent steps in three phases (A-C). The first phase (A) clarifies the research aim and operationalizes the research question into two distinct fields of interest: barriers to PfR and action recommendations to overcome these barriers. Phase B begins with the contex-

tualization of research (step B2, Introduction). The identification of barriers is based on the framework of the reverse five market forces (based on Stindt et al. (2016)) and is assessed by semi-structured interviews. Action recommendations to increase the share of products undergoing PfR are derived from a structured literature review (both step B2). In the third research phase (C), action recommendations are classified according to the previously gained findings concerning the actors and barriers of PfR. Based on each action recommendation's potential to overcome barriers and the relevance in literature, the main success factors for PfR are derived.

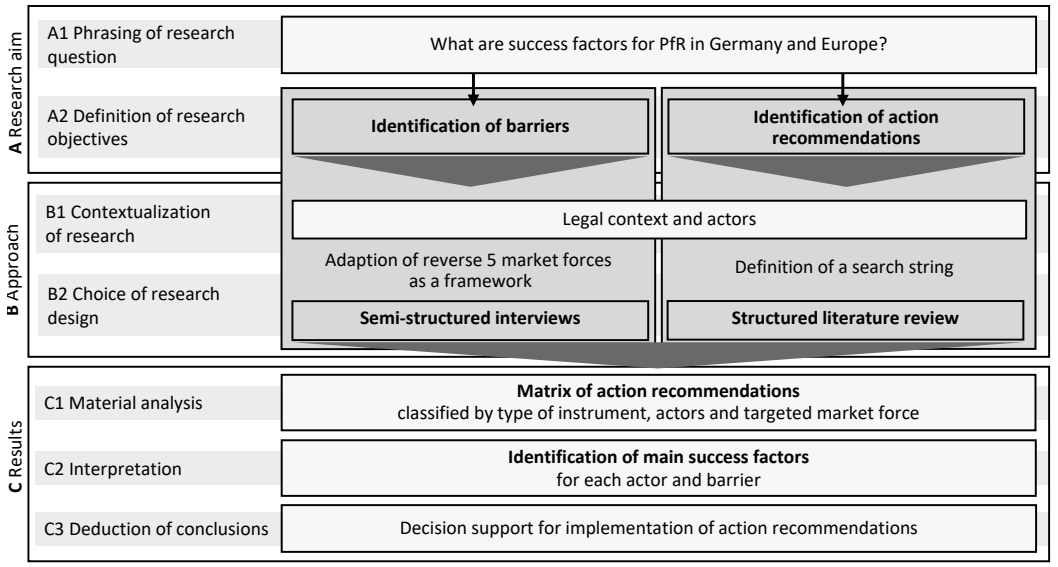


Figure 2: Research approach for the identification of success factors for PfR

Identification of barriers

In order to evaluate action recommendations and measures, information on characteristics, mechanisms, and interdependencies of the market must be retrieved. The Reverse Five Forces (R5F) offer a framework for evaluating the attractiveness of take-back markets for goods and groups of goods and various actors in a structured manner (Stindt et al., 2016). The framework of the R5F is based on Porter's Five Forces. Porter's Five Forces is a widely accepted model that identifies and analyzes five competitive forces that shape every industry and helps determine an industry's weaknesses and strengths (Porter, 1979, 2008). The model can be applied to any sector of the economy to understand the level of competition within the industry and improve a company's long-term profitability. Nevertheless, the model cannot be directly applied to markets for recoverable products and has therefore been adapted by Stindt et al. (2016). Stindt´s R5F take the perspective of original equipment manufacturers (OEMs). Since the main actors of PfR operations are non-commercial ones, the R5F are tailored to the case of PfR based on discussions within the project steering board and iterative pre-tests with a subset of interviewees (see Appendix C). Figure 3 depicts the R5F with adapted subordinate attributes that determine the power of each force. The three necessary steps for a successful PfR are located within

these forces. The identification of goods suitable for PfR is described by attributes within the force access, operations of PfR are included in the market entry, and re-provision of the goods on the market is covered by the remarketing. Competition and interactions with the primary market are forces that allow a more extensive assessment of the take-back market.

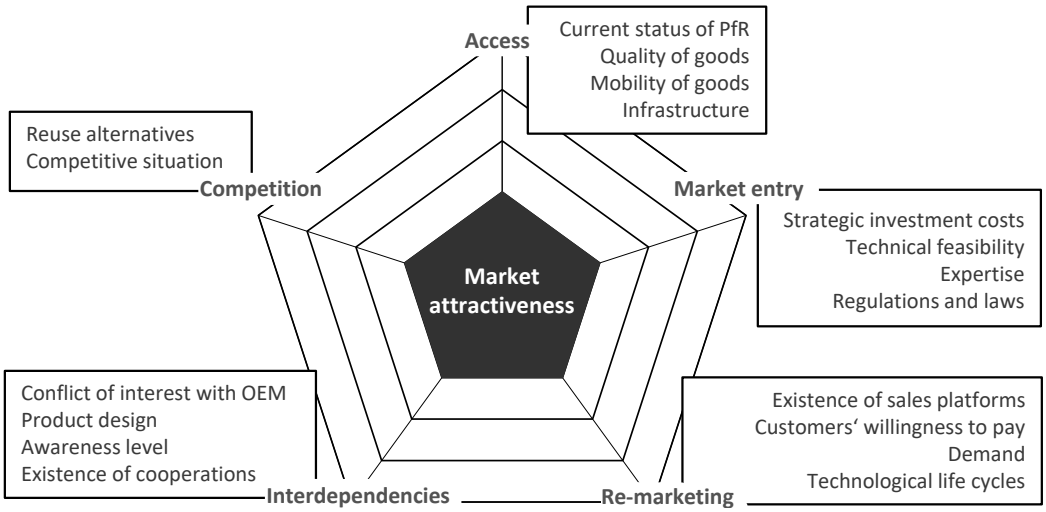


Figure 3: The Reverse Five Forces (R5F) of PfR (based on Stindt et al., 2016)

A set of attributes defines each force. For example, the force of access is assessed by the status quo of PfR, quality of available products, mobility of products, and infrastructure for collection. The scale ranges from 1 (not prevalent) to 5 (optimal condition). In terms of access, this optimal design would provide unrestricted access to reusable goods. The difference to the optimal value (5) represents the potential, which can be exploited by different instruments and actions. Since no literature data is available, primary data had to be gathered for the evaluation of the attributes. For that purpose, the independent opinions of individual stakeholders were analyzed through semi-structured expert interviews. Semi-structured interviews yield the benefit that questions can be put into context and queries from respondents can be answered directly. This allows for a similar understanding of the questions by all interviewees and improves comparability of the results. The interview guide is provided in Appendix B. The experts are all based in southern Germany and stem from the areas of waste management, repair networks, remarketing, and science, thus covering the entire spectrum of the R5F. A list of the interviewees and documentation of interview results are provided in Appendix C to E, respectively. The individual assessments are equally weighted and aggregated to form the status quo of the PfR market's attractiveness. Equal weighting among the experts and among the attributes is chosen, since neither Stindt et al. (2016) gives an indication concerning weighting factors nor is other scientific foundation available.

Identification of action recommendations

The material collection is carried out in careful database research, for which the online catalog of Google Scholar and Web of Science are selected. A Google search is performed to identify scientific and other types of formal reports that are not published as peer-reviewed journal articles. Literature in English and German language is included, and the Boolean search string is therefore applied in both languages. The search was finished on 20 January 2021 and employed the following search string:

("preparation for (reuse OR re-use)" AND (action OR recommendation OR "success factor" OR "best practice") – for English results

("Vorbereitung zur Wiederverwendung" AND ("Empfehlung" OR „Handlungsempfehlung" OR „Maßnahme" or „best practice") – for German results

In order to be referenced in this study, an article needs to meet the following criteria:

- The article is written in English or German.
- The article targets preparation for reuse.
- The article includes at least one action recommendation.

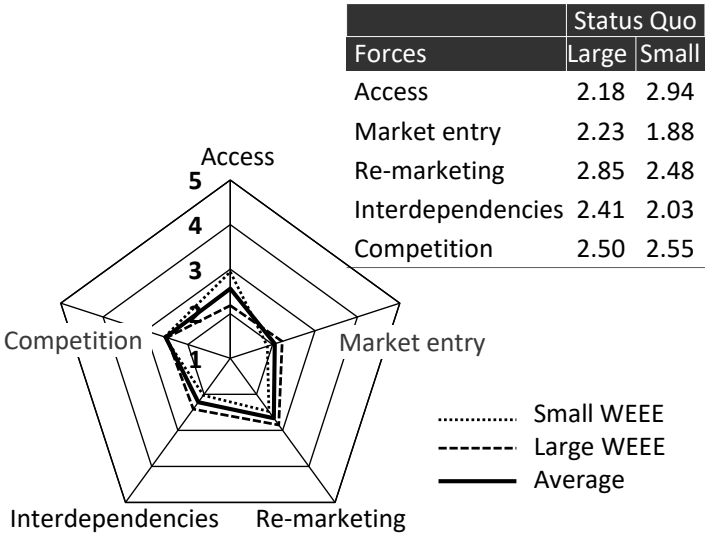
The final sample comprises a total of 22 articles that are analyzed in this study with respect to the research questions. Appendix A shows the list of identified publications, according to the scope and type of article. The referenced studies are given an additional number in square brackets (in lexicographic order, see Appendix A) to distinguish them from other references and ease their citation in tables and other lists. All articles were scanned for potential action recommendations. After extracting all mentioned recommendations, similar ones among different articles were grouped together and a suitable designation was defined by the authors of this study. In the following sections, results of the market analysis and the literature review are presented.

3 Material evaluation

First, the current market situation for PfR of WEEE is presented. Subsequently, action recommendations are derived. Action recommendations target either one or more of the barriers identified by the R5F. For each of the R5F approaches for improvement are presented.

3.1 Market analysis

Experts were asked to assess small and large WEEE individually. The Directive on Waste Electrical and Electronic Equipment (Directive 2012/19/EU) divides WEEE into six categories, which, for the purpose of this study, are grouped into small (screens and monitors, lamps, small equipment, and small IT equipment) and large WEEE (temperature exchange equipment, large equipment). The results of the market analyses are shown in Figure 4 as a web chart, detailed data and boxplot diagrams of the answers are provided in Appendix D and E. Each axis represents the assessment of the status quo of the respective market force. In the following findings of the semi-structured interviews are summarized for each market force.



	Status Quo	
Forces	Large	Small
Access	2.18	2.94
Market entry	2.23	1.88
Re-marketing	2.85	2.48
Interdependencies	2.41	2.03
Competition	2.50	2.55

Figure 4: Evaluation of market attractiveness for PfR of WEEE

Access to goods is rated with 2.18 (large WEEE) and 2.94 (small WEE) out of 5 points, indicating room for improvement. A recent case study quantifies the amount of accessible products for PfR in the German state of Bavaria. The study states that up to 44 % of WEEE arriving at municipal collection points could be prepared for reuse with reasonable effort. Currently, less than 2 % of this potential is prepared for reuse. While 14 % would directly be suitable for PfR, another 29 % can be realized with improvements in the collection mode. More extensive interventions in existing collection systems, market mechanisms, consumption patterns, and legal requirements are needed to enable PfR for an additional 42 %. Only 13 % is regarded as inapt for PfR (Messmann et al., 2019). Regarding mobility of the goods, a distinction can be made between household appliances, which have limited mobility, and other WEEE. Smaller WEEE can be easily transported, facilitating access to goods but also enabling illegal collection and export. This leads to improper recycling, lower domestic reuse rates, damage to health, and increased environmental impacts abroad (Kissling et al., 2013). The collection of large household appliances is challenging due to their restricted mobility. Easy access to collection points plays a crucial role in this regard. Besides, the collection mode has a significant impact on the quality of the goods, as, for example, improper transport or insertion into containers can lead to damage.

The need for high investment in the expansion of reuse facilities restricts market entry into the secondary market. In addition to trained employees' expertise, reprocessing of WEEE also requires appropriate technical equipment and availability of spare parts. This is even more prevalent for small products (1.88 points) than for large WEEE (2.23 points). Also, especially for large household appliances, the requirements for size and design of storage areas must be met. These factors lead to high strategic costs for PfR. According to German law, the processing of WEEE must be conducted by primary treatment facilities (§ 21 ElektroG). Thus, PfR can only take place at certified recycling centers (LAGA,

2017). If legal conditions are met, repair options also depend on the technical feasibility. Electrical appliances are becoming increasingly complex, and repair options are limited.

Remarketing depends on sales platforms' existence and is evaluated comparatively well, with close to 3 points on average. IT equipment can be sold nationally or internationally, whereas large household appliances are mainly traded regionally due to low mobility. No or poor remarketing opportunities arise for certain small household appliances such as electric toothbrushes or shavers due to hygienic aspects (Broehl-Kerner et al., 2012). Demand for secondary electrical appliances exceeds supply in some places but fluctuates widely (Kissling et al., 2013). A strong correlation between existing demand and well-known manufacturer brands can be observed for major household appliances and consumer electronics. Branded products have a higher perceived product value and thus increase customers' willingness to pay. Short innovation cycles, characteristic of IT and consumer electronics, lead to a time restriction for secondary products' remarketing. After a certain time, compatibility with other devices and software is no longer guaranteed, or technology has progressed so quickly that there is no more demand for a specific product. This psychological obsolescence hinders remarketing in the case of IT devices. These problems are negligible for large household appliances (NABU, 2016). On the other hand, planned obsolescence ensures a constant number of returns for manufacturers but conflicts with waste prevention goals. For the most part, existing markets are already well developed but have further development potential in terms of nationwide distribution networks (Broehl-Kerner et al., 2012). One competitive advantage of secondary markets is the availability of spare parts or old technologies whose technological life cycles have already passed, and they can thus no longer be acquired on the primary market. This niche can be tapped by offering them on secondary markets.

In the course of remarketing WEEE, strong interdependencies with external actors arise, especially for small WEEE (2.03 points). If secondary products partly serve the market, this can lead to a decline in demand for primary products. Successful remarketing of WEEE may result in conflicts of interest with manufacturers (Kissling et al., 2013). One way to counteract this competition is the strategic involvement of manufacturers. They are legally obliged to ensure take-back and proper recycling of their products. In this context, the EAR foundation serves as a joint coordination body for manufacturers (stiftung ear, n.d.). By integrating product take-back into the corporate strategy, the market entry of other players is prevented. In addition to joint coordination points, cooperation between collection points and repair or sales platforms is crucial to the success of PfR and has not been sufficiently developed to date. Cross-linking existing channels and awareness among the population for reuse possibilities still hold significant potential for improvement. Consumers' responsibility lies in the return of old appliances, whereas manufacturers can already start at the product design stage. The Ecodesign Directive already aims for an increased eco-friendly product design. Manufacturers' efforts to "design to repair", which facilitates the reparability and thus reusability of products, have not yet emerged.

From PfR operators' perspective, potential competitors for WEEE are recycling facilities interested in metallic raw materials. In this context, the attractiveness of PfR compared to other forms of treatment is related to the current raw material prices (NABU, 2016). Competition is prevalent but is not evaluated as the most pressing restriction.

This concludes the evaluation of the market attractiveness for PfR of WEEE, which gives insights towards barriers of PfR. In the next step action recommendations to increase the share of products undergoing PfR are derived from a structured literature review.

3.2 Action recommendations

First, a descriptive analysis shows that 18 out of 22 identified studies are published as reports, three as journal articles, and one as a conference proceeding. The majority of the studies are written in German and set the regional focus to Germany or Austria. This leads to the conclusion that PfR is a topic that is mostly discussed on a national or regional level. Action recommendations for PfR have not yet been the focus of a scientific discourse but are rather investigated by administrative bodies or associations such as federal environmental agencies or nature conservation authorities. An analysis of the affiliations of the first author(s) shows that nine authors stem from to research institutes, seven from universities, two from NGOs and the remaining four authors belong to either other institutions or no information is given. A total of 26 action recommendations are derived from the articles. On average, each publication yields 8.23 action recommendations, with a minimum of one (study number [10], Luger at al., 2010) and a maximum of 20 recommendations (study number [9], Löhle et al., 2016). A detailed overview of the studies is provided in Appendix A. The authors of this study classify the measures according to the type of instrument. A distinction between the following four categories has proved to be appropriate:

- Information
- Legal framework
- Organizational structure
- Process change

Table 1 shows an overview of all identified measures, clustered according to the type of instrument, targeted market forces, and actors. Six measures belong to the category of information and aim to raise awareness among the population and eliminate barriers to PfR that exist due to information deficits. Additionally, the willingness of stakeholders to actively participate in PfR is targeted. The provision of information alone is not sufficient to overcome all barriers to PfR. However, in addition to more practical measures, it is necessary to bring about behavioral changes (González 2013). A total of eight measures targets the legal framework. The goal of all measures in this category is to set legal conditions that facilitate the implementation of PfR and reduce existing obstacles. Changes to the legal framework are primarily the legislator's responsibility and characterized by a long-term planning horizon. Seven measures concern the organizational structure and have an effect on a supraregional level (comprising several municipalities). Improved organizational structures enhance collaboration between all actors, which allows synergy effects to be exploited. The category of process change comprises five action recommendations which, due to their more regional character, particularly address collection points and municipalities. By implementing these measures, process changes can be brought about in the short term. In the following detailed findings of the literature review are described for each of the four types of instruments.

Table 1:. Identified action recommendations by type of instrument, targeted market forces, and actors

		Market Force					Actor					
Instrument	Title	Access	Market entry	Remarketing	Interdependencies	Competition	Legislator	Public authorities	(non-)commercial	Associations	# mentions	References
Information	Public relations work	x		x			x	x	x	x	14	[2],[3],[4],[6],[7],[9],[11],[12], [13],[15],[16],[18],[19],[22]
	Employee qualification	x	x						x	x	12	[1],[2],[3],[7],[9],[11],[13],[15], [16],[18],[19],[22]
	Advertisement			x					x	x	11	[2],[4],[5],[8],[9],[11],[15],[16], [17],[19],[22]
	Liability and warranty		x				x	x			9	[2],[3],[9],[14],[15],[16],[19], [21],[22]
	Information sharing	x	x	x	x	x			x	x	4	[2],[15],[19],[22]
	PfR Ranking	x	x	x	x	x		x		x	1	[15]
Legal framework	Design to repair				x		x				8	[4],[6],[7],[9],[13],[16],[15],[22]
	Repair manual		x				x				7	[1],[9],[15],[16],[17],[18],[22]
	Incentive system	x	x	x	x	x	x	x			5	[2],[6],[9],[15],[22]
	Illegal collection	x					x	x			5	[6],[7],[8],[15],[16]
	Deposit system	x					x				4	[4],[8],[9],[21]
	PTF certification		x				x				4	[9],[14],[20],[21]
	VAT reduction			x			x				1	[9]
	Public procurement			x			x	x			1	[9]
Organizational structure	Umbrella brand			x					x	x	14	[1],[2],[3],[5],[7],[9],[11],[14], [15],[16],[17],[19],[21],[22]
	Cooperation				x				x		14	[2],[3],[5],[7],[9],[11],[12],[14], [15],[18],[19],[20],[22]
	Alternative sales structures			x					x	x	7	[5],[9],[12],[13],[15],[19],[22]
	Project support		x	x			x	x			6	[3],[4],[14],[15],[19],[22]
	intra-municipal second-hand store			x					x		4	[9],[15],[19],[22]
	Mobile testing unit		x					x	x	x	2	[2],[21]
	Upcycling			x					x		1	[4]

		Market Force					Actor					
Instrument	Title	Access	Market entry	Remarketing	Interdependencies	Competition	Legislator	Public authorities	(non-)commercial	Associations	# mentions	References
Process change	Value-conserving logistics	x							x		16	[1],[2],[3],[5],[6],[7],[8],[9],[12],[13],[15],[16],[18],[19],[21],[22]
	Separate collection	x							x		11	[2],[3],[9],[11],[15],[16],[17],[19],[20],[21],[22]
	Transport	x					X	x	x		9	[1],[2],[9],[10],[13],[15],[19],[21],[22]
	Secure data deletion			x					x		8	[3],[6],[7],[8],[9],[16],[21],[22]
	Collection mode	x						x	x		4	[2],[9],[15],[19]

INFORMATION

Within the category "information", the measure of public relations work is mentioned most frequently. Successful public relations work aims to improve access to high-quality goods as well as remarketing conditions. By raising awareness among the population for the potential reuse of products, more conscious handling of goods can be achieved. This leads to an improved quality of collected goods. Additionally, public relations work helps build up a positive image of second-hand goods and strengthens sales. A first step is to create transparency regarding the processes of PfR (J. G. González, 2013). Presentations and campaigns with informative brochures and flyers or contributions by regional media address a more extensive customer base for PfR products and inform about drop-off and sales opportunities for second-hand goods (Broehl-Kerner et al., 2012). Public relations work and the dissemination of information about the positive impacts of PfR on the environment are all actors' responsibilities. Within this category, the second and third most relevant action recommendations by the number of references are employee qualification and advertisement. Qualification of employees forms the basis for the implementation of PfR. On the one hand, trained employees are needed for sorting and identifying reusable goods at municipal collections points (Spitzbart et al., 2009). On the other hand, PfR operations of WEEE require specific knowledge to carry out standard measures such as functional tests or safety checks. These activities can be performed independently by in-house employees after training by a master electrician or with the help of a manual for less complex goods (Broehl-Kerner et al., 2012). Commercial or non-commercial actors or associations can organize this training or workshops. Access to suitable goods for PfR can be expanded through a qualified examination of the disposed of goods (Sander et al., 2013). Also, market entry of PfR operators requires both legal and technical knowledge in the implementation of PfR. Reuse facilities should effect the active promotion of reused products. The goal is to build up a positive image of reused goods and draw attention to environmental impact reduction and resource conservation through reuse (Spitzbart et al., 2009). Reuse facilities can increase their brand awareness by participating in regional events, social media presence, and their own homepage. In

addition, targeted marketing campaigns explicitly address different customer groups such as "antique/vintage, green, thrifty" (Sander et al., 2013). Particularly in the case of WEEE, uncertainties concerning liability and warranty issues inhibit this equipment's reintroduction into the market (Sander et al., 2013). Clarification of existing requirements and laws as well as pragmatic approaches facilitate the market entry for practical businesses. For example, a used appliance's warranty can be shortened to one year in the general terms and conditions. Further shortening is not allowed (Broehl-Kerner et al., 2012). Educational and informational measures include standardized procedures for collection, processing, and remarketing, as well as an easily understandable fact sheet on liability and warranty. In terms of implementation, both the legislator and public authorities can initiate changes. Supraregional exchange of information targets stronger networking activities among reuse facilities and associations and further disseminates best practice examples. Improved information exchange has a positive effect on all aspects of PfR, as the actors benefit from the experience already gained by others, and solutions to existing obstacles can be sought jointly (Sander et al., 2013). Exchange of experience can take place both at network meetings and via internet platforms and results in new structures of cooperation (Broehl-Kerner et al., 2012). The recommendation of a PfR ranking among municipal reuse operators is mentioned only once. Supraregional PfR rankings create incentive systems for municipalities and reuse facilities. The design offers a wide range of possibilities and can influence all aspects of the market. Examples include rankings of reuse quotas, best practice examples, or incentives for efficient pick-up or drop-off systems (Neitsch et al., 2010). The initiative to implement and publicize ranking systems origins from public authorities and associations.

LEGAL FRAMEWORK

According to § 4 (1) ElektroG, manufacturers are required "[...] to design their electrical and electronic equipment in such a way as to facilitate, in particular, the reuse, dismantling and recovery of waste equipment, its components, and materials […]". NABU (2016) points out that this is merely a design requirement. § 4 (2) ElektroG specifies that manufacturers should not adopt design features or manufacturing processes that prevent reuse. However, these are "weak" legal instruments (NABU, 2016). Thus, there is a need for a stronger binding force concerning product design and reparability, which the legislator must define. The provision of information relevant to the reuse and treatment of WEEE is already required by law under § 28 (1) ElektroG. However, stricter implementation of the law is required, so that reuse facilities receive information electronically or in the form of manuals. The responsibility of implementing this requirement lies with manufacturers (NABU, 2016; Neitsch et al., 2010). The aim is to facilitate market entry for reuse facilities and repair companies. Besides those two most commonly mentioned measures, the introduction of an incentive system and the prevention of illegal collection are frequently proposed. An incentive system for the implementation of the waste hierarchy can, for example, be subsidies from municipal administration. In this context, a legal target (e.g., a PfR quota) is necessary to differentiate PfR from recycling (Neitsch et al., 2010). Separate PfR targets combined with monetary or reputational incentives have a positive impact on all aspects of PfR. The legislator and authorities are primarily involved in the implementation of incentive systems. Illegal waste collection restricts access to goods for commercial actors, public utilities, and social-charitable institutions, acting in compliance

with the law. The goal is to either prevent illegal actors from collecting through stricter regulation or integrate them into regular waste collection systems (Neitsch et al., 2010). As a best practice example, the EU-funded project "Trans-Waste", completed in 2013, addresses both the risks of improper disposal and the opportunities of cross-border waste management. Further measures concerning the legal framework are the introduction of a deposit system to increase the return rate of used goods and the facilitation of certification procedures for PfR operators. A legally required deposit can be charged on the purchase of certain goods, which is refunded upon "return for the purpose of resource-friendly disposal" (J. G. González, 2013). An innovative extension of the deposit system can be achieved through the use of RFID chips. This allows product routes to be tracked and important information on repair or recycling to be stored directly in the chip and retrieved autonomously when the good arrives at a collection point (O'Connell et al. 2013). According to § 3 (24) ElektroG, initial treatment includes "the primary treatment of WEEE in which the WEEE is prepared for reuse or freed from pollutants and recyclable materials are separated from WEEE, including preparatory actions related to this; initial treatment also includes the recovery processes R 12 and R 13 according to Annex 2 to the Closed Substance Cycle Waste Management Act". According to this definition, preparatory operations such as sorting, dismantling and storage can only be conducted by primary treatment facilities (PTF). Thus, every collection point would need a PTF certification. However, in literature there are controversial interpretations of the certification obligation according to ElektroG; these are explained in detail by NABU (2016). On the one hand, strict legal requirements are necessary to enable all actors to operate in a legally secure manner. On the other hand, complicated certification processes should not prevent PfR. This recommendation for action aims to reduce the legal hurdles and increase legal certainty for the players involved and is intended to facilitate market entry into PfR. Implementation is the responsibility of the legislator. The last two recommendations are mentioned once in literature, and both aim to improve remarketing possibilities. The current tax system does not encourage the reuse of goods. After goods are depreciated, they no longer have value for accounting purposes, and repairs become unprofitable (J. G. González, 2013). To counteract this type of economic activity, goods from PfR can be promoted through a reduced VAT rate or the possibility of tax depreciation (NABU, 2016). Such subsidies initiated by the legislator increase the demand for secondary goods and thus have a positive effect on remarketing. Also, the consideration of used goods in public procurement increases remarketing opportunities (NABU, 2016). On the one hand, public authorities can give preference to used goods over new goods through their initiatives. On the other hand, they can be obliged by the legislator to cover a predefined proportion of their requirements through secondary goods (Neitsch et al., 2010).

ORGANIZATIONAL STRUCTURE

With 14 mentions each, the introduction of an umbrella brand and increase in cooperation are the most relevant measures within this category. A (supra)regional umbrella brand improves remarketing conditions and forms a basis for implementing further action recommendations. It enables a uniform appearance of reuse facilities, which creates a recognition value that customers associate with quality standards and which they trust. In addition, the umbrella brand provides a basis for advertising measures and thus increases awareness of reuse facilities (NABU, 2013; Neitsch et al., 2010; Spitzbart et al.,

2009). The implementation includes uniform processes (from collection to remarketing), transparent cachets, an appealing "corporate design," and a joint marketing strategy of participating reuse facilities (Sander et al., 2013). In addition to reuse facilities, associations can also be involved in establishing the umbrella brand. "Currently, only very few reuse companies are able to map the entire logistics and process chain in their own company; the majority is dependent on cooperation with other companies" (Spitzbart et al., 2009). Cooperation between municipal disposal services and repair and distribution networks leads to a financial alleviation of the actors, as individual companies can specialize. Besides, cooperation makes it possible to balance regional differences in demand, repair capacities and remarketing opportunities. In addition to the positive effects on profitability, cooperation strengthens the PfR segment compared to competing processes and products (Jepsen & Vollmer, 2015; Milios & Dalhammar, 2020; Neitsch et al., 2010). More detailed design options of cooperation models are discussed by NABU (2016). The measures subsequently described are recommended by between seven to four articles. The implementation of alternative sales structures and specifically an intra-municipal second-hand store target remarketing opportunities. By expanding sales structures, standard remarketing concepts, such as sales areas directly affiliated with repair stores, are supplemented with alternative models. The success of remarketing depends on accessibility and the level of awareness. Repair stores are usually located outside of pedestrian and shopping areas, depriving them of walk-in customers. Second-hand stores that specialize only in remarketing and do not require space for sorting or repair tend to be more centrally located and thus reach a larger group of customers (Spitzbart et al., 2009). To enable supraregional remarketing, sales via own or external internet platforms are a good option (Spitzbart et al., 2009). In particular, distribution via one's own internet presence becomes more lucrative through a joint presence of several reuse facilities or higher-level associations, as there is strong competition from some large sales platforms (e.g., eBay) (NABU, 2016). Another opportunity is an intra-municipally operated second-hand store. This can be considered as a preliminary stage or supplement to an umbrella brand in the sense of an operationally active network of reuse facilities (NABU, 2016). Supplied by the collection of several municipalities, it is characterized by a significantly more diverse range of secondary goods and enables balancing services and logistics. Besides, remarketing benefits from supraregional marketing and thus an increased level of awareness. Government subsidies and organizational support from public authorities and legislators offer the opportunity to bridge the often difficult start-up phase of PfR operators (Löhle et al., 2016; Neitsch et al., 2010; Spitzbart et al., 2009). Both one-time grants and ongoing grants in the areas of "research & development, operational and network development, education and training, quality assurance, support of the running operation of networks and reuse operators in the start-up phase, know-how development and -exchange, and public relations [...]" (Neitsch et al., 2010) are necessary to promote "repair networks, swap circles, flea markets, give-away exchanges [...]" (Neitsch et al., 2010) in addition to start-ups and repair cafés that are already establishing themselves (Sander et al., 2013). Subsidies for these activities can, on the one hand, facilitate market entry of new actors and, on the other hand, strengthen remarketing opportunities. The least frequently mentioned measures in this category are the use of a mobile testing unit and options for upcycling rather than just repairing. An autonomous mobile testing unit "comprises a variable number of up to four or, if necessary, more test stations for testing

the safety (DIN VDE 0701) and functionality of entire electrical appliances and replacement components" (Broehl-Kerner et al., 2012). The goal of the testing unit, which can be used intra-municipally, is to facilitate market entry for WEEE reuse facilities and thus increase the reuse rate. Especially in rural regions, the acquisition of infrastructure for the testing and repair of WEEE is not necessarily worthwhile due to lower collection volumes. Costs for a mobile testing facility that is deployed on specific days at the respective municipalities can be borne jointly and, also, a more flexible collection and on-site testing can be realized. Broehl-Kerner et al. (2012) describe the structure, possible applications, and other advantages of the mobile testing unit. Upcycling, e.g., by remanufacturing products, consists of more comprehensive measures than mere repair (Dekker et al. 2004). In some cases, this improves the product properties, resulting in increased performance, higher equipment safety, or an extension of the service life, leading to an increase in the value of the products (LAGA, 2009). Thus, remanufacturing of used goods significantly strengthens the possibilities of remarketing. Implementation can be carried out directly by reuse facilities.

PROCESS CHANGE

A large proportion of damage to goods arises due to handling at collection points. 54 % of WEEE are damaged by storage and another 6 % by pre-treatment (Messmann et al., 2019). Protecting WEEE from adverse weather conditions by covering collection areas can prevent up to 86 % of damage during storage. Improper storage and pre-treatment represent another critical source of damage. The latter results from compacting goods or cutting cables (Messmann et al., 2019). The results of Messmann et al. (2019) are based on a visual inspection, therefore it cannot be assured that the goods damaged by storage or pre-treatment have been fully functional before. Nevertheless, data shows that it is important to handle these products with care in order to maintain the existing functionality. To address these problems, suitable logistics must be developed to ensure a space-saving, flexible and damage-free process chain (Neitsch et al., 2010). The action recommendation of value-conserving logistics is mentioned most frequently throughout all categories. One starting point is to switch from bulk containers to equipment-specific, value-preserving container systems (such as mesh boxes) that can be combined and stacked in different sizes, as well as changes in filling and unloading techniques (Spitzbart et al., 2009). As already required by the ElektroG, value-conserving logistics is within the reuse facilities' remit and has a high potential to increase quality and thus access to reusable goods. A similarly import process step is the separate collection of reusable goods. The viability of PfR should best be checked directly at the point of handover (Sander et al., 2013) since later separation leads to a strongly reduced quality of the goods (Neitsch et al., 2010). Separation can be performed directly at the point of collection by two vehicles in case of collection systems or by qualified personnel by drop off at collection points in case of bringing systems. Appropriate weather-protected areas are to be provided at collection points for this purpose. The space requirement at collection points can be kept as small as possible through consultation with reuse facilities and regular collection of reusable goods (Sander et al., 2013). According to the ElektroG, WEEE must be collected so that subsequent reuse is not hindered; this includes transport in the course of the collection and further transport to downstream reuse facilities. However, current collection and transport methods do not meet value retention requirements (Broehl-Kerner et al., 2012).

By using appropriate collection containers, damage during transport can be avoided. In addition, compressing goods, reloading collection containers, and emptying containers by pouring should be refrained from (NABU, 2016). Especially for devices of information and communications technology, secure data deletion poses an important success factor for remarketing. Reuse facilities have so far been exempt from the obligation to delete personal data. Nevertheless, for reasons of both data protection and professionalism, it is recommended that reuse facilities implement procedures that take data protection into account (Löhle et al., 2016). The proven quality of PfR processes through certified data destruction helps to dissolve the negative public perception of the reuse sector and has a positive effect on remarketing (Kissling et al., 2013). The last recommendation within the category of process change is the optimization of the collection mode, which improves access to used goods. The accessibility of collection points represents a central factor for citizens (Sander et al., 2013). The collection system can be improved by integrating additional drop-off options, such as the introduction of collection systems with separate collection of reusable goods or a higher container density, as well as the optimization of existing systems, by extending or adjusting opening hours at collection points. The organization of these improvement measures is to be specified by the authorities, whereas the implementation is the responsibility of reuse facilities.

4 Discussion and conclusion

This paper identifies relevant actors, evaluates barriers to PfR by an analysis of the market attractiveness based on the reverse five forces, and derives action recommendations for PfR from literature. Action recommendations are grouped into four categories information, legal framework, organizational structure, and process change, according to the type of instrument. Additionally, the influence of each measure on the reverse market forces and relevant actors are mapped out. The relevance of each measure is evaluated based on the number of references from literature. For further prioritization, an evaluation of the personnel and financial effort required to implement each measure and the potential quantities of WEEE that could additionally be prepared for reuse after the implementation of each measure needs to be assessed. So far, only a limited amount of best practice examples exists.

The market analysis shows substantial barriers within the market entry for reuse operators, the access mainly to large WEEE in sufficient quality, and strong interdependencies with external actors as successful remarketing of WEEE may result in conflicts of interest with manufacturers. To overcome these barriers, a range of action recommendations are proposed in literature. The analysis of all 26 identified action recommendations reveals the main success factors for each actor. The legislator influences all other actors in the field of reuse operations and defines the scope of action. Public authorities commonly implement the legislation on a regional level. Concerning these actors, the most pressing success factors for PfR of WEEE are raising awareness among the population for potential reuse of products through public relations work and clarifying uncertainties concerning liability and warranty issues. The actors involved directly in PfR operations are commercial reuse businesses, OEMs, municipal disposal services, and social-charitable institutions as non-commercial actors. Public relations work should also be pursued from these actors. A particular focus is to be set on preventing damage to potentially reusable goods by implementing value-conserving logistics, the introduction of an umbrella brand and increased

cooperation between municipal disposal services and repair and distribution networks. Associations function as a mediator between all actors. They should mainly focus on public relations work and advertisement for reuse, the implementation of an umbrella brand, and qualification programs for employees.

In the context of the paper, the focus is solely on the second priority of the European waste hierarchy, preparation for reuse. To only consider this point, however, would fall short. In particular, transforming our economic system towards sustainability will not succeed without accompanying "prevention"-approaches. While measures of efficiency has long been focus of academic discourse, the decoupling of economic growth from resource use and measures of sufficiency gain greater attention (Sandberg, 2021) and should be part of a global discussion towards a sustainable future.

Boldoczki et al. (2020, 2021) further show that PfR is not always preferable to recycling from an environmental point of view. When it comes to the selection of products for reuse, also aspects influencing the environmental impacts of products such as the energy efficiency or the remaining expected lifetime of products should be taken into consideration.

Another limitation of this work is a missing assessment of action recommendations' feasibility concerning the associated costs and benefits. Further work could focus on this aspect. The currently available best practice examples do not provide information on the related costs of implementing single measures. It can be argued that the economic feasibility currently hinders reuse at an individual company level. For society as a whole, however reuse yields environmental as well as social benefits. Against this background, it appears to be the task of the political actor in particular to significantly increase the PfR-quota in the medium term.

Quantification of the additional realizable volumes of WEEE reuse is hardly feasible for the categories information and legal framework. A previous case study from the German state of Bavaria finds that through the measures "employment of value-preserving boxes instead of bulk cargo containers" (Transport), "early separation of reusable devices" (separate collection), "employment of weatherproof and value-preserving containers," and "prohibiting pre-treatment" (both value-conserving logistics) close to 30 % of WEEE arising at municipal collection points could additionally be prepared for reuse (Messmann et al., 2019). This shows a significant potential of the recommended measures to increase the share of PfR. As discussed before, the implementation of a binding PfR target for WEEE can be expected in the future for Germany and other European countries. To meet a future PfR quota, it is necessary to follow an effective strategy to increase the share of PfR. This structured overview serves as a guide for decision-makers as to which recommendations for action should be given priority and implemented.

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Role of the funding source

Provision of resources for research activities.

Declaration of competing interest

None.

Appendix

Appendix A: Overview on referenced articles

No	Author(s)	Year	Geographical scope	Type of article	Affiliation first author	# recommendations
[1]	Arold et al.	2008	Europe	Report	Research institute	5
[2]	Broehl-Kerner et al.	2012	Germany	Report	NGO	13
[3]	Fitzpatrick & Hickey	2016	Belgium, Ireland, UK	Report	University	9
[4]	González	2013	Germany	Report	University	6
[5]	Jepsen & Vollmer	2015	Germany	Report	Research institute	5
[6]	Kissling et al.	2013	Global	Journal article	Research institute	6
[7]	Kissling	2011	Belgium, UK	Report	Research institute	8
[8]	Lambert et al.	2014	Germany, Sweden	Report	Research institute	5
[9]	Löhle et al.	2016	Germany	Report	Other	20
[10]	Luger et al.	2010	Germany	Journal article	University	1
[11]	Meissner & Pladerer	n.d.	Austria	Report	Research institute	6
[12]	Milios & Dalhammar	2020	Sweden	Journal article	University	4
[13]	Miller et al.	2017	Europe, Focus on Ireland	Report	Research institute	6
[14]	NABU-Bundesverband	2013	Germany	Report	NGO	5
[15]	Neitsch et al.	2010	Austria	Report	n.a.	19
[16]	O'Connell & Fitzpatrick	2013	Global, Focus on Ireland	Report	University	11
[17]	O'Connell et al.	2010	Europe, Focus on Ireland	Conference Proceedings	University	4
[18]	Rreuse	2013	Europe	Report	n.a.	5
[19]	Sander et al.	2013	Germany	Report	Research institute	14
[20]	Sander et al.	2019	Germany	Report	Research institute	3
[21]	Schomerus et al.	2014	Germany	Report	University	9
[22]	Spitzbart et al.	2009	Austria	Report	n.a.	17

Appendix B: Interview guide

Market Force	Attributes	Description	Rating: 1	Rating: 5
Access	Current status of PfR	Share of goods currently being prepared for reuse	Current share of reuse <20 %	Current share of reuse >80 %
	Quality of goods	Quality of the goods arriving at collection points	Very poor quality	Very good quality
	Mobility of goods	Transportability of the goods	Good is big, heavy and hard to transport	Good is small, lightweight and easy to transport
	Infrastructure	Accessibility and number of collection points	Few collection points, poor accessibility	Many collection point, good accessibility
Market entry	Strategic investment costs	Investment requirements for PfR (costs for personnel, space, infrastructure)	High investments required (a lot of personnel, large areas)	Low investment required (few personnel, small area)
	Technical feasibility	Complexity, spare parts availability, etc. (theoretical possibility of repair)	High effort required to prepare good for remarketing	Good is not complex and can be easily prepared
	Expertise	Required expertise of the personnel to perform PfR	Employees need special training/expertise	No special knowledge is required
	Regulations and laws	Regulations in the area of PfR (e.g. certifications, warranty and guarantee)	Regulations hamper PfR operations	Laws and regulations favor PfR operations
Remarketing	Existence of sales platforms	Existing sales platforms (number, size, regional distribution, networking)	Design of sales platforms limited remarketing	Design of sales platforms is optimal
	Customers' willingness to pay	Customers' willingness to pay for secondary goods compared with primary products	Willingness to pay is significantly lower than for new products	Willingness to pay is very high (>80 % of new price)
	Demand	Demand for second-hand products	Very low demand (oversupply)	Very high demand (any secondary good can be sold)

Market Force	Attributes	Description	Rating: 1	Rating: 5
	Technological life cycles	Time span in which secondary products can be marketed (with regard to the state of the art)	Good has very short life cycle, is quickly obsolete	Good can still be marketed over a long period of time
Interdependencies	Conflicts of interest with OEMs	Conflicts of interest with manufacturers due to remarketing of secondary goods	There are strong conflicts of interest	There are no conflicts of interest
	Product design	Aligning product design for potential repair and reuse	Good is not repairable/rebuildable	Good is easily repairable and modular, for example.
	Awareness level	Awareness of consumer responsibility towards reuse	The level of awareness is very low	The level of awareness is very high
	Existence of cooperation	Existing cooperation between collection points and repair stores / sales platforms	No cooperation exist	Many cooperation exist
Competition	Reuse alternatives	Existing alternatives to PfR(e.g. recycling, energy recovery).	Many alternatives exist	No alternatives exist
	Competitive situation	Number, structure, concentration of competitors or rivals	There is strong competition	There is no competition

Appendix C: Documentation of interviewees and dates

Interviewee	Professional background	Date of interview
Lukas Messmann	Research Assistant, Resource Lab, University of Augsburg	16 May 2017
Sandra Köhler	Research Assistant, Resource Lab, University of Augsburg	16 May 2017
Isabella Wagner	Research Assistant, Resource Lab, University of Augsburg	16 May 2017
Petra Hutner	Research Assistant, Resource Lab, University of Augsburg	16 May 2017
Dietmar Lange	Head of municipal collection points and "Halle 2", Waste management Munich	14 June 2017
Werner Bauer	Managing partner with divisional management in knowledge management, ia GmbH – Municipal consulting and knowledge management	22 June 2017
Christian Daehn	Head of department, State office for environment, Dep. 31: Circular economy strategies and systems	26 June 2017
Jürgen Beckmann	State office for environment, Dep. 31: Circular economy strategies and systems	26 June 2017
Günther Langer	Office management, Waste management Munich	27 June 2017
Prof. Dr. Axel Tuma	Chair of Production & Supply Chain Management, University of Augsburg	27 June 2017

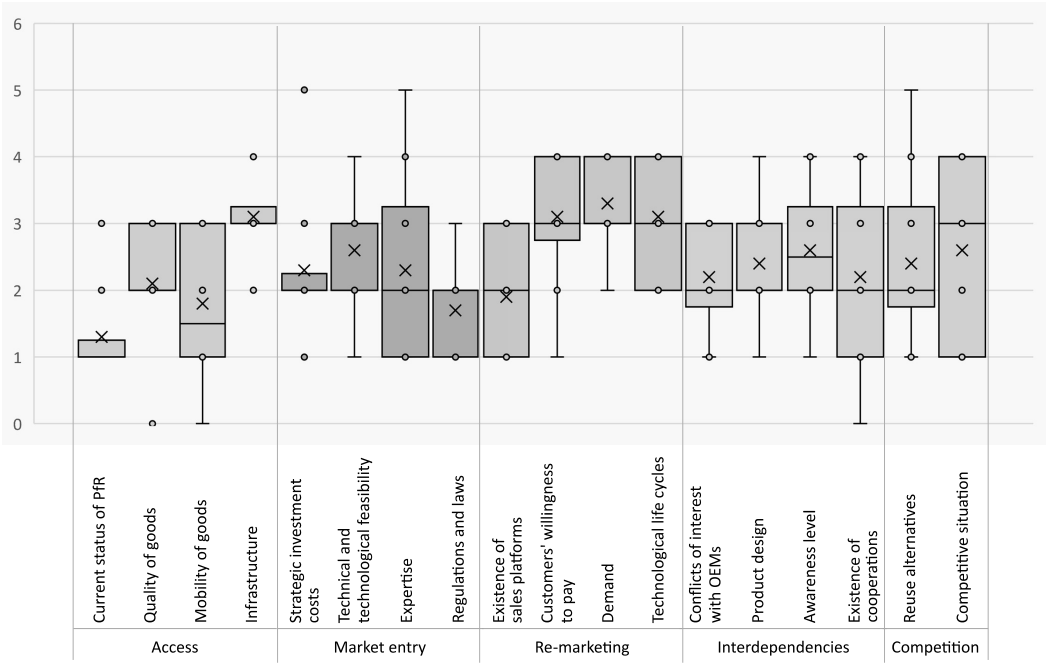
Appendix D: Results of market analysis for large WEEE

a) Data

	Current status of PfR	Quality of goods	Mobility of goods	Infrastructure	Strategic investment costs	Technical feasibility	Expertise	Regulations and laws	Existence of sales platforms	Customers' willingness to pay	Demand	Technological life cycles	Conflicts of interest with OEMs	Product design	Awareness level	Existence of cooperation	Reuse alternatives	Competitive situation
Expert 1	1	2	3	3	2	3	1	3	3	4	4	4	2	3	4	2	2	4
Expert 2	1	2	3	3	2	2	2	1	2	3	4	2	3	2	3	3	2	4
Expert 3	1	2	3	3	3	2	1	2	1	3	4	2	3	1	4	2	2	3
Expert 4	1	2	3	3	2	3	2	1	2	3	4	2	3	2	1	1	2	3
Expert 5	1	2	2	4	2	3	4	2	3	4	3	4	1	4	3	3	1	1
Expert 6	1	3	1	3	2	4	5	2	1	4	3	4	3	2	2	1	4	4
Expert 7	3	3	1	3	2	3	2	1	2	3	3	4	2	3	3	4	3	1
Expert 8	1	3	1	4	5	3	3	2	1	2	3	3	1	2	2	2	5	1
Expert 9	2	n.a.	n.a.	3	2	2	2	2	3	4	3	3	2	3	2	4	1	2
Expert 10	1	2	1	2	1	1	1	1	1	1	2	3	2	2	2	n.a.	2	3
Mean	1.3	2.3	2.0	3.1	2.3	2.6	2.3	1.7	1.9	3.1	3.3	3.1	2.2	2.4	2.6	2.4	2.4	2.6
Minimum	1	2	1	2	1	1	1	1	1	1	2	2	1	1	1	1	1	1
Maximum	3	3	3	4	5	4	5	3	3	4	4	4	3	4	4	4	5	4
max. Difference	2	1	2	2	4	3	4	2	2	3	2	2	2	3	3	3	4	3
Standard Deviation	0.6	0.5	0.9	0.5	1.0	0.8	1.3	0.6	0.8	0.9	0.6	0.8	0.7	0.8	0.9	1.1	1.2	1.2

b) Boxplot diagram

The results of the market analysis are plotted as boxplots with a first quartile (25th percentile), median (50th percentile), third quartile (75th percentile), and whiskers.



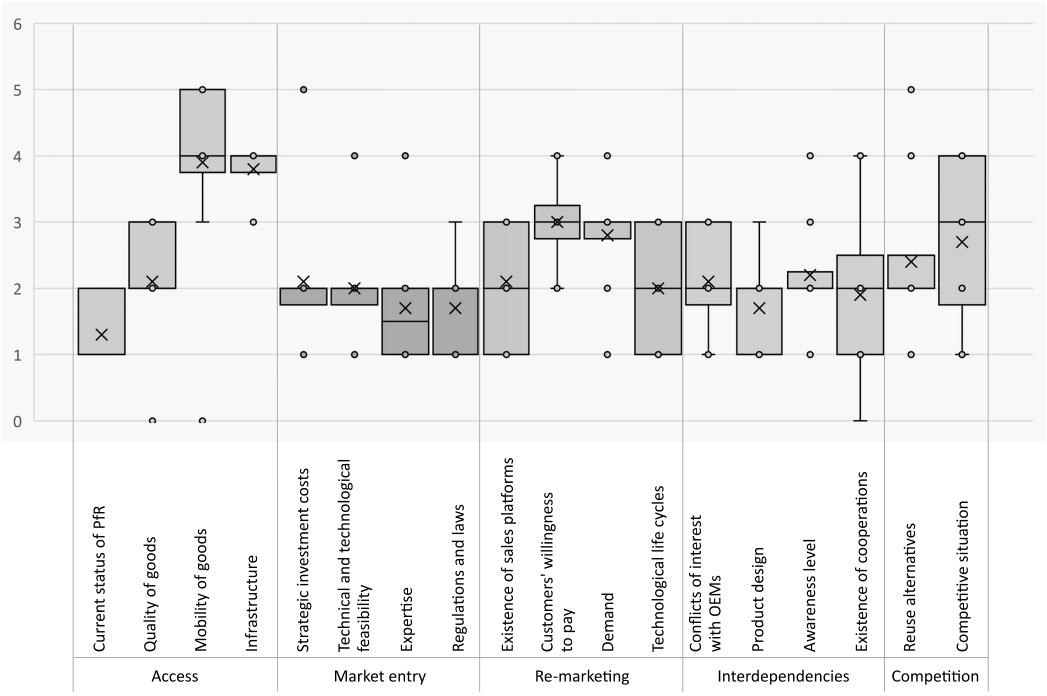
Appendix E: Results of market analysis for small WEEE

a) Data

	Current status of PfR	Quality of goods	Mobility of goods	Infrastructure	Strategic investment costs	Technical feasibility	Expertise	Regulations and laws	Existence of sales platforms	Customers' willingness to pay	Demand	Technological life cycles	Conflicts of interest with OEMs	Product design	Awareness level	Existence of cooperation	Reuse alternatives	Competitive situation
Expert 1	1	2	5	4	2	2	1	3	3	3	3	2	2	1	2	1	2	4
Expert 2	1	2	4	4	2	1	1	1	3	3	3	1	3	1	2	2	2	4
Expert 3	1	2	5	4	2	1	1	2	2	3	3	1	3	2	4	2	2	1
Expert 4	1	2	5	4	2	2	1	1	3	3	3	1	3	1	1	1	2	3
Expert 5	2	2	3	4	2	2	4	2	2	3	3	3	1	2	2	2	2	2
Expert 6	1	3	4	4	2	2	2	2	1	4	3	3	2	2	2	1	4	4
Expert 7	2	3	4	4	2	2	2	1	2	3	3	3	2	2	3	4	2	1
Expert 8	1	3	5	4	5	4	2	2	1	2	1	1	1	1	2	2	5	3
Expert 9	2	n.a.	n.a.	3	1	2	2	2	3	4	4	3	2	3	2	4	1	2
Expert 10	1	2	4	3	1	2	1	1	1	2	2	2	2	2	2	n.a.	2	3
Mean	1.3	2.3	4.3	3.8	2.1	2.0	1.7	1.7	2.1	3.0	2.8	2.0	2.1	1.7	2.2	2.1	2.4	2.7
Minimum	1	2	3	3	1	1	1	1	1	2	1	1	1	1	1	1	1	1
Maximum	2	3	5	4	5	4	4	3	3	4	4	3	3	3	4	4	5	4
max. Difference	1	1	2	1	4	3	3	2	2	2	3	2	2	2	3	3	4	3
Standard Deviation	0.5	0.5	0.7	0.4	1.0	0.8	0.9	0.6	0.8	0.6	0.7	0.9	0.7	0.6	0.7	1.1	1.1	1.1

b) Boxplot diagram

The results of the market analysis are plotted as boxplots with a first quartile (25th percentile), median (50th percentile), third quartile (75th percentile), and whiskers.



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Sandra Köhler, Dr. rer. pol., research assistant at Resource Lab, University of Augsburg

Address: University of Augsburg, Universitaetsstr. 16, 86159 Augsburg, Germany, Phone: +49 (0) 821 598–3951, Fax: + 49 (0) 821 598–4353,
E-Mail: sandra.koehler@wiwi.uni-augsburg.de, ORCID: 0000–0002–4337–4788