Circularity in the Danish WEEE Management System

A study on emphasizing reuse of electronic equipment in Denmark

Master Thesis

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Abstract:

Waste from Electrical and Electronic Equipment (WEEE) is one of the fastest growing waste streams. Proper waste management is required to reduce negative externalities from improper waste treatment. Recycling is currently the most common way of treating WEEE, even though reuse is more desirable in accordance to the principles of a more circular economy. In this thesis the prevalence of recycling over reuse is discussed and recommendations are proposed to increase preparation for reuse (PfR) and reuse in the Danish WEEE management system. This was done by carrying out a literature review and a series of interviews discussing the main constraints preventing reuse, possible improvements to the system, as well as providing examples of promoting reuse in other Member States. Based on these results, the main recommendations in this thesis are to promote a unified network of reuse centres in the Danish WEEE management system, increase harmonization of the WEEE Directive across Member States, implementation of modulated fees to promote ecodesign, the marking of electronic products to facilitate disassembly as well as demonstrating the product's effort in ecodesign, and to implement quotas on reuse targets.

Preface

This thesis has been conducted by Sybren D.F. Idzerda, a Dutch student studying the Masters program Environmental Management and Sustainability Science at Aalborg University.

In this thesis, Chicago-style is used for referencing and the bibliography will show the title, author, and the publisher of the source. Furthermore, interviews are listed in the bibliography as "Interviewer last name, initials (Year, Month, Day)".

I would like to thank my supervisor Anja Marie Bundgaard for the multiple feedback sessions and support in writing this thesis.

I would also like to thank the interviewees for all their valuable input: Éleonore Maitre-Ekern, Thomas Lindhqvist, Stig Hirsbak, Henrik Riisgaard (AVV), Johnny Bøwig (DPA), and Alberto Huerta Morales (Nilfisk).

Summary

The increasing amount of waste have become of growing concern. Poorly managed waste can harm the environment, but also negatively affect public health, economic development and political stability. One of the fastest growing waste streams is the Waste from Electrical and Electronic Equipment (WEEE). Each year 200 million tonnes of WEEE is generated from which 25% to 40% origins from the EU. WEEE contains finite resources, as well as hazardous substances that can pose health risk if not discarded correctly. Therefore proper waste management is essential.

The WEEE Directive was introduced to guide the management of WEEE and is applicable to each European Member State. Central of this directive is the extended producer responsibility (EPR), a concept that holds the producer of electronic products responsible for the end-of-life of their products. However, this responsibility is often delegated to a producer responsibility organization (PRO). The WEEE Directive had to be implemented into national law and obligated Member States to collect up to 85% of the disposed electronic products, from which most gets recycled. However, reuse of products and preparation for reuse (PfR) occurs to a much lesser extent, even though these options are preferred over recycling, as in line with the principles of a more circular economy.

In this master thesis, it is analysed how reuse and PfR of WEEE can be incentivized in the Danish WEEE management system. The main question of this thesis is therefore: *How can the WEEE management system be improved to incentivize preparation for reuse and reuse of WEEE in Denmark?*. In order to answer this question it was important to understand the current challenges that were preventing PfR and reuse in the management system. Furthermore, the effort of other Member States in regards to promoting reuse was investigated, and lastly it was looked at how the WEEE management system could become more in line with the principles of a more circular economy. A literature review and qualitative interviews were carried out with several experts in the field of circular economy and EPR, and actors in the Danish WEEE management system.

The constraints regarding the WEEE management system preventing PfR and reuse are multidimensional; there is a 'lock in' of technologies facilitating recycling, the public perception on reuse is low, there was little economic incentive to promote reuse, and the physical condition of the electronic products was generally disregarded.

The effort in regards to promoting reuse in other Member States would therefore be interesting to look at. The region of Flanders (Belgium) is home to a network of unified reuse centres called 'De Kringwinkel', that is incorporated in the Flemish waste policy, formed collaborations with important actors in the WEEE management system, and created a quality brand that increased the public's perception on reused products. France introduced the repairability index that shows consumers the repairability of their produced products, and Ireland announced the ReMark quality brand in order to communicate to consumers that reusable products are of high quality.

The several experts and actors in the WEEE management system also provided information on how the WEEE management system can be improved to facilitate the core elements of a more circular

economy. The intervention of the government was mentioned by most of the interviewees, where stricter rules on a reuse quota should be implemented, and that national agreements should facilitate interaction between actors and third party reuse centres. Other points included the harmonization of the WEEE Directive between Member States to facilitate international producers, the implementation of modulated fees and the marking of electronics to facilitate easier disassembly, but also to demonstrate to consumers that the product considers hte design for the environment

Based on the aforementioned challenges and possible improvements, the main question could be answered. The central recommendation of this thesis is to promote the creation of a unified network of reuse centres, such as De Kringwinkel, in the Danish WEEE management system. Certain prerequisites need to be met to support this: 1.) Manufacturers of electronic products need to permit repairment of their products. This can be achieved by providing a full tracing of the repaired product, further assisting the manufacturer in understanding the repairability of their product. 2.) Government intervention in form of financial support. Third party reuse centres would create buisness and economic value, but also social equity by offering possibilities for the less fortunate on the labour market, and 3) Collaboration between the third party and PRO's, as the PRO's currently have the right on the disposed products. This can be done either by a regulation or by providing a fee for each sold repaired product.

Table of Contents

List of Figures

Problem Analysis

This chapter will introduce the problem at hand in regards to waste and and elaborate on relevant strategies introduced to combat the expected increase in global waste. Furthermore, this chapter will highlight a more specific waste type, namely waste from electrical and electronic equipment (WEEE), and elaborate on the environmental relevancy of this waste stream, as well as the implementation of the WEEE directive to manage the WEEE. Subsequently, the problem in regards to managing WEEE and becoming more circular will be introduced. This chapter will therefore form the basis of the problem formulation.

1.1 Introduction to waste and circular economy

1.1.1 Waste

The increasing amount of end-of-life products has become an important societal issue Liu *et al.* (2022). Poorly managed waste can have detrimental consequences to the environment, such as the contamination of oceans, soils and plants, by serious heavy metal pollution, harming the ecosystem when animals unknowingly consume waste, and emission of greenhouse gases such as CO, CO2, SO, NO, and PM10 into the atmosphere due to open burning (Ferronato and Torretta 2019). These environmental issues can subsequently result in negative externalities in other dimensions, such as public health, economic development and political instability (World Bank Group 2018).

The world generates currently 2.01 billion tonnes of municipal waste annually, from which 33% is not managed correctly from an environmental standpoint. Developed countries, even though they only account for 16% of the worldwide population, share more than a third of the total waste emissions (World Bank Group 2018). Furthermore, global waste is expected to grow in the future in line with the population growth. This is trend is strengthened by the high urbanisation rate where waste problems are more acute, especially in cities from developing countries (Hoornweg *et al.* 2013). Prognosis for 2050 shows an expected waste generation of 3.40 billion tonnes annually, with an increase of 19% in developed countries and 40% in developing countries (World Bank Group 2018).

1.1.2 Circular Economy

The expected increase of waste calls for action to reduce the negative impact of waste on the environment, but more importantly to reduce waste altogether. The past few years have seen a shift in promoting a more circular economy (CE) over the traditional linear economy (Andersen *et al.* 2020).
The Ellen MacArthur foundation is one of the biggest organizations promoting the transition to a more circular economy. According to MacArthur (2015) p.5 a circular economy can be characterized as an "economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles".

The circular economy depends on three principles (MacArthur 2015) p.5-7:

1. Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows
2. Optimise resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles.
3. Foster system effectiveness by revealing and designing out negative externalities

The CE concept aims at extending the useful life of materials by organizing reuse, repair, refurbish and recycling (Tisserant *et al.* 2017). Central of the CE is that the lifetime of products should be prolonged as much as possible before the materials are recovered from waste (Maitre-Ekern 2021).
The following image shows an overview of such a regenerative system:

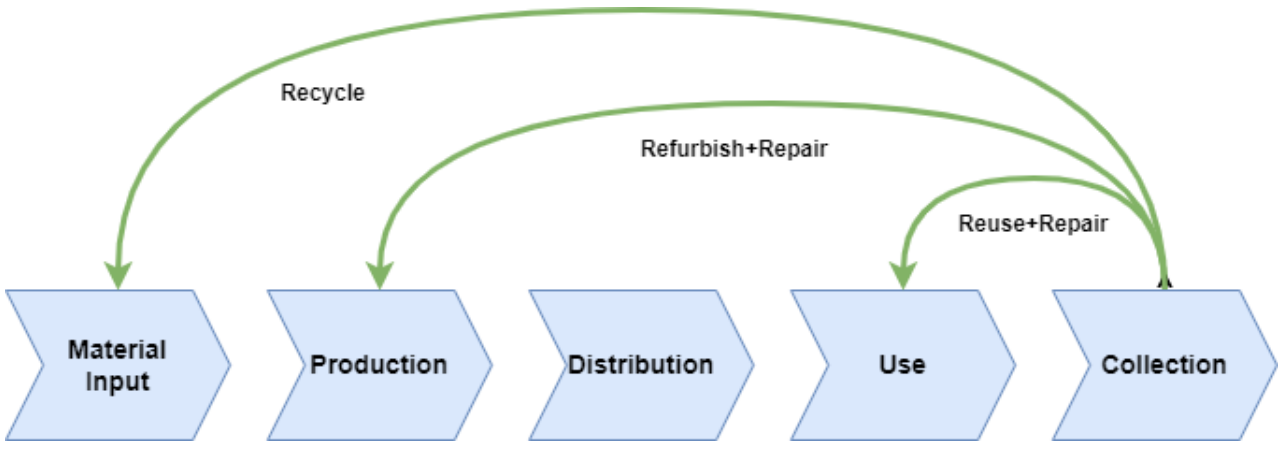

Figure 1.1: Inclusion of reuse, repair, refurbish and recycling in the system

In order to achieve a more circular economy, the European Commission has put the concept of CE on the European political agenda by publicising the Circular Economy Action plan in 2015. This included 54 actions, as well as various legislative proposals on waste that focus on targets for the amount

of landfill, recycling and re-use that needs to be met in in the year 2030-2035 (MacArthur 2015). In March 2020 an updated Circular Economy Action plan was published that builds on the previous plan by ensuring that regulatory frameworks are streamlined for a sustainable future and that new opportunities from the transition are maximized. The framework is progressively rolled out, with further measures being implemented to reduce waste (European Commission 2020a).

1.2 European Waste directives

1.2.1 Waste Framework Directive

Several European directives and waste laws have been put in place to develop a sustainable and resource-efficient economy (Maitre-Ekern 2021). For instance, the Waste Framework Directive offers basic waste management principals and introduced the waste hierarchy that ranks various waste management options according to its potential to assist the promotion of a CE. The waste hierarchy can be seen in Figure 1.2

Figure 1.2: Waste Hierarchy (European Commission 2022c)

Throughout the years, this directive have been ambitious towards a more circular economy (Andersen *et al.* 2020). For instance, Directive 2008/98/EC has set out targets for municipal waste, predominantly household plastics, and implemented preparation for reuse (PfR) targets. By 2020, the preparing for reuse and the recycling of waste materials from households, shall be increased to a minimum of 70% by weight (Maitre-Ekern 2021).

1.2.2 WEEE Directive

A directive has also been introduced in order to guide the management of another fast growing waste stream, namely the Waste from Electrical and Electronic Equipment (WEEE) (Andersen *et al.* 2020). It is estimated that 200 million tonnes of WEEE is being generated annually from which 25 to 40% is coming from the EU (O'Connell *et al.* 2011). This number is expected to increase, as the last 10 years show a rise of 50% in the amount of WEEE produced (Parajuly and Wenzel 2017b). Due to the presence of hazardous materials and finite resources present in electronic equipment, a need arose to reduce the environmental impact of WEEE, as well as ensuring the production of electronic equipment in the future (Parajuly and Wenzel 2017b). Grant *et al.* (2013) investigated the health risk of exposure to WEEE and discovered that exposure can reduce lung function of children, which is correlated with blood chromium levels in places where informal recycling of WEEE takes place. However, the recovery of precious and hazardous materials is costly and requires a system to properly manage WEEE (Andersen *et al.* 2020). In order to manage the increasing WEEE, the European Union introduced the WEEE Directive.

The first WEEE Directive was introduced in 2002 and European e-manufacturers were required to follow the WEEE Directive, where each country needs to implement the directive in the national law by 2004 (European Commission 2014). Several Member States were not able to implement the directive into national law. A second directive was introduced in 2012, repealing the previous directive, where Member States were required to implement the directive in 2014 (European Commission 2014). One of the main difference between the directives was that the 2002 directive had a closed scope where the directive only covered specific product categories, whereas the new WEEE Directive has an open scope, including all electronic equipment (EE) (Andersen 2021). The period between 2012 and 2018 is a transitional period (European Commission 2014), where the scope of products are the same as in the old directive (10 categories of EE). In 2018 this was widened to all EE categories and divided into 6 categories. This means that from 2018 all EE needs to be placed in one of the 6 categories (European Commission 2014). The following figures illustrate the implementation of the 2012 WEEE Directive and transitional period 1.3 as well as the different WEEE categories 1.4

Figure 1.3: Timeline of WEEE Directive, alterations made from (European Commission 2014)

WEEE categories before 15 August 2018	WEEE categories after 15 August 2018
1 Large household appliances	1 Temperature exchange equipment
2 Small household appliances	2 Screens, monitors, equipment with surface screens > 100 cm^2
3 IT and telecommunications equipment	3 Lamps
4 Electronic and consumer equipment	4 Large equipment (any external dimension more than 50 cm)
5 Lighting equipment	5 Small equipment (no external dimension more than 50 cm)
6 Electrical and electronic tools	6 Small IT and telecommunications equipment (no external dimension more than 50 cm)
7 Toys, leisure, and sports equipment	
8 Medical devices	
9 Monitoring and control instruments	
10 Automatic dispensers	

Figure 1.4: Categories current and old WEEE Directive (Andersen 2021)

The transitional period also lead to an increase in the required collection rates of EE. Initial recovery targets before 2015 ranged from 70-80% and are now increased to 75-85% and recycling/reuse targets are increased from 50-75% to 55-80% (Andersen 2021). Furthermore, the aim is to incentivize take-backs, recycling and energy recovery of electronic waste. The WEEE Directive therefore also values the PfR of electronic products. However, even though the reuse concept was introduced to the directive, there were no specific targets that Member States need to follow. Each member state is therefore free to implement their own reuse targets (Andersen 2021). For instance, Spain is the only member state to have implemented obligatory separate PfR targets (McMahon *et al.* 2019). Nevertheless, according to Zacho *et al.* (2018) The United Kingdom and Belgium are the Member States with the highest rate of reuse, with 0.6 kg per capita and 0.5 kg per capita respectively. This is due to the fact the United Kingdom puts emphasis to include reuse in their collection targets. There is therefore a certain degree of freedom for each member state to implement the WEEE Directive, as long a the collection and recycling rates are achieved. This includes the funding to reach this goal as well as different ways to collect EE (McMahon *et al.* 2019).

1.2.3 Extended producer responsibility

One of the main components of the WEEE Directive is the extended producer responsibility (EPR), that forces the manufacturers of EE to be responsible for the complete life-cycle of their products and the polluter pays principle (PPP), where the producer is required to pay the cost of electronic waste in a sustainable way (Andersen 2021). This therefore forces the producer to take environmental concerns into account (Maitre-Ekern 2021). The introduction of the EPR principle also resulted in a new type of organization, namely the producer responsibility organization (PRO). The manufacturers can delegate the responsibility of end-of-life (EOL) treatment of their product to the PRO (Andersen *et al.* 2020).

The concept of EPR has been present since the early 1990's, where the Swedish academic Thomas Lindhqvist introduced the model for the EPR as a policy principle to protect the environment by making the manufacturers responsible for the entire life-cycle of the product (Lindhqvist 2000). Here Lindhqvist recognized four types of producer responsibility, namely economic, informative, liability, and

physical responsibility. These refer to the costs involved for properly disposal of waste, involvement of the actual management of the waste products, providing information to the consumer on how their products are treated in the EOL phase, and lastly being responsible for any negative externalities associated to the disposal of the product (Maitre-Ekern 2021). EPR schemes have shown to be quite effective policy approach to shift waste management costs from tax payers to the producers of the waste generating products. Moreover, the EPR has lead to an increase of recycling rates and reduced final disposal of covered materials, however the EPR has not shown to facilitate ecodesign and reuse to the same extent (Laubinger *et al.* 2021)

1.3 Instruments coacting with the WEEE Directive

1.3.1 Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS)

The WEEE Directive is linked with the Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive, which restricts the usage of certain hazardous substances used in the production of EE to protect human health and the environment (Sarjaš 2018). This directive requires that all heavy metals in EE, such as mercury, lead, cadmium, hexavelent chromium and flame retardants should be substituted by less hazardous materials (Sarjaš 2018). If electrical products do not comply with the RoHS Directive, the products are not allowed to enter the market. National authorities cooperate by identifying products not fulfilling the requirements and remove them from the market (Remmen 2012). The RoHs Directive can therefore facilitate the WEEE Directive by making disassembly of products safer and increase the potential of reuse by making older products generally safer to handle.

1.3.2 Ecodesign Directive

Other directives for EE that support the transition to a more circular economy is the Ecodesign Directive. Originally, the Ecodesign Directive was introduced to provide a framework for ecodesign requirements for energy using- and related products (Huulgaard *et al.* 2013). Manufacturers are required to put products on the market that are not only in agreement with energy requirements, but also on other environmental aspects, such as water usage, emissions levels, and minimum durability of certain components (Polverini and Miretti 2019). Furthermore, the Ecodesign Directive has the capacity to increase the potential of reuse by implementing circular aspects, such as improving the durability, or design to facilitate easier disassembly of products (Zacho *et al.* 2018). The Ecodesign Directive can promote the reuse of WEEE, by designing products to be more easily repaired from the beginning, such as using glue instead of screws to facilitate disassembly (Maitre-Ekern and Dalhammar 2016). There are currently few requirements that focus on extending the lifetime of a product and the Ecodesign Directive does not cover all electronic products, such as smartphones (Maitre-Ekern, 2022).

1.3.3 EU Ecolabel

The European Commission also implemented the EU Ecolabel and energy label. The EU ecolabel is the official European environmental label and adopted by all Member States including Norway and Iceland (European Commission 2022a). Its aim is to promote the production of sustainable products on the market and to encourage consumers to purchase these products (Cordella *et al.* 2020). It does so by setting minimum requirements for non-food products, before they enter the market and are revised every few years to cover technical innovations (European Commission 2022a). For electronic equipment the ecolabel covers electronic displays for televisions, computers, and monitors throughout its life time (European Commission 2022a), and sets criteria on: Energy consumption, restricted substances, repairability, EoL management, corporate social responsibility, and information criteria (European Commission 2020b). However, the ecolabel does therefore not cover all categories of electronic equipment present in the WEEE Directive, resulting in the fact that not all WEEE categories are able to receive the eco label. The ecolabel is recognized by a green flower, which ensures people that the product fulfills the ecolabel criteria without having to inspect the details regarding the product (Europees Ecolabel 2022).

1.3.4 Energy labelling

The Energy labelling was implemented back in 1994 for a set of household appliances to score these appliances on their energy consumption, where a score of A depicts the most efficient products to G (least efficient) (European Commission 2022b). This allows the consumer to compare products on their energy consumption. Due to the increased energy efficiency throughout the years, more appliances received A+ A++, and A+++ ratings. For instance, in 2006 only two thirds of white goods has received a score of A, whereas in 2017 90% of the white goods had a score of A+ or higher. In the beginning of 2021, the European Commissions therefore reintroduced the scale of A to G to incentive the development of even more energy efficient products (European Commission 2022b). Also, here the energy labeling covers a wide range of electronic equipment, similar to the ecolabel. However, common electronic products such as laptops and smartphones are not included. The energy label works closely with the Ecodesign Directive, but while the Ecodesign Directive focuses on improving the energy efficiency and environmental performance of the product, the energy labeling functions as providing the information on this performance (ECEEE 2022)

The following figure shows a timeline from 1990-2022 on the various instruments implemented in Europe to promote sustainability and environmental performance of products. Only the instruments discussed in this thesis are shown. This timeline also illustrates the increased focus on electronic products in the last 10 years.

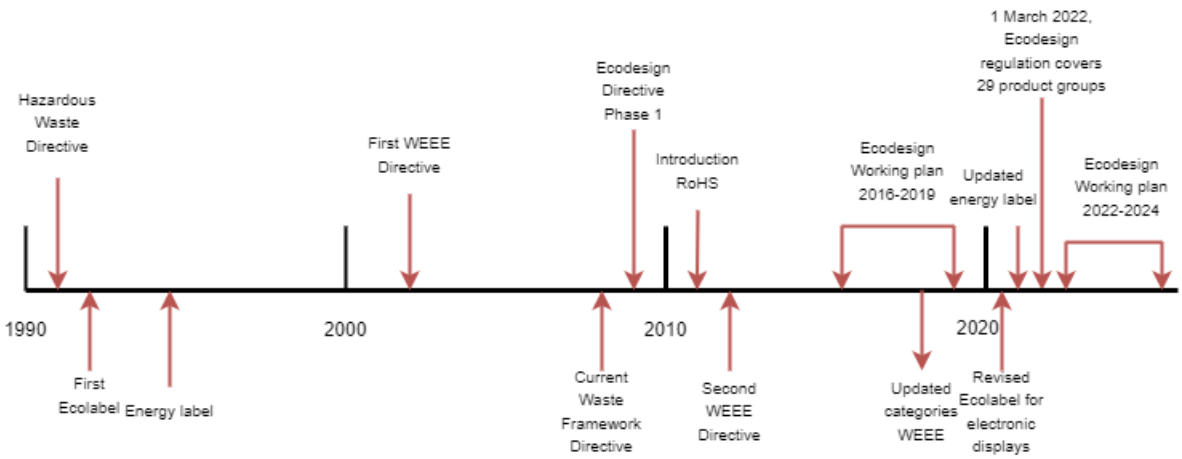

Figure 1.5: Timeline of European instruments involving electronic equipment

1.4 Extending product lifetime of EE by PfR and reuse

1.4.1 Preparation for reuse and reuse

From the Waste Hierarchy shown in figure 1.2 both PfR and reuse belong on the same hierarchical level. These two 'operations' occur in different parts of a product's lifetime, even though they are often blurred in literature and practice (McMahon *et al.* 2019). But as both terms are used in this thesis it is necessary to distinguish between the two terms.

Preparation for reuse Preparing for reuse is defined as "checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing" (Johnson *et al.* 2020)p.3. PfR occurs after the product has entered its waste stream.

Reuse Reuse occurs before the products has entered its respective waste stream, where reuse can be defined as any operation by which products are used again for the same intention as they were made (McMahon *et al.* 2019).

1.4.2 Environmental potential of reuse of EE

Results of a recent LCA (Boldoczki *et al.* 2020) investigating the environmental potential of reuse of electronic equipment has shown that the potential of reuse depends on various stages of the product's life cycle. The saving potential for electronic products in terms of resource scarcity confirms the positive effect of reuse. This is therefore also in line with the principals of a circular economy in maximizing resource efficiency. The potential of reuse on for instance Global Warming Potential (GWP) and energy efficiency depends on the type of product, as the use phase dominates the impact. For older white goods, reuse is therefore not always suitable, where the energy efficiency is characteristically low. However, for smaller electronic equipment, the GWP lies predominantly in the manufacturing stage of the product and less in the use-phase (Boldoczki *et al.* 2020). Furthermore, the energy efficiency of

electronic equipment has increased significantly over the past few years (Urban *et al.* 2017), therefore highlighting the potential of reuse in the WEEE management system. Another aspect emphasizing the potential of reuse of electronic product is the reduced life time of products. Smartphones are one of the most common electronic equipment used currently, and it is estimated that the average smartphone in the consumer segment is replaced after 2,75 years based on data from 2021 (Nasiri and Shokouhyar 2021), where it was an average of 2,96 years for 2019. Furthermore the current trend shows an estimated lifespan of 2,49 years in 2025 (Statista 2022). The share of the environmental impact will increase for the manufacturing phase and, especially when consumers buy smartphones more frequently. Smartphones are good examples for the importance of a well functioning WEEE management system due to the high amount of rare materials present in smartphones, the prevalence of smartphones, and its high potential for reuse. (Nasiri and Shokouhyar 2021).

The trend in the estimated lifespan of smartphones over the past few years is shown in the following graph, where data is gathered from (Statista 2022) and graph is constructed in Microsoft Excel.

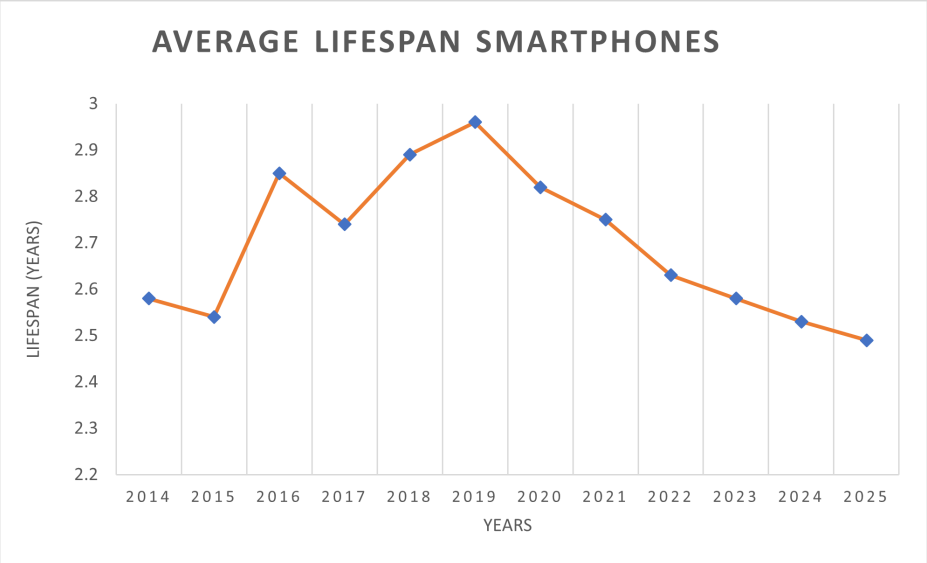

Figure 1.6: Average projected lifespan of smartphones (US), data from (Statista 2022)

1.4.3 Limitations of the WEEE Directive and EPR

Despite the implementation of the WEEE Directive and the accompanying concept of EPR, the waste management of EE has shown various limitations throughout the years. In reality, producer responsibility rarely happens on an individual level, where take-back and collection occur via certain collection schemes by PRO's, which will be elaborated upon later in this thesis (Maitre-Ekern 2021). Based on Danish data collection from 2015, it showed that only 0.2% of the collected WEEE was re-used. The recycling rate in contrary was particularly high with 83,9% (Zacho *et al.* 2018). This clearly indicates that the current WEEE Directive and the accompanying EPR are not effective in the prevention of waste.

That the WEEE Directive does not serve its purpose for ecodesign is not only a recent observation. A report from the Danish Ministry of the Environment from 2012 already elaborated on the fact that the WEEE Directive does not fulfill its objective in facilitating ecodesign (Remmen 2012). Especially as other directives such as the Ecodesign Directive and energy label continue to facilitate a more circular economy, it is important that the WEEE Directive follows suit, by promoting preparation for reuse, but also preventing products to enter the waste stream altogether. Parajuly and Wenzel (2017a) also showed that there is a large potential for revenue generation of household WEEE, but that a lack of an official system in place to exploit the reuse and material recovery of discarded EE is missing.

1.4.4 Danish WEEE management system

As this thesis will revolve around the Danish WEEE management system, it is necessary to first discuss the implementation of the Danish WEEE system. The following figure is made to assist in explaining the various actors.

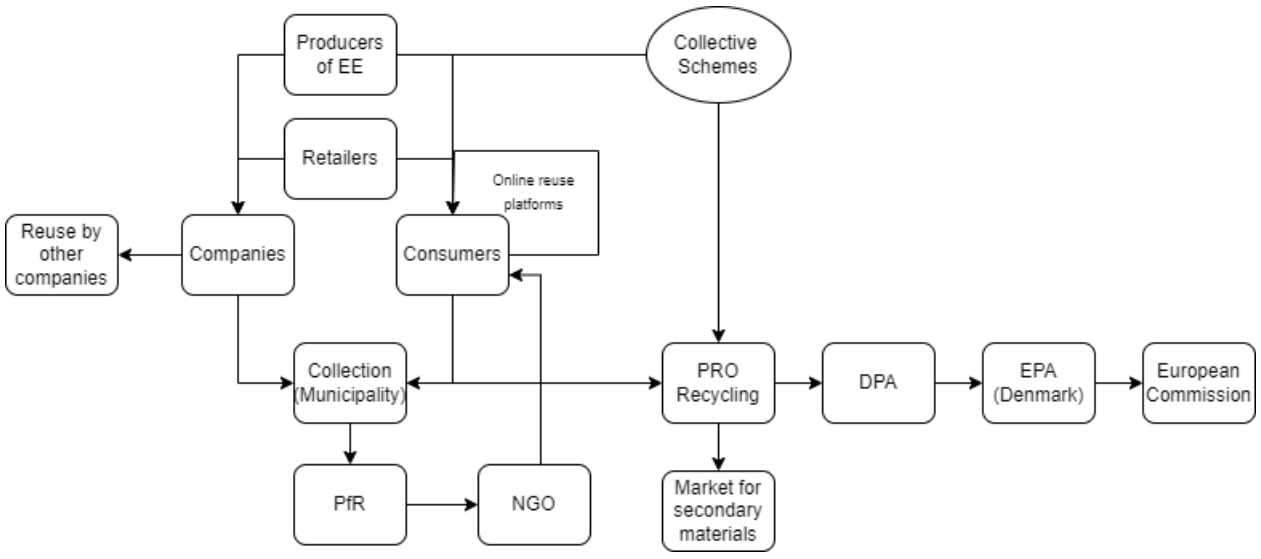

Figure 1.7: WEEE management system in Denmark showing the actors and flows. Inspiration was made from Zacho *et al.* (2018) and few alterations were made

Both companies and customers can dispose their WEEE products in collection centres managed by the municipality (Bøwig, 2022). After it is collected, the PRO's will be able to transport the discarded products to the recycling centres. There are currently five Danish approved PROs, namely Elretur, ERP Danmark, Rene, Recipio, and LWF (Andersen *et al.* 2020) The producers collect environmental fees which are incorporated in the product's price and pay this fee to the PRO's for the disposal of their products, therefore complying with the EPR (Andersen *et al.* 2020). The DPA is in charge of the Danish central producer register for WEEE and is responsible for assigning the municipal collection sites to producers, which is done based on the reported volume of products put on the market by the producers (Bøwig, 2022). The DPA reports to the Danish Environmental Protection Agency (EPA), who ultimately follows the WEEE Directive implemented by the European Commission (Ministry of

Environment of Denmark 2022).

As previously stated, PfR currently occurs in Denmark, where individual socio-economic enterprises can sell second hand product back to the consumer. However, the numbers on reuse are rather low in comparison to the recycling rate. Reuse also occurs when consumers sell their used products on online platforms, such as Ebay or Facebook Marketplace, from which it is hard to estimate the total amount (Bøwig, 2022).

The following chapter will elaborate on the main problem formulation of this thesis, followed by a section on the main methodology highlighting the methods used to find an answer for the aforementioned challenges.

Problem formulation

2.1 Research question and sub-questions

The previous section gave a general overview of the problem at hand. Currently, the WEEE Directive and the EPR do not contribute to a more circular economy, as the majority of electronic products get recycled. Furthermore, the change to a CE is hindered by the view on waste in general. Many might perceive proper waste management as a pivotal point in the CE, whereas the term 'waste' does not go along with the core principles of a CE. Recovery and recycling are not necessarily the end and all scenarios for products, as recovery processes require energy and resources (Maitre-Ekern 2021). It is therefore necessary to avoid waste altogether and promote PfR and reuse. As previously mentioned, the WEEE Directive does promote takeback and PfR, but reality has shown that the EPR responsible for PfR does not incentivize this goal.

This thesis therefore wants to identify the challenges in the WEEE management system preventing PfR and reuse. Moreover, this thesis sets out to pose improvements to the current WEEE management system model and investigate how PfR and reuse of electronic equipment can be incentivized in Denmark.

The problem formulation is as followed:

> *How can the WEEE management system be improved to incentivize preparation for reuse and reuse of WEEE in Denmark?*

A set of sub-questions are posed to create a natural structure through the report with its purpose to assist in answering the problem formulation.

Question 1: What challenges are present in the current implementation of the WEEE management system in Denmark preventing reuse and PfR?

Question 2: What practices and incentives are introduced in other Member States to facilitate reuse and PfR of electronic equipment?

Question 3: How can the current implementation of the WEEE management system be improved to be in line with the core elements of a more circular economy?

This thesis will contribute to previous works on the EPR and WEEE Directive and therefore support the transition to a more circular economy. Furthermore, this thesis will elaborate on possible solutions

for a better implementation of the WEEE management system by using examples within the WEEE management system and expert opinions. This will be further discussed in the next chapter, which will elaborate on the methods used to answer the problem formulation.

2.2 Delimitation

The delimitation of this thesis will define the boundaries of the research problem previously discussed. Firstly, the WEEE management system includes WEEE from households, where electronic products are sold to the consumer directly via the producer or a retailer (business to consumer), and WEEE from businesses, where products are sold from producer to businesses (Business to Business)(Coughlan and Fitzpatrick 2020). In this thesis the focus will be on business to consumer electronic products, as they include a high amount of electronic products such as smartphones and laptops. Business to business electronic products are more often larger in size, such as industrial machines and ICT equipment (Servers), and are not collected in a similar fashion i.e municipal collection sites. These larger products are often sold to other companies, and might be located in other countries (Bøwig, 2022).

This thesis has the management of WEEE in Denmark as baseline, due to the location in which this thesis is constructed and by data obtained from various actors based in Denmark. However, as many Member States have similar WEEE management systems with producers delegating the responsibility of the EoL products to the PRO and municipal collection sites to collect discarded electronic products, the focus of this thesis is not solely limited to Denmark and results could also apply to other Member States.

Methodology and Research Design

In this chapter the main methods used to answer the problem formulation will be discussed. This thesis will make use of both a literature review and qualitative interviews. Furthermore the research design will be shown and elaborated upon.

3.0.1 Literature review

A literature review will be used as the first data collection method in this study in order to look at the challenges in the WEEE management system and the implementation of WEEE management system in other countries. A literature review plays an important role in scholarship and it brings structure, as well as forming a basis for new theory making by capturing important aspects throughout a specific research area (Islam and Huda 2018). The literature review provides the basis for a research (Seuring *et al.* 2005).

In this case an examination is done of existing literature in order to investigate what improvements can be made to the WEEE management system. A particular focus will be on the challenges that are current present in order to identify possible improvements to the EPR and the WEEE management system. The literature review therefore aims to answer the first sub-question: 'What challenges are present in the current implementation of the WEEE Directive preventing the preparation for reuse in Denmark?'.

There will also be a document analysis on the the implementation of the WEEE Directive and PfR practices in other countries, such as *De Kringwinkel* located in Flanders, Belgium. De Kringwinkel is a non-profit organisation that consists of autonomous social economy firms and promote the reuse of old materials (Cools and Oosterlynck 2015). By using existing literature, De Kringwinkel's effectiveness on the PfR and reuse of electronic products will be investigated.

The literature review is carried out according to the Preferred Reporting Items for Systematic Reviews and meta-Analyses (PRISMA) guidelines (Moher *et al.* 2009) that follows a four step process to ensure transparency throughout the review process.

1. Identification: Records identified by database searching

2. Screening: Removing duplicated and screen articles by reading title and abstract

3. Eligibility and Inclusion: Articles that are read fully and assessed for eligibility

4. Included: Articles included in the qualitative synthesis

3.0.2 Identification

Material collection will be done by using the main website on Scopus, the citation database for Elsevier. Certain keywords were used to identify relevant publications. The key word 'WEEE' was used as a basis and resulted in 3,526 documents. Throughout the past few years the number of publications related to WEEE have been rapidly increasing. This shows that the WEEE Directive and the WEEE management system is an interesting topic to be looked at. An analysis of the results can be seen in figure 3.1.

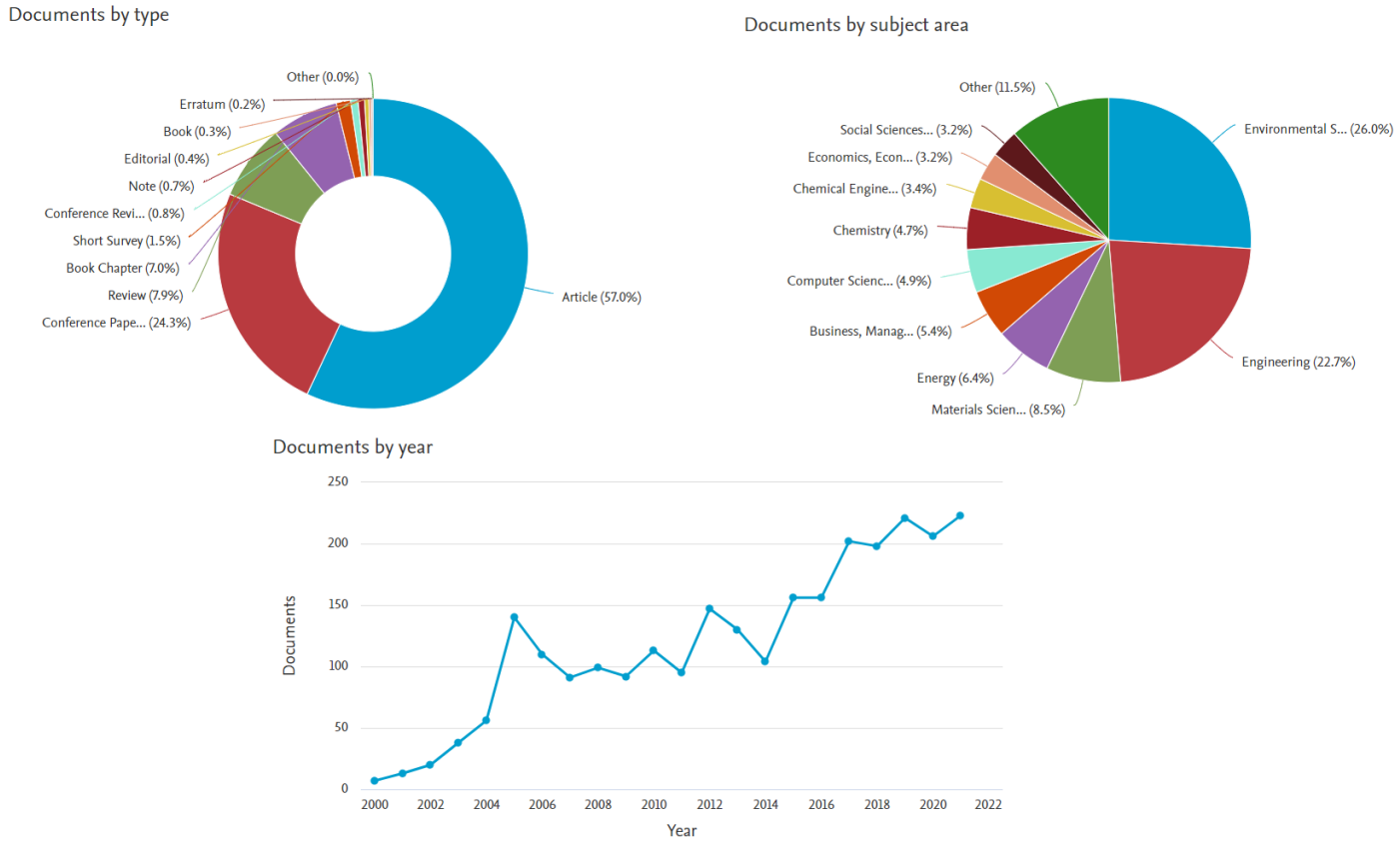

Figure 3.1: Document type, subject area and amount per year for search term WEEE in Scopus, data derived from www.scopus.com

3.0.3 Screening

A second keyword 'reuse' has been added to fit the purpose of this thesis to identify the challenges in the WEEE management system preventing reuse and PfR, leading to 581 documents. Furthermore, as this thesis has a focus on the current WEEE Directive of 2012, where after 2015 the WEEE Directive included a combined target of PfR and recycling, relevant publications are chosen for the years 2015-2022. Furthermore, as the WEEE Directive is posed on European Member States, only publications for Europe are included. This narrowed down the available documents to 78 documents.

3.0.4 Eligibility and Inclusion

From these the titles and abstract have been read. Some published articles are not related to environmental science, but more focused on engineering or energy aspect of electronic equipment. Therefore, some criteria were made based on the abstract where 1. the study is related to environmental science, and 2. the implications of the WEEE Directive on reuse is discussed. A final set of 20 articles are considered for the analysis. These articles discuss the challenges that are common in the WEEE management system across European Member States as well as providing solution in form of frameworks, simulations, and models.

3.0.5 Qualitative Interview

The subquestions "What challenges are present in the current implementation of the WEEE management system in Denmark preventing reuse and PfR?" and "How can the current implementation of the WEEE management system be improved to be in line with the core elements of a more circular economy?" will be answered with a combination of a literature review and qualitative interview of three experts in the field of EPR and circular economy, and two actors within the Danish WEEE management system.

The first interviewee is Thomas Lindhqvist, credited for introducing the concept of EPR in the beginning of the 1990's and currently a professor at the university of Lund in the International Institute for Industrial Environmental Economics (Lindhqvist 2022).

The second interviewee is Eléonore Maitre-Ekern, an expert in the field of developing policy frameworks to promote CE and EPR. She is now occupied with a postdoctoral on a project featuring Nordic sustainable business. Furthermore, she has done projects on company law and sustainable finance (Maitre-Ekern 2022).

Furthermore, an exploratory interview will be done with Henrik Riisgaard, CE developer at AVV, a waste company dealing in the recycling and reuse of white goods in northern Denmark. Valuable information on how EPR functions in the Danish market is necessary to identify challenges and solutions (Riisgaard 2022).

An interview will be conducted with the Danish Producer Responsibility (DPA). The DPA manages the Danish central producer register for electrical and electronic equipment, batteries and end-of-life-vehicles. The DPA also assigns collected WEEE and batteries from the municipal collection sites to the producers and/or the collective producer schemes (Ministry of Environment of Denmark 2022). Furthermore, the DPA are responsible for the process called 'scoping' which includes fitting the products in the predefined categories of the WEEE Directive and secondly whether the producer is inside the

scope for the EPR. The representative of the DPA is Johnny Bøwig, the director of the DPA (Bøwig 2022)

Lastly, an interview will be done with Alberto Huerta Morales, an ecodesign specialist at Nilfisk. Nilfisk is one of the world's leading manufacturers of professional cleaning equipment. They supply commercial, industrial cleaning machines, and high-pressure cleaning equipment (Morales 2022). The standpoint of a producer on how they think reuse can be incentivized could be very informative. As Nilfisk also provide smaller cleaning equipment sold by retailers to consumers, questions will largely revolve around this as discussed in the delimitation.

Interview Number	Country	Actor	Type	Duration
1.	Denmark	CE Developer AVV	In-person	2h
2.	Sweden	Expert on EPR and Senior Lecturer	Online	1.5h
3.	Denmark	Dansk Producent Ansvar (DPA)	Online	1.5h
4.	Norway	Expert on CE and sustainable business models	Online	1.5h
5.	Denmark	Nilfisk (Producer)	Online	0.5h

Table 3.1

The interviews conducted will be in line with the seven stages of interview inquiry by Kvale (2007). For this thesis, a qualitative interview and exploratory method has been chosen, due to the freedom the interviewer has during the interview. It is characterized by an absence of a prescribed set of rules enabling the interviewer's skills and knowledge (Kvale 2007). The seven different stages of interview are shown in the following figure.

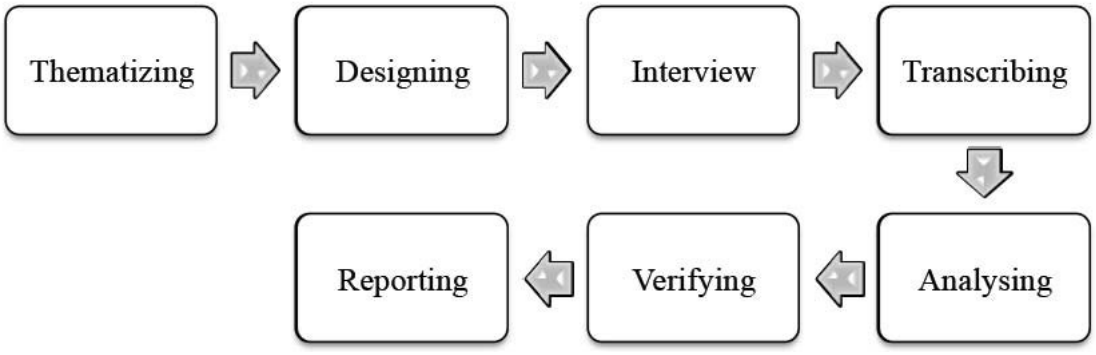

Figure 3.2: Stages of interview inquiry (Kvale 2007)

Special attention is put on the first stage (*Thematizing*) of conducting an interview. In this case the researcher clarifies the purpose of the study, which is acquiring different insights on how EPR can be improved to facilitate reuse and PfR. Furthermore, this stage also lets the researcher decide what type of interview is carried out. This is important for this thesis, as both exploratory and qualitative interviews are used. The exploratory interview is more open, with no pre-planned questions and where a general issue is brought forward. In this way new angles on the topic can be found and gives the interviewee

freedom to uncover problems. This method was therefore chosen for an interview with someone who is an actor in the waste management system and can therefore uncover possible challenges within waste management system and EPR. The exploratory interview will be the first interview that is conducted, as the interviewer can discover new dimensions of the research topic, which could consequently be used to create questions for the qualitative interviews. Qualitative interview was chosen for the interviews with two experts, the DPA, and Nilfisk. Here the questions are made beforehand, in order to make the interview more structured and gain specific insights. *Transcribing* was carried out with transcription program present on the website www.otter.ai by importing the recorded audio file onto the website. Further changes to the transcription can then be made. Consequently, *analyzing* can take place. Kvale (2007) provides six steps of analysis, however not all six steps are mandatory. Here the third and fourth step of analyzing by was used. The third step occurs already during the interview where the researcher interprets what the interviewee elaborated on and 'sends' the meaning back so the interviewee has the opportunity to confirm or reiterate what they mean. The fourth steps includes the researchers own understanding of the interview as well as forming new perspectives from the researcher. *Verifying* will be done by categorizing and summarizing the main points used and confirm with the interviewee if the researcher has understood their points correctly. Ultimately the *reporting* is done where the researcher uses the main points in the assessment.

3.1 Research Design

The following image will show the research design that shows how to researcher integrated different components in the study:

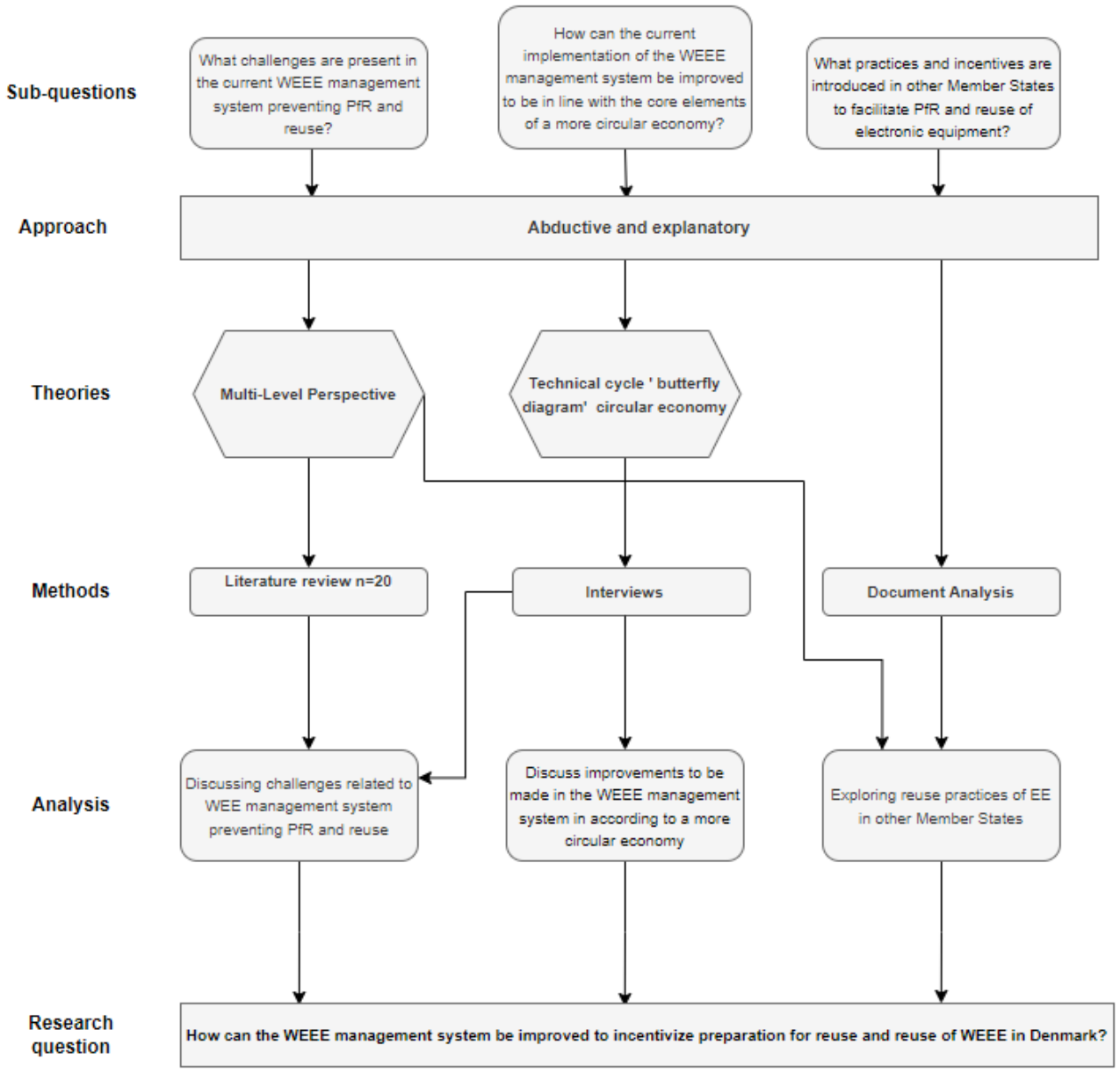

Figure 3.3: Research design of this thesis showing the subquestions, the approach, theories, methods used, analysis and ultimately the main research question to be answered.

The top of the image represents the sub questions posed in this thesis. For structural clarity the subquestions are not ordered according to the problem formulation. The approach in this thesis is abductive and explanatory. Abductive reasoning involves creating conclusions from the (incomplete)

information that is available (Business Research Methodology 2022). In this thesis this is illustrated by 1. highlighting the constraints regarding the WEEE management system with use of a literature review and interview, 2. Discussing the reuse practices in different Member States with a document analysis and 3. Elaborate on the possible improvements to the WEEE management to be in line with the core elements of a more circular economy by use of qualitative interviews. These three questions can then be used to answer the main question. Lastly, the Multi-Level Perspective theory and the circular economy theory are used as a lens to address the aforementioned research questions. Where the Multi-Level Perspective can be used to clarify why certain challenges in regards to the WEEE management exist and can elaborate on the different reuse practices between Member States. These theories will be further discussed in the following chapter.

Theory

Theories can be used to help design research questions, but also help in the process of selecting relevant data, interpret this data, and introduce explanation of causes and influences (Reeves *et al.* 2008). Theories can give the researchers different lenses to which the person can look through to explain a certain problem (Reeves *et al.* 2008) In this thesis, two theories will be used, namely the theory of the Multi-Level Perspective, introduced by Frank Geels, and the circular strategy framework by Ellen MacArthur.

4.0.1 The Multi-Level Perspective

The Multi-Level Perspective (MLP) is a theory that is able to conceptualize overall dynamic patterns in socio-technical transitions (Geels 2011). These transitions are made through interplay of developments processes between three analytical levels: regimes, niches and socio-technical landscape (El Bilali 2019; Geels 2011). Furthermore, it can be used as a means to understand the interaction between various actors, innovations and environments (Steward 2012). The three analytical levels can be explained as followed:

Regimes Main stream society that is supported by social norms and integrated systems. It serves for the stability of an existing socio-technical system and are characterized by lock ins on technological, cultural, political and scientific dimensions where innovation occurs slowly (Geels 2011).

Niches The place where radical innovations occur and can thrive in a protective space. Examples of these are laboratories and subsidies projects or small market niches where actors are willing to support upcoming innovations (Geels 2011). Niches put pressure on the existing regimes by offering a large amount of possible innovations. If there is tension in the current regime, some of these niche innovations has space to move into the regime level or provide support to current technologies (Steward 2012).

Socio-technical landscape The social-technical landscape includes exogenous events and trends, such as political ideologies, societal values, demographic trends, but also macro-economic patterns, and cannot be easily influenced by the niche and regime level (El Bilali 2019; Geels 2011). However, changes in the socio-technical landscape can create opportunities for niches to transit into or put pressure on the regime level (El Bilali 2019)

The following image shows a representation on how the three different levels interact with each other:

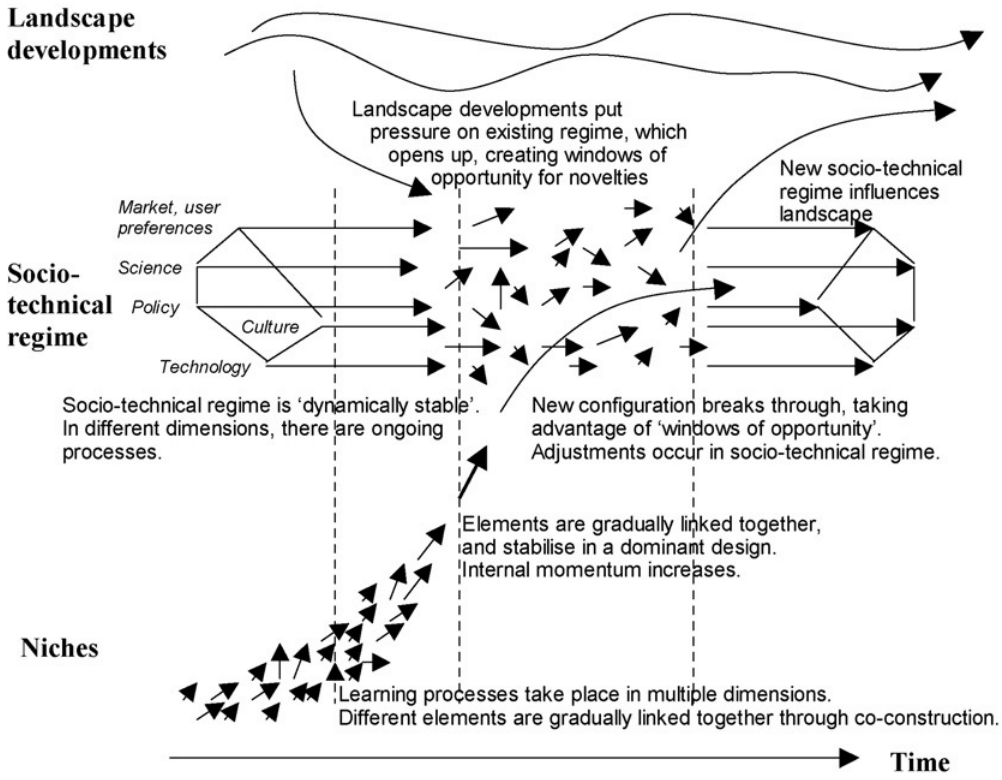

Figure 4.1: Interaction between the three different levels in the MLP (Geels 2011)

The MLP framework can be used to help transition to new systems for persistent environmental problems, such as climate change, biodiversity, and resource problems (Geels 2011). In this thesis, the MLP theory can help describing the challenges that are present in the current WEEE waste management and elaborate on why this is the case. As previously mentioned, the last decennial has seen a a shift in the promotion of ecodesign initiatives and instruments in order to become more circular. This includes the promotion of recycling, reuse, refurbishment and waste prevention. Even though recycling is a component of a circular economy, it should only be seen as an option if other alternatives are not present. The current WEEE management system is dominated by recycling, and the prevalence of recycling might be better explained by taking the current regime on recycling into account. Furthermore, the second sub-question relating to the implementation of the WEEE management in other countries might be better understood by using the MLP framework as a 'lens' to understand how the WEEE management system in those countries came into place.

4.0.2 Circular economy theory

The previous section has already discussed the core strategies of a circular economy by organizing reuse, repair, refurbish, and recycling with its aim to prolong the products life time. These strategies are depicted by the Ellen MacArthur foundation in 2015, also known as the 'butterfly diagram', consisting of a technical and biological cycle, where the technical cycle depicts the preservation of products in a closed loop system, and the biological cycle shows an open loop system where biological and renewable materials are cascading through steps of extraction and have the ability to decompose when it returns to the biosphere (Velenturf *et al.* 2019). This thesis will focus on the technical cycle and is depicted in the following image:

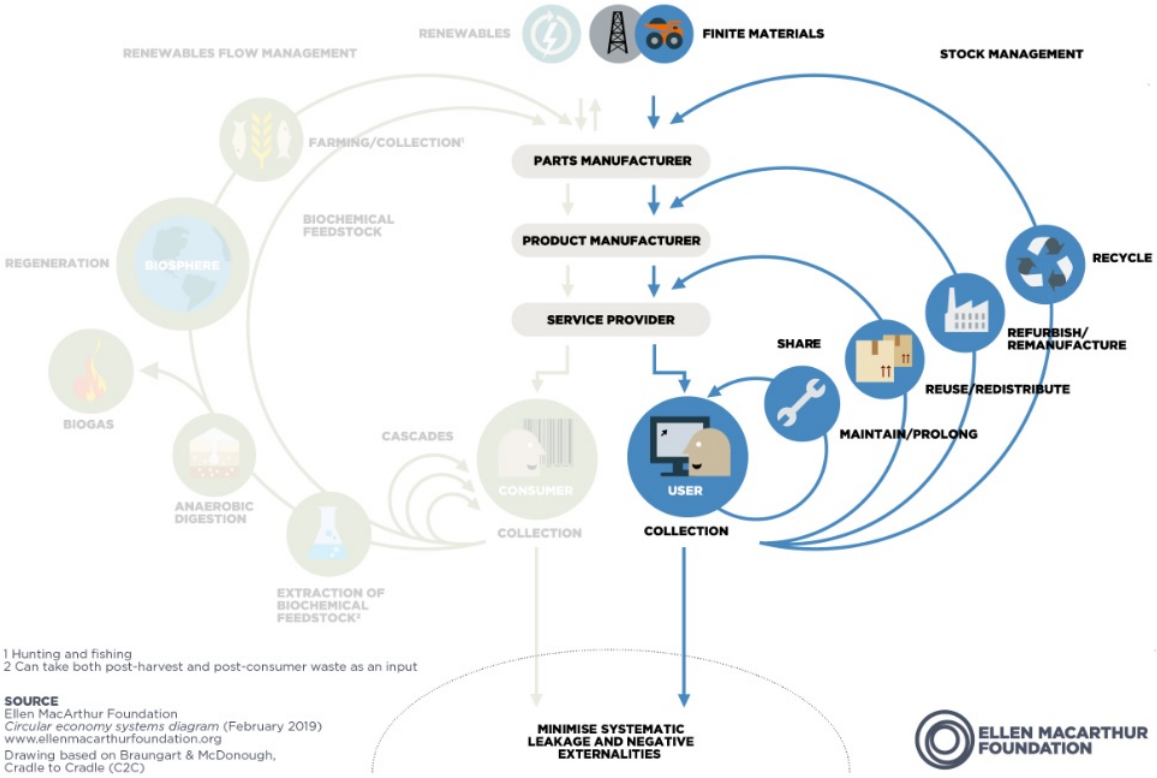

Figure 4.2: Butterfly diagram depicting the biological and technical cycle (MacArthur 2015)

The technical system will be taken into account as the core elements of a more circular economy. It therefore assists in answering the last sub-question " How can the current implementation of the WEEE management system be improved to be in line with the core elements of a more circular economy?"

Analysis

5.1 Challenges in the WEEE management system

In this analysis section the subquestions posed in Chapter 2 will be answered. In order to identify how the EPR can be improved to incentivize PfR and reuse, the underlying challenges needs to be laid out as it covers multidisciplinary dimensions. As discussed in 3 this will be done by conducting a literature review. Furthermore, information based on the qualitative interviews will elaborate on the challenges where necessary.

5.1.1 What challenges are present preventing PfR and reuse?

The following figures shows the synthesis matrix consisting of the 20 articles reviewed for this section and the challenges discussed relating the WEEE management system, in particular to reuse.

Cole&Cooper, 2016	Parajuly&Wenzel, 2017
- Waste collection staff damages products and little is done to protect the reuse potential - Lack of expertise and skilled workers to ensure items are safe to sell reused - Little involvement by the producer of EE in the end-of-life phase	- No effective communication between the actors within the full life cycle of the product. - No sorting present in the municipal collection cages (Denmark) - No proper handling in the collection stage can lead to emission of dangerous substances into the environment
Shittu, et al. 2021	**Lu, et al. 2018**
- Different methodologies for classification and reporting the numbers of WEEE prevents meaningful comparison between Member States - Transboundary movement of WEEE to developing countries reduce the reuse rate of discarded EE - Challenging to keep spare parts for each type of product to facilitate reuse	- Standards concerned to reuse in EU do not work efficiently with the EPR based WEEE management system - Large stream of WEEE exported from EU Member States to Africa - Ambiguity in the terminology to describe EoL processes, and the lack of understanding their advantages and disadvantages

Zacho, et al. 2018	**Andersen, et al. 2020**
-Technological constraints: Presence of destructive disassembly technologies incentivize recycling - Organizational constraints: The established infrastructure does not take physical condition and functionality of discarded EEE into account - Institutional constraints: No specific set of targets specified for reuse. Moreover, uncertainty among actors regarding regulation.	- EEE manufacturers were unaware of the changes in the WEEE directive from 2012 - PRO had no easy access to product information and were therefore often unaware with the characteristics of the products - WEEE was seen by the manufacturers as a waste stream - EEE manufacturers are often global, whereas WEEE is managed on a national scale
Börner&Hegger, 2018	**Elia, et al. 2018**
- Lack of a track&trace method hinders the collection for reuse - Absence of interdependencies between different actors reduces the effectiveness of the WEEE management system	- Reverse logistic need to be more responsive and efficient
Sousa, et al. 2018	**Habib, et al. 2022**
- For countries with classic PRO system, WEEE management system is less efficient due to disparity in transparency	- Low quality of products with high economic potential - The WEEE Directive goals are limited to only reported collection and not on complementary flows - Interpretation of the WEEE legislation is different among the European Member States

Andersen, 2021	**Andersen&Jæger, 2021**
- There is a focus on recycling which is the least sustainable option according to the CE model - Difference in reporting of statistics about recycling and reuse between the different Member States. - Lack of expertise in the producers of EE on the WEEE	- Mentions that the social part of social supply chain management is under researched and is important for the realization of a circular economy - Manufacturers should be more responsible and play a key role in the transition to a circular economy rather than the PRO
Cole, et al. 2019	**McMahon, et al. 2019**
- Municipal collection system is insufficient, and products are damaged in the collection process - Higher costs related to handling EE carefully - Technology in the WEEE management system is concentrated on recovery and shedding technologies - It is not economically viable to promote reuse over recycling - Environmental potential is not considered while looking at	- Lack of legislation leads to homogenous waste streams and mixed waste - Leakage of waste from formal waste streams to informal waste streams - Lack of enforceable product requirements to encourage reuse
Aminoff, et al. 2021	**Kumar, et al. 2022**
- 'Lock in ' of technologies promoting recycling - There is no economic incentive to focus on reuse in the WEEE management system - Existing consumer-supplier relation on reuse is not common in the current socio-technical system - No regulatory pressure to increase PfR	- EE manufacturers are not well equipped yet with green infrastructure, such as clean technologies
Boldoczki, et al. 2020	**Clarke, et al. 2019**
- Reuse is not always environmentally beneficial over recycling for some products - Whether reuse or recycling is more environmentally beneficial depends on the regional scope and energy mix	- The concept of hoarding reduces the amount of functional EE entering the EoL stream - The potential of reuse can be affected by contamination or damage during transport

Figure 5.1: Synthesis matrix on the challenges regarding the WEEE management system

5.1.2 Available product information

There are many challenges present within the European Member States that limits a proper WEEE management system. The current literature selected for these thesis have various concerns regarding the functioning of the WEEE management in common, particularly concerns on why circularity is challenging to achieve with the current WEEE Directive. Andersen *et al.* (2020) reveals several challenges regarding the traditional collective schemes, where it is stressed that a lack of available information is detrimental in the process of achieving circularity. These concerns are shared by Börner and Hegger (2018) that argue that the lack of a track&trace method and transparency is hindering the collection for reuse. As the WEEE product categories contain various hazardous materials, the reuse potential is limited if follow-up information on chemicals is unavailable throughout the reverse supply chain. This influences whether products are safe for disassembly. The lack of information sharing between PRO's and the manufacturer is highlighted by Andersen *et al.* (2020), who conducted several interviews with PRO's in different countries. According to the WEEE Directive (2012/19/EU), every product that is covered by the WEEE legislation is required to be labeled with a specific WEEE label. However, other than this label, there is no product labeling available that specifies the product information (Andersen *et al.* 2020). Moreover, the available product specific information via documents and data sheets were not specifically made for the EOL treatment, and information regarding disassembly or recovery was limited (Andersen *et al.* 2020). Information on for instance the energy efficiency of WEEE products is important to understand whether reuse is the beneficial EOL treatment in an environmental perspective (Boldoczki *et al.* 2020).

5.1.3 Technological, organizational and institutional constraints

Zacho *et al.* (2018) mentions technological, organizational and institutional constraints regarding PfR in the Danish WEEE management. The current EOL facilities in Denmark are focused on destructive disassembly, which gives actors the incentive to recycle and not on reuse. This is strengthened by the fact that the recycling industry is dependable on large streams of WEEE in order to make a business case from it. There is therefore hesitation to invest into new, and more sustainable technologies (Zacho *et al.* 2018). Aminoff and Sundqvist-Andberg (2021) elaborated on this by discussing the 'concept of lock in' regarding the WEEE technologies. They state that the existing technology are defined by a co-evolutionary process, involving multiple stakeholders. Political, social, and technological factors co-evolve and create a technological system from which it's challenging to disperse from. This is reinforced when the actors in this system benefit from the current technologies. This can be seen in the WEEE management system, where the PRO's, the producers benefit from the current destructive technologies by earning money and fulfilling the collection target (Aminoff and Sundqvist-Andberg 2021). This is furthermore strengthened by ' organizational inertia', which is seen as the source of these lock ins. Ownership of the WEEE plays an important role, actors, such as the municipality, do not have ownership over the products, therefore lacking the motivation to change the current system (Aminoff and Sundqvist-Andberg 2021). In addition, the knowledge required in recycling is lower than in mak-

ing a product suitable for reuse. For instance, the mechanized system of recycling does not require a high skill base, nor requires any specialist testing. However, making EE suitable for reuse requires a highly skilled engineer (Cole *et al.* 2017). The surrounding infrastructure shaped around these types of technologies, where the quality of the disposed WEEE products are of small concern (Zacho *et al.* 2018). This is also mentioned by (Cole *et al.* 2019), stating that whenever a product is perceived as waste it will receive less careful handling, which is the case not only in Denmark but also other Member States. Cole *et al.* (2019) interviewed various actors in the collection and treatment of WEEE in the UK. The majority of the interviewees put blame on the current municipal collection systems, where the staff damages the discarded products and no measures were taken to protect the products. The interviewee from the DPA (Bøwig, 2022) confirms the bad collecting infrastructure negatively affecting the reuse potential. He recalls that current collection stations managed by the (Danish) municipality are deep containers where WEEE products would likely be destroyed on impact. Institutional constraints were also discussed in the published articles part of the literature review. These challenges refer mostly to the weight-based indicators that monitors WEEE system efficiency, namely recovery rate, recycling rate/reuse rate and collection rate (Habib *et al.* 2022), but also the voluntary nature of reuse targets in the WEEE Directive itself (Andersen *et al.* 2020; Andersen 2021; Zacho *et al.* 2018; Habib *et al.* 2022; Aminoff and Sundqvist-Andberg 2021).

5.2 Challenges highlighted in the interviews

All the interviewees were asked to highlight the challenges they would consider are most important in the WEEE management system. In order to obtain genuine answers it was made sure that the question was open to reduce bias on the interviewer's part.
Some of the challenges discussed in the previous section are similar to the challenges the interviewees brought up. For instance, the DPA (Bøwig, 2022) mentions the low quality of the collected household waste in the municipal collection containers. Here the interviewee from the DPA states his personal experience:

> When I was actually getting rid of eight different kind of screens at the same time I experienced it as putting it into a 'black hole' at the center station and I heard this 'poem' when they were hitting down the bottom of the containers and I couldn't see it. I was glad that I couldn't because I know now they were for certain destroyed

This quote does not only highlight the insufficient method of collection of household WEEE, but also implies the importance of perception from a consumer standpoint. The way the WEEE is collected at the municipal stations does not promote consumers to discard their relinquished equipment, but are more likely to store them inside and potentially reuse the equipment by giving it to family or other acquaintances (Bøwig, 2022). The DPA also refer to this as the graveyard phenomenon, where potential

fully operational equipment is stored for a long time due to the lack of trust in the reuse system. Consequently, there is a large amount of informal streams of EE between family, friends, but also online platforms such as Ebay or Facebook Market Place. These items are then reused before they enter the official waste stream where the WEEE Directive does not apply, making it challenging to calculate and record the total amount of reuse of household EE. The total amount of reuse of EE is likely to be higher than the official numbers suggest (Bøwig, 2022) .

From the 20 publications reviewed, most of them do not discuss socio-political factors to great extent even though Zacho *et al.* (2018) mention that WEEE management is legitimized by its social effects. This was therefore also asked to the interviewees. Here the questions related to what the interviewees view was if socio-cultural factors were of importance when discussing the challenges regarding the EPR and the reuse in general. Maitre-Ekern (2022) explained this by highlighting that the current waste laws are focused on the visible part of our consumption society and that it is an explanation on how waste directives have shaped over the years. The waste directives therefore do not focus on questions such as 'why do we have certain products becoming waste?'. The ingrained principles of waste directives and the perception of waste throughout the years is now challenging the transition to a more circular economy which includes PfR and reuse.

This was also elaborated by Lindhqvist (2022) who discussed how the vision of waste in the eighties and nineties shaped the principles present in the current waste directives. Even though the collection of waste has evolved over the years and collection has increased, some of the management system remains the same. For instance, household kitchen equipment was put together with broken cars to extract steel from the products. As this is efficient and lucrative for recycling companies to do, there is no incentive to separate these products from each other as it is lucrative and efficient. Furthermore, they adhere to the collection and recycling rate posed by the different waste directives.

In terms of the EPR, many of the interviewees did not see particular problem with the principle in general (Lindhqvist, Bøwig, 2022). Lindhqvist (2022) stresses that the EPR is a principle and not a policy instrument and that the EPR itself does not need to be changed, but that measures surrounding the EPR can shape it. For instance the collective schemes implemented in numerous Member States are very effective in achieving high amount of collection, but they intrinsically reduce the incentive for the EE producer to become involved in the process of waste collection. The Ecodesign Directive (2016-2019) aims to promote producers to establish product specific and horizontal requirements, such as durability, reparability (Design for Repair) upgradeability, and design for disassembly (Commission 2016). The Ecodesign Directive can therefore facilitate the PfR, as it covers the full life cycle of the product.

Bøwig (2022) (DPA) highlights another barrier that reduces the incentive for producers to partake in the EoL of their products. He mentions that the producer is not guaranteed to have the product back after it has fulfilled their active lives. He uses a company purchasing heavy machines as an example

as an end user. This company then purchases these machines that consist of high amount of steel and copper, but also other valuable resources. When these products become obsolete, the company in question is likely to sell the machines to other companies rather than discard them. In Denmark for instance, these machines might also be sold off to other countries. In this way the company retrieves some part of the total cost they needed to pay to obtain the machine. The original producer, however, is not likely to receive the machine after it has fulfilled its lifetime. Bøwig, (2022) sees this as one of the major constraints restricting producers to take environmental concerns in the production of the product. He proposes that the producers should have the right to receive the product after its expected life time, but it requires a re-thinking of the standard purchase rights.

Here the economic factors also play an important role. The EPR is a market principle and invites competition (Lindhqvist, 2022). However, currently there is no economic incentive for producers to actually join the EPR scheme. Each producer of EE is required to register in the EPR scheme, but some EE producers regularly do not apply for the scheme. Bøwig, (2022) form the DPA mentions the following regarding the lack of registration of certain EE producers:

> Each EE producer has the obligation, but yes, they do not register. And they can keep out of the obligations that way around. If they are not registered, the DPA is not aware of their existence and we cannot place any obligation on the shoulders of those companies. So they are keeping out of the whole show you could say.

The DPA also refers to this problem as 'free riding' and has as consequence that it violates the competition as companies not registered do not have similar costs regarding the EoL treatment of their products. Furthermore, he mentions that companies not part of the EPR want to avoid the bureaucracy of the EPR. When asked further on how companies can avoid being registered in the EPR, the DPA replies that it is hard to determine which company is the producer of the EE and which company is further down in the distribution line. This is strengthened by 'distance selling' where products are sold directly to the consumer via online platforms. Bøwig, (2022) mentions that the definition on the term producers is uncertain, as the DPA cannot explicitly state whether for instance online platforms or the producer using the platform is required to register in the EPR. Authorities are therefore not in the position to receive validated information about who the actual producer is.

Some of the interviewees also highlight the paradox between reuse and shorter lifespans of products. Bøwig, (2022) mentions that the trend of shortening the lifecycle of a product is interfering in the process of increasing preparation for reuse and reuse, as companies benefit from increased sales due to shorter life spans. The interviewee from the DPA recalls instance where a large mobile phone manufacturers glue the batteries into the phones, making it challenging to replace the battery as consumer. However, the expectation is that this will be improved upon due the the emergence and more stricter requirements regarding reparability in the Ecodesign Directive. Bøwig, (2022) therefore expects that the Ecodesign Directive will therefore have more potential to increase the direct reuse than the WEEE Directive. Products can also obsolete due to technical changes, such as changing standards in televi-

sion from MPEG2 to MPEG4 resulting in perfectly function screens becoming obsolete. This is rather significant for electronic equipment where technical changes are not uncommon.

Another challenge discussed was the lack of economic incentives for the producers to focus on producing products from an environmental standpoint (Bøwig, 2022). The representative from the DPA elaborated on the lack of economic incentive by explaining that the PRO's demand similar prices for the EoL treatment of products. A producer of EE that focus more on increasing the lifetime of the product, reparability, and easy dismantling will pay similar prices as a producer with a product that does not include environmental concerns into the product. The PRO was therefore neutralizing the competition and producers were less inclined to take environmental concerns into account (Bøwig, 2022). The original goal however of the WEEE Directive was to induce competition where producers with products with the best environmental performance is rewarded by lower EoL costs. Furthermore, EoL costs are put on top of the original price of the product, where the consumer is not aware that the increased cost is due to the EPR (Bøwig, 2022).

The following tables will give an overview of all the constraints identified , with the aim to summarize this chapter and to illustrate the occurrence of these constraints in the different literature and interviews. Some constraints are combined in a single category.

	Zacho, et al. 2018	Andersen, et al. 2020	Habib, et al. 2022	Borner & Hegger (2018)	Elia, et al. 2018	Sousa, et al. 2018	Andersen, 2021
Lack of track&trace, product information, and inefficiency of reverse logistics	X	X	X	X	X	X	
Disregard of physical condition during collection	X	X	X				
Producer's perception on discarded EE (seen as waste stream)	X	X					
Technology 'lock in' on recycling of WEEE	X						X
Consumer's perception of the reuse system	X						
Lack of clear legislation reduced the number of products prepared for reuse	X						
Challenges in assessing effectiveness of WEEE management between Member States		X	X				X
Little producer involvement in the EPR, including the knowledge on the WEEE management system and communication through EoL phase		X					X
Transboundary movement of WEEE							
Environmental potential of reuse over recycling not comprehensive for all WEEE categories							
No economic incentive to promote reuse over recycling			X				

Figure 5.2: Challenges raised in literature and interviews

	Cole, et al. 2019	Andersen & Jaeger (2021)	McMahon, et al. 2019	Aminoff, et al. 2021	Kumar, et al. 2022	Cole & Cooper (2016)	Parajuly & Wenzel (2017)	Petcu, et al. 2020	McMahon, et al. 2021	Shittu, et al. 2021
Lack of track&trace, product information, and inefficiency of reverse logistics	X		X		X		X		X	X
Disregard of physical condition during collection	X					X	X			
Producer's perception on discarded EE (seen as waste stream)		X								
Technology 'lock in' on recycling of WEEE	X			X						
Consumer's perception on the reuse system										
Lack of clear legislation reduced the number of products prepared for reuse			X	X						
Challenges in assessing effectiveness of WEEE management between Member States								X		X
Little producer involvement in the EPR, including the knowledge on the WEEE management system and communication through EoL phase		X	X	X		X	X			
Transboundary movement of WEEE										X
Environmental potential of reuse over recycling not comprehensive for all WEEE categories										
No economic incentive to promote reuse over recycling	X			X						

Figure 5.3: Challenges raised in literature and interviews

	Lu, et al. 2018	Boldoczki, et al. 2020	Clarke, et al. 2019	Bøwig, 2022	Ekern, 2022	Lindhqvist, 2022
Lack of track&trace, product information, and inefficiency of reverse logistics				X		
Disregard of physical condition during collection			X	X	X	
Producer's perception on discarded EE (seen as waste stream)			X		X	X
Technology 'lock in' on recycling of WEEE				X		X
Consumer's perception on the reuse system				X		
Lack of clear legislation reduced the number of products prepared for reuse	X			X	X	X
Challenges in assessing effectiveness of WEEE management between Member States	X	X				
Little producer involvement in the EPR, including the knowledge on the WEEE management system and communication through EoL phase				X	X	
Transboundary movement of WEEE	X			X		
Environmental potential of reuse over recycling not comprehensive for all WEEE categories		X				
No economic incentive to promote reuse over recycling	X					

Figure 5.4: Challenges raised in literature and interviews

Reuse of EE in different countries

6.1 Reuse of EE in different countries

In order to propose ways to incentivize reuse and PfR, it is interesting to investigate how different Member States have developed their waste management system. A particular focus will be on the Kringwinkel in Flanders (Belgium) that implemented a network of reuse centers across the country. This section therefore seeks to answer subquestion 2 "How can the implementation of the WEEE Directive and EPR in other countries be an example?"

6.1.1 De Kringwinkel

De Kringwinkel is a brand name for a network of reuse centers across the Flanders region of Belgium and is active since the beginning of the nineties (De Kringwinkel 2022). The basic principle of the Kringwinkel centres is to collect and repair donated goods and consequently sell them as second hand products. A variety of product types are included, such as clothes, furniture, but also electronic equipment, where the latter is sorted, controlled and repaired if necessary (Cools and Oosterlynck 2015).

De Kringwinkel companies are non-profit organizations and are dependent on both their own income (52%) and governmental subsidies (48%) (Hirsbak 2022). With the remaining funds and revenue, employment opportunities is created, especially for people with lower chances in the labour market. De Kringwinkel therefore also aims to reduce the unemployment rate in the country (Hirsbak 2022)

Originally De Kringwinkel initiatives combine three goals (Cools and Oosterlynck 2015):

1. Waste reduction and sustainable use of materials

2. Jobs and learning experience for long-term unemployed

3. Providing quality materials for low prices

Currently there are 28 different reuse centres under the name of de Kringwinkel following the same infrastructure for waste collection, share principles and identity. However, every reuse centre puts different amount of emphasis on the aforementioned goals (De Kringwinkel 2019). Furthermore, all Kringwinkel centres have the same organization (Herwin) representing them to the government, and other stakeholders. Herwin is an organization engaged in circular economy and is responsible for all the reporting, legislation, and representation of all the Kringwinkel centres. This also includes all lobbying with trade unions, funding, and national communication (Hirsbak 2022).

6.1.2 Environmental and social potential of De Kringwinkel

In addition to the 28 different reuse centres, there are 145 reuse shops present in the Flanders region. In total 5311 people work here from which 45% are poeple that have limited chances on the labor market. The aim for 2022 is to create 2000 more jobs for this specific group (De Kringwinkel 2019)

A large amount of products are collected, and divided into 600 categories. The high amount of categories poses certain challenges, such as outdated products and changes in the standard weight of products (Hirsbak 2022), for instance the decreasing weight of laptops over the years.

In total 83000 ton of products is collected, from which 28% are electronic products and equipment (Peeters *et al.* 2018). This leads to a total of reused products per inhabitant to be 5,4 kg. In the year 2019, the environmental impact savings were 34000 tons CO2-eq which could be compared to driving a car across the globe 5300 times (Peeters *et al.* 2018). This amount shows the significant potential of reusing products (De Kringwinkel 2019). Furthermore, De Kringwinkel regards the product performance of EE closely and determines whether expanding a products life time has positive environmental potential. For instance, older television technologies such as CRT, or Plasma will not be prepared for reuse as they have significant electricity usage tied to it (De Kringwinkel 2019).

As mentioned in the previous section, the perception and trust of consumers in reuse is a constraint in Denmark an other Member States, reducing the amount of EE delivered to the collection stations, as well as limiting the amount of used products bought. De Kringwinkel has seen a significant increase in the amount of customers over the past few years, which could indicate in an increase in the perception of people on reused products. The following figure shows the sold reused products over the past 15 years in De Kringwinkel. Data was gathered from the Kringwinkel report (OVAM 2015) that shows the data for the amount of sold reused products per year until 2015. More recent data was available for 2019 on the website of De Kringwinkel (De Kringwinkel 2022). For the years between 2015 and 2019 the data was fitted accordingly and is depicted as a dotted line.

Figure 6.1: Amount of reused products sold per year

The previous image shows a significant increase over the years in the amount of reused products sold to costumers. This could be explained by the high effort De Kringwinkel puts in creating a well thought out communication policy linked with the increasing popularity. Also very noteworthy is the focus from De Kringwinkel in creating a quality brand, where a huge focus was put on transitioning the image of De Kringwinkel from a 'store for poor people' to a store reselling a wide variety of quality products (Cools and Oosterlynck 2015). In terms of the EE, De Kringwinkel has established a quality label named the Revisie, which is a label that ensures the proper collection of EE and repairment activities by creating a network of repair centres with skilled laborers. This label therefore demonstrates the quality of the product to consumers (OVAM 2015).

6.1.3 Extended Producer Responsibility

The EPR is also present in Belgium under the WEEE Directive. This works similarly as in other countries, where the producers of EE delegate the responsibility of the waste management to PRO's. In the case of Flanders, the largest PRO is RECUPEL, who collects old electronic equipment from companies, and offer collection containers for consumers to put their discarded products in (De Meester *et al.* 2019). De Kringwinkel is using the organizational process of collection from RECUPEL and separates reusable and non-reusable, where the reusable products are repaired in the workshops(Hirsbak 2022). This therefore also shows consumers that their products are getting sorted and that their products might be repaired and reused. This was one of the barriers discussed in the previous section, where

consumers indicated to have a lack of trust in the current collection containers. RECUPEL benefits from the cooperation with De Kringwinkel as they now do not have the responsibility to fulfill the PfR goals set in the WEEE Directive and can focus solely on organizing the transport. Furthermore, when a repaired or reused item is sold, RECUPEL receives a small fee for handling and collecting the products (Hirsbak 2022). Important to note is that the producers of EE had to agree on this resolution where De Kringwinkel was allowed to repair and resell used products. De Kringwinkel therefore offered a full tracking of the products from its origins to repair and consequently the sale of the products (Hirsbak 2022). Further collaboration between Herwin (De Kringwinkel) and RECUPEL allowed the creation of the previously mentioned 'Revisie' quality brand, showing that collaboration of PRO's and reuse centres can strengthen the quality of reused products (OVAM 2015). A biennial external audit evaluates the quality by using 67 different criteria on the collection, handling, quality of repairment, but also the management of the organization as a shop that sells repaired items (OVAM 2015).

6.1.4 Success factors

Highlighting the success factors could give an insight on how De Kringwinkel managed to obtain a well functioning infrastructure allowing reuse and PfR, as well as improving the perception of reused products nationally. These factors, based on (OVAM 2015) are elaborated upon, and presented in the following diagram.

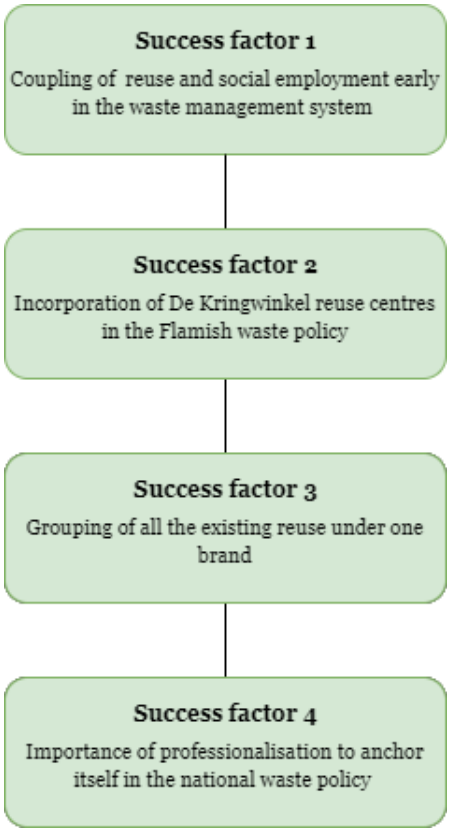

Figure 6.2: Success factors leading to the successful integration of de Kringwinkel in the Flemish waste policy

The first success factor was the early focus on social targets in addition to managing waste. This focus therefore contributed positively to a national wide problem, namely the unemployment rate, where De Kringwinkel specifically focused on offering unemployed inhabitant a place to work. This combination of combining environmental factors with socio-economic factors in the nineties, presented the Flemish government with opportunities to combat two problems concurrently (OVAM 2015).

The second success factor is a continuation of combining socio-economic factors with environmental factors. One of the interviewees (Linhdqvist, 2022) mentioned that waste policies received more attention in the early nineties, after the Basel Convention in 1989, prohibiting trans-boundary movements of waste, requiring countries to set up waste management systems (Williams 2015). The emergence of reuse centres where waste was collected from the population in the early nineties activities gave therefore the opportunity for the incorporation of reuse centres in the local waste policies. This was further encouraged after a study was carried out on request of the OVAM confirming the feasibility of reuse centres and their role in preventing waste (OVAM 2015).

The third success factor was the creation of a single brand. Prior to 2001 there were independent reuse companies in the waste sector, limiting the creation of a coherent reuse sector. In 2002 these (66) companies decided to group themselves under De Kringwinkel quality brand, where they embraced a uniform house style and communication towards customers, guaranteeing the quality of their products and reaching a wider audience (Cools and Oosterlynck 2015) Consequently, this created a strong and organized reuse sector in Flanders with significant lobbying power.

The last success factor presented is the importance of professionalism to anchor itself in the national waste policy. De Kringwinkel invested significantly in creating professional workplaces with skilled workers, especially to repair WEEE. Furthermore, a focus was put on streamlining the way of collecting WEEE. All collected EE is screened on site, where the origin, age and its current state is determined. This ensures that the capacity of the repair centres are not exceeded (Hirsbak 2022). The aforementioned label 'revisie' was created to communicate to customers on the ensured quality of the repaired products (OVAM 2015).

6.1.5 Ireland - ReMark Standard

Since mid 2021, Ireland announced the implementation of a new quality standard 'ReMark' to address concerns of consumers on quality, but also safety of reused goods (EMRI 2022). Research was carried out to investigate peoples perception of buying reused equipment in Ireland and showed that 32% of the population were not willing to buy reused products, from which 79% were concerned about the quality. 75% were concerned about the safety of the product and 53% were worried about the appearance of the product (Downey 2019). Based on these numbers, the amount of people willing to buy reused products is high, however there could be much potential to further increase this as the perception on reuse is a large constraint for consumers (Downey 2019).

A quality standard, such as the ReMark, can function to ensure that the reuse sector in Ireland is of high operational standard. Creating a quality label involves accreditation of a reuse organization to show it is fully functional (Downey 2019). Furthermore, a quality label functions as a recognizable logo and indicates that the organization has met the quality requirements. This was done by focusing on three different aspects (Downey 2019), namely:

1. Improving the standard of service and customer by encouraging reuse organizations to sign up to quality protocols
2. Display the commitment of improving quality of the reuse sector to the public
3. Emphasize the environmental and social advantages of the reused products

Ultimately, the implementation of the ReMark is an example of branding that can promote the reuse sector in Ireland. Results of the ReMark label on the amount of reused products in Ireland is not yet available due to its short time of implementation. However, as the ReMark can be compared to the creation of De Kringwinkel, where the reuse sector significantly grew due to the creation of a common brand and label, it is expected that ReMark will positively influence the Irish reuse sector. Especially for EE, where the functionality of the product is crucial, a quality label can have a significant impact.

6.1.6 France's Anti-waste and Circular Economy Law

In early 2021, France has implemented the first repairability index in Europe in order to promote the Right to Repair for electronics (Right to Repair Europe 2021). Currently, Right to Repair is part of the Ecodesign Directive, which has been updated in March 2021, making it easier for consumers to repair their own electronic products, such as lighting, televisions, and larger home appliances (Eversheds Sutherland and Gough 2022). Opening the access to repair for consumers, can increase the amount of reuse and reduce waste contributing to the core elements of circular economy. However, currently the market is structured against any real incentives for producers to enable more repairs, even less outside their own network (Svensson *et al.* 2018).

In order to increase the producer's responsibility, France has implemented the repairability index, that obligates producers to inform consumers on the repairability of their products (Right to Repair

Europe 2021). Another aim of implementing this index is reducing planned obsolescence, where products are deliberately made finite to encourage consumers to purchase new products. This contributes therefore to the EPR, with its difference that it applies to the product before it reaches its EoL (Right to Repair Europe 2021).

The repairability index ranges from a score from 1 to 10, with one indicating very low repairability and 10 very high repairability. This is further clarified by different colors for each score (Right to Repair Europe 2021). An example is given in the following figure.

Figure 6.3: Repairability Index with scores ranging from 1 (Very low repairability) to 10 (Very high repairability). Image derived from www.accerio.com

The repairability index applies to 5 categories of EE: 1. Smartphones 2. Laptops 3. Televisions 4. Washing machines, and 5. Lawnmowers. Furthermore, the index assesses 5 criteria (Right to Repair Europe 2021):

1. Documentation - Based on the availability of free of charge documents

2. Disassembly - Based on how easy a product is disassembled and type of tools required

3. Availability of spare parts - Based on the time the producers is able to deliver spare parts

4. Price of spare parts - Based on the ratio between product price and spare parts

5. Product specific - Product specific ie. software updates, remote support, etc.

It is important to note, that the repairability index applies especially for products with low EPR fees to influence consumer choices (Sachdeva 2021). As mentioned in chapter 5, producers have less incentive to improve product design when the EoL costs of a product is not reflective of the real EoL costs and is only based on the weight of the product (Sachdeva 2021).

6.1.7 Summary

This section has presented De Kringwinkel as an example of network of reuse centers under a single name. The presence of De Kringwinkel has proven to be very positive on the amount of reused electronic products. This can be explained by the aforementioned success factors: 1. Coupling of reuse and social employment early in the waste management system, 2. Incorporation of De Kringwinkel reuse centres in the Flemish waste policy 3. Unifying reuse centres under one brand, and 4. The importance of professionalisation to anchor itself in the national waste policy. Furthermore, De Kringwinkel has created a quality brand, therefore increasing the perception of consumers on reused products

The repairability index implemented in France was given as an example to show that opening the access to repair for consumers can increase the amount of reuse and reduce waste. It is an example of increasing the responsibility of the producer before the product enters the waste stream.

Lastly, the Irish ReMark was introduced to illustrate how labeling can increase the perception on reuse to combat the stigma that consumers have on used products.

Improving the WEEE management system

The previous section has shown examples of countries successfully promoting the reuse of WEEE. These included both the reuse and preparation for reuse stages of the EoL of a product. This section will focus on the last sub-question, namely "How can the current implementation of the WEEE Directive be improved to be in line with the core elements of a more circular economy?". Information from the interviewees as well as literature will be used to answer this question.

7.0.1 Government intervention

All the interviewees were asked to elaborate on how to facilitate the core elements of a circular economy in the WEEE management system. Even though Chapter 5 elaborated on the several challenges related to the EPR, none of the interviewees were against the basic principle of collective schemes. Maitre-Ekern (2022) mentioned that collective schemes are very functional for the current way of collecting material for the purpose of recycling, but that they are problematic for collection for the purpose of reuse. She therefore stresses that targets for both reuse and recycling should be separated. Furthermore, she mentions that producers should take more responsibility in regards to promoting more durable products. When asked about incentivizing producers to facilitate reuse and PfR, Maitre-Ekern (2022) states:

> It's not a question of incentives, it's a question of saying, either you participate, or you don't, these are their options.

The representative of Nilfisk was also asked on how reuse and EPR from a manufacturer could be increased. He mentions that a public partnership in Denmark is currently hard to achieve, as there is no national agreement that facilitates the interaction between third party social enterprises with the manufacturers and the manufacturers do not have the administrative capabilities and strategy to go ahead and do these national agreements (Morales, 2022). He also mentioned the regulation of the repairability index, implemented in France, as a good example that facilitates repairability of their products by consumers or third parties and a way to mandate the interaction between the manufacturer and third party social enterprises, by giving guidelines and assistance in how to achieve this (Morales, 2022)

The DPA states that new legislation is needed to increase the quality of products after it is collected and argues that governmental intervention is required in this regard as the collection station are organized by the municipality. Collection should improve in such a way that products are not destroyed upon impact after depositing products in the collection boxes and preventative measures are required to reduce the weather's impact on the quality of the disposed product (Bøwig, 2022).

Lindhqvist (2022) discusses that careful handling should get higher priority and that screening of the products at the collection site should be possible. Furthermore, he mentions an integrated system where initially the consumers state what they view as reusable or easily repairable, and that legal requirements should be put in place to ensure this process for the PRO. This also includes making it more convenient for consumers to hand in their electronic products (Lindhqvist, 2022)

7.0.2 Pre-market producer responsibility

The interviewees also stress that most potential of dealing with waste is the prevention of waste altogether. This means going beyond recycling and repair and focus on the design of the product (Maitre-ekern, 2022; Bøwig, 2022). Maitre-Ekern (2022) proposes introducing new concept, namely the 'pre-market producer responsibility' (PPR) in addition to the EPR. The PPR should make the producers of EE responsible for extending lifetime of the products and reducing environmental impact in line with the core principle of a CE before they are placed on the market (Maitre-Ekern 2021). Examples of possible PPR are as followed (Maitre-Ekern 2021):

1. Producers should acquire and provide a predefined amount of information on the expected lifetime, repairability, and disassembly characteristics of their products, before placing it on the market

2. Availability and affordability of spare parts to facilitate the lifetime extension

3. Take back schemes organized by producers

4. Reuse sections in (online) stores of producers

It is interesting to discuss the PPR, even though the PPR is not part of the waste management system. The implementation of this concept could influence the repairability of EE when it becomes part of the WEEE management system. It can also incite change and offer new possibilities in the current EPR concept as the EPR and waste laws have been developed in a different time and context than the circular economy concepts. Interestingly, the proposed description of the PPR is similar to the 5 criteria the French repairability index is based on, showing further attention to increase producers responsibility in facilitating repair

7.0.3 Harmonization of the WEEE Directive

Harmonization of the WEEE Directive between Member States was also mentioned several times by the interviewees. The representative of Nilfisk (Morales, 2022) elaborated that taking more producer responsibility is challenging due to the fact that Nilfisk has establishments in Member States where the WEEE Directive is implemented differently. Even though most Member States have the option to delegate responsibility to a PRO, the directive allows for high degree for variability on the implementation in each country (Andersen 2021). For instance Denmark PRO are identified as non-profit organizations, whereas The Netherlands are commercial companies. Furthermore, the environmental fee that PRO's receive may differ in Member states as the fee can be calculated based on the weight, volume, size, or value of the product (Andersen 2021). In some Member States it is expected that the environmental fee on invoices are separated, whereas in other Member States this is not necessary (Andersen 2021). This inconsistency hampers multinational producers of electronic products and distances them from EPR obligations as it is challenging to calculate exactly how many products are being handled by the PRO (Andersen 2021). Therefore harmonization of the WEEE Directive is needed between Member States, where there is transparency on the amount of products being recycled and reused by using the same calculation on determining the environmental fee.

The DPA elaborates on this topic by mentioning the difference between a directive and a regulation. Directives propose results that needs to be achieved with certain freedom on how the results are achieved, whereas regulations have binding legal force throughout every Member State (United States Department Of Agriculture 2022). The DPA states that each Member State should receive guidelines on how to implement procedures in terms of WEEE management from the European Commission.

Lindhqvist (2022) mentioned that there is a tendency to find a middle ground when considering harmonization, even though it is necessary to push requirements. Furthermore, he argues that harmonization would lead to more cheating in Member States that are not able to meet the requirements. Therefore, the circumstances in these countries should be taken into account, but could lead to less strict requirements.

7.0.4 Increase incentive to include ecodesign in EE

As mentioned in Chapter 5, environmental fees do not reflect the environmental performance of a product, and does not give an incentive for producers to promote ecodesign of their products. Morales (2022) highlighted this and mentioned that, other than the Ecodesign Directive, the WEEE Directive does not accolade products with increased ecodesign. He mentions that fees are modulated based on how many units a producer places on the market, regardless of the design. A fee should therefore reflect the efforts a producer puts in facilitating repairability of a product. Morales (2022) states:

> As a company, we are very much willing to embrace in this type of transition to produce more sustainable products. Ofcourse, someone needs to tell us why it makes sense to in-

> clude this and if the environmental fees paid would reflect this transition, it would make a business case.

Elaborating on the previous quote, Morales (2002) stresses that a net revenue is not necessary to include transition to produce more sustainable products. Reflecting some of the transition into the environmental fee would already build up a case with for example potential business opportunities or reduce the expenses in terms of WEEE management. Consequently, this can lead to more resources put into understanding the design of products.

The DPA proposed advanced modulated fees as a requirement to incentivize ecodesign in produced EE. These modulated fees should reflect the environmental performance of a product (Bøwig, 2022). How exactly the advanced modulated fees should be calculated was not elaborated on by the DPA, however the representative of the DPA stated that ability to repair the product, the lifespan, and the ability to disassembly should be high priority aspects that influence the modulated fee producers have to pay as part of their responsibility. The DPA mention that this advanced modulated fee should be incorporated in the WEEE Directive and not be imposed by the PRO's, as PRO's are probably not favourable of this approach out of fear of losing customers (Bøwig, 2022). Furthermore, it was stressed that fees need to be complemented by other policy tools such as the Ecodesign Directive or Green Public Procurement.

7.0.5 Promote third party initiatives

Many of the interviewees state that an increase of third party initiatives could increase the rate of PfR, and reuse, where customers can either directly deliver their used products to an organization or they are picked up from the collection boxes managed by the municipality. The DPA states that for instance in Denmark, the organizations that repair products are an extension from the municipality, but that it creates conflict with the PRO's about the ownership of the product. The PRO consider it their products the moment they are discarded by the consumer as part of the agreement between producer and PRO, whereas the municipality is responsible for the collection. As this creates conflict, the DPA suggest that third party initiatives should not be extensions from the municipality or the PRO's (Bøwig, 2022).

The representative from Nilfisk also supported the inclusion of third party organizations to increase reuse and PfR of consumer products (Morales, 2002). He specified that consumer products are more suitable rather than products sold to businesses, as the latter often consists of larger machines that follow safety requirements within the Machinery Directive 2006/42/EC. Furthermore he states:

> My first thought is that we would have to make sure that we can coordinate this with our current EPR and our PRO. It makes sense that the interaction with a third party organization is facilitated by a PRO that screens potential organizations to make sure that the whole process is done in a safely manner.

At the moment Nilfisk has no data or control over the amount of products that are reused, even though the products produced have a high degree of repairability. If the PRO's can facilitate the reuse and repairability of Nilfisk's products by third party organization, Nilfisk can obtain data on the amount that is repaired and reused in relation to the products put on the market. This data can consequently help Nilfisk in understanding the repairability of their products in practice (Morales, 2022).

7.0.6 Marking of electronic products

Morales (2022) introduced that marking of products could facilitate reuse and PfR of specific components in the WEEE management system, predominantly for the PRO's and potential third party organizations. By clearly identifying the pieces of the product inside the individual components that requires special attention, such as heavy metals or flame retardants, the person handling the material can observe what component is hazardous and what component can be reused. Such a 'blueprint', according to Morales (2022), would facilitate reuse of individual components.

Maitre-Ekern (2022), proposed that electronic products should be marked in a way so it reflects the design for the environment of the product. She states the following:

> When you go to your shop at the moment, you see the price and that is about it. If you buy a washing machine, you will see the energy efficiency and that is already quite well developed. You can easily compare whether a certain machine will use more energy in consumption. That is what we need for repair and for durability.

Here she also gives the repairability index introduced in France as an example that indicates the repairability to the consumer. Furthermore, she indicates that this is something consumer are currently interested in and she therefore expects that it will cause a domino effect between producers, where produces will observe competitors and follow suit in the initiative (Maitre-Ekern, 2022). Furthermore, consumers could consequently see the labeling of a product on the repairability as the 'norm' and change their consumption pattern. However, whether such a label should be implemented by the WEEE Directive or another directive is not specified.

7.0.7 Summary

This chapter introduced points from the interviewees on how the WEEE management system can be improved to facilitate the core elements of a more circular economy.

Government intervention was to some extent mentioned by all interviewees. These included new legislation to improve collection methods, reuse quota's, and promotion of third party organizations. The pre-market producer responsibility was brought up as a principle that makes producers more responsible in extending the lifetime of electronic products. Harmonization of the WEEE Directive was mentioned to reach an equal playing field within the Member States through for instance a regulation instead of a directive. However, awareness is needed in regards to the tendency to form a middle

ground to facilitate Member States that are less developed. Also, modulated fees were mentioned to increase incentive to include ecodesign. The promotion of third parties were introduced as well, where it was specified that third party organizations should not be extensions from the municipality and that a focus should be on treating consumer products. Lastly, marking of electronic products was mentioned as a means to show the product's effort in ecodesign and to assist in dismantling of the product.

The following table provides an overview of the points introduced per interviewee:

	DPA (Bøwig, 2022)	Maitre-Ekern (2022)	Morales (2022)	Lindhqvist (2022)
Government Intervention	Intervention to increase quality of disposed products	Stricter rules on reuse quota by national policies or the WEEE Directive	National agreements should facilitate interaction between third party social enterprises	Requirements for the PRO that consumers hand in products that they state are reusable
Pre-market producer responsibility		Producers should be more responsible in extending lifetime of products		
Harmonization of the WEEE Directive	Regulation instead of Directive and Member states should receive guidelines			Harmonization might tend to form a middle ground to facilitate Member States that are less developed
Increase incentive to include ecodesign in EE	Modulated fee based on the product's environmental performance		Environmental fee should reflect the producers effort to increase ecodesign	
Promotion of third party initiatives	Third party initiatives are desirable, but should not be extensions from the municipality		Promotion of third party organization, but only for consumer products	
Marking of EE		Mark to show consumers the product's effort in ecodesign (similar to Energy Label)	Providing blueprint for individual components inside a product	

Figure 7.1: Points raised to promote reuse and PfR

Discussion

At the moment, the WEEE management system is very effective in recycling of EE. The prevalence of recycling can be explained with assistance of the Multi-Level Perspective theory introduced in Section 2. There are major technological, organizational and institutional constrains present that reduces the potential of PfR and reuse of WEEE. The concept of 'lock in' of the technologies facilitating recycling is grounded in the socio-technical regime and kept in place by landscape developments. For instance, the perception of recycling as the be-all and end-all of sustainable waste management is an example of exogenous trends keeping the existing regime, supported by societal values, but also macro-economic patterns, as recycling is currently more profitable than reusing. These landscape developments need to be changed in order to to put pressure on the current socio-technical regime.

8.0.1 Incorporation of a unified network of third party reuse centres

Based on the examined WEEE management system and initiatives on increasing reuse and PfR could be seen potential resolutions can be introduced. De Kringwinkel example in Flanders have illustrated that reuse of electronic products can be significantly increased by the introduction of a third party organization. Third party organizations on themselves are not only limited to Flanders, with multiple individual reuse centres across Member States. However a collective organization, consisting of 28 reuse centres and 145 reuse shops which are not extensions of the municipality nor any other actor in the traditional WEEE management system, is innovative. The main recommendation of this thesis is therefore to promote the creation of third-party organization, like De Kringwinkel, in Denmark.

In order to achieve this, there are several prerequisites that need to be met. Firstly, the manufacturers of electronic products need to support this development to allow the repairment of products by third party organizations. De Kringwinkel achieved this by offering full tracing of the product from its origin to repair and the sale of the products. This was then supported by the representative of Nilfisk, who stated that data on the amount of reused and repaired products could be beneficial in understanding the repairability of their products.

The second requirement is government intervention. The government should likely be the main driving factor by partly financing the operations. De Kringwinkel has shown that reuse shops - and centres can offer exceptional possibilities for the less fortunate on the labour market. A collective third party organization would create business and economic value, but also social equity and prosperity, therefore providing the government with an incentive. However, as de Kringwinkel has illustrated, a

collective third party organization would not prosper if not for a change in political vision that combines socio-economic factors with environmental factors.

The third requirement is collaboration between the PRO's and the third party organizations. Currently, the PRO receives an environmental fee from the producers and therefore receives the right to manage the EE after it is discarded. The PRO's require an incentive or a decree to allow third party organization to extract potential repairable and reusable products. Incentives can be made, by for instance providing a small fee to the PRO when a product is sold or sharing the responsibility in collecting and sorting of WEEE. This can be further strengthened if consumers are aware and can identify products with potential of reusability or repairability before disposing it.

Based on these requirements the following image is made that illustrates the incorporation of a third party organization in the WEEE management system. A red colour is added where changes were made from the original image introduced in chapter 1. Here the "overlying organization" is added, and a flow from consumers directly to the third party organization depicting take back of products from the consumers. Also a flow from the EPA to the overlying organization is added, illustrating the proposed financial support by the government.

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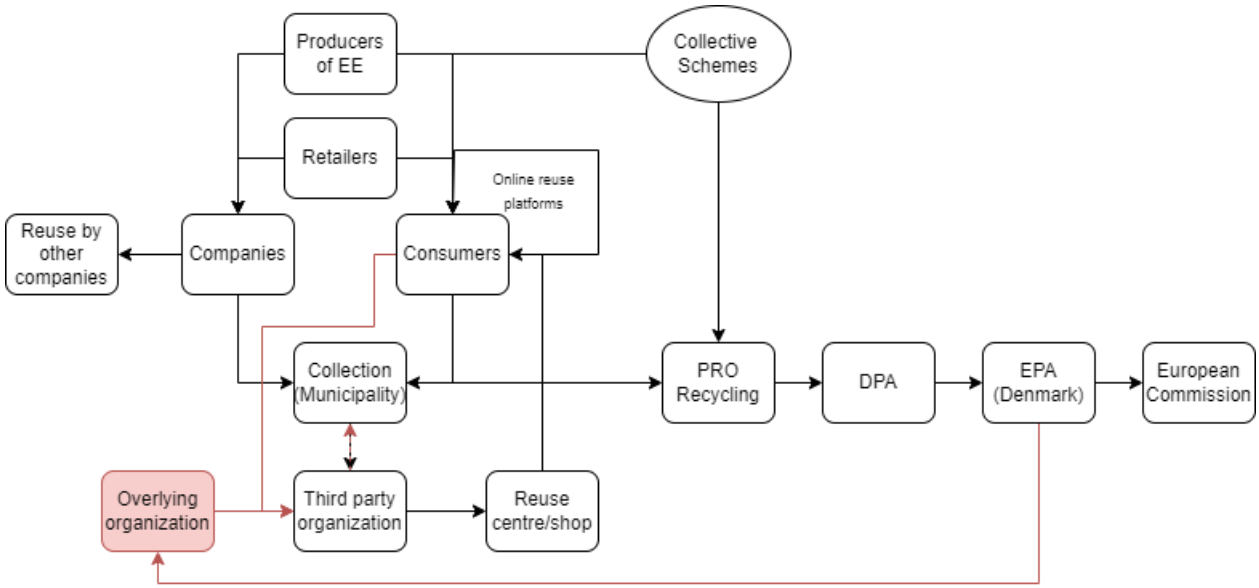

Figure 8.1: WEEE management system where third party organizations are incorporated.

Third party organizations in Denmark that repair and provide reused products are not uncommon. For instance, municipal household waste recycle and reuse centres are already present, such as the AVV in Hjørring, located in Northern Denmark. However, these reuse centres do not have much lobbying power on their own. This was also highlighted in the exploratory interview with the representative of

AVV, that reflected on the challenges in reaching an agreement with PRO's, especially as the PRO's have the legal right on the disposed products (Riisgaard, 2022). If third party reuse centres are combined together, their lobbying power will increase and might therefore reach more favourable deals, as well as being the driving force behind processes of professionalization and innovation in the sector (Cools and Oosterlynck 2015), which is illustrated by Herwin, the overlying organization of De Kringwinkel. A third party organization can also benefit the PRO's by sorting the WEEE for reuseable products, thus reducing expenses for PRO's to sort WEEE one one's own.

The recommendation of a third party is based on the success De Kringwinkel obtained in facilitating reuse of electronic products but also due to the challenges preventing PfR and reuse in in the current WEEE management system. In this thesis it is argued that the rate of innovation is likely higher when third party organizations are included rather than an existing actor in the system. An actor, which is also focused on recycling has lower tendency to innovate as there is also profit in the current way of recycling. A third party organization is more likely to innovate as they rely on the profits made by repairing electronic products.

Individual success factors are hard to predict for each specific Member State. However, the success factors from de Kringwinkel could be seen as an example. The creation of a single brand would be recommended in order to show customers that the products they sell are of high quality. This would therefore positively influence the perception of reuse, where the lack of trust in reusable products was highlighted by several interviewees. Furthermore, it can affect the 'graveyard' principle in a positive way, where consumers have more trust in the collection system and are more likely to dispose their products at the collection system.

Not all success factors discussed on De Kringwinkel are applicable for Denmark. For instance, the early incorporation of De Kringwinkel in the Flemish Waste policy cannot be replicated. De Kringwinkel was a result of several reuse centres utilizing the untapped potential of household waste to provide conscious consumers with reused products back in the nineties (Hirsbak 2022). As the emergence of these reuse centres coincided with the development of waste policies in Flanders, it opened up a possibility for the Flemish government to combine socio-economic factors and environmental factors. This can be further explained with assistance of the Multi-Level Perspective theory. The several reuse centres can be perceived as a small market niche that, with assistance of trends in the socio-technical landscape, created opportunities for this market niche to transit into the regime. Currently in Denmark, this pressure from the socio-technical landscape seems to be absent, making it more challenging for a similar unified network of third party reuse centres, to enter the regime.

8.0.2 Additional recommendations

Other recommendations where discussed in this thesis to improve the reuse rate of WEEE. These included incentivizing producers to put higher emphasis on ecodesign. The Ecodesign Directive promotes this as of now, however the WEEE Directive could further advocate this by offering modulated fees reflecting the ecodesign of an electronic product. Introducing mandatory reuse targets could also benefit ecodesign of products as the the PRO's and Member State have a legal requirement to increase reuse targets and can put pressure on producers to emphasize ecodesign.

Harmonization of the WEEE Directive is also presented as a driving force to increase reuse and PfR. One of the challenges discussed in section 5 was that there are constraints in regards to the reporting of WEEE (Andersen 2021). Morales, 2022 elaborated that Member states report the numbers on WEEE differently, either in weight sold, volume, size or value of the product. Especially as producers are often situated throughout different Member States a consistent reporting of the WEEE would reduce the administrative burden on producers. For instance, a digital system linking the producers with the same method of reporting would be beneficial.

Other recommendations to improve the repairability and PfR of electronic products can be received from the repairability index in France and the ReMark in Ireland. These affect the amount of reuse indirectly by increasing the perception on reuse. The repairability index gives consumers an idea to what extent they are able to repair their product and might convince consumers to repair their product individually rather than discard them. A label such as the Irish ReMark can emphasize the environmental and social advantages of reuse and promote a more circular economy.

8.0.3 Limitations

This thesis has given general recommendations based on the various interviewees, the literature review, and document analysis. The challenges in regards to the WEEE management were laid out and the recommendations were made to resolve these constraints. However, this thesis does not provide resolutions for all constraints introduced in section 5. The concept of 'free riding', where producers do not register for the EPR scheme is challenging to resolve as the DPA is not aware of their existence and they avoid responsibilities. Furthermore, it is hard to determine who is the actual manufacturer and which company is further down in the distribution line. A study could be carried out that investigates the percentage of producers that are free riding and not present in the DPA's register.

The trans-boundary movement of electronic products is an additional constraint that this thesis does not provide a solution for. Even though 184 countries have signed for the Basel Convention, there is still a lack of enforcement of the export ban (Lee *et al.* 2018). A research has been done to promote location tracking on international movement by planting hidden trackers inside the product to assist

in enabling new ways to monitor and regulate trans-boundary movement Lee *et al.* (2018). However, more research can be done to further quantify and resolve the trans-boundary movement of WEEE.

Another limitation of this thesis is that solutions for these challenges could be more nuanced. For instance, implementation of modulated fees to incentivize design for the environment adds complexity to the EPR scheme and could result in additional issues and considerations. From a quick glance, adding a value to a product based on the extent a product is designed for the environment could become quite arbitrary if not defined correctly. Research is therefore necessary that investigates how to implement modulated fees based on the ecodesign of a product.

Another limitation of this thesis is the generalization of the Member States. Even though many Member States have similar WEEE management systems in terms of delegating the EPR to collective schemes from PRO's, there are individual differences between the Member States. Recommendations, such as harmonizing the WEEE Directive throughout Member States, or success factors for implementation of third party organizations could vary significantly.

Furthermore how a unified network of third party reuse centres is to be implemented in Denmark in detail is not discussed. For instance, it would be interesting to get an understanding how the specific reverse logistics, cooperation with the PRO's, and environmental fees should be carried out. Furthermore, as an interview with the largest PRO in Denmark was not possible, this thesis lacks the point of view of one of the major actors in the WEEE management system. A pilot test on the feasibility of a unified network could therefore be very useful.

This thesis did not focus on a single product nor a single category. As previously mentioned, since 2018 there are 6 WEEE categories that are quite distinct from each other. Moreover, the environmental potential of reuse differs between various product categories.Focusing on a single product in the WEEE Directive could give more specific results for a category.

Conclusion

This conclusion will summarize the main points of this thesis and will answer the problem formulation and its three sub-questions. The problem formulation was as followed:

> *How can the WEEE management system be improved to incentivize preparation for reuse and reuse of WEEE in Denmark?*

Currently, recycling of WEEE is the most common EoL scenario for electronic products in the Danish WEEE management system. In order to provide recommendations to promote PfR and reuse of WEEE, the challenges regarding the current system were laid out. This was done with assistance of a literature review (n=20) and a series of qualitative interviews with experts in the field of circular economy, the Danish WEEE management system, and the extended producer responsibility. The constraints in regards to the WEEE mannagement system are multidimensional, where challenges were present in the current collection system of electronic products, the 'lock in' of technologies facilitating recycling, inefficiency of reverse logistics, the public perception on reuse, shortcoming of an economic incentive to promote reuse, and lack of involvement of the producer in the EoL phase of the products. The effort of other Member States to promote reuse of electronic products were demonstrated to serve as examples on how reuse and PfR can be increased. De Kringwinkel in Flanders showed that a unified network of centres can incentivize reuse by coupling of reuse and social employment, the incorporation of this network in the waste policy, and the importance of demonstrating professionalization by creating a quality brand to increase the consumer's perception on reuse. Furthermore, the repairability index implemented in France showed that facilitating access of consumers to repair can promote reuse. The Irish ReMark quality standard has illustrated the importance of quality labeling to combat the stigma consumers have on used products. These examples of advocating reuse in other Member States and recommendations given by several experts and actors through qualitative interviews, were used to form the main recommendation. The creation of a unified network of reuse centres, such as De Kringwinkel, is the main recommendation to incentivize PfR and reuse of WEEE in Denmark. Prerequisites to meet this recommendation need to be met: The manufacturers of electronic products need to support this development, the government needs to assist this transition, and collaboration between PRO's and these third party organizations is required. Other recommendations to increase PfR and reuse in Denmark were also listed. These include the harmonization of the WEEE Directive across Member States, the implementation of modulated fees to promote ecodesign by producers, and the marking of electronic produicts to facilitate easy disassembly, but also demonstrate the product's effort in ecodesign. There are still challenges in regards to the WEEE management that are not resolved, such

as the trans-boundary movement of WEEE and the 'free riding' where producers can avoid taking responsibility on the EoL of their products. Furthermore, more research is needed to the details in how a unified network of reuse centres should be implemented, and how collaborations with the PRO and producers should be made.

Bibliography

Aminoff, A. and H. Sundqvist-Andberg, 2021 Constraints leading to system-level lock-ins—the case of electronic waste management in the circular economy. Journal of Cleaner Production **322**: 129029.

Andersen, T., 2021 A comparative study of national variations of the european weee directive: manufacturer's view. Environmental Science and Pollution Research p. 1–20.

Andersen, T. and B. Jæger, 2021 Circularity for electric and electronic equipment (eee), the edge and distributed ledger (edge&dl) model. Sustainability **13**: 9924.

Andersen, T., B. Jæger, and A. Mishra, 2020 Circularity in waste electrical and electronic equipment (weee) directive. comparison of a manufacturer's danish and norwegian operations. Sustainability **12**: 5236.

Boldoczki, S., A. Thorenz, and A. Tuma, 2020 The environmental impacts of preparation for reuse: A case study of weee reuse in germany. Journal of Cleaner Production **252**: 119736.

Börner, L. and D. L. Hegger, 2018 Toward design principles for sound e-waste governance: A research approach illustrated with the case of the netherlands. Resources, conservation and recycling **134**: 271–281.

Business Research Methodology, 2022 Abductive reasoning (abductive approach).

Bøwig, J., 2022 Interview. Conducted by Idzerda S 20-04-2022 .

Clarke, C., I. D. Williams, and D. A. Turner, 2019 Evaluating the carbon footprint of weee management in the uk. Resources, Conservation and Recycling **141**: 465–473.

Cole, C., T. Cooper, and A. Gnanapragasam, 2017 Extending product lifetimes through weee reuse and repair: opportunities and challenges in the uk. 2017 Electronics Goes Green 2017+(EGG) p. 1–9.

Cole, C., A. Gnanapragasam, T. Cooper, and J. Singh, 2019 An assessment of achievements of the weee directive in promoting movement up the waste hierarchy: experiences in the uk. Waste Management **87**: 417–427.

Commission, E., 2016 Ecodesign Working Plan 2016-2019. Technical Report 773.

Cools, P. and S. Oosterlynck, 2015 De kringwinkel: a symbiosis between jobs for the long term unemployed and waste reduction? .

Cordella, M., F. Alfieri, J. Sanfelix, S. Donatello, R. Kaps, *et al.*, 2020 Improving material efficiency in the life cycle of products: a review of eu ecolabel criteria. The International Journal of Life Cycle Assessment **25**: 921–935.

Coughlan, D. and C. Fitzpatrick, 2020 Trialling the preparation for reuse of consumer ict weee in ireland. Journal of Cleaner Production **256**: 120512.

De Kringwinkel, 2019 Kringmagazine 2019. Kringmagazine **1**.

De Kringwinkel, 2022 Kies voor tweedehands, ga voor De Kringwinkel.

De Meester, S., P. Nachtergaele, S. Debaveye, P. Vos, and J. Dewulf, 2019 Using material flow analysis and life cycle assessment in decision support: A case study on weee valorization in belgium. Resources, Conservation and Recycling **142**: 1–9.

Downey, C., 2019 Final Report Template for Project Based Awards1 and Green Enterprise Projects. Technical report.

ECEEE, 2022 Ecodesign and labelling.

El Bilali, H., 2019 The multi-level perspective in research on sustainability transitions in agriculture and food systems: A systematic review. Agriculture **9**: 74.

Elia, V., M. G. Gnoni, and F. Tornese, 2018 Improving logistic efficiency of weee collection through dynamic scheduling using simulation modeling. Waste management **72**: 78–86.

EMRl, 2022 What is ReMark? | Eastern Midlands Western Region.

European Commission , 2014 Frequently Asked Questions on Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE). Technical report.

European Commission, 2020a A new Circular Economy Action Plan. Technical report.

European Commission, 2020b COMMISSION DECISION (EU) 2020/1804 of 27 November 2020 establishing the EU Ecolabel criteria for electronic displays . Technical Report 402/73.

European Commission, 2022a Electronic equipment.

European Commission, 2022b Over energielabels en ecodesign.

European Commission, 2022c Waste Framework Directive.

Europees Ecolabel, 2022 Home.

Eversheds Sutherland and M. Gough, 2022 Right to repair rules introduced in Europe- Publications - Eversheds Sutherland.

Ferronato, N. and V. Torretta, 2019 Waste mismanagement in developing countries: A review of global issues. International journal of environmental research and public health **16**: 1060.

Geels, F. W., 2011 The multi-level perspective on sustainability transitions: Responses to seven criticisms. Environmental innovation and societal transitions **1**: 24–40.

Grant, K., F. C. Goldizen, P. D. Sly, M.-N. Brune, M. Neira, *et al.*, 2013 Health consequences of exposure to e-waste: a systematic review. The lancet global health **1**: e350–e361.

Habib, H., M. Wagner, C. P. Baldé, L. H. Martínez, J. Huisman, *et al.*, 2022 What gets measured gets managed–does it? uncovering the waste electrical and electronic equipment flows in the european union. Resources, Conservation and Recycling **181**: 106222.

Hirsbak, S., 2022 Intereg project FUTURE, case 7, AAU report about the Kringwinkel case. Technical Report 1.

Hoornweg, D., P. Bhada-Tata, and C. Kennedy, 2013 Environment: Waste production must peak this century. Nature **502**: 615–617.

Huulgaard, R. D., R. Dalgaard, and S. Merciai, 2013 Ecodesign requirements for televisions—is energy consumption in the use phase the only relevant requirement? The International Journal of Life Cycle Assessment **18**: 1098–1105.

Islam, M. T. and N. Huda, 2018 Reverse logistics and closed-loop supply chain of waste electrical and electronic equipment (weee)/e-waste: A comprehensive literature review. Resources, Conservation and Recycling **137**: 48–75.

Johnson, M., K. McMahon, and C. Fitzpatrick, 2020 A preparation for reuse trial of washing machines in ireland. Sustainability **12**: 1175.

Kumar, A., D. Gaur, Y. Liu, and D. Sharma, 2022 Sustainable waste electrical and electronic equipment management guide in emerging economies context: A structural model approach. Journal of Cleaner Production pp. 130391.

Kvale, S., 2007 Planning an interview study. Doing interviews **1**: 34–51.

Laubinger, F., A. Brown, M. Dubois, and P. Börkey, 2021 Modulated fees for extended producer responsibility schemes (epr) .

Lee, D., D. Offenhuber, F. Duarte, A. Biderman, and C. Ratti, 2018 Monitour: Tracking global routes of electronic waste. Waste management **72**: 362–370.

Lindhqvist, T., 2000 *Extended producer responsibility in cleaner production: Policy principle to promote environmental improvements of product systems*. Lund University.

Lindhqvist, T., 2022 Interview. Conducted by Idzerda S 19-04-2022 .

Liu, Z., M.-D. Wan, X.-X. Zheng, and S. L. Koh, 2022 Fairness concerns and extended producer responsibility transmission in a circular supply chain. Industrial Marketing Management **102**: 216–228.

Lu, B., J. Yang, W. Ijomah, W. Wu, and G. Zlamparet, 2018 Perspectives on reuse of weee in china: lessons from the eu. Resources, Conservation and Recycling **135**: 83–92.

MacArthur, E., 2015 Towards a circular economy: business rationale for an accelerated transition. Accessed October **25**: 2016.

Maitre-Ekern, E., 2021 Re-thinking producer responsibility for a sustainable circular economy from extended producer responsibility to pre-market producer responsibility. Journal of Cleaner Production **286**: 125454.

Maitre-Ekern, E., 2022 Interview. Conducted by Idzerda S 25-04-2022 .

Maitre-Ekern, E. and C. Dalhammar, 2016 Regulating planned obsolescence: a review of legal approaches to increase product durability and reparability in europe. Review of European, Comparative & International Environmental Law **25**: 378–394.

McMahon, K., M. Johnson, and C. Fitzpatrick, 2019 Enabling preparation for re-use of waste electrical and electronic equipment in ireland: Lessons from other eu member states. Journal of Cleaner Production **232**: 1005–1017.

Ministry of Environment of Denmark, 2022 Electronical waste (WEEE).

Moher, D., A. Liberati, J. Tetzlaff, D. G. Altman, and P. Group*, 2009 Preferred reporting items for systematic reviews and meta-analyses: the prisma statement. Annals of internal medicine **151**: 264–269.

Morales, A. H., 2022 Interview. Conducted by Idzerda S 23-05-2022 .

Nasiri, M. S. and S. Shokouhyar, 2021 Actual consumers' response to purchase refurbished smart-

phones: Exploring perceived value from product reviews in online retailing. Journal of Retailing and Consumer Services **62**: 102652.

O'Connell, M., C. Fitzpatrick, and S. Hickey, 2011 Weee reuse trials in ireland. I *Proceedings of the 2011 IEEE International Symposium on Sustainable Systems and Technology*, p. 1–6, IEEE.

OVAM, 2015 Hoe een kringloopwinkel opstarten? Een overzicht van meer dan twee decennia hergebruik in Vlaanderen. Technical Report 1.

Parajuly, K. and H. Wenzel, 2017a Potential for circular economy in household weee management. Journal of Cleaner Production **151**: 272–285.

Parajuly, K. and H. Wenzel, 2017b Product family approach in e-waste management: a conceptual framework for circular economy. Sustainability **9**: 768.

Peeters, J., P. TECCHIO, F. ARDENTE, P. Vanegas Pena, D. COUGHLAN, *et al.*, 2018 edim: further development of the method to assess the ease of disassembly and reassembly of products: application to notebook computers .

Polverini, D. and U. Miretti, 2019 An approach for the techno-economic assessment of circular economy requirements under the ecodesign directive. Resources, Conservation and Recycling **150**: 104425.

Reeves, S., M. Albert, A. Kuper, and B. D. Hodges, 2008 Why use theories in qualitative research? Bmj **337**.

Remmen, A., 2012 Eco-design requirements for televisions .

Right to Repair Europe, 2021 The French repairability index: challenges and opportunities.

Riisgaard, H., 2022 Interview. Conducted by Idzerda S 16-03-2022 .

Sachdeva, A., 2021 Extended Producer Responsibility and Ecomodulation of Fees. Technical report.

Sarjaš, A., 2018 Ecodesign of electronic devices. Technical Report UNIT 7.

Seuring, S., M. Müller, M. Westhaus, and R. Morana, 2005 Conducting a literature review—the example of sustainability in supply chains. Research methodologies in supply chain management p. 91–106.

Shittu, O. S., I. D. Williams, and P. J. Shaw, 2021 Global e-waste management: Can weee make a difference? a review of e-waste trends, legislation, contemporary issues and future challenges. Waste Management **120**: 549–563.

Sousa, R., E. Agante, J. Cerejeira, and M. Portela, 2018 Eee fees and the weee system–a model of efficiency and income in european countries. Waste Management **79**: 770–780.

Statista, 2022 Replacement cycle length of smartphones in the United States 2014-2025, in years.

Steward, T., 2012 A Brief Introduction to the Multi-Level Perspective (MLP).

Svensson, S., J. L. Richter, E. Maitre-Ekern, T. Pihlajarinne, A. Maigret, *et al.*, 2018 The emerging 'right to repair'legislation in the eu and the us. Proceedings from Going Green–Care Innovation p. 27–29.

Tisserant, A., S. Pauliuk, S. Merciai, J. Schmidt, J. Fry, *et al.*, 2017 Solid waste and the circular economy: a global analysis of waste treatment and waste footprints. Journal of Industrial Ecology **21**: 628–640.

United States Department Of Agriculture, 2022 Difference between a Regulation, Directive and Decision.

Urban, B., K. Roth, M. Singh, and D. Howes, 2017 Energy consumption of consumer electronics in us

homes in 2017: Final report to the consumer technology association. Center for Sustainable Energy Systems Fraunhofer USA: Plymouth, MI, USA .

Velenturf, A. P., S. A. Archer, H. I. Gomes, B. Christgen, A. J. Lag-Brotons, *et al.*, 2019 Circular economy and the matter of integrated resources. Science of the Total Environment **689**: 963–969.

Williams, I., 2015 Hierarchy history. CIWM Journal **2015**: 20–22.

World Bank Group, 2018 What a waste 2.0. Technical report.

Zacho, K. O., A. M. Bundgaard, and M. A. Mosgaard, 2018 Constraints and opportunities for integrating preparation for reuse in the danish weee management system. Resources, Conservation and Recycling **138**: 13–23.

9.1 Appendix

The interview guides used for the interviews are present in the following document:

Link to Interview guides