Sustainable Development Programme, Natural Resources Management Track
at the University of Utrecht and the University of Leipzig

The Influence of Extended Producer Responsibility on Eco-Design Practices:

Insights from Six Producer Case Studies in the European ICT Sector

Master Thesis

45 ECTS

Submission: August 6 2012

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Abstract

Background: E-waste constitutes an increasing problem due to its growing amount and its hazardous substances content, and stands diametrically opposed to an increasing resource scarcity. In response, the EU introduced the WEEE Directive, which embraces the market-based policy principle of Extended Producer Responsibility (EPR). EPR requires electronics manufacturers to take their products back and organise proper end-of-life management. The assumption that this would promote eco-design practices, as manufacturers have an incentive to design products that are easier to treat and recycle, is contested in the academic literature. Particular disagreement concerns the question if producers have to fulfil their responsibility individually or may also choose a collective approach.

Method: This thesis aims to enrich the discussion of EPR by empirical insights from in the ICT sector. To this end, six producers were examined through a qualitative multiple case study approach: Dell, HP, LG, Nokia, Philips, and Sony. The case studies are largely based on expert interviews with company representatives; additional information was gathered from company websites, annual and CSR reports, white papers, available case studies and NGO reports.

Results: The examined producers adopt different approaches of EPR compliance. While all producers rely on collective systems, some run additional individual schemes in order to gain competitive edge. Three feedback loops from end-of-life management to the production phase are identified, by which EPR can potentially influence eco-design. Informational feedback is found to have the strongest influence, followed by financial feedback. Material feedback loops are hardly established, which suggests that EPR does not contribute significantly to the closure of material loops. Furthermore, seven eco-design strategies with end-of-life relevance are identified. The examined producers are particularly active with regards to conducting measures that reduce the waste treatment costs, as well as increasing their use of recycled materials. Strategies to reduce the volume of WEEE are conducted by half of the sample, and strategies that promise to increase the amount of recovered materials are the least relevant.

Conclusions: The findings of this thesis suggest that EPR, as implemented in the WEEE Directive, positively affects eco-design. Next to the identified feedback loops, EPR promotes eco-design through several mediate effects. The principle has raised awareness of the e-waste problem and contributed to a shifting mindset among ICT producers.

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Abbreviations

BBP	Benzylbutylphthalate
CPR	Collective Producer Responsibility
CRT	Cathode Ray Tube (TV)
CSR	Corporate Social Responsibility
DBP	Dibutyl Phthalate
DEHP	Disethylhexylphthalate
EPR	Extended Producer Responsibility
ICT	Information and Communication Technology
IPR	Individual Producer Responsibility
PRO	Producer Responsibility Organisation
PVC	Poly Vinyl Chloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Directive)
RoHS	Restriction of Hazardous Substances (Directive)
WEEE	Waste Electronic and Electrical Equipment

"The biggest problem with progress is that the disadvantages develop, too."
Ernst Ferstl

1. Introduction

1.1. The e-waste problem

Life today would be unimaginable without information and communication technology (ICT). ICT has influenced the way we work, live, leisure and communicate, the way in which we perceive the world and organise our society. In the last 20 years, mobile phones have become our constant companions and computers have conquered nearly every office and home. The ample benefits of the 'digital revolution', as this development has been termed, are obvious. Communication has never been as fast and easy, information has never been as readily available, and possibilities have never been as manifold as they are today. Unsurprisingly, electronics arouse a certain sense of fascination. State-of the art devices are perceived as symbols of progress. New developments take place continuously. Devices become increasingly complex, small and powerful. At the same time electronics become increasingly affordable, what enables more and more people around the globe to participate in the digital revolution.

However, there are also severe downsides to this development. Both the production and the disposal of electronic equipment pose significant challenges to sustainable development. This thesis will mainly focus on the second aspect: the problem of electronic waste (or e-waste). However, many linkages to the production phase exist, as will be pointed out later.

Three main issues characterise the problem:

1. *The amount of e-waste grows steadily.* Electronic products have become ubiquitous and continue to expand to new fields of applications. According to the Consumer Electronics Association (2012) the average US household today owns 24 electronic devices. A similar figure can be assumed for the European Union. In addition to that, there are ever shorter periods of time until devices become outdated and are replaced. This is particularly the case for ICT products. Moore's law[1], which states that processor and memory chips double in speed and performance approximately every two years, has proven to be an adequate estimation. Software requirements, feature upgrades, and lifestyle fashions change accordingly. According to Greenpeace (2011b), the average lifespan of personal computers in developed countries has dropped to just two years and mobile phones are replaced every 18 months. What once has been a valuable high-tech product suddenly becomes obsolete electronic waste. As electronics become affordable for an increasing number of people globally this dynamic exacerbates. As a result, the amount of annually generated e-waste is on the rise. Current estimations amount to 40 million tons a year globally, of which 8.2 – 9.1 million tons are generated in the EU alone (Huisman et al. 2007; Schluep et al. 2007). Currently this makes up only about 5 % of the municipal waste stream in Europe, but the amount is expected to grow annually by 2.5 % or more (Huisman et al. 2007; Shinn 2005). The growing amount of e-waste becomes an increasing financial burden for municipalities. Moreover, space limitations, hazardous

[1] Named after Intel co-founder Gordon E. Moore who is credited for having recognized this development first. (Moore 1995)

substance (see 2.) and resource scarcity (see 3.) make landfilling and incineration an unacceptable option.

2. *E-waste is a burden to the environment.* Apart from valuable metals and slowly degrading plastics, discarded electronics contain various toxic and hazardous substances. When landfilled or incinerated they can contaminate large areas with long-lasting consequences to the environment and human health. Hence, they need to be separated from other waste and require expensive special treatment. Leaching of these substances from e-waste already caused severe environmental degradation in many developing countries (Robinson 2009). There are numerous known or presumed effects on human health, such as damage to the liver, heart, brain, nervous and respiratory systems, as well as carcinogenic effects (Wong 2008). Some of these substances (lead, mercury, cadmium, and PVC) have been banned in the EU by the RoHS Directive (2003) and the REACH Directive (2006). However these regulations have many exemptions and leave many other problematic substances unrestricted

Hazardous substance	Use
Lead	CRTs, circuit boards, solder
Mercury	Circuit boards, switches, screen lamps
Cadmium	Plated contacts and switches
Poly vinyl chloride (PVC)	Insulation of wires
Brominated flame retardants	Circuit boards, insulation of wires
Chlorinated flame retardants	Circuit boards, insulation of wires
Phthalates, particularly - Disethylhexylphthalate (DEHP) - Benzylbutylphthalate (BBP) - Dibutyl phthalate (DBP)	Plasticisers (softeners)
Antimony	Solders, conductors
Beryllium	Connection slots

Table 1: Hazardous substances common in ICT products (based on Greenpeace 2010, Sinha 2004, and Tsydenova and Bengtsson 2011)

3. *Growing amounts of e-waste stand diametrically opposed to an increasing resource scarcity and problems connected to mineral extraction.* The increasing pressure on natural resources is a significant sustainability problem touching economic, environmental, and social aspects. Resource scarcity can have significant economic impacts if the increasing demand (c.f. Angerer et al. 2009) cannot be satisfied anymore. Critical minerals for ICT products include cobalt, germanium, palladium, tantalum (extracted from coltan), silver and rare earth minerals (European Commission 2010). Moreover the extraction of most virgin materials causes long-lasting environmental impacts, including land and air pollution and significant transformations of landscapes. Furthermore, mining activities often contribute to and intensify local social problems, particularly in conflict areas, but also due to the social consequences of environmental destruction (Richert and Richter 2010; Young 2000). An effective recovery of components and materials from e-waste could alleviate the situation, but recycling is still considered expansive and often not profitable. To a large extend this is due to an undervaluation of primary resources resulting from perverse incentives and

the externalisation of costs to society (Young 2000). But also the complexity and variety of electronic products complicates the recovery process and reduces profitability. Most valuable materials in waste electronics are contained in small parts in microscopic quantities. Larger elements made up of other non-ferrous and ferrous metals, plastics, glass and ceramics can usually be recycled, but are often intermingled unfavourably so that only one material can be recovered (van Rossem 2008).

1.2. Extended Producer Responsibility as the solution?

The European Union reacted to the problem of e-waste with an innovative, market-based policy approach. In 2003 the Commission issued the Directive on Waste Electronic and Electrical Equipment (WEEE Directive), which embraces the concept of Extended Producer Responsibility (EPR). The basic idea is that manufacturers[2] of electronic goods are held responsible for the end-of-life management of their products. They are obliged to take their products back after the consumer discarded them, organise proper treatment and bear the costs of recycling, but may also yield the benefits if valuable materials can be regained in the process. It is assumed that this will provide producers with an incentive to design their products in such a way that they are easier to recycle, contain fewer materials, especially fewer hazardous ones, live longer, or are easier to be reused or remanufactured. In this way, EPR is expected to alleviate all three aspects of the e-waste problem characterised above and result in environmental benefits over the products whole life-cycle.

The EU's adoption of the EPR concept is in line with a general trend towards market-based policy approaches to address environmental issues (van Rossem, Tojo, and Lindhqvist 2006a; Scheuer 2005). While conventional command and control legislation has been reasonably successful in regulating comprehensible problems within specified geographical boundaries, there are evident limitations in coping with the complexity of contemporary environmental problems (Kautto 2009). Scholars have criticised conventional approaches for their inflexibility, cost-ineffectiveness, poor capacity to resolve contradictions, limited scope, and their generally reactive nature (Glasbergen 1998; Meadowcroft 1999). Moreover, prescribed technology standards may discourage technological innovation (Jaffe, Newell, and Stavins 2003).

Contrary to conventional command and control regulation, market-based approaches aim at promoting desired behaviour by providing incentives instead of prohibiting undesired behaviour by enforcing legal standards. They do usually not prescribe specific solutions, but stipulate general objectives. A number of scholars have noted several advantages connected to this approach. First, in order to provide meaningful incentives, the relevant actors in a system, their interactions and system effects have to be taken into account. Thus, market-based approaches are more likely to bring about comprehensive solutions (Scheuer 2005). Second, more room is provided for creative and flexible solutions. Those concerned can adapt their compliance dynamically to their circumstances, technological progress and other developments (van Rossem, Tojo, and Lindhqvist 2006a). Third, collaborating with businesses and other major stakeholders can increase the problem-solving capacities of policymakers. Fourth, the inclusion of stakeholders in the process of policy formulation can lead to a higher acceptance of regulation

[2] The terms producer and manufacturer are used synonymously in this thesis.

(Scheuer 2005). And fifth, involved business actors may begin to institutionalise the proposed policy principles, and integrate them into their own objectives (Jennings and Zandbergen 1995).

However, nine years after the WEEE Directive has been introduced, its outcomes are contested. While it is difficult to measure the effects of the Directive on product design quantitatively, criticism has extended to the EPR concept itself, which is considered to fail in providing the desired incentives (Gottberg et al. 2006; Huisman et al. 2007; Sachs 2006). Some authors therefore voice support for more regulative approaches in order to tackle the e-waste problem (Sachs 2006). Proponents of EPR counter that the concept itself would work if it had not been watered down by wrong implementation in the member states (Castell, Clift, and Francae 2004; Dempsey et al. 2010; Lifset and Lindhqvist 2008; van Rossem, Tojo, and Lindhqvist 2006b; van Rossem 2008). Again others claim that even in its current form of implementation EPR has a positive influence on product design (Tojo 2001; WEEE Forum 2011a).

1.3. Research question and objectives

Until now, the debate on whether or not EPR and the WEEE Directive promote environmentally conscious product design has been largely fed by theoretical and juridical works. Empirical research is surprisingly scarce. Thus, this thesis aims to enhance the debate with empirical insights from the perspective of affected producers. To this end, six case studies of companies in the ICT sector are conducted.

The central research question addressed by this thesis is:

How and to what extend does Extended Producer Responsibility (EPR), as implemented by the WEEE Directive, promote eco-design among producers in the ICT sector?

The following theoretical chapter will help to specify the existing research gap. Adjacently, the research question will be revisited and refined into sub-questions. At the core of this thesis are six case studies on the takeback and eco-design approaches of producers in the ICT sector. The case studies provide empirical insights to answerer the research questions and enrich the discussion on Extended Producer Responsibility.

The thesis is structured into five main chapters. Adjacently to the introduction, chapter 2 sets out the theoretical foundation for this research. It explains the concept of EPR and its implementation through the WEEE Directive. Furthermore, it clarifies the notion of eco-design and describes its basic application. The chapter concludes with developing an explanatory model that brings down EPR theory onto the level of producers and explores the potential links between EPR and eco-design. Adjacently, chapter 3 explains the methodological foundation of this thesis. Chapter 4 comprises the descriptive part of the analysis, which consists of the six producer case studies. Chapter 5 then synthesises the empirical findings in a comparative analysis. On this basis, the final chapter summarises the findings and connects them to the ongoing discussions on EPR in the literature.

2. Theoretical Framework

2.1. Extended Producer Responsibility (EPR)

2.1.1 Basic assumption of EPR

According to its conceptual originator Thomas Lindhqvist, the concept of Extended Producer Responsibility (EPR) constitutes *"a policy principle to promote total life cycle environmental improvements of product systems by extending the responsibilities of the manufacturer of the product to various parts of the product's life cycle, and especially to the take-back, recovery and final disposal of the product"* (Lindhqvist 2000, 154).

EPR requires producers to take products back after consumers have discarded them. Adjacently, producers are obliged to organise waste management, ensure proper treatment, which is often tied to a certain recycling target, and bear the costs of it. The key assumption of EPR proponents is that this extended responsibility establishes a feedback loop to earlier stages of the product lifecycle. The basic reasoning is that rational market actors would react to this obligation by attempting to cut down the costs of waste treatment and increase the benefits from recycling by making changes in their product design (Fishbein 2000b; Lindhqvist 1992; van Rossem, Tojo, and Lindhqvist 2006a; Tojo 2004). In other words, the assumption is that EPR promotes the adoption of eco-design strategies, which results in less wasteful and better recyclable products.

EPR can be seen as an elaboration of another important axiom of sustainable development: the polluter pays principle (Sachs 2006). Both concepts identify producers as the main actors in the industrial process and require them to assume responsibility for environmental issues. Yet while the latter remains a retroactive approach to deal with problems that have already emerged, EPR attempts to prevent or minimize problems arising in the future. In this way, EPR goes beyond factory-based or end-of-pipe approaches. It transfers the polluter pays principle from the level of actors onto products and their specific environmental performances.

Although EPR, as a market-based approach, is often conceived in terms of costs and financial incentives, the principle is not limited to monetary aspects. Producer responsibility can also extend to a physical or informational dimension; Lindhqvist (1992) speaks of three 'types of responsibility'. *Financial responsibility*[3] means that producers bear the costs related to end-of-life treatment. *Physical responsibility* comprises the actual task of treating the products. It means that producers retain the ownership of products through take-back schemes and manage adequate treatment. *Informational responsibility* requires producers to provide information on the environmental properties of their products to consumers and, more importantly, to recyclers, so that they can optimise treatment processes accordingly (Lindhqvist 1992; Tojo 2004). The distinction between these three types of responsibility will play a role in the analytical part of this thesis.

2.1.2 Lifecycle perspective

EPR builds on a holistic perspective on products, which takes their whole life cycle into account (Figure 1). A product's lifecycle is typically conceived in six stages (in blue). Prior to production, a product's life begins with the acquisition and processing of required raw materials. Usually this

[3] Some authors use the term 'economic responsibility', e.g. Sachs (2006).

involves the extraction of virgin resources. The subsequent production phase comprises the manufacture of product components by suppliers, as well as the final assembly by the producer. Then, retailers distribute the product and sell it to a consumer who keeps using it as long as it satisfies his or her needs. Notably, product obsolescence may not only occur for functional, but also for technical or aesthetic reasons (Sinha 2004). While a still functional product may be passed on to further users it will eventually be discarded at the end of this chain. At this point the product reaches its end-of-life phase.

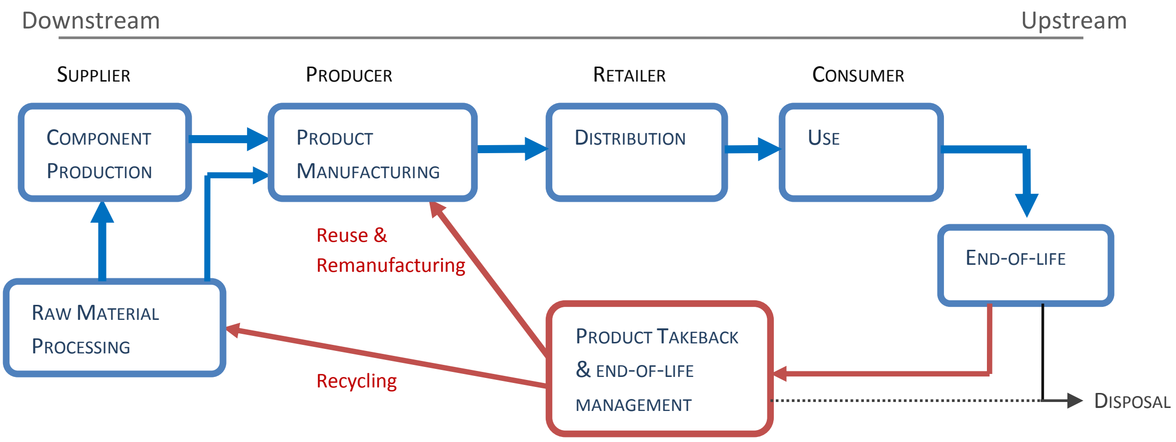

Figure 1: Product Lifecycle with EPR

Environmental impacts can occur at all stages of a product's life cycle. While other sustainable industry concepts such as 'green supply chain management' or 'eco-efficiency' emphasise the role of producers in reducing environmental impacts during pre-production and production phases, EPR picks up at the end-of-life stage of products. The common 'cradle to grave' scenario usually ends at this point. Product end-of-life is equalled with disposal, mostly in the form of landfill or incineration. Only some of the materials are recycled by external actors. Extended producer responsibility shifts the responsibility for product end-of-life management to producers and thereby adds a reverse supply chain to the picture (in red). Product takeback and end-of-life management includes the collection, sorting, disassembly and treatment of discarded products.

There are several possible treatment options. Direct reuse is the most preferable one from an environmental point of view. Yet, considering the rapidly changing product landscape in the ICT sector, reuse options are limited.[4] Remanufacturing allows for more adaptation to technological progress. In this approach, still functional components are recovered and rebuilt into new products. Refurbishing describes a related process, which aims at restoring the functionality of an original product. This is, however, often undertaken by third party manufacturers (Bryant 2009) and hence less relevant for an examination of EPR. Recycling describes the recovery of raw materials. The process is very energy intensive and therefore inferior to reuse and remanufacturing. Moreover, current recycling practices have been criticised of being often not more than *downcycling*, which means that materials are not regained in the original quality and end up being used for inferior products such as flower pots or road asphalt (McDonough and Braungart 2002). Finally, disposal through landfilling or incineration are the least preferable

[4] For products distributed through leasing arrangements there appears to be a higher reuse potential (Fishbein 2000a).

options, meaning a loss of materials (Fishbein 2000b). However, even with cutting edge facilities a fraction of WEEE remains that cannot be recycled and needs to be disposed of.

By creating the framework conditions for remanufacturing and recycling, EPR can help to close material loops. One may generally refer to closed-loop supply chains when producers take back end-of-life products and thus return the same materials that they had previously put on the market (Herold 2007). However, there are different degrees of immediacy, depending on who receives the recovered materials. A *direct closed loop* is achieved when materials or product components go straight back to the producer who uses them for new manufacture. When recovered materials are sold at secondary markets, there is an *indirect closed loop*. Although in this case the recovered materials are likely to be used for other purposes, they are kept within the industrial process and available for new production.

2.1.3 Producers in focus

There needs to be some clarification on the term 'producer'. Today's production patterns are strongly based on a global division of labour. Component production and assembly is performed in several steps and often outsourced to other companies. The main activity of producers became product design, marketing, sales, and supply chain management (Plepys 2002). Nevertheless, the producer remains the actor responsible for product development and is therefore the appropriate addressee of product responsibility. Actors involved at earlier production phases are called suppliers. While some studies refer to them as Original Equipment Manufacturers (OEM), this term is used with contradictory meanings elsewhere (Investopedia 2012) and therefore not applied in this thesis.

Some critics have questioned whether producers are indeed the right addressing to burden with the e-waste problem. Harsch (1999) argues that environmental problems are ultimately caused by consumers rather than by producers, since their preferences steer producer action. While consumer sufficiency is certainly an important issue in achieving sustainable development, reducing all policy efforts on this aspect would mean to focus merely on an end-of-pipe approach with limited effectiveness. Consumers may generally be able to steer product supply and production patterns into more sustainable realms, but they have hardly any influence on the specific environmental properties of products. Consumers cannot do much to increase a product's recyclability and a waste treatment levy is unlikely to influence consumption decisions in a high-price segment such as electronics. Without EPR, waste management is usually left to municipalities, which means an externalisation of costs on the general public. In this way those who create the waste have no incentive to reduce or recycle it.

Producers are arguably in the best position to manage end-of-life products. In other words, the approach "highlights the capabilities of producers" (Deutz 2009). They are the main identifiable knot in a product's lifecycle. Only they have the capacity to link end-of-life consideration with the prevention of damage at the source (van Rossem, Tojo, and Lindhqvist 2006a). Moreover, producers are the only stakeholders involved - with the possible exception of a small number of NGOs – that have global organisation capabilities (Marinelli 2008). From a socio-economic perspective, producer responsibility is the most cost-effective option, because the producer is in the best position to ensure low treatment costs and high recyclability, thus minimising the overall costs of e-waste to society. Prevention at the source is potentially cheaper and more effective than any later attempt to mitigate environmental damage.

2.1.4 Expected benefits of EPR

The literature does not agree on a specific set of goals of EPR. According to Lindhqvist and Lifset (1998) there are weak and strong understandings, ranging from the view that EPR is merely a tool for diverting WEEE away from landfilling to the view that EPR can improve the environmental performance of products throughout their whole lifecycle and close material loops. But also scholars endorsing a strong understanding of EPR do not concur with a uniform set of objectives. Van Rossem, Tojo and Lindhqvist (2006a) for instance speak of two principal goals: improving product design and improving resource efficiency; whereas the OECD (2001) lists four: resource conservation, waste prevention, eco-friendly product design and closure of material loops. Walls (2006) identifies even six goals: reduction of waste volumes generated, reduction of waste disposed, reduction of hazardous constituents in the waste stream, decrease in virgin material use, lowering of pollution in the production stage, and increased design for environment.[5] There are even more potential benefits that can be added to this list. Shifting responsibility to producers is considered to increase collection rates as well as to ensure that WEEE is collected separately and does not perish in the regular municipal waste stream (Fishbein 2000b).

Taking a wider sustainability perspective, EPR is considered an important step towards creating a circular economy. The vision of a circular economy has become a widely recognised notion in alternative economics and sustainable development discourses. It describes an industrial economy that overcomes waste and resource problems by closing material loops and feeding all materials back into either the industrial process or natural cycles. Most prominently, the idea of circular economy is captured in the kindred concepts of industrial ecology and cradle-to cradle. Industrial ecology aims at mimicking nature in industrial processes. Particular emphasis is thereby placed on cyclical patterns, symbiotic relationships and renewable energy (c.f. Vermeulen 2006). There are clear links between this concept and EPR. Industrial ecologists have generally proposed market-based policies to foster the application of the concept (Ayres 1989). Deutz (Deutz 2009) considers EPR as a first step towards a system-scale application. Herold (2007) even tends to equate EPR with industrial ecology. Braungart and Mc Donough's (2002) cradle to cradle approach is in many respects similar to industrial ecology. The basic idea is to overcome linear cradle to grave production, eliminate the concept of waste and establish cyclical material flows. The main difference to industrial ecology is a stronger emphasis placed on products. Several authors have made a connection between cradle to cradle and EPR (Kumar and Putnam 2008; Sachs 2006). Both concepts, albeit popular in the academic world, so far count few practical applications. Industrial ecology has been trialled in pilot projects in the form of so called eco-industrial parks (Deutz 2009; Vermeulen 2006). Cradle to cradle extends to a short list certified products (MBDC 2010). EPR can help to increase practical application of the concepts. A circular economy provides a vision for overcoming the problem of e-waste, even though establishing perfectly closed loops may be an ideal that can never be reached.

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[5] In her view this multitude of goals constitutes a problem, because a single policy cannot address all of them effectively (Walls 2006).

In this thesis, the focus is placed on the effects that EPR has on producers. It examines the assumptions connected to a strong understanding of the concept, particularly the assumption that EPR promotes eco-design. Furthermore, some consideration will be given to the extent in which closed material loops have been realised and to the question whether EPR can set the path for a circular economy.

2.1.5 Individual versus Collective Producer Responsibility

Before the influence of EPR can be examined in more detail, a central debate concerning EPR has to be considered. This debate relates to the dichotomy of individual and collective responsibility. *Individual Producer Responsibility (IPR)* refers to a situation where a producer is responsible for the end-of-life management of products of its own brands. *Collective Producer Responsibility (CPR)* describes a situation where several producers of the same product group manage their WEEE jointly and irrespective of brands (Tojo 2004). In the EPR literature and political commentary one can find numerous statements regarding this issue. The prevailing opinion is that while only the individual variant provides for strong design incentives, only the collective variant is practical (Atasu and Subramanian 2011; Lifset and Lindhqvist 2008; van Rossem 2008; Sachs 2006; Tojo 2004; Walls 2006).

Proponents of IPR argue that this variant offers better environmental results and ensures that proactive producers are rewarded with economic benefits (Dempsey et al. 2010). Some authors note that this is the original form of EPR (Lifset and Lindhqvist 2008). The argument is that IPR provides for strong design incentives because it establishes direct feedback loops that allow producers to benefit from easily treatable and recyclable products. Furthermore, producers are relatively safe from freeriders as they are only responsible for their own products. However, IPR also poses significant administrative and logistical challenges (Sachs 2006). Either differently branded products need to be collected and treated completely separated from each other or a brand sorting has to take place at one point. Both are considered very expensive. Moreover, there is a risk of duplicated infrastructure, which would be inefficient and raise costs even more (Veerman 2004). A further complication results from the relatively long time until a newly developed electronic product will find its way into the recycling scheme. The incentive for design improvements may suffer from this long payback time and the uncertainties connected to it. In addition, so-called orphan products, of which the producer has ceased to exist, fall out of the system and require a separate solution (Tojo 2004).

Considering these challenges, it appears reasonable for producers to join forces and manage their WEEE collectively. Proponents of CPR argue this is the simplest and most cost-effective way of implementing extended producer responsibility (WEEE Forum 2011a). In this way producers can achieve economies of scale resulting in cheaper and more effective collection and treatment (Walls 2006). Collective systems are also more convenient for consumers who can return all discarded products to a single system without having to worry about brand-specific requirements (Sinha 2004). Many policymakers seem to prefer this variant, because it guarantees that all returned WEEE is taken care of. When all products are handled by the same system regardless of any brand there is no need for an extra regulation regarding orphan products. CPR, however, involves significant drawbacks. When all brands are mixed and producers are charged with a flat fee based on average costs, producers cannot directly benefit from any design improvements they have made to enhance end of life management. Moreover, those producers who devote significant efforts and resources into enhancing product design end up subsidising those who do not (van Rossem, Tojo, and Lindhqvist 2006a). In a highly competitive market CPR may thereby invite producers to not spend any resources on eco-design and to freeride on the endeavours of their competitors instead.

As a reaction to the criticism of IPR, its proponents suggested that individual responsibility may also be achieved under collective treatment of WEEE. Fishbein (2000b) and van Rossem (2008) speak of a "common misunderstanding" of IPR that has become prevalent in many studies. It results from different interpretations to what IPR exactly means. Tojo (2004) has thrown light on the matter by applying the distinction of physical and financial responsibilities (see section 2.1.1) upon the IPR-CPR dichotomy. Accordingly, under *individual physical responsibility* products are treated and recycled in brand-specific schemes and "the producer has the control over the fate of their discarded products with some degree of involvement in the organisation of the downstream operation" (Tojo 2004, 273). Contrary to that, under *collective physical responsibility* "products of similar kind are physically handled together regardless of the brand and [...] the handling rests in the hands of a third party" (Tojo 2004, 273). Irrespective of whether there is individual or collective physical responsibility, financial responsibility may be organised individually or not.[6] *Individual financial responsibility* means that a producer bears the end-of-life management costs of its own products only. This does not necessarily require each producer to set up own recycling plants, but can also be realised under collective physical responsibility. If producers, however, pay a fee based on the average treatment costs of all products of similar kind regardless of brand, their *financial responsibility* is *collective.* (Tojo 2004)

This results in three possible set-ups:

	Individual physical responsibility	**Collective physical responsibility**
Individual financial responsibility	(full) Individual scheme	Hybrid scheme
Collective financial responsibility	not applicable	(full) Collective scheme

Table 2: Responsibilities in individual, collective, and hybrid schemes

- An **individual scheme** constitutes the full realisation of IPR. In such a scheme, producers bear both physical and financial responsibility individually by maintaining their own recycling schemes or contracting third parties who treat their products separately from WEEE of other brands. In this way producers bear the end-of-life costs of their own products and are directly involved in the treatment process. This is considered to provide for strong and direct feedback on product design. However, such a system requires that the products of one producer are collected individually or sorted out of the collective waste stream.

- In a **collective scheme**, producers organise WEEE treatment and recycling collectively. For this purpose, producers join producer responsibility organisations (PROs), which undertake the tasks of organising collection, ensuring proper treatment and recycling, and

[6] Of course, collective financing under physical IPR would not make much sense.

monitoring (WEEE Forum 2011b). These non-profit associations usually charge their members a fixed fee based on average end-of-life costs per ton or unit. When EPR is implemented in a collective system, this does not mean that there is no feedback anymore to product design. In a collective system, EPR can still provide 'collective feedback' on the environmental performance of products, which is indirect and therefore less powerful (Sander et al. 2007). Nevertheless, also collective feedback may have an effect on product design, for example when all producers in one scheme agree on certain ecological standards in order to reduce costs collectively (WEEE Forum 2011a).

- In a **hybrid scheme**, producers organise WEEE treatment and recycling collectively, but certain mechanisms are in place to ensure that the costs are connected to the individual products of each producer (cost-differentiation). In this way individual financial responsibility is established, as each producer pays only for the specific costs of its own products. Such a hybrid system promises to make EPR both economically feasible and environmentally effective. A hybrid system also gives immediate feedback on individual products and thus is seen to provide for strong design incentives (Dempsey et al. 2010; Sander et al. 2007).

Figure 2 summarises the different steps in individual, collective and hybrid systems:

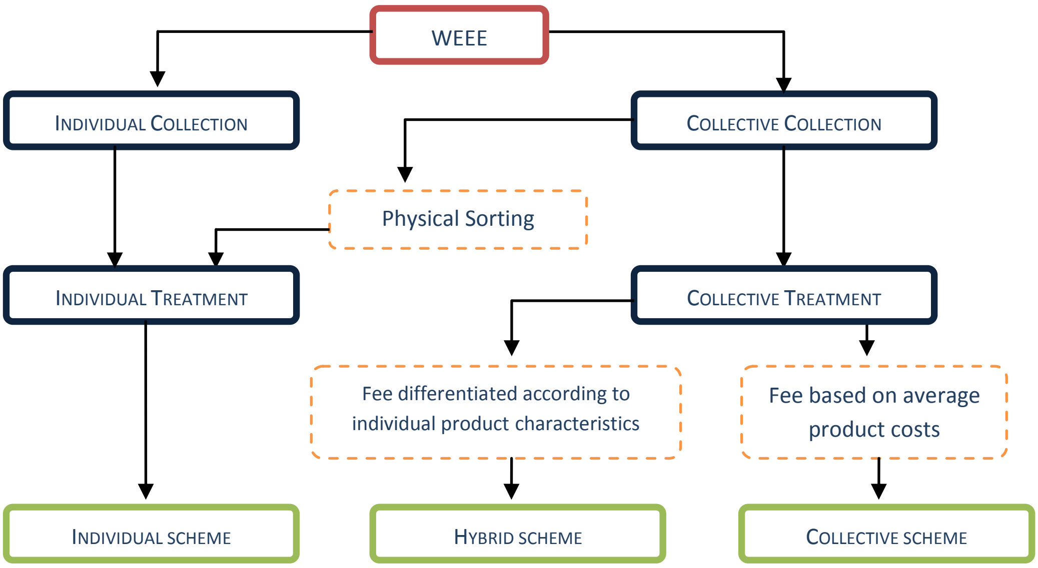

Figure 2: Visualisation of EPR approaches (adapted and modified from Walther et al. 2009)

2.2. Implementation of EPR in the WEEE Directive

2.2.1 The provisions of the directive

The WEEE Directive is not the first policy to implement EPR in Europe. In the 1990s Germany, Sweden, the Netherlands, Austria and Switzerland pioneered practical implementation of the concept to address various waste streams, such as packaging, batteries, automobiles, and electronics (Tojo, Lindhqvist, and Davis 2001). The European Union adopted the concept for the first time in 2000 in the Directive on End-of-life Vehicles (2000/53/EC). Three other directives embracing elements of EPR followed: the RoHS Directive (2002/95/EC Directive on the Restrictions of Hazardous Substances); the WEEE Directive (2002/96/EC Directive on Waste Electrical and Electronic Equipment Directive), and the Battery Directive (2006/66/EC Directive on Batteries and Accumulators). Among the four, only the WEEE Directive has incorporated producer responsibility comprehensively (van Rossem 2008).

The WEEE directive covers a diverse scope of electrical and electronic equipment, which is classified into ten categories.[7] The products examined in this thesis (ICT) fall into category 3. Producers are assigned with informational, financial and physical responsibilities. With regards to informational responsibility, the directive requires producers to provide treatment facilities with information on the material composition of their products, particularly about the existence and location of hazardous substances in the product (WEEE Directive 2003, Art. 11). Furthermore, producers have to inform consumers about the particularities of electronic waste and specific collection requirements (WEEE Directive 2003, Art. 10). The provisions regarding physical and financial responsibility are more complicated. Basically, producers are put in charge of financing and organising the treatment, recovery and environmentally sound disposal of waste from their own products. For waste that is generated from private households the responsibility of producers starts at WEEE aggregation points. The actor responsible for the prior collection from households to these aggregation points can be determined by each member state (van Rossem 2008). Consequently, this task has been distributed very differently throughout Europe. Some countries shift this responsibility to producers, others to municipalities and again others to distributors and retailers (Sander et al. 2007).[8] By contrast, in the case of non-household WEEE (business-to-business) the directive holds producers responsible already from the point of collection (WEEE Directive 2003, Art. 9).

Next to responsibilities, the Directive provides for specific targets to be reached. Irrespective of who is in charge of collection, an annual collection target of 4kg of WEEE per inhabitant was mandated in the original text (WEEE Directive 2003, Art. 5). A Recast of the WEEE Directive (2012) raised this target to 65 % of all covered products placed on the market in the same year. Furthermore, producers are obliged to ensure that collected products meet noticeable recovery rates. In the case of ICT products, at least 65 % of the average weight per appliance needs to be reused or recycled and a total of 75 % has to be recovered[9] (WEEE Directive 2003, Art. 7).

The controversy between IPR and CPR accompanied the formulation of the directive from the start. In the lengthy discussions preceding the directive, the Parliament argued for a strict implementation of individual responsibility while the Council advocated more flexibility (Castell, Clift, and Francae 2004). Parliament and Council eventually agreed on the following text:

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[7] The ten categories are: 1. Large household appliances; 2. Small household appliances ; 3. IT and telecommunications equipment; 4. Consumer equipment; 5. Lighting equipment; 6. Electrical and electronic tools; 7. Toys, leisure and sports equipment; 8. Medical devices; 9. Monitoring and control instruments; 10. Automatic dispensers (WEEE Directive 2003, Annex IA).

[8] Obligations for collection may also vary regarding financial and physical responsibilities. For a detailed discussion see: (Sander et al. 2007).

[9] In EU terminology the notion of recovery includes the energy recovery of materials, i.e. incineration that retains a certain extent of the heat value of materials. For the remaining part of this thesis, the term recovery will refer only to retaining materials through reuse or recycling.

"In order to give maximum effect to the concept of producer responsibility, each producer should be responsible for financing the management of the waste from his own products. The producer should be able to choose to fulfil this obligation either individually or by joining a collective scheme." (WEEE Directive 2003, Recital 20)

The ambiguity of this text is reflected in the academic discussion. Sachs' (2006) interpretation is that producers have a choice to fulfil their financial responsibility individually or collectively. Consequently, the directive would allow both full individual and full collective schemes. Van Rossem (2008), on the other side, understands that the paragraph reiterates individual financial responsibility and leaves producers only the choice between individual or collective physical responsibility. In this reading, the choice is between full individual and hybrid schemes, but does not allow full collective schemes. This inconsistency is carried on in the various transpositions of the directive in the member states.

2.2.2 Transposition of the directive and options available to producers

The provisions of the WEEE Directive have been transposed very differently in the European member states. This has triggered discussion and criticism among academics, NGOs and producer associations (c.f. Orgalime 2007; van Rossem, Tojo, and Lindhqvist 2006b; van Rossem 2008; Sander et al. 2007). It is not possible to go into all details of the member states' transpositions of the directive here. Instead, with respect to the question raised in this thesis, it is more interesting to consider the different compliance options that arise for producers throughout the EU. In the following, the practical options are presented on the basis of the three possible schemes characterised in section 2.1.5.

a) Individual approach

Nearly all member states[10] allow producers to fulfil their responsibility individually by establishing own systems and assuming individual physical responsibility. However, although many producers publicly advocate for IPR (IPR Works Coalition 2009), no electronics producer in Europe so far fully relies on an individual system (van Rossem, Tojo, and Lindhqvist 2006a). Sander et al. (2007) suggest that this is in part due to the structural disadvantages the legislations provide for individual systems. In many states, individual schemes have to provide a financial guarantee to ensure end-of-life costs are covered in case that the respective producer goes bankrupt, whereas collective schemes do not have to provide such a guarantee, because the remaining producers can offset the loss. This places an additional burden on producers interested in running their own schemes.

Nevertheless, individual schemes can also be beneficial for producers. Atasu and Subramanian (2011) suppose that large multinational corporations acquire sufficient economies of scale on their own to be able to profit from individual systems. In this way, they avoid subsidising products from their competitors and are safe from freeriders. Furthermore, they have exclusive control over the system. Consequently, some producers run individual schemes in addition to their collective compliance. In many states they are able to deduct the amount of WEEE handled by their own schemes from their collective obligations (Dempsey et al. 2010).

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[10] Exemptions are Belgium, France and Ireland who deprive producers of this option (Atasu and van Wassenhove 2011).

b) Collective approach

Throughout the member states there are differing regulations regarding how producers organise in responsibility organisations. A few member states[11] oblige all producers to join a single national PRO whereas most countries allow competition between different organisations. The first can often be found in countries that already had such a system in place prior to the WEEE Directive and were reluctant to change it (van Rossem, Tojo, and Lindhqvist 2006b). Arguments in favour of single national schemes are increased economies of scale and less administrative efforts, whereas the competition between PROs is connected to greater efficiency and avoidance of inflated monopoly costs (Herold 2007).

In addition, regulations differ with regards to how the costs of end-of-life management are allocated to the participating producers. Discussions in the literature suggest that the details of this cost allocation are a relevant aspect influencing the financial incentives provided by the respective EPR system in place. Hence, they are discussed in some detail here. There are principally six different ways to calculate the financial contribution of a producer, as shown in the table below. The various methods are based on three different factors (Dempsey et al. 2010; Rotter, Chancerel, and Schill 2011; Sander et al. 2007):

1. The point in time when the fee is charged: Fees can be either charged at the moment when the product is sold (ex-ante) or when the product enters the waste stream (ex-post). An ex-ante fee is a flat fee based on average treatment costs. Usually, ex-ante fees are charged directly to consumers in the form of visible or non-visible recycling fees (so-called advance recycling fees) as surcharge to the product price. Similar to a pension fund (van Rossem 2008), the collected money is used to pay for the products that are currently undergoing treatment. In an ex-post system, the calculation is based on current costs of WEEE treatment. These are divided among the members of one scheme and adjusted dynamically (monthly or quarterly) to reflect changes in the cost for WEEE treatment.
2. The considered share of producers: The relevant share of a producer can be either determined by the amount of products sold (*market share*) or by the amount of its products collected as WEEE (*return-share*). Ex-ante fees naturally imply the consideration of market share, since fees are charged on top of products at the point of sale. Hence, the more products one producer sells, the higher is its contribution to the financing of the end-of-life scheme. If fees are charged ex-post, both market share and return share calculation are possible. In the first variant, the current costs of WEEE treatment are simply divided among producers on the basis of their current market shares. The second variant, the calculation of return-share, requires that the collected WEEE is distinguished by brands. This does not necessarily require the physical sorting of the whole amount of WEEE, but can be done by statistical sampling[12]. In future, also technological identification solutions[13] are conceivable. The measurement can take place at different

[11] Belgium, Cyprus, Greece, Latvia, Luxembourg, the Netherlands and Sweden. In the Netherlands, there are two national PROs covering different product groups (van Rossem, Tojo, and Lindhqvist 2006b).

[12] In the US-state of Washington, for example, an EPR system has been established that is based on statistical samples drawn at product aggregation points to estimate the overall composition of WEEE (Atasu and van Wassenhove 2011; Dempsey et al. 2010).

[13] In future, brand distinction might become considerably easier assisted by technological solutions such as optical bar codes, magnetic tags or radio frequency identification (RFID) (Dempsey et al. 2010; Rotter, Chancerel, and Schill 2011).

stages of the downstream process, i.e. the point of collection, at product aggregation points or at recovery facilities (van Rossem, Tojo, and Lindhqvist 2006a).

3. The unit of measurement: The share of a producer can be measured in weight (kg or tons) or in the number of products.

Point in time	Considered share	Measurement Unit
Ex-ante	Market-share	No of products
"	"	Weight
Ex-post	Market-share	No of products
"	"	Weight
Ex-post	Return-share	No of products
"	"	Weight

Table 3: Cost allocation systems in collective schemes

The EPR literature offers different opinions about the consequences of these cost allocation methods. An ex-ante fee is considered simpler and more transparent than an ex-post calculation. Furthermore, it may decrease consumption and thereby reduce waste (Walls 2006); and it can be easily combined with a differentiation of cost based on eco-design criteria (see below). However, most authors disapprove of fixed ex-ante fees, because they are usually charged directly to consumers rather than to producers (van Rossem 2008). Furthermore, they do not dynamically adjust to the treatment costs of current WEEE, which means that the link between products and end-of-life costs is disturbed. Often, PROs that charge flat fees tend to build up significant funding reserves in order to avoid deficits. As a result, the fees are often higher than the actual treatment costs (van Rossem, Tojo, and Lindhqvist 2006a).

Many EPR proponents (van Rossem, Tojo, and Lindhqvist 2006a; van Rossem 2008; Sander et al. 2007) favour return-share calculation over market-share, arguing that the latter would not establish a straightforward link between the fee paid by a producer and later end-of-life costs of its products. In a market-share system, *"when products are put on the market, the producer pays not for the products' future end-of-life costs, but the products that have been collected in the same year. This does not lead to a reward for design change and hence does not drive development of better products"* (van Rossem, Tojo, and Lindhqvist 2006a, 8). The long time span between product sale and product disposal makes it difficult to connect current efforts by producers to improve the environmental properties with the allocation of costs for current WEEE. Van Rossem (2008) compares the market-share system to a pension fund, in which the products that are placed on the market today finance the waste from products that have been placed on the market yesterday. Moreover, this method discriminates producers' efforts to safeguard resources by increasing their products' useful life and their reusability or remanufacturability (Atasu and van Wassenhove 2011). However, the market-share system is generally considered to be more practical and connected to less administrative costs than the return-share system, which requires an expensive brand identification of the WEEE. Furthermore, a return-share scheme does not reflect the current economic powers of producers. It may place an additional burden on a producers who was successful in the past, but is now struggles with competitors, as this producer would have to bear much of the current costs of WEEE treatment (Dempsey et al. 2010).

In addition, there is also some disagreement on the unit of measurement. Using weight is seen as beneficial, because it encourages producers to make products lighter and thus decrease material use (Atasu and van Wassenhove 2011). Others warn that weight is not a good measure, because it shifts the focus on heavy goods and materials rather than on those which are better recyclable or require more attention (Mayers et al. 2011).

c) Hybrid systems with differentiated fees

As explained above, a hybrid system attempts to base the financial contribution of producers to collective schemes on the specific end-of-life costs of their individual products. To establish this link, the fee for producers is differentiated on the basis of relevant product design criteria, such as ease of disassembly, level of hazardous substances, content of precious metals, etc. Mobile phones containing mercury, for example, would then be charged with a higher fee than comparable products without this substance. The calculation would need to be based on current best-practices of eco-design and "could be realised by a tool that processes information about the material composition of the product and about decisive constructive elements in conjunction with treatment and recovery technologies" (Sander et al. 2007, 175).

Cost differentiation can be implemented relatively easily in a system with ex-ante fees. Hereby, so-called differentiated upfront fees are charged on top of a product's price at the time of sale. In an ex-post system, however, it is more difficult to introduce differentiated fees, because the total amount of fees collected needs to be dynamically adjusted to the current costs of WEEE treatment. In a scheme that divides costs ex-post according to market share, this is likely to turn out into a complicated and fault-prone system, because the end-of-life costs of current WEE would need to be adjusted to the eco-design characteristics of products currently placed on the market. In a return share scheme, a highly complex database of products and their characteristics would need to be available. Furthermore, in the time between product sale and product disposal, recycling technologies may change and cause different costs than producers could foresee at the time the product was developed.

To date, a hybrid system with differentiated fees can only be found in France, where it was implemented in 2010 (Perrier 2010). The system works with differentiated upfront fees that are charged ex-ante when a product is sold (Geldron 2008). The differentiation criteria comprise weight, plastic content, and presence of specific hazardous substances (Ecologic 2011).

2.2.3 Academic discussion of the effects of the directive

The academic literature largely agrees on certain achievements of the WEEE Directive. In compliance with the polluter pays principle, the costs of end-of-life management are now largely borne by producers to the benefit of municipal coffers (c.f. Sander et al. 2007; Walther et al. 2009). The collection of discarded electronics has been reinforced. While a few authors point at portions of WEEE that still fall through the collection schemes established in the course of EPR (Huisman et al. 2007; Mayers et al. 2011) most studies observe considerable improvements of the collection rate (Hischier, Wäger, and Gauglhofer 2005; van Rossem, Tojo, and Lindhqvist 2006a; Veerman 2004). Furthermore, there are improvements with regards to recycling infrastructure. End-of-life management is now organised more effectively (c.f. Walther et al. 2009) and the technical capacities of facilities have been intensified (c.f. Huisman et al. 2007).

However, there is much dissent on the question whether or not EPR achieves its primary goal of promoting eco-design. Tojo (2001) conducts an empirical analysis of the anticipatory effects of the WEEE Directive. Her findings confirm the assumption that EPR drives design changes among producers in the electronics and car sectors. Sachs (2006), by contrast, is generally sceptical of the principle. He concludes that the transaction costs of EPR posed by logistical and bureaucratic challenges outweigh any potential benefits that might be derived from improved product design and hence preclude respective incentives. A study by Gottberg et al. (2006) on the European lighting sector takes a similar line. The authors find that the marginal costs associated with end-of-life management are often not sufficient to provide incentives to make profound changes in order to minimise them. Costs may be passed on to consumers without significantly affecting demand.

Interestingly, critical views can also be found among proponents of EPR. Their critique is directed at the way the principle has been implemented. Van Rossem (2008) holds that legislations in most countries have not realised EPR to its full potential. He posits that most member states failed to implement individual financial responsibility and therefore the results of many critical investigations *"are hardly surprising given that in the particular EPR programmes reviewed, there was never an intention to illicit change on behalf of producers, as the focus was rather on designing cost-covering measures*" (van Rossem 2008, 306). Furthermore, Castell, Clift, and Francae (2004) conclude that compromises between the European Commission and Parliament, the fear of free-riders and different approaches by member states have watered down the implementation of the principle. In this way, "[w]hat had been intended as a racehorse had become [... a] camel with local breeds" (Castell, Clift, and Francae 2004, 5). Similarly, Rossem, Tojo und Lindhqvist (2006b) complain that EPR got "lost in transposition". This view is underlined by the fact that the European Commission opened 14 cases of infringement against member states where transpositions fail to maintain a direct link between the production of products generating WEEE and the financial contribution of producers (European Union 2010).

The discussion has so far been largely fed by theoretical and juridical studies. There is a remarkable lack of empirical contributions. In the literature review only three studies could be found that focus on gathering empirical insights on how EPR is approached by companies. Tojo (2001, 2004) was one of the first to examine producer behaviour related to EPR. She found evidence of EPR promoting design changes among car and electronics manufacturers. However, she conducted her studies prior to the passage of the WEEE Directive; her findings therefore include only anticipatory effects. Moreover, Tojo's work does not systematically take available eco-design strategies into account. Gottberg et al. (2006) examine companies in the lighting sector. The authors conclude that EPR does not have a strong influence on eco-design. However, their work is confined to financial incentives and does not look at potential other influences. Herold (2007) looks at producer involvement in end-of-life management. However, her comparison of EPR situations in Europe, Japan, the US and China, does not examine impacts on eco-design. Instead, it focuses on the degrees of producer involvement in end-of-life management and compares regional differences.

It becomes apparent that more research is needed to resolve this debate. Much of the disagreement on the actual effects of EPR is connected to the controversy between individual and collective responsibility. To summarise the above, three prevalent views can be identified:

1. One view finds that EPR, as implemented in the WEEE Directive, has positive influence on eco-design, even though the majority of schemes comply with collective responsibility.

2. Other scholars conclude that the concept has not been implemented well by the WEEE Directive and the EU member states. They assert that EPR would promote eco-design if strict individual responsibility had been mandated, but fails to do so with prevalent collective responsibility schemes.
3. The third position is principally sceptical about the influence of EPR on product design and considers neither IPR nor CPR as effective.

2.3. Eco-Design

In order to investigate the assumption that EPR provides incentives for eco-design, there needs to be clarification of what the latter actually is. Eco-design is not a specific 'thing to do', "not a specific method or a tool, but rather a way of thinking and analysing" (Knight and Jenkins 2009, 550). The term comprises a variety of approaches and strategies, each emphasising different aspects and objectives. The following sections discuss the notion of eco-design, present a model of how producers integrate eco-design in their product development process, and examine available eco-design strategies which have an influence on end-of-life issues.

2.3.1 The notion of eco-design

Irrespective of EPR, the domain of design has opened up significantly to environmental considerations over the last decade. The need for a more environmentally friendly design is now widely acknowledged among experts and practitioners in the field. Various terms are used to describe this fusion of environment and design, such as 'eco-design', 'environmentally conscious design', 'design for environment', or 'design for sustainability'. Often, they are used largely synonymously. 'Eco-design' appears to be the most widespread notion and is therefore used in this thesis.

Following Tukker, Haag and Eder's (2000, 7) definition, eco-design is understood here as the *"systematic incorporation of environmental factors into product design and development"*. This definition fits to the focus of this thesis for two reasons. First, it places emphasis on environmental issues. Although EPR potentially implies social benefits[14], it does not directly provide incentives for producers to consider the social implications of product design, as embodied in the term "design for sustainability" (Crul and Diehl 2007). Therefore, social aspects are only considered marginally here. Second, Tukker, Haag and Eder's definition places emphasis on the process of applying eco-design rather than on its outcomes. Similarly, this thesis examines to what extent producers have taken up eco-design initiatives. As explained before, a sound evaluation of design outcomes is not conducted as this would require a more profound base of available data.

With regards to scope, eco-design is understood here as an "inside the box approach" (Crul and Diehl 2007). This means it seeks to improve product setups and material use, but remains confined to existing product concepts. Approaches "outside of the box", i.e. the development of entirely new product concepts, such as offering product functions as services[15] instead of selling the product itself, go beyond the focus of this thesis. As Vermeulen and Weterings (1997) point out, such far reaching functional innovations are not directly encouraged by EPR and are

[14] As illustrated in the description of the problem of e-waste (section I.2), social and environmental issues are inherently linked. Thus, it can be assumed that environmental improvements in products often also entail social benefits. Furthermore, EPR can help fighting illegal WEEE exports and thereby reduce related social problems.
[15] An example for this are car sharing systems, which are sometime offered directly by car manufacturers.

generally difficult to promote through governmental regulation as they require high degrees of expertise and creativity available among producers.

2.3.2 Eco-design application

Product design is embedded in the larger process of product innovation within a company, which goes beyond the work of product development teams and involves various other departments within a company.

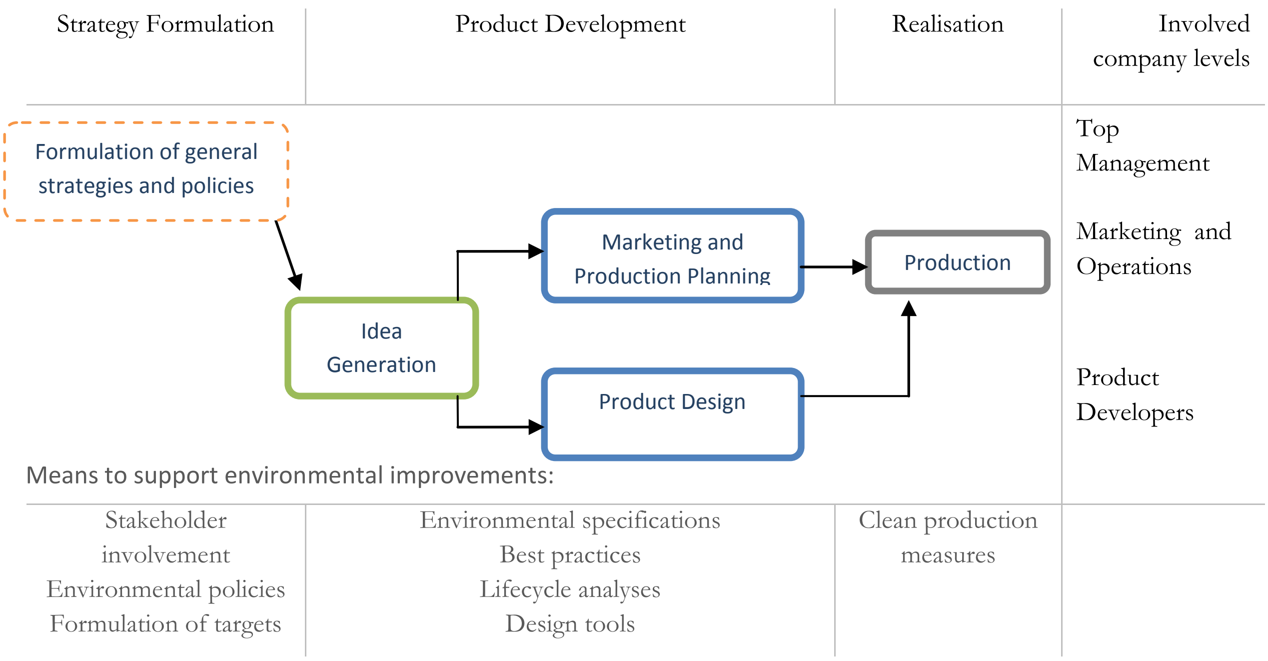

Figure 3: Product innovation process (adapted and modified from Tukker, Haag and Eder 2000)

Product innovation begins with the formulation of general strategies and policies. This is usually done at top management levels. Ideally, already at this stage companies take environmental issues into account (Tukker, Haag, and Eder 2000). Proactive companies may orient their overall strategy at striving to be sustainable or reducing environmental impact and may formulate environmental policies with clear goals and provisions. In addition, effective internal communication structures between the involved company departments is key to realise good eco-design results (Boks and Stevels 2003; Rifer and Stitzhal 2002).

The next phase comprises the actual product development. This includes two steps: generating product ideas and realising product design. At both of them, the application of eco-design can be supported by several means. Manuals, design guidelines, checklists, and samples of best-practices can provide general guidance. In addition, more sophisticated means such as lifecycle analyses and software tools to evaluate specific eco-design aspects such as recyclability or material composition can be used to pointedly improve product features.

The way in which eco-design is implemented says something about how proactive a company is. Advanced companies see a strategic orientation at environmental issues as a way of gaining competitive edge. Best practice examples show a clear management commitment, clear allocations of responsibilities, the involvement of experienced eco-design staff, and the application of tools, manuals and databases (Tukker, Haag, and Eder 2000). Boks and Stevels (2003) identify three maturity levels of environmental awareness among large multinational companies. Their classification can be used to assess the eco-design activities of a company (table 4) and will be used for the analytical part of this thesis. At the first level, companies are relatively ignorant towards environmental issues. Respective activities are pursued inconsistently and do not go beyond some initial projects. At the second level, producers adopt company-wide environmental policies and undertake systematic efforts to improve eco-design. At the third maturity level, companies pursue ambitious strategies connected to specific targets to reach within a specified time horizon. Eco-design is implemented with the help of customised tools and other sophisticated means.

Maturity level	**Environmental approaches**	**Means of implementing eco-design**
Relatively ignorant	General principles, slogans	General principles
Advanced	Company-wide environmental policies	Checklists, guidelines, best practices
Mature / Proactive	Company-wide policies with clear targets and deadlines	Customized tools and databases

Table 4: Maturity levels of eco-design application (adapted and modified from Boks and Stevels 2003)

2.3.3 Factors influencing the application of eco-design

With regards to the research question posed in this thesis, it is important to note that the application of eco-design is influenced by a variety of factors. It is (almost) impossible to isolate EPR as explanatory variable for eco-design. For this reason, it is not attempted here to measure and compare the influence of EPR against other factors. Instead, the thesis aims to clarify whether or not feedback from EPR can be identified at all, and if yes, how significant this feedback is. To provide the reader with a comprehensive picture, the following briefly discusses other influences on eco-design.

Obviously, a basic requirement for the application of eco-design is that respective skills and knowledge are available to a company (Tukker, Haag, and Eder 2000). If that is given, van Rossem (2002) identifies regulative pressures and market pressures as the two main drivers for eco-design. In the EU, the two most significant examples for regulative pressures are the Ecodesign Directive (2005) and the Restriction of Hazardous Substances Directive (RoHS Directive 2003). Both legislations employ mandatory requirements. As discussed in section 1.2, such approaches are usually effective, but limited to the content of the standards they prescribe. While the Ecodesign Directive mainly focuses on energy use requirements, the RoHS Directive requires producers to phase out a number of specified hazardous substances. Market pressures have a more dynamic influence. They comprise factors such as customer demand for green products, competition, emphasis on green image, etc. Market pressures are often nourished by social pressures, most notably in the form of NGO campaigning and media attention.

EPR can be related to both regulative and market pressures. While policies prescribing the implementation of EPR are government induced regulative pressures, EPR mainly seeks to strengthen market pressures on companies. Available design literature takes notice of EPR as an important driver for eco-design (Rodrigo and Castells 2002; Veerakamolmar and Gupta 2000).

However, no study has been found that looks into more detail at various eco-design strategies and their connection to EPR.

2.3.4 Eco-design strategies

In an eco-design guidance manual commissioned by the UNEP, Crul and Diehl (2007) outline seven strategies producers can pursue to improve the environmental performance of their products: 1) Selection of low-impact materials; 2) Reduction of material usage; 3) Optimisation of production techniques; 4) Optimisation of distribution system; 5) Reduction of impact during use; 6) Optimisation of initial lifetime; and 7) Optimisation of end-of-life stage. This list is based on the so-called 'eco-design wheel', which was introduced by Brezet and can Hemel (1997) and has become widely recognised classification of eco-design strategies. However, it cannot be simply adopted wholesale to the purposes of this thesis. On the one hand, EPR is strongly connected to the seventh strategy – optimisation of end-of life stage. Crul and Diehl's distinction does not appear precise enough with regards to that aspect. Other scholars identify more differentiated strategies with regards to improving product end-of-life management stage, such as Design for Disassembly, Design for Recyclability, and Design for Reuse (Bogue 2007; Henstock 1988; Kuo, Huang, and Zhang 2001). On the other hand, there are several other eco-design strategies that do not have end-of-life relevance. Measures focusing on the manufacturing stage (such as decreasing pollution, energy use, etc.) and measures to reduce a product's impact during use are not relevant for the end-of-life stage. Thus, they are not affected by EPR and not considered in this thesis. The same applies to the optimisation of distribution systems. While packaging materials also require end-life management, they do not constitute WEEE and are targeted by other policies.

On this basis, seven strategies can be identified that can be influenced by EPR as summarised and elucidated in table 5.

Strategies potentially affected by EPR

	Eco-Design Strategy	*Explanation*	*End-of-life relevance*
I.	Design for Longevity	Measures to increase the useful life of a product.	*Promised effect:* Reduces volume of WEEE
	a) Durability	Measures to build more robust and long-lasting products	Products with a longer lifetime need to be replaced less frequently
	b) Upgradability	Enabling hardware and software upgrades to prevent a fast outdating of products	Upgradable products need to be replaced less frequently
II.	Reduction of Material Use	Using less material in terms of weight or volume, also known as dematerialisation.	*Promised effect:* Reduces volume of WEEE
III.	Use of Low-Impact Materials	Low-Impact Materials comprise substances that cause less pollution and environmental concern than comparable conventional materials.	*Promised effect:* Reduces end-of-life costs

	a) Phase out of hazardous substances	Voluntary phase-outs of hazardous substances that are not banned by other regulations (RoHs, REACH). The substances in focus here are: PVC, BFRs and CFRs, Phthalates, Antimony and its compounds, Beryllium and its compounds, and Volatile Organic Compounds[16]	Hazardous substances contained in WEEE require special treatment and complicate the recycling process (c.f. Tsydenova and Bengtsson 2011).
	b) Use of renewable materials	Use of natural and renewable materials with a particularly low impact, also in terms of sourcing.	Natural and renewable materials are generally inexpensive to treat can usually be recycled (or composted) easily
IV.	Design for Disassembly	Making products easy to disassemble by standardisation, easily accessible and detachable connectors	*Promised effect:* Reduces end-of-life costs Simplifies the recycling process and reducing costs. Manual disassembly is one of the highest cost factors in WEEE treatment.
V.	Design for Recyclability (DfR)	Comprises various measures to increase the recyclability of products	*Promised effect:* Increases the amount of recovered materials and components
	a) Use of recyclable materials	Using materials with a high recycling efficiency (e.g. glass, metals, or certain plastics) and keeping them pure.	Increases the output of recycled materials
	b) Reducing material diversity	Relying on a reduced variety of standardised materials. Often, a mix-up of too many materials prevents recycling.	Avoiding mix up of materials to increase recyclability.
VI.	Design for Reuse	Modularisation and other measures to increase the chances that products or components can be reused, refurbished or remanufactured.	*Promised effect:* Increases the amount of recovered materials and components
VII.	Use of Recycled Materials	Using recycled materials for the production of new products	*Promised effect:* Increases the demand for recycled materials

Table 5: Eco-design strategies with end-of-life relevance

The listed eco-design strategies have different effects on the end-of-life phase of products. Design for Longevity (I) promises to prolong the time until products will be discarded. Reduction of Material Use (II) reduces the weight of discarded products. If a producer pursues these strategies over a long period of time, it can reduce its share of products in the overall load WEEE. Using Low Impact Materials (III) makes the treatment of collected products less difficult and thus reduces costs. The distinction between Design for Disassembly (IV) and Design for

[16] For more information on these substances please refer to chapter 1.2

Recyclability (V) measures is not always clear. Available studies use the terms with various meanings. In this thesis the terms are distinguished according to the promised effects of the strategies. Design for Disassembly primarily reduces the effort of recycling products and thus promises to reduce costs, whereas Design for Recyclability is focused on the outcome of recycling processes and promises to increase the amount of recovered materials. Design for Reuse (VI) allows taking out components of waste electronics and reusing them, either directly or for renewed production. The latter is usually described as remanufacturing or refurbishing. Remanufacturing is conducted by the producer or original equipment manufacturer itself, whereas refurbishment is done by unauthorised third parties (Bryant 2009).

Some scholars criticise that commonplace eco-design approaches would merely strive for eco-efficiency while any serious attempt to move towards a circular economy, particularly as conceptualized by the cradle-to-cradle approach, would require adopting eco-effective approaches (Hukkinen 2001; McDonough and Braungart 2002; Sherwin 2004). According to this argument, eco-efficient design would be limited to reducing impact while eco-effective design aims at optimising the positive effects of a product, that is designing products to become a useful part for further biological or industrial processes at their end-of-life (McDonough and Braungart 2002). However, this distinction is only of limited usefulness, as in practice the border between efficiency and effectiveness is blurred. As Vermeulen (2012) points out, the ten cradle-to-cradle principles largely resemble the strategies outlined in Brezet and van Hemel's eco-design wheel, even though the first is supposedly connected to effectiveness while the second would be limited to efficiency. Another criticism is directed at EPR's prioritisation of end-of-life improvements. Huisman et al. (2007) posit that the environmental impact at the end of a product's lifecycle is not particularly important compared to other stages. The authors stress that especially the environmental problems caused by resource extraction normally outweigh any damage caused at later stages and hence recommend focusing on the first aspect. However, it is not clear why end-of-life improvements should conflict with other eco-design goals. Moreover, many of the eco-design strategies listed above do not merely promise improvements with regards to a product's end-of-life stage, but can produce benefits over the whole life cycle. For instance, the Use of Low Impact Materials is also relevant with regards to a product's use phase, Design for Longevity may diminish the impact of product distribution, and the Use of Recycled Materials can reduce the need for new virgin materials and thus have a positive impact on the material extraction phase (Fishbein 2000b).

2.4. Towards an analytical framework

The preceding chapters examined the theoretical foundation of EPR, the implementation of the concept by the WEEE Directive, and the relevant aspects of eco-design. It becomes clear that available studies on Extended Producer Responsibility are too obscure about the presumed influence on design strategies. Most proponents of the concept appear content with the explanation that EPR established a financial incentive for eco-design. However, considering that there are different types of responsibility (see section 2.1.1) there is reason to assume that the potential influence of EPR is not confined financial incentives. Moreover, as explained in section 2.3.4, there is a diversity of eco-design strategies with end-of life relevance. The available literature remains unclear about which strategies are promoted and which are not. In order to provide an explanatory model for the adjacent analysis, the following takes a closer look on the potential influence of EPR on product development and which specific eco-design strategies it promotes.

2.4.1 In which ways can EPR affect product design?

As stated above, Lindhqvist's (1992) observation that EPR does not only refer to financial responsibility, but also includes physical and informational responsibility, casts doubt on the narrow focus on financial incentives. The distinction between the three types of responsibility can be applied to the potential feedback that comes from end-of-life management (figure 4).

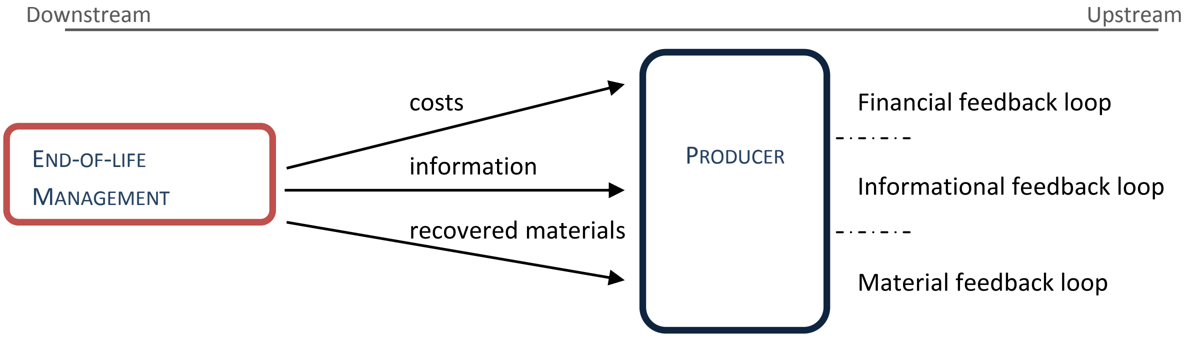

Figure 4: Types of feedback loops

- *Financial responsibility* generally results in additional costs to the producers for WEEE end-of-life management and treatment (Atasu and van Wassenhove 2011). For certain products recycling may also be profitable if valuable materials can be regained in the process. As explained above, this is expected to provide a financial incentive for producers to make appropriate changes to their product design. Depending on the nature of the contracts between recyclers and producers, the revenues from recycled materials can go directly upstream to producers or remain with the recyclers, but eventually result in lower fees charged to producers. Regardless of whether there is a positive or negative monetary flow, a *financial feedback loop* from downstream recyclers to upstream producers is established.
- *Informational responsibility* establishes informational communication channels between recyclers and producers, i.e. an *informational feedback loop* from downstream end-of-life management to upstream production. Recycling practitioners may forward their experiences with the recycling of a certain product and respective ideas to product designers and developers. This is expected to cause learning effects among producers who could incorporate this information into future products to facilitate reuse or recycling and improve material reclamation.
- *Physical responsibility* means that producers retain the ownership of the materials by taking back discarded products and recycling them. A *material feedback loop*[17] from end-of-life management to production is established when reclaimed materials or product components can be used for new production or remanufacturing. In this way, EPR could set path for closed material loops and a circular economy.

[17] The term 'material feedback loop' is preferred over 'physical feedback loop', as it captures more clearly what it transfers from downstream to upstream.

2.4.2 Influence of EPR feedback on various eco-design strategies

The distinction of the three feedback types already casts more light on the influence of EPR on product design. However, not every eco-design strategy is likely to be equally affected by one type of feedback. As described, eco-design strategies have different effects on a products' end-of-life phase.

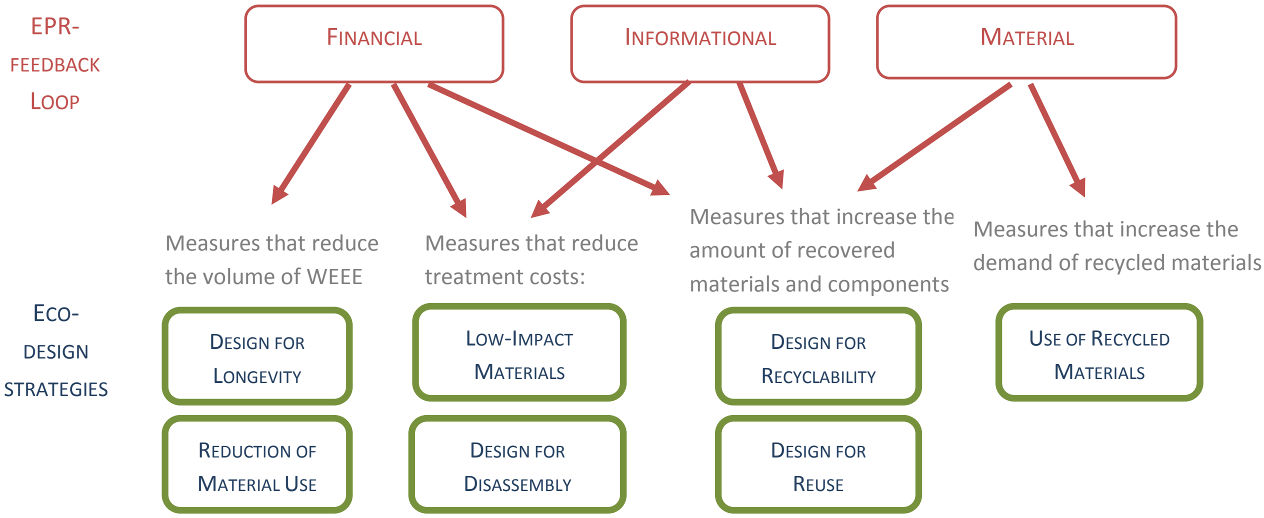

Figure 5: Potential influence of EPR feedback loops on individual eco-design strategies

Financial feedback can be expected to promote strategies that reduce the costs of end-of-life management. This can be achieved by measures that reduce the volume of WEEE (Design for Longevity, Reduction of Material use), reduce the treatment costs (Low Impact Materials, Design for Disassembly, Reduction of Material Use) or increase the output of recovered materials (Design for Reuse, Use of Recyclable Materials), which can then be sold at secondary markets.

Informational feedback from recyclers can raise the awareness of product developers of problematic issues and can increase their knowledge on eco-design. Informational feedback can thus promote eco-design strategies that directly relate to the recycling process. This includes measures that simplify the process and reduce treatment costs (Low Impact Materials, Design for Disassembly, Reduction of Material Use) and measures to increase the amount of recovered materials (Design for Reuse, Use of Recyclable Materials). When producers start using recycled materials in their production, they have an interest in increasing the amount of available recycled materials. Thus, material feedback can promote eco-design strategies that improve the amount of materials that can be recycled from discarded products (Design for Reuse, Use of Recyclable Materials). Furthermore, if takeback and recycling activities increase the amount of available recycled resources, their prices are likely to fall. It can be assumed that this increases the attractiveness for producers to use recycled materials in their products (Use of Recycled Materials).

3. Research Design

3.1. Research gap

As described in the theory chapter, there are diverging views on Extended Producer Responsibility and the way it has been implemented by the WEEE Directive. Whether or not EPR in its current form promotes environmentally conscious product design is highly contested. With regards to this debate, the available literature reveals three main shortcomings. Firstly, EPR is merely discussed in an abstract manner. Empirical research is surprisingly scarce. The impact of schemes and actor behaviour are only explained from a macro-perspective. In order to better understand the effects of EPR, the concept and its implementation has to be examined from the perspective of its central addressees: the producers. More light needs to be shed on how producers cope with the practicalities of extended responsibility and how they evaluate its effects on product design. Secondly, available studies tend to conceptualise producers as a 'black box', where EPR feedback goes in at one side and eco-design comes out at the other. However, the way from end-of-life management to product development usually involves several company departments and teams. This raises the question of how producers organise their end-of-life management activities and to what extent takeback teams are linked to product developers. Thirdly, available literature tends to look at EPR only from a financial perspective. The potential influence of the concept is reduced to providing financial incentives for eco-design. A more differentiated examination of how EPR can influence eco-design and which specific eco-design strategies it affects could enrich the present discussion.

3.2. Revisiting the research question

The central research question, which was posed in the introduction of this thesis, is:

How and to what extend does Extended Producer Responsibility (EPR), as implemented by the WEEE Directive, promote eco-design among producers in the ICT sector?

Considering the identified research need, the question can be further specified. In order to answer this question, five sub-questions are examined:

1. *In which ways do producers comply with EPR requirements and manage product takeback; and to what extent do they differ?*
2. *Which eco-design strategies can facilitate product end-of-life management or reduce end-of-life costs and to what extent are these strategies applied by producers in practice?*
3. *In which ways can EPR (potentially) influence eco-design and to what extent can this be observed in practice?*
4. *Which chances and obstacles do producers see with regards to EPR?*
5. *To what extent does EPR set path for a circular economy with closed material loops?*

The first sub-question was already touched upon in the theory chapter. As discussed, all producers joined collective schemes and some run additional individual activities. However, the available literature does not provide a comprehensive description of these approaches or compare several producer compliance strategies. Therefore, the case studies are intended to shed light on the extent to which producers run individual schemes, how they fulfil their responsibility collectively and if they have a preference for a specific cost allocation method. The theory chapter already provides part of the answer to the second sub-question. Section 2.3.4 provides a list of eco-design strategies that can facilitate end-of-life management and elaborates on their potential effects. However, none of the available works on EPR study which of these strategies are actually applied by producers in practice. By examining this in the case studies it is aimed to provide a more comprehensive picture on this aspect. The third sub-question builds upon the model of EPR feedback loops developed in the analytical framework at the end of chapter 2. As explained, these feedback loops may have different effects on specific eco-design strategies Similar to the previous sub-question, the actual presence and influence of these feedback loops need to be examined. The fourth sub-question is intended to open the discussion to the perceptions of the involved producers with regards to the problems and chances of EPR and its influence on eco-design. Eventually, the fifth sub-question examines if the situation in practice provides indications for the expectation expressed by some scholars that EPR represents a first step towards a circular closed-loop economy.

3.3. Delineation

The WEEE Directive implemented EPR for producers in the ICT sector on a European scale and serves as point of departure for this study. By investigating the influence of EPR on design practices, this thesis will in part evaluate the success of the directive. Nevertheless it is not the intention to perform a full-fledged policy analysis. Rather than analysing the WEEE Directive as a whole, the focus is placed on the coherence and practical relevance of its underlying theory, namely the concept of EPR. The aim of this study is to gain insights about how EPR affects producers, about the approaches companies take in response to EPR and with regard to eco-design.

Furthermore, it is not intended to measure the effectiveness of EPR or to compare its influence against other factors that determine to what extent companies implement eco-design. As discussed in section 2.3.3, it is not possible to isolate EPR from these other influences. Instead, the thesis aims to clarify whether or not feedback from EPR can be identified at all, and if yes, how significant this feedback is.

3.4. Research approach

Considering the limited availability of previous empirical works on the topic, the study at hand is somewhat explorative. For this reason, a multiple case study design is adopted. This inductive qualitative approach appears more suitable to the context than a deductive quantitative one. The latter would require a profound knowledge base from which testable hypotheses could be defined. This thesis focuses on understanding rather than measurement. Due to a variety of influences and factors, the effectiveness of EPR cannot be simply measured in terms of product design output. An inside view into the companies is needed to better understand the application of and the relationship between EPR and eco-design. Multiple case studies can be defined as a collection of empirical enquiries that investigate a contemporary phenomenon within its real-life context (c.f. Yin 2003). This approach is particularly suitable at early stages of research and recommended for theory building (Eisenhardt 1989). While case study research is generally limited with regards to generalisation, the examination of several different cases allows to identify similarities and differences between the cases and thus to consider them independent of their unique contexts. This allows making "petite generalisations" (Stake 1995), i.e. assertions on the overall context which provide the basis for further enquiries.

3.4.1 Case selection

The cases for this study comprise six hardware producers in the ICT segment. ICT has been chosen for analysis because it represents one of the fastest moving sectors in the electronics domain, which makes the e-waste problem particularly evident. The sample can be roughly distinguished into three manufacturers of mobile phones and three manufacturers of personal computers.[18] These two products show very high rates of obsolescence and replacement (see section 1.2). Potential effects of EPR on eco-design could therefore be recognised more quickly than for other products.

The cases were selected according to purposeful sampling (Patton 2002). This means to focus on particularly relevant cases that promise to be rich in information. The sample comprises leading multinational producers in the mobile phone and PC sectors. Taken together, the selected companies share nearly a third of the global mobile phones market (Gartner Inc. 2012b) and almost a quarter of the market for personal computers (Gartner Inc. 2012a).

3.4.2 Method

The analysis of the cases is based on a variety sources. Both internal and external information on the companies' end-of-life and eco-design activities were gathered. Internal information was gathered from interviews with company representatives, as well as from additional information disclosed by the companies, such as websites, annual and corporate social responsibility (CSR) reports, white papers and case studies conducted by company employees. External information was collected from available academic case studies and NGO reports.

Expert interviews represent the most important data source of this thesis. As interview method, a semi-structured approach with open questions was chosen. This method takes middle ground between structured and unstructured interviews. While the first approach strictly works off a list of closed questions with pre-defined answer options and is common in quantitative research settings, the second resembles conversations and is useful to gain fresh ideas, but lacks consistency and is not suitable for comparison (Leech 2002). The semi-structured approach is based on a prepared set of questions, which is the same for all interviews, but can be changed in order or wording by the interviewer, who can also leave out questions that appear redundant (Keller 2011). This approach provides for the necessary flexibility to learn from the experiences and expertise of the interview partners and for going into details where relevant. Yet, at the same time this method ensures comparability and an organised collection of data.

The interviewed representatives are all involved with end-of-life management in their companies. Their functions differ – some interview partners are more involved with takeback issues while

[18] Mobile phones: LG, Nokia, Phillips; Personal computers: Dell, HP, Sony. However, this distinction is not 100% accurate and only meant to be a guideline. There are some overlaps (Sony produces laptops and mobile phones, and Philips has experiences with laptops) and most companies have generally large product portfolios, from which it is difficult to isolate just this one product group. Moreover, Philips has severely reduced its mobile phone section and began focusing more on other telecommunication devices.

others work on product development and eco-design. Where possible, the interviews were conducted in person (face-to-face). In total, eight interviews of 60 – 90 minutes each were conducted. Additional questions were communicated by email.

Person	Company	Location	Position	Area	Mode	Date
Jonathan Perry	Dell	Bracknell, UK	Takeback Compliance Consultant	Takeback Management	Phone Interview	April 2012
Daniel Seager	HP	Amsterdam, Netherlands	Takeback Regulations and Implementation Manager	Takeback Management	Personal Interview	March 2012
Dimitar Dimitrov	HP	Sofia, Bulgaria	Environmental Support Specialist	CSR	E-Mail Interview	April 2012
Yu-Mi Mun	LG	Amstelveen, Netherlands	Senior Manager Energy and Environmental Affairs	Environmental Regulatory Affairs	Personal Interview	April 2012
Gregor Margetson	LG	Amstelveen, Netherlands	Takeback Manager	Takeback Management	Personal Interview	April 2012
Helen Castrén	Nokia	Espoo, Finland	Senior Environmental Manager	CSR	Personal Interview	March 2012
Noora Pasanen	Nokia	Espoo, Finland	Project Manager Sustainability	Eco-Design R&D	Personal Interview	March 2012
Eelco Smit	Philips	Amsterdam, Netherlands	Senior Manager Sustainability	CSR, Eco-Design R&D	Personal Interview	April 2012
Frans Loen	Sony	Stuttgart, Germany	Environmental Affairs Manager	Environmental Regulatory Affairs	Personal Interview	April 2012

Table 6: List of interview partners

3.4.3 Validity and reliability

Yin (2003) identifies four criteria to test the quality of case study research: construct validity, internal validity, external validity, and reliability.

Construct validity entails using correct operational measures for the concepts being studied and reducing subjectivity (Yin 2003). The semi-structured interview method applied in this thesis naturally provides for acceptable construct validity, as expert respondents are able to answer relatively freely with little directions from the researcher (Leech 2002). Furthermore, the interviewees reviewed the case reports for confirmation. Moreover, construct validity is increased by the use of multiple sources of evidence (Yin 2003). In this thesis, information is collected from interviews, company reports and documents, academic studies, and NGO reports.

Internal validity refers to establishing causal relationships in the analysis. According to Yin (2003), in case studies internal validity can be ensured by taking account of existing literature and explanations on the subject. This has been done in the theory chapter of this thesis. Furthermore, an explanatory model describing the potential influence of EPR on eco-design is developed in section 2.4. External validity describes the extent to which the findings can be generalised. As discussed above, the comparative analysis of multiple cases, embracing two product groups, allows for some degree of generalisation.

Reliability refers to the extent to which the analysis can be repeated with the same results. In qualitative case studies this mainly implies reducing interview effects and other biases by appropriate documentation (Yin 2003). The interviews conducted for this thesis were oriented at a prepared outline of questions. Furthermore, all interviews were recorded and adjacently transcribed. Before they were finally included in this report, the case studies were reviewed by the interviewees.

3.4.4 Biases and limitations

In spite of sufficient validity and reliability, the adopted research design is subject to certain limitations. The chosen qualitative inductive approach generally entails a risk of subjectivism and 'over-interpretation' by the researcher. This risk is amplified by the explorative character of this study and the somewhat anecdotal knowledge gained though interviews, which require that the findings of this study are verified by further research.

Some specific biases may result from the chosen research method. With regards to the sample, the existence of a 'positive selection bias' cannot be ruled out. This research was dependent on the cooperation of the investigated companies. The producers that were willing to give insight into their end-of-life management are likely those that are among the most advanced companies in this area. While the selected cases promise to be very rich in information and are considerably relevant with regards to their market shares, less advanced companies are likely to fall out of the scope of this thesis.

The chosen method for collecting data is not free of biases either. First, the interviews are subject to a sensitivity bias. The interviewed companies are exposed to a highly competitive market and are thus careful not to reveal too much of their strategies and to not disclose anything that could cause negative PR. Second, the provided answers may suffer from poor recall or inaccurate articulation. It was attempted to reduce these biases by the inclusion of various external sources into the analysis.

3.5. Structure of the analysis and the case studies

The case studies form the first part of the analysis. In this part the information derived from interviews, company reports and websites and secondary sources such as available academic literature, case studies and NGO reports, is structured and presented. The first part is more descriptive in nature and lays the foundation for a comparative analysis in the second part.

To provide for comparison, the case studies are all structured in the same way. To begin with, each company is briefly introduced. The first section of each case study is devoted to the company's specific approaches to takeback and EPR compliance. In this section it is first discussed if and to what extent companies run voluntary individual schemes, what motivates them to do so, or which obstacles they see. Second, it is described how the companies fulfil their collective responsibility and which criteria are established towards producer responsibility organisations (PROs). Third, the firm's position on hybrid systems, i.e. systems that combine collective physical responsibility and individual financial responsibility on the basis of differentiated fees, is discussed. It is presumed that the companies can already draw some practical conclusions on hybrid systems following the introduction of differentiated systems in France in 2010 (c.f. Perrier 2010). Fourth, it is examined whether the company has set-up any closed-loop initiates. Fifth, a quantitative overview of the company's takeback efforts is presented, as far as figures are disclosed. Adjacent to the description of takeback, the second section of the case study deals with the company's approach to eco-design. This comprises a reflection of the company's course on eco-design over the last decades, an investigation of how eco-design is incorporated into the product development process, and an analysis of the company's eco-design strategies that have end-of-life relevance. The final section of the case study investigates the influence of EPR on the company's eco-design activities. It is analysed to what extent the company experiences financial, informational and physical feedback and how the company perceives the WEEE Directive.

The adjacent comparative analysis synthesises the findings of the individual case studies. In this way, central differences between the examined cases as well as general patterns can be identified.

4. Case Studies

4.1. Dell

4.1.1 Company profile

Dell is headquartered in Round Rock, USA. The company manufactures laptops, computers, server and storage solutions, projectors, monitor screens, and other computer peripherals. In contrast to its competitors, Dell adopted a direct-selling business model, which surpasses retailers, and configures computers to individual customer specifications. In 2011, the company had revenues of 50.9 billion € and employed 103,300 people (Dell 2012b). Its market share in the European PC market was estimated 10.5% in the fourth quarter of 2011 (Gartner Inc. 2012a).

4.1.2 Takeback and EPR compliance

a) Organisation

Dell organises its takeback activities in a centralised way. It has one operations team responsible for takeback across the whole EMEA region (Europe, Middle East, and Africa). According to Dell's takeback manager, the central organisation of product takeback ensures a clear view and control of compliance.[19] Team members are based across Europe (UK, Ireland, Germany, Italy, and Austria) and responsibilities are distributed with regards to various aspects, such as declarations, audits, reporting or policy change. The team solely focuses on takeback (commercial and mandatory) and related activities. Its work is supported by a centralised reporting system.

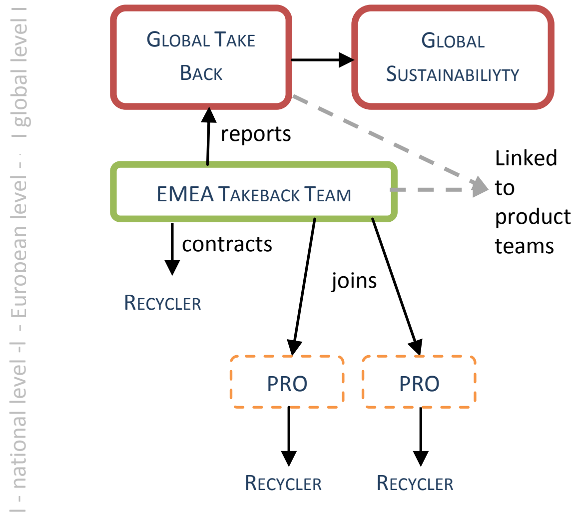

Figure 6: Takeback Organisation at Dell

Takeback management is seen from two angles. On the one hand, the team has to ensure that the company complies with legislation, such as the WEEE Directive or the Battery Directive. On the other hand, it offers a customer service to recover and dispose of owned or leased equipment, which can also take the form of a paid for service for customers who want reporting or assessment of products before they go back to a lease company. Therefore, the takeback team has to take both legal and marketing aspects into account.

b) Individual approaches

Of all companies investigated, Dell runs the most extensive individual takeback programme, which is available in countries both with and without mandatory EPR legislation. For households, the company offers a takeback service in 79 countries (Dell 2012a). Logistic partners pick up old products at home and ship them free of charge to an assessment centre, where they

[19] Phone interview with Johnathan Perry, Takeback Compliance Consultant at Dell, on April 23rd 2012.

are stripped down into components and checked for functionality. Reportedly, some still functional parts are refurbished and reused, however there is no further information available on this aspect. The majority of collected WEEE is handed over to recyclers. Dell's service applies to all of its own products, as well as to those of other brands if replaced by a Dell product. For business customers, Dell's Asset Recovery and Recycling Service offers logistics and organisation to recover and dispose of owned or leased equipment in 44 countries (Dell 2012a). Dell's individual collection is not set against any collective responsibility of the company, but in fact, fed into those schemes. Where possible, Dell reports the volume of individually collected WEEE to PROs or national authorities to obtain a respective compliance credit (Dempsey et al. 2010).

Despite operating its individual collection programme, Dell does not run its own recycling facilities. After products have been stripped down and assessed at a Dell environmental partner facility, parts not suitable for reuse or refurbishing are then treated by recyclers. To maintain some control over the final process, Dell set out requirements in its Electronics Disposition Policy (Dell 2009a). The takeback team conducts annual audits, where it investigates waste streams and mass balance rates to confirm that products are recycled in line with Dell's environmental partner standards (Dell 2009b). However the company has been criticised for not disclosing its recycling vendors or audit results (Electronics Takeback Coalition 2010a).

c) Collective approaches

Despite of its comprehensive individual takeback programme, Dell is also a member of collective schemes. The company regards these two approaches as complementary (Dempsey et al. 2010). The company established several criteria with regards to its membership in collective compliance schemes. Dell's takeback manager states that the decision for a scheme is looked at in a much broader sense than just costs.[20] Emphasis is placed on the capabilities of a scheme, including its downstream operations and treatment standards. Furthermore, it is important for Dell that a scheme also provides services that go beyond compliance, for example engagement with policy development. According to the interviewee, these aspects combined have more value for the company than direct financial benefits.

The company does not prefer a specific cost-allocation mechanism; as they are all connected with own challenges. Each scheme in each country provides different circumstances, therefore variances are considered normal. However, Dell hopes to see a better alignment between countries over the next three years.[21]

d) Stance on hybrid systems

The introduction of differentiated fees as in France is regarded with scepticism. Dell's takeback manager notes that while differentiated fees may lead some producers to making their products more eco-friendly they do add some initial complexity to the design stage. He points out that from the implementation perspective it is complex to gather all required data from each product placed on the market, particularly if it is required in a short time period to ensure compliance. Furthermore, end-of-life management becomes more expensive, as more evaluation has to be done to determine which product comes into which category, particularly when it goes down to a

[20] Ibid.
[21] Ibid.

component level.[22] Hence, Dell does not find that such a strictly defined differentiated fee system would decrease end-of-life costs or provide any benefits at this point in time.

e) Closed-loop initiatives

There are no direct closed-loop programmes in place. Recovered materials go to the secondary market. While Dell's takeback manager sees the potential that certain strategic materials could be secured from own product takeback, he notes that at this stage the volumes of the material recovered are not significant enough to make it effective given the potentially long transportation distances. However, possible downstream synergies are investigated.[23]

Hence, Dell places emphasis on indirectly closed loops. The interviewee considers selling recycled materials as the best option to move towards closed material loops. In this way it can be ensured that they go back into the material stream in a responsible way and find a useful purpose. The company strives to increase its own use of recycled materials. However, efforts appear to have focused so far mainly on plastic from recycled water bottles rather than creating a demand for post-WEEE recycled materials. Furthermore, Dell emphasises the use of recycled materials in certain flagship products rather than presenting a systematic approach embracing the entire product line.

f) Quantitative reporting

Taken together, the company's individual takeback scheme handled worldwide a volume of 375,500 tons in fiscal year 2012[24] (Dell 2012a). It is unclear, how much this is compared to the overall quantity of goods produced. There is no data disclosed on the volume of WEEE handled on behalf of the company in collective schemes.

Dell reports that it used approximately 3300 tons of postconsumer recycled plastic in selected monitors and systems in fiscal year 2012 (Dell 2012a).

4.1.3 Eco-design

a) Company's environmental approach

The company published a white paper, which outlines its environmental product strategy (Dell 2010). In this document it presents a systematic approach to eco-design that spans over the entire product line. Dell committed itself to a proactive approach towards environmental issues (Dell 2011a) and is recognised by Greenpeace (2011a) as one of the leading green companies in the electronics sector.

b) Integration of eco-design into product development

Dell asserts that it integrates environmental aspects early into products during the design stage. The company mainly relies on environmental specifications and guidelines to help its designers creating greener products. In addition, the company's environmental management system based on ISO 14001 supports steering this process (Dell 2011a).

[22] Ibid.
[23] Ibid.
[24] February 2011 – February 2012.

c) Adopted eco-design strategies with end-of-life relevance

Dell states that it is committed to minimizing environmental impact from the start while taking every step of a product's lifecycle into account (Dell 2011a). Particular emphasis is placed on phasing out hazardous substances (strategy IIIa). The company issued a regularly updated list of Materials Restricted for Use (Dell 2011b), which is obligatory for designers and suppliers. Current efforts concentrate on the phase out of mercury and the phthalates DEHP, BBP, DBP, which are used to make plastics softer or more flexible. A further goal is to eliminate BFRs and CFRs and PVC by the end of 2011 (Dell 2011a). However, this goal just applies to computing products and not to the whole product range. A guide issued by Greenpeace (2011) therefore attests the company a mediocre performance on hazardous substances.

The second cornerstone of Dell's eco-design strategy is the optimisation of product end-of-life treatment and facilitating reuse. The company declares that it uses modular components and standardised parts where feasible (strategy VI) and designs products to be upgraded to increase their useful life (strategy Ia). Disassembly is simplified by an appropriate choice of fasteners. Snap fits are preferred over screws, and glues and adhesives are eliminated (strategy IV). Furthermore, the company prohibits paints that can inhibit the recycling of plastic parts. (Dell 2010)

A further focus point is the use of recycled materials (Dell 2010). The company has some flagship products with post-consumer recycled content (strategy VII) (Electronics Takeback Coalition 2010a). However, no information is available that would indicate a systematic effort to increase the share of recycled materials across the whole product range. Greenpeace (2011a) criticises that Dell does not have a public target for increasing the use of recycled materials and does not disclose information on their overall quantities.

4.1.4 Indications of EPR affecting the company's eco-design activities

a) Financial feedback loop

There is some indication that financial feedback from EPR affects Dell's eco-design strategy. The company makes an explicit connection between end-of-life costs and product design. According to the interviewee, Dell focuses on two aspects in order to cut down product end-of-life costs.[25] The primary approach is respective eco-design, particularly with regards to hazardous chemicals and disassembly feasibility (snap-in, snap-out connections). The second way is to save costs in the schemes' operations. In some situations Dell sees itself confronted with a trade-off between higher costs and higher environmental benefits. The company then seeks a balance by finding the most cost-effective scheme for a specified environmental advantage. Furthermore Cox-Kearns (Cox-Kearns 2012), who is involved with Dell's takeback management, holds that the company saves money by regularly auditing its recycling programme and carrying out initiatives against illegal exports of e-waste, as these activities increase the profitability of recycling.

However, the company's individual takeback efforts do not appear to be linked to financial incentives. According to Dell's takeback manager, the company's programme is motivated by corporate social responsibility efforts and not seen to provide any cost-benefits at this stage.[26]

[25] Phone interview with Johnathan Perry, Takeback Compliance Consultant at Dell, on April 23rd 2012.
[26] Ibid.

Product takeback allows offering product responsibility as a global service and attracts positive attention.

b) Informational feedback loop

There are indications for strong informational feedback from end-of-life management. Internally, the company maintains regular and close communication streams between takeback departments and product development teams. On a grassroots level, takeback managers are in close contact with developers in their day-to-day work and have an assigned counterpart to whom they can talk. On a managerial level, takeback and eco-design strategies are linked and coordinated. Although Dell does not run own recycling facilities, it uses information from recyclers and recycling trade organisations to assess the impact of product design, materials use, and recycling technology. Product designers perform site visits and are involved in audits (Dell 2010). Furthermore, the individual scheme is seen to provide learning possibilities that can be useful for future takeback innovation (Dempsey et al. 2010). However, the company's takeback manager notes that laptops are quite generic products, which recyclers are already able to treat very competently and confidently.[27] Early discussions, at times when the WEEE Directive was still pending, showed that recyclers are very knowledgeable on the subject and do not require any help from producers.

c) Material feedback loop

There is no indication for a material feedback loop from end-of-life management, as the materials recycled through Dell's takeback programme do not go back to the company, but are sold at secondary markets. The use of recycled materials in production is not related to Dell's takeback activities. While the company reports that some still functional parts recovered from takeback are refurbished and reused, this does not appear to be done on a large scale.

d) Assessment of the WEEE Directive and obstacles faced

Dell supports the idea of extended producer responsibility and is convinced that it works.[28] The company is engaged in the IPR Works Coalition, which supports a legal implementation of individual responsibility (IPR Works Coalition 2009). The WEEE Directive is attributed with indirect effects on eco-design. In conjunction with other directives and other influences it creates a collective influence which has improved eco-design of equipment noticeably. However, Dell's takeback manager explains that the WEEE Directive did not incur many changes for the company. It joined collective compliance schemes but continued to run its individual takeback programme. Already existing projects required no or only minimal changes. Eco-design was already on the company's agenda before the directive and related efforts were continued as before.

[27] Ibid.
[28] Ibid.

4.2. Hewlett-Packard (HP)

4.2.1 Company profile

HP is based in Paolo Alto, USA and is the world's largest IT company in terms of sales. Its product line includes hardware, laptops, printers, and other PC accessories; as well as software, server and IT solutions for businesses. In 2011 the company had a turnover of 104.2 billion € and employed 324,600 people (HP 2012a). HP has the highest market share in the PC sector in Western Europe. In the fourth quarter of 2011 it was estimated at 22.2% (Gartner Inc. 2012a).

4.2.2 Takeback and EPR compliance

a) Organisation

HP's takeback activities are jointly conducted by its Take Back Operations Organisation (TBOO) and its Environmental Business Management Organisation (EBMO). TBOO is responsible for the management and implementation of individual and collective schemes as well as reporting. EBMO is in charge of monitoring and compliance assurance.[29] The departments comprise 20-30 people. While many other companies delegate takeback tasks partly or fully to individual country subsidiaries, HP's Environmental Business Management Organisation is responsible for the whole region of Europe, Middle East and Africa. Together with Dell, HP has adopted the most centralised approach to takeback.

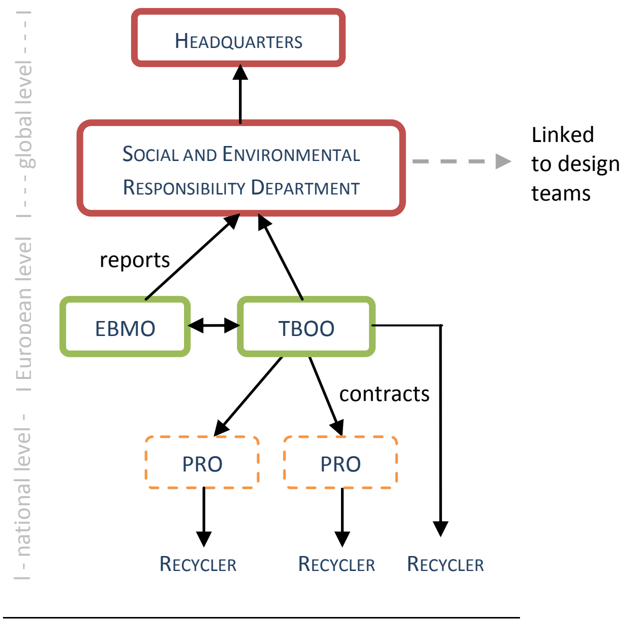

Figure 7: Takeback Organisation at HP

b) Individual approaches

The company's first takeback activities date back to the 1980s, more than 20 years before the WEEE Directive was introduced. Today, HP's Planet Partners Program, an individual takeback and collection scheme, is available in 49 countries (HP 2011a). The programme covers printer supplies (cartridges and toner) and hardware. The offered service includes pickup and transportation to a central assessment location (where possible), where products are evaluated. Functioning hardware products are donated to charity (Degher 2002). The remaining e-waste is recycled by contracted vendors. Regular audits are conducted to ensure that vendors are meeting HP's recycling standards. In 2010, 37 audits were carried out (HP 2011a).

In addition to CSR, HP sees commercial value in a credible individual takeback system, "because businesses and consumers increasingly choose manufacturers that offer responsible takeback

[29] Personal interview with Daniel Seager, Takeback Regulations and Implementation Manager at HP, on March 23rd 2012.

options for used equipment" (HP 2011a, 77). However, the scope of the programme differs from country to country. In the European Union, it only extends to hardware from business customers and printer supplies. WEEE from private households is not covered and instead handled via collective schemes. HP's IPR approach therefore has to be regarded as supplementary to its collective engagement (Dempsey et al. 2010). The company's takeback manager explains that relying fully on an IPR approach would be not feasible at present, and too expensive with regards to sorting and collection logistics.[30]

c) Collective approaches

The company decided to fulfil its responsibility for household WEEE collectively. However, instead of joining existing PROs, HP partnered with Braun, Electrolux and Sony to set up a producer responsibility organisation on their own. The European Recycling Platform, as it has been called, has become one of the largest collective systems (European Recycling Platform 2012). According to HP's takeback manager, there were various reasons to initiate the scheme.[31] The main goal was to establish competition with existing monopolistic schemes, which tend to overcharge producers. A competitive scheme is considered to drive the fees down to a level where they reflect the real costs of recycling and takeback. Furthermore, HP aimed to increase the number of options it has in the takeback process. Another reason was to come to an easier organisation of takeback. The European Recycling Platform operates in 12 countries and brokers collective compliance in another 17 countries (European Recycling Platform 2012). This pan-European approach is well aligned to HP's centralised takeback organisation.

HP has a clear preference for how end-of-life costs should be allocated within a collective scheme. The company prefers a system based on ex-post market-share allocation. In this way, a transparent line between volumes of WEEE and costs is seen. In contrast, ex-ante fees charged on top of individual products are rejected where possible. According to HP's takeback manager, ex-ante fees are prone to miscalculations and lead to surpluses of the scheme.[32] Furthermore, he considers return-share allocation impractical regarding the costs and technical difficulties of separation mechanisms. While the interviewee notes that HP may subsidise products of other manufacturers that are more expensive to recycle, such as CRT TVs, he does currently not see an alternative to this practice. He acknowledges that IPR would avoid this situation; but this is, as described above, not currently considered a feasible option.

d) Stance on hybrid systems

HP is generally opposed to visible ex-ante fees charged on top of products at the point of sale. This includes differentiated upfront fees such as introduced in France. HP's takeback manager points to the difficulty to know already at the point of sale how much it will cost to recycle a product several years later when it enters the waste stream.[33] The company does not object to differentiated fees if they can be combined with an ex-post calculation. However, such a system has not been trialled yet.

[30] Ibid.
[31] Ibid.
[32] Ibid.
[33] Ibid.

e) Closed-loop initiatives

The company established a direct closed-loop process for printer supplies. Plastic from returned cartridges is used to make new cartridges. Furthermore, HP reuses and refurbishes equipment recovered from its leasing programme (HP 2011a). However, there is no indication that a closed-loop programme for other hardware will be initiated in the near future. Recycled content recovered from HP's hardware takeback is not directly used by the company, but sold on secondary markets.

The company aims to promote indirectly closed loops by increasing the share of recycled materials in products. However, no detailed information is disclosed on this subject.

f) Quantitative reporting

In 2012 HP recovered 120,000 tons of electronic products and supplies for recycling. This figure also includes toners and cartridges. Additionally, 30,000 tons of hardware were reused and remarketed. However, it is unclear whether these figures refer solely to HP's individual takeback programme or also include WEEE treated on behalf of the company in collective schemes. The total amount of reused and recycled products constituted 16% of HP's relevant hardware sales worldwide. (HP 2011a)

800 million cartridges were produced with recycled plastics from HP's closed-loop programme, and an additional 200 million with recycled plastics from secondary sources (HP 2011a). However, it is not clear how much this is in relation to the overall quantity produced. No quantities are reported on the amounts of recycled materials used to manufacture PC hardware.

4.2.3 Eco-design

a) Company's eco-design approach

HP's design teams are distributed globally.[34] The company's various product lines operate independently, with own responsibility and own research and development (Korpalski 1996). In 1992, HP formulated a companywide Design for Environment guideline (HP 2011a). Simultaneously, it enacted an innovative product stewardship programme to facilitate compliance with the standard across the company. The product stewards serve as focal points for decentred business units. Their role is to coordinate efforts, maintain communication networks, bundle information and foster cooperation between different teams (Korpalski 1996). If needed the stewards form cross-functional teams to deliberate on issues and weigh up various aspects of design from cost and performance to environmental impact (Dillon 1997).

b) Integration of eco-design into product development

The stewards and design teams have various tools and methods at hand to substantiate environmental product design considerations. So called Product Environmental Metrics are the company's central tool to target improvements and measure results. The metrics comprise a collection of basic data on energy consumption, carbon footprint, manufacturing processes, design features and material and recycling properties (Korpalski 1996). The measures are fundamentally based on lifecycle analyses. In addition, the company assesses some issues with

[34] E-Mail Correspondance with Dimitar Dimitrov, Environmental Support Specialist at HP, on April 11th 2012.

more specific tools, such as HP's Recyclability Assessment Tool, and Green Screen, an open source tool to benchmark and identify safer materials. Designers are informed about these tools and eco-design in mandatory trainings (HP 2011a).

c) Adopted eco-design strategies with end-of-life relevance

HP's Design for Environment Strategy focuses mainly on two end-of-life related aspects: hazardous substances and recyclability.

With regards to hazardous substances (strategy IIIa), the company issued 'General Specifications for the Environment' (HP 2011b) to communicate its substance requirements to suppliers and designers. A hazard-based assessment framework called Green Screen, which was developed by the NGO Clean Production Action, is used to analyse replacement materials. The tool works with a simple one to four benchmark score, which enables engineers to quickly evaluate the human health and environmental implications of a particular substance (HP 2011a). Product advances and remaining concerns are reported transparently. The company discloses a full overview of all substances of concern identified in its products, including those that have not yet been addressed (HP 2011a). As of 2010, HP's notebook line is free of BFRs, PVC and mercury. Eventually this shall be achieved for the complete product range, but no public deadline is set. HP explains that many suppliers have found it difficult to identify substitutes for these substances that are available at sufficient volumes and equivalent quality. Recently, arsenic-free display glasses and tighter restrictions on mercury and beryllium have been initiated (HP 2011a, 2011b). The company's target to phase out the phthalates DEHP, DBP and BBP in new computing products has been rescheduled to the end of 2012. However, there is no related objective covering other phthalates and further product lines (Greenpeace 2011a).

Recyclability is tackled with a specific 'Design for Recycling' programme. It covers disassembly improvements, such as common fasteners, snap-in features and avoiding the use of glues, adhesives, and welds (strategy IV). In addition, efforts are made to reduce material variety (strategy Vb). HP claims that its new notebooks are on average more than 90% recyclable by weight (HP 2011a).

Furthermore, the company aims to reduce the quantity of materials used by designing thinner and smaller products (strategy II), and to increase the use of recycled materials (strategy VII) (HP 2011a). However, apart from information on a few flagship products, no further details or specific goals are reported with regards to these aspects.

4.2.4 Indications of EPR affecting the company's eco-design activities

a) Financial feedback loop

While HP confirms financial feedback from end-of-life management, there is no evidence that this has any effect on the company's eco-design activities. Within the company, the takeback team communicates general information on the costs of its end-of-life operations. However, cost reduction strategies focus on other means, such as spurring scheme competition and negotiating appropriate contracts.[35] While connections between takeback and eco-design are made at higher levels, on the operational side there are no links between the respective departments.

HP's takeback manager emphasises that WEEE is an important cost factor in the company's operations. It undertakes several efforts to drive down end-of-life costs. By having initiated the establishment of a competitive PRO, the company already benefits from lower fees. Moreover, HP is now able to negotiate on the contract details with the schemes. Costs can be saved for example by connecting material recovery to current resource prices (index pricing) or renegotiating the point of time when containers have to be collected. Another way HP attempts to cut down costs lies in policy advocacy, by which it aims at deconstructing system barriers and achieving an optimisation of the regulation. Furthermore, the organisation of takeback events can help to reduce costs, as the company is able to treat self-collected waste at a better price than through the official system.[36] However, this financial feedback does not appear to promote respective design changes. While HP undertakes considerable efforts with regard to eco-design it does not explicitly incorporate this in its efforts of cutting down the costs for end-of-life management.

b) Informational feedback loop

In the case of HP there are indications that informational feedback from the end-of-life stage affects eco-design practices. Direct informational exchange between the company's design teams and recyclers, as well as HP's involvement in recycling processes and its collaboration with recyclers in the development of new recycling technologies all support the companies' efforts to increase product recyclability.[37] HP's product stewardship approach increases the informational accessibility, as it establishes a bottom-up approach which is generally more open to new inputs.

There is considerable informational exchange between HP and recyclers. The company maintains direct relationships with a global network of recyclers for its Planet Partners Program. In Europe, business-to-business takeback goes directly to recyclers and is not handled by ERP. All vendors are required to comply with HP's recycling standards (HP 2012b). A third party has been contracted to carry out audits. The gaps that were identified with several recyclers are addressed though corrective action plans (HP 2011a). Furthermore, HP is considerably involved with the development of new recycling processes and techniques (Hudson-Hanley, Terhune, and Degher 2002).

c) Material feedback loop

To some extent, also material feedback in form of the company's closed-loop cartridges programme has fostered eco-design developments. However, so far this applies only to a very limited share of the company's product range.

d) Assessment of the WEEE Directive and obstacles faced

HP takeback manager agrees with the principle that producers should have a responsibility for the end-of-life stage of their products. However, he notes several weak points of the directive.

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[35] Personal interview with Daniel Seager, Takeback Regulations and Implementation Manager at HP, on March 23rd 2012.
[36] Ibid.
[37] E-Mail Correspondance with Dimitar Dimitrov, Environmental Support Specialist at HP, on April 11th 2012.

Firstly, he objects to the existence of mandatory national PROs in some countries. The company considers it important to be able to have some control over its end-of-life management and have the opportunity to choose between different vendors. Secondly, the interviewee criticises that the regulation does not recognize many of the other actors involved in takeback and product end-of-life management, because it failed to grasp the real value of WEEE. The recycling of some WEEE categories, including most IT products, has become profitable and generates revenues rather than costs. This opens the scene to several other actors, which take some of the WEEE out of the waste stream and recycle it for profit. HP is not against the involvement of other actors, but contests that it should be adequately reflected in the legal requirements. While the directive itself mandates measuring of all WEEE at the point of recyclers, regardless of whether it is coming from producers or commercial actors, it has often not been transposed in this way. Instead, collection and recycling data are gathered only for producer schemes. In a situation where commercial actors recycle large parts of the waste stream for profit, HP would like to reduce its end-of life involvement. The company interprets its responsibility to offer a kind of safety net for WEEE that is not recycled by others. HP's takeback manager remarks: "We don't mind recycling WEEE with value, but this is not our core business. We're in the business of selling and we'll offer a safety net for all end-of-life products which are handed over to us, but we do not need to collect products from actors who would recycle them otherwise. That's the business of others."[38]

4.3. LG Electronics

4.3.1 Company profile

LG Electronics is a manufacturer of mobile phones, televisions and other consumer electronics, household appliances, notebooks and computer peripherals, based in Seoul, South Korea. In 2010, the company had a turnover of 40.1 billion € and employed 90,587 people (LG Electronics 2011b). In the first quarter of 2011 the company's estimated market share in the global mobile phones market was estimated 3.5% (Gartner Inc. 2012b).

4.3.2 Takeback and EPR compliance

a) Organisation

LG's end-of-life management is predominantly decentralised. The company delegates most of the related tasks in Europe to its national sales subsidiaries, which are responsible for implementation, reporting, paying bills, and contracting schemes. Usually, the national sales offices do not have own environmental departments, therefore takeback is attributed to either legal, accounting, services, or supply chain departments,

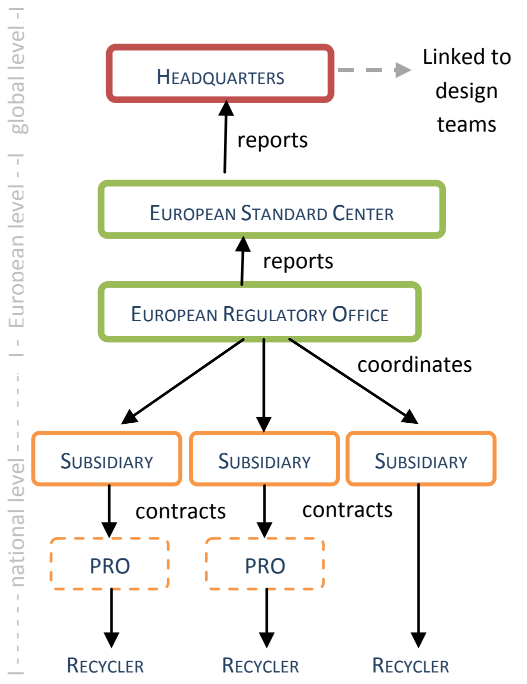

Figure 8: Takeback Organisation at LG

[38] Personal interview with Daniel Seager, Takeback Regulations and Implementation Manager at HP, on March 23rd 2012.

depending on the organisation of the individual subsidiaries.[39] The various takeback compliance activities are coordinated by a central European Regulatory Office, which also provides guidance and recommendation to national sales offices. Moreover, the Regulatory Office interacts with governments and schemes and is engaged in policy development. Within the company, takeback is essentially considered a legal compliance issue and thus managed by legal departments. LG's central European Regulatory Office is part of the company's European Standard Centre, which organises product compliance by combining legal and technical expertise.[40]

b) Individual approaches

LG publicly supports IPR and states that it has been promoting the concept through forums and associations. However, the company does not yet consider IPR a technically and economically feasible option and hopes that practical identification solutions will become available in the near future (LG Electronics 2012b). Therefore, the company handles most of the WEEE in Europe via collective takeback. This includes discarded products from professional customers, which is usually treated the same as WEEE from households to avoid complicacies resulting from dissimilar definitions of business-to-business WEEE across countries. LG's takeback manager criticises that an item sold for professional use might be considered business-to-business in one country and business-to-consumer in another.[41]

In addition to collective efforts, LG runs a voluntary mobile phone takeback programme with 392 drop-off points globally. In most European countries a few drop-off points can be found (for instance two in the Netherlands, six in Germany, and nine in the UK). LG provides the relevant information for consumers on its website (LG Electronics 2012b). NGOs, however, criticise the low number of drop-off points (Electronics Takeback Coalition 2010b; Greenpeace 2011a).

c) Collective approaches

LG contracted a variety of different recycling schemes in Europe. A full list is disclosed on the company's website (LG Electronics 2012a). In a few countries, such as in Germany, LG works directly with recyclers who offer collective compliance solutions. LG's sales subsidiaries are free to decide which recycling scheme they use. The central European office provides them with general guidance and a hierarchy of criteria to evaluate between different scheme options. The first criterion is the capability of a scheme to handle the expected volumes. Due to the considerable rise of LG's market-share over the last five years, some of the previous arrangements were not capable anymore of coping with the company's takeback requirements and different solutions had to be sought. Second, LG places value on a scheme's service and compliance quality. Third, if a scheme displays satisfactory capabilities and quality, the sales subsidiaries are advised to decide according to the prices charged by a scheme.[42]

d) Stance on hybrid systems

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[39] Personal Interview with Gregor Margetson, Takeback Manager at LG Electronics, on April 5th 2012.
[40] Personal Interview with Yu-Mi Mun, Senior Manager Energy and Environmental Affairs at LG Electronics, on April 5th 2012.
[41] Personal Interview with Gregor Margetson, Takeback Manager at LG Electronics, on April 5th 2012.
[42] Ibid.

LG's environmental manager appreciates France's approach to introduce differentiated fees. She is convinced that in this way a more just allocation of costs and a better promotion of eco-design can be reached. A particular advantage is that financial feedback reacts to changes made in product design without delay. However, she sees only limited options for LG to initiate such systems and calls upon governments to enact respective legislation.[43]

e) Closed-loop initiatives

Currently, all recovered materials from LG's product takeback are sold at secondary markets. The company intends to initiate direct closed loop recycling programmes in the future, but has not yet adopted concrete measures in this direction (Electronics Takeback Coalition 2010b). Indirectly, closed loops are fostered through LG's approach to increase the share of recycled plastics in its products (see eco-design strategies).

f) Quantitative reporting

LG reports takeback figures for its individual and collective programs in Korea, Japan, Europe and North America. In these areas the company handled a total of 198,984 tons in 2010. As one of few companies LG discloses the amount handled on their behalf by collective schemes in Europe. In 2010, this figure was 148,284 tons. (LG Electronics 2011a)

In 2010, the company used 2014 tons of recycled plastics (LG Electronics 2011a). This amounts to 11% of all plastics used in LG products. The company aims to increase this share to 25% by 2025 (LG Electronics 2012b).

4.3.3 Eco-design

a) Company's environmental approach

LG began embracing environmental issues in the early 1990s. In 1992 an Environmental Committee was established and in 1994 the company announced its Environmental Proclamation in which it committed itself to minimise environmental impact and develop greener products. Gradually the company set up a systematic approach to eco-design. The adoption of lifecycle analyses in 1995 and the ATROiD[44] tool one year later established a methodological foundation for green product design. In 2003, LG introduced an 'Eco Design System', which incorporates environmental considerations as a regular component into several stages of the product development process. The introduction of an Eco Index in 2006 allows for a quantitative measurement of results. (LG Electronics 2009)

b) Integration of eco-design into product development

The company has developed several tools and methodologies to support the incorporation of eco-design into product development. One of them is the Eco Index, a methodology to assess the eco-design level of products, manage environmental performance and set goals. The rating system classifies products into the categories (Green 1 Star, Green 2 Star, and Green 3 Star), to symbolise different levels of eco-design. The fundamental category, Green 1 Star, indicates

[43] Personal Interview with Yu-Mi Mun, Senior Manager Energy and Environmental Affairs at LG Electronics, on April 5th 2012.
[44] The tool is explained in more detail in the following section.

compliance with required legal and basic internal environmental standards and covers the whole product range. Moreover, in 2010 71 % of LG's products further classified for Green 2 Star, which comprises a set of stricter company environmental standards. Green 3 Star comprises the companies' leading green products which make up 17 % of the product range (LG Electronics 2011a). The company's objective is to gradually increase the share of 2 Star and 3 Star products, however, no specific target is published and the rating is only of minor relevance to end-of-life management as most emphasis is placed on energy efficiency. Next to its Eco Index, LG uses Lifecycle Assessment according to ISO 14040 as a tool to analyse, measure, and improve the environmental impact of products. Next to manufacturing, use, and distribution the disposal stage is of particular relevance here (LG Electronics 2011a).

Furthermore, the company uses ATROiD[45], a specific tool to improve product design with regards to disassembly and recycling qualities, which it developed in collaboration with the University of Braunschweig in Germany (LG Electronics 2009). The tool uses input information about parts, materials and connections to calculate disassembly and recycling sequences, which can then be used to optimise a product's disassembly time and recycling rate. Notably, the tool explicitly takes end-of-life management into account as it offers a function to minimise end-of-life costs (Kang 2003).

Apart from these tools, LG has aligned its research & development to promote eco-design. The company established various research laboratories which focus on specific eco-design strategies and feed designers with new inputs (LG Electronics 2011a).

c) Adopted eco-design strategies with end-of-life relevance

With regards to product end-of-life improvements, LG concentrates on strategies to phase out hazardous substances, minimise resource use, and improve the recyclability of products.

The company has phase-out plans for PVC, BFRs, phthalates, antimony, and beryllium oxide (strategy IIIa). Each plan is tied to a specific deadline. Currently, most progress has been achieved for mobile phones, where newly developed products are free of beryllium oxide since 2002 and free of PVC and BFRs since 2010. Phthalates and antimony are planned to be phased out by 2012. The plan for PCs foresees the elimination of all five substances mentioned by 2012 (LG Electronics 2012c). The phase out of hazardous substances is supported by a dedicated research team (Hazardous Substance Analysis Lab). It developed standardized analysis methods, which are used to identify high-risk materials, support the replacement of hazardous substances and verify greener products. To assess the level of hazardous substances in products and components, a testing system based on x-ray fluorescence technology has been developed (LG Electronics 2011a).

LG's target to improve resource efficiency is based on three eco-design strategies. The first, minimisation of resource use in products, mainly focuses on measures to reduce the weight and volume of products or to increase the capabilities of the products while keeping their size (strategy II). A dedicated research unit (Slim Product and Mounting Technology Development Lab) has been established to support to this work (LG Electronics 2011a). However, so far only certain flagship products reflect these efforts. The second, improving product recyclability,

[45] Assessment Tool for Recycling Oriented Design.

involves more complex measures to improve products with regards to material identification, component accessibility, disassembly opportunities, and recyclability (strategy IV) (LG Electronics 2011a). This work is supported by checklists, guidelines and the ATROiD tool explained above. However, no quantitative information is available on the overall recyclability of LG products. The third strategy to improve resource efficiency consists in the use of recycled resources (strategy VII). Although the focus is placed exclusively on recycled plastics (LG Electronics 2011a), it appears that LG adopted a comprehensive approach that covers the entire product line. The company set an ambitious target to increase the total share of recycled plastics to 25% by 2025 (LG Electronics 2012b).

4.3.4 Indications of EPR affecting the company's eco-design activities

a) Financial feedback loop

There are indications that financial feedback from end-of-life-management affects the company's product design procedures. Eco-design is seen as a means to obtain competitive advantage by reducing the costs of production and waste management. The ATROiD tool employed by the company during design processes has particular functions focusing on the optimisation of end-of-life treatment costs (Kang 2003). According to the company's environmental manager, the financial incentive set by EPR regulation may tip the scales in some decisions in favour of greener design, by adding a financial argument to less tangible motivations such as positive brand image and CSR.[46] However, financial feedback is impaired by uncertainties regarding developments in recycling technology. Some design improvements may become irrelevant if recycling processes have changed until respective products enter the waste stream. It is difficult to make a business case for design innovations, which are uncertain to ultimately result in End-of-life costs. Furthermore there is an uncertainty if the producer will benefit from changes itself or rather the recycler or the scheme.[47]

The financial burden incurred by takeback has become a significant factor for the company. While some years ago the specifics of product end-of-life management was only relevant for the company's takeback team, now LG's Korean Head Office has become more involved in the subject. This change not only results from increasing volumes that have to be treated, but also relates to a gradual shift in the way costs are allocated. Visible fees paid by consumers on top of a product's price did not have a strong effect on the company. They were considered by the company as external fees that have administrated similar to value-added taxes. The retrieval of visible fees by the Recast of the WEEE Directive (2012) has promoted other forms of cost-allocation which internalise the fee and thereby receive more attention by company managers. LG's takeback team generally opposes undifferentiated flat fees per unit sold and criticises that many schemes have build up significant financial reserves. It prefers systems that either base fees on the weight of WEEE collected (return-share) or differentiate fees according to product characteristics.

b) Informational feedback loop

[46] Personal Interview with Yu-Mi Mun, Senior Manager Energy and Environmental Affairs at LG Electronics, on April 5th 2012.
[47] Personal Interview with Gregor Margetson, Takeback Manager at LG Electronics, on April 5th 2012.

The informational feedback loop appears to be less mature. The interviewee explains that relevant end-of-life information gathered by the takeback team reaches design teams indirectly via headquarters. LG's takeback managers are in regular contact with recyclers, particularly in countries where compliance solutions are directly offered by recyclers. The European office meets with recyclers every one or two years and sales subsidiaries several times a year to discuss relevant topics. LG regularly receives questions from recyclers regarding product properties and material composition. These questions provide useful feedback for the company as they point to information gaps and problematic materials. However, the feedback LG has received in the past from recyclers often discouraged rather than promoted eco-design. The company learnt that design for disassembly is of little relevance to many recyclers as they rely fully on automated shredding and sorting mechanisms. A dilemma however, is seen in the time span between current design innovations and point of disposal. Feedback from recyclers always refers to past product design treated with currently available recycling technology.[48]

c) **Material feedback loop**

There is no indication for a material feedback loop from end-of-life management. The company does not have a closed-loop programme and does not make a connection between its takeback activities and its efforts to increase the use of recycled plastics in products.

d) **Assessment of the WEEE Directive and obstacles faced**

LG's takeback team voices some scepticism about EPR and the market-based approach taken by the WEEE Directive. It criticises weak transpositions of the directive and suspect that some member states were more concerned about their national waste management budgets rather than establishing meaningful incentives for eco-design. Particularly national collective schemes would prevent any opportunity for a company to establish a Europe-wide IPR system. A further nuisance is seen in the heterogeneity of product category classification, which makes reporting a laborious task.[49] The takeback team appreciates, however, the combination of EPR with mandatory requirements and the introduction of differentiation of fees as advanced by the Recast of the WEEE Directive (2012).

4.4. Nokia

4.4.1 Company profile

Nokia is headquartered in Espoo, Finland and one of the leading companies in the mobile phones sector. In 2011, the company had a sales volume of 38.7 billion € and employed 130,050 people (Nokia 2012c). In the first quarter of 2012, the company's market share in the European mobile phones market was estimated 19%, which is the second highest after Samsung (IDC 2012).

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[48] Ibid.
[49] Ibid.

4.4.2 Takeback and EPR compliance

a) Organisation

At Nokia, take-back activities are managed to a large extent directly by the company's Sustainability Department, which decides upon organisational issues regarding the implementation of takeback obligations and the collaboration with recycling schemes. At the subsidiary level, local Responsibility Managers who are familiar with the language and local circumstances then organise the realisation of the decisions.[50] Because major decisions are made by the global Sustainability Department, the company's approach to takeback compliance can be described as centralised. The Sustainability Department reports directly to the head office.

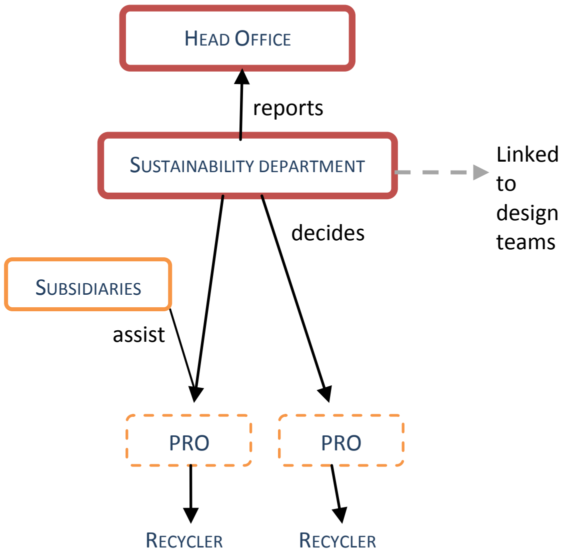

Figure 9: Takeback Organisation at Nokia

b) Individual approaches

In some countries (Finland, Norway, Spain, Sweden, and the UK), Nokia runs sporadic takeback campaigns. In Norway and Finland, consumers can make use of a free mail-back system (Nokia 2011b). With these activities Nokia aims at raising recycling awareness and boosting the collection rates of obsolete mobile phones. Discarded phones of any brand are accepted and handed over to Nokia's local responsibility schemes. These activities can therefore not be considered as proper individual takeback approaches. The company's sustainability manager states that relying solely on individual mail-back systems is not considered a viable alternative to collective engagement, as it would be inconvenient for consumers and likely to negatively affect collection rates if each producer runs its own system with different procedures.[51] Outside of the European Union, however, the company is engaged in various voluntary takeback and recycling activities. Globally, the company provides more than 6000 collection points in close to 100 countries (Nokia 2012d).

c) Collective approaches

Nokia joined several collective recycling schemes to fulfil its extended producer responsibilities. In countries with competitive PROs, Nokia usually joined the majority scheme. According to the interviewed sustainability manager, economic considerations play only a minor role in the decisions for or against specific schemes. In the beginning it was more important to avoid uncertainties that accompanied the development of many of the newer schemes. Moreover, the choice was often predetermined by industry association set-ups or previous relations with some schemes, such as Valpak in the UK, which was already handling Nokia's packaging materials

[50] Personal interview with Helena Castren, Senior Sustainability Manager at Nokia, on March 30th 2012.
[51] Ibid.

obligation.[52] Aspects regarding the controllability of schemes or specific standards do not seem to play a major role for the decision.

d) Stance on hybrid systems

Nokia has a reputation as proactive proponent of individual producer responsibility and lobbied for the introduction of differentiated fees (Greenpeace 2011a). The sustainability manager is convinced that a fairer allocation of costs is possible. The company does not have a preference for a specific method, but generally sees room for integrating differentiated fees into the calculation. These fees could be based on a certain price catalogue, which differentiates between product types, size and weight. Such a catalogue would need to rely on certain averages on the level of product types (i.e. mobile phones, laptops, toasters, etc.). A precise distinction between individual products based on design elements is seen as currently impossible and not useful, considering that all products of one type usually contain the same elements, some of which cause costs and some cause benefits.[53]

e) Closed-loop initiatives

Nokia is concerned about limited resource availability and the environmental and social implications of resource exploitation (Nokia 2011b). The company conducted research on closing loops for cobalt used in batteries (Nokia 2005), but to date no direct closed-loop programme is in place. Nokia's sustainability manager emphasises that closing material loops becomes more difficult with long supply chains and also requires appropriate consumer behaviour to achieve sufficient collection rates. However, she sees a potential if the prevalent form of mobile phone distribution via operators can be combined with leasing solutions in which the producer or the operator retain ownership of the product.[54]

Nokia aims to advance indirectly closed material loops in the form of using secondary raw materials for production. The company has adopted a respective eco-design strategy (see below) but lacks a comprehensive programme that covers the whole product range.

f) Quantitative reporting

In its individual schemes Nokia collected and recycled 661 tons of e-waste in 2011 (Nokia 2011b). Regarding the share of WEEE treated by collective schemes on behalf of the company in Europe no figures are reported.

No data is disclosed on the total amount or share of recycled materials used in products.

4.4.3 Eco-design

a) Company's eco-design approach

Nokia adopted a comprehensive environmental policy in 1994, in which it commits to continuous environmental improvements (Nokia 2012b). At the end of the 1990s Nokia assumed an increasingly proactive role in environmental issues. The company was involved in the

52 Ibid.
53 Ibid.
54 Ibid.

formulation of many environmental policy documents and anticipated forthcoming legislative requirements (Kautto 2009).

Nokia's eco-design approach is essentially based on lifecycle thinking (Nokia 2011b). Energy issues and reducing greenhouse gas emissions play the most important role in the company's communication strategy. However, internally more impact categories are considered. Nokia is careful not to cause any burden shifting from one impact category to another.[55]

b) Integration of eco-design into product development

Nokia's product development process is largely a bottom-up approach. Common rules and global standards are defined centrally, but particular design questions are solved at local facilities. Each site has at least one local staff to manage and look after environmental issues. The company's project manager asserts that "each and every product has a responsible environmental manager."[56]

Software-supported lifecycle analyses are used to identify hotspots for product improvements. As a result, the company devotes particular attention to the raw material acquisition and component manufacturing stages, which have been identified to cause the highest impact in terms of climate change and primary energy consumption. However, also end-of-life aspects play an important role.[57] Nokia developed own tools (e.g. Recycling Assessment Tool, see below) and methodologies to integrate end-of-life considerations into the product development process in a systematic manner. There are formulated environmental requirements for each phase of product development. Particular attention is paid to the earliest stage, where the design and functionality of the product are laid down. Product concepts have to be in line with Nokia's general environmental targets and meet specific Design for Environment guidelines. The company undertakes staff trainings to increase knowledge about environmental issues and eco-design. In the design implementation and product manufacturing phases, material choices and recycling possibilities are assessed. (Lindholm 2003)

c) Adopted eco-design strategies with end-of-life relevance

Nokia adopted several eco-design measures that take end-of-life considerations into account. The company claims that it begins its product planning and design from the end (Lindholm 2003). For this purpose it developed a tool called 'Recycling Assessment' to define the recyclability of its products on the basis of four factors: 1. Use of recyclable materials (strategy Va); 2. Use of renewable materials (strategy IIIb); 3. Facilitating disassembly by material markings on products (strategy IV), and 4. Minimization of harmful materials and substances (strategy IIIa) (Lindholm 2003). It appears that the company considers these issues in all new product developments. Furthermore the company developed a method to evaluate the time it takes to recycle a product and the materials that can be recovered.

Particular emphasis is placed on the identification of materials and substances contained in products. Greenpeace (2011a) attests the company a well-marked substance management of its products. The company provides full material declarations of its mobile devices (Nokia 2012d) .

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[55] Personal Interview with Noora Paronen, Project Manager Sustainability at Nokia, on March 30th 2012.
[56] Ibid.
[57] Ibid.

So called 'Material Data Forms' were developed to provide designers and recyclers with information on the material composition of products and thereby support end-of-life treatment and to help the company towards phasing out certain materials. By means of a 'Nokia Substance List' the company communicates material requirements to its suppliers and controls the substances used in products (Lindholm 2003; Nokia 2011a). As of 2006, Nokia phased out PVC, phthalates, as well as brominated and chlorinated flame retardants from all its products (Nokia 2012d). However, with regards to its strategy of increasing the use of recycled materials (strategy VII), less progress has been made (Greenpeace 2011a). Recycled materials are to date only used in a number of showcase products, but not yet systematically approached with respect to the whole product range. No figures are disclosed on the overall quantities of recycled materials relative to non-recycled. The company states that it continues to actively research on the subject and tries to find ways to overcome durability issues (Nokia 2011b).

4.4.4 Indications of EPR affecting the company's eco-design activities

a) Financial feedback loop

Nokia explicitly integrates end-of-life costs considerations into its product design strategy. Several product and takeback parameters are taken into account in order to optimise end-of life costs, including takeback process, takeback logistics, material value, and processing costs (Lindholm 2003). The company continuously analyses which materials and substances cause extra costs and attempts to limit these factors.

The company's costs for treating waste mobile phones are continually decreasing. While a positive value can be derived from the recycling of mobile phones, this is still outweighed by the related costs. As the devices are usually treated together with other ICT products, cross-subsidisation takes place. Hence, the company's sustainability manager considers current EPR systems as immature and not providing strong financial incentives for eco-design.[58]

b) Informational feedback loop

Nokia manages takeback issues directly from its sustainability department, which is well connected within the company. It can therefore be assumed that information from end-of-life management is internally distributed. There is extensive communication and collaboration between the sustainability department and the global design department on many issues, including end-of-life management.[59] Furthermore, the sustainability department reports directly to the head office, which increases the likelihood that the company would consider takeback and recycling in major strategic decisions.

Nokia has recognised that great eco-efficiency gains can be achieved if product planners and designers work with recyclers and others involved in end-of-life management (Lindholm 2003). Although Nokia does not run own recycling facilities, the company's sustainability manager states that it has been in direct contact with recyclers for more than ten years. Thus informational feedback was already exchanged before the WEEE Directive. There is a two-directional flow of information between the company and recyclers. On the one hand, Nokia communicates information about substances and materials to recyclers and publishes 'eco profiles' on the

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[58] Personal interview with Helena Castren, Senior Sustainability Manager at Nokia, on March 30th 2012.
[59] Ibid.

environmental characteristics of all its products on its website (Nokia 2012a). On the other hand it asks recyclers for feedback to improve the recyclability of its products. However, the company shows some disappointment with the information it has received from recyclers. Apart from impractical suggestions such as increasing the amount of gold and other valuable substances in products, no feedback was received. According to the interviewee, most existing recycling facilities are very well suited to treat simple products, such as a toaster, but struggle to keep pace with trends of integration and miniaturisation in ICT equipment. [60]

c) Material feedback loop

Takeback activities do not seem to provide material feedback for Nokia. While the company is concerned about limited resources, the environmental and social issues related to their extraction, and introduced internal requirements for the use of recycled materials (Nokia 2011b), it does not explicitly link this issue to its takeback activities.

d) Assessment of the WEEE Directive and obstacles faced

While the company's focus on a single product type simplifies takeback management, the long stakeholder chains characterising the mobile phones sector (producers, resellers, operators, customers) complicate the situation. Nokia's sustainability manager criticises that this aspect is not properly reflected in the WEEE Directive. Furthermore, the company is concerned about the low collection rates of waste mobile phones. In part, the interviewee ascribes this to poor national regulations and weak transpositions of the Directive. By focusing solely on producers, the directive would avoid the main challenge of changing consumer behaviour. This is much harder to achieve than shifting responsibility to producers.[61]

4.5. Philips

4.5.1 Company profile

Philips is headquartered in Amsterdam, the Netherlands, and manufactures a broad range of communication and entertainment equipment, household appliances, lighting, healthcare and medical products. In 2011, 125,241 employees generated 22.6 billion € revenues (Philips 2012b). While the company retrieved from the European mobile phones market in 2007, the production of Philips mobile phones continues for Asian markets, particularly in India and China.

4.5.2 Takeback and EPR compliance

a) Organisation

Philips is separated into three major business segments, Consumer Lifestyle, Lighting, and Healthcare, which are all organised as individual businesses and have own takeback arrangements. The company aims to align the various approaches, but this is not always possible as each sector has to face different takeback challenges. For instance, the healthcare sector is predominantly concerned with business-to-business WEEE, while Philips Lighting has to deal with significantly

[60] Ibid.
[61] Ibid.

higher end-of-life treatment costs in this sector.[62] The company aims to align the various approaches to the greatest possible extent. This case study mainly focuses on Philips Consumer Lifestyle, which covers the company's range of consumer electronics, domestic appliances and communication equipment.

The segment's central recycling team is in charge of coordination and lobbying concerning the takeback and recycling of WEEE, Batteries, Packaging. Furthermore, the team is responsible for the promotion of resource efficiency and the use of recycled materials within the company. The implementation and management of takeback schemes is delegated to the company's national subsidiaries. The central team supports the local management with guidelines, background information, and trainings. It offers advice on specific issues, but the final responsibility lies with local subsidiaries. The interviewed Sustainability Manager points at several advantages connected to this decentralised approach: "Managers at the subsidiary level understand the local situation better. Furthermore this approach fosters the understanding of the relevance of the subject among local managers, which otherwise might only see the costs aspect if takeback was managed from a European level."[63]

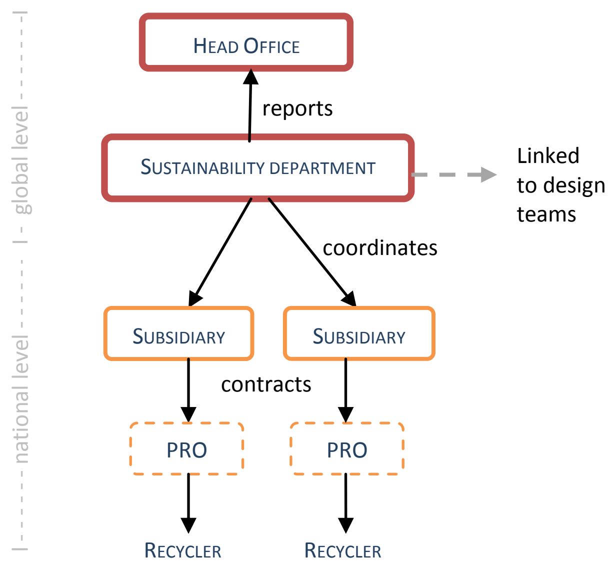

Figure 10: Takeback Organisation at Philips

The organisational structuring of takeback in Philips' subsidiaries differs by country. Some of the larger subsidiaries have a dedicated environmental coordinator; others integrate the task into the service or accounting departments.

b) Individual approaches

Philips publicly supports the principle of IPR (Philips 2012d) and lobbies for a European-wide implementation of the concept (IPR Works Coalition 2009). Yet in practice, the company has so far almost exclusively relied on collective approaches. In Europe only Philips' Healthcare segment offers individual takeback of medical equipment to businesses customers. In addition, in some countries the company runs occasional trade-in campaigns for old appliances of certain product categories. Outside of Europe, the company conducts voluntary take-back activities in a small number of countries, such as in Brazil, Argentina, India, Canada, New Zealand, and several US states (Philips 2011).

There are several reasons for the company's reluctance to set up individual schemes. Atasu and Subramanian (Atasu and Subramanian 2011) note that Philips has - despite of its recent support of IPR - shown a historic preference of CPR. Company representatives haves emphasised the

[62] Personal Interview with Eelco Smit, Senior Manager Sustainability at Philips Consumer Lifestyle, on April 16th 2012.
[63] Ibid.

need for ‘eco-efficient’ takeback solutions based on economies of scale in processing in order to avoid unnecessary costs to society (Stevels, Ram, and Deckers 1999). Currently, the company is testing some trade-in programs where consumers can hand in an old product upon purchase of a new device. However, on a larger scale the logistical efforts of individual approaches are not seen in an appropriate balance to the benefits. “It will be impossible for all companies to set up their own nation-wide collection schemes for their products. So you need common collection - then you would have to do sorting - which is at this moment too complicated.”[64]

The company claims that it is working towards creating the right boundary conditions for IPR in cooperation with industry, recycling community and other stakeholders (Philips 2012d). In particular, it concentrates its efforts on hybrid systems with differentiated fees.

c) Collective approaches

“Philips’ view is that for many of its products collective recycling infrastructures provide the best solution from both economical as well as environmental perspective” (Philips 2012d).

Philips does not have a fixed set of criteria for choosing PROs. Generally, the subsidiaries are advised to join systems that perform well and exceed the minimum collection targets of the WEEE Directive. The company joined a variety of collective schemes, which are disclosed on its website (Philips 2012e). It preferably joined systems based on ex-ante visible fees, which can only be found in bigger systems where several producers are involved.

Philips has argued against the phase-out of visible fees decided in the Recast of the WEEE Directive and continues to advocate for the visibility of recycling costs (Philips 2012d). The company connects several advantages to this way of allocating costs. Philips’ Sustainability Manager emphasises that such systems ensure that the funding of WEEE treatment is reliably organised. Otherwise, producers would have to finance end-of-life treatment from their own budgets, which may cause funding problems for products that are expensive to treat. The interviewee warns of de-incentivizing return rates and a malicious race to the bottom with regards to collection and treatment quality: “Especially with companies that are less environmentally friendly than we are, you end up in this competition where you don’t want to be.”[65] Furthermore, Philips argues that visible fees help to prevent abusive actions and illegal exports (Philips 2012d).

In systems without visible fees, Philips prefers ex-post calculations based on market share, which are considered fairer and more transparent than ex-ante fees. According to the Philips’ sustainability manger an advance calculation of fixed fees per product or kg is not only difficult and connected to high administrative costs, but also unfair. Fixed fees would usually focus on large and heavy products, as the individual fees for small products are negligible. Furthermore, ex-ante fees are considered inaccurate as they rest on assumptions about the sales volume. Cross-subsidisation is not regarded a major concern as products in one category generally have similar end-of-life costs.

[64] Ibid.
[65] Ibid.

d) Stance on hybrid systems

Philips supports the idea of differentiated fees (Philips 2012d). The company's sustainability manager remarks that hybrid systems based on differentiated fees generate an immediate incentive to design greener products and are therefore preferable over regular IPR or CPR systems in which eco-design pay off is too far away from the investment.[66]

Philip's sees producers responsible to act and work towards the implementation of differentiated fees. In the Netherlands the company claims to have made some efforts in that direction. However in countries with a large number of competitive schemes governmental involvement is required. "When governments mandate it, that would be the easiest option, then everybody would have to do it."[67] The company is now focussing on the recast of the WEEE Directive which may enable a wider introduction of differentiated fees.

e) Closed-loop initiatives

Philips states to share the ambition of closing material loops and takes, for instance, the cradle-to-cradle approach as a basis for further sustainable innovations (Philips 2012b). According to Philips' sustainability manager, closing material loops is less a problem of technical feasibility rather than of retrieving all discarded products.[68] In the company's healthcare segment a first approach to closed-loop activities can be observed. WEEE from business customers is taken back and partly refurbished.

The company actively engages with recyclers to increase usage of plastics recycled from WEEE. Philips has a target to increase its own use of recycled plastics in production to annually 4000 tons by 2015. The company hopes to thereby increase demand and initiate a market for recycled plastics

f) Quantitative reporting

Philips reports a global collection and recycling amount of 35,000 tons of WEEE in 2010, which includes waste from both individual and collective schemes that can be attributed to the company. Compared to the previous year, the figure slightly decreased. (Philips 2012b). The firm committed to double the global collection and recycling amounts by 2015 against a 2009 baseline (Philips 2012b).

The amount of recycled material per product is measured for the whole consumer electronics product range (Philips 2011). Philips targets to double the amount of all recycled materials (including plastics and other materials) by 2015 compared to a 2009 baseline of 7500 tons. In 2011, the total amount of recycled materials was determined at some 10,000 tons (Philips 2012b). It remains, however, unclear how much this is in relation to Philip's overall material use.

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[66] Ibid.
[67] Ibid.
[68] Ibid.

4.5.3 Eco-design

a) Company's eco-design approach

Philips has a reputation of playing a leading role in eco design and innovations (Tukker, Haag, and Eder 2000). In the 1990s Philips set up a systematic approach to environmental issues. The firm developed internal organisational structures to ensure legislative compliance and mandatory design standards are followed up (Boks and Stevels 2003). Furthermore, the company launched several projects on eco-design innovations (Philips 2012b). The projects, however, did not produce substantial results as they often lacked follow-up. "[They] were mostly carried out fairly isolated from the day-to-day business. After completion, project teams were disbanded and team members were dispersed in their organization" (Boks and Stevels 2003, 132). Learning from these experiences, the company launched its EcoVision programme in 1998 with the goal to drive eco-design innovations consistently. In the years after, further versions (EcoVision 2 till 5) with new targets followed. As part of the scheme, the Green Flagship programme was introduced, which was renamed to Green Products in 2007. It focuses on the development and promotion of selected flagship products that have a better environmental performance than any similar previous or competitive products. To qualify for the label, a product has to show at least 10% improved environmental performance in one of six specified Green Focal Areas[69] while the performance in the other areas must be at least equal (Philips 2011). The measurements are based on a comprehensive benchmarking method, which will be described in more detail in the next section. Each of the company's product divisions is obliged to develop at least one Green Product a year (Philips 2009). The share of green products has grown steadily over the last years. In 2011, 39% of the company's product sales were Green Products. The company aims to increase the share to 50% by 2015 (Philips 2012b). In this way, Philips gradually invalidates criticism that its eco-design efforts would only focus on selected leading products and leaves the remaining product range unaffected. Moreover, the company enacted a number of environmental specifications and policies that affect the whole product range.

b) Integration of eco-design into product development

Phillips has a formalised process to implement eco-design. The company's central sustainability team defines what eco-design means for Philips and formulates guidelines and targets on specific issues. The company's innovation teams then work towards the actual implementation of these principles. Innovation teams are found within each major business group such as coffee, domestic appliances, personal care, etc. In each innovation team there are one or two people specialised in sustainability.

As part of its Green Flagships Program the company developed a comprehensive environmental benchmark method, which influences the work of designers as it provides orientation for and assessment of their concepts. "Environmental benchmarking was seen as the ideal link between creating awareness and design itself because a proper benchmark tells where current products stand, thus creating a platform for discussions and brainstorms in where to go "(Boks and Stevels 2003, 122). In addition to other environmental aspects, the tool assesses several end-of-life

[69] The six Green Focal Areas are explained in the section on eco-design strategies.

criteria, such as materials' weight, toxic substances, content of recycled materials, and recyclability. Besides environmental benchmarking, the company works on the development of other tools, such as a recyclability indicator, which calculates the ease of recycling into a product specific score.[70]

c) Adopted eco-design strategies with end-of-life relevance

Philips' eco-design approach concentrates on six "Green Focal Areas", four of which are end-of-life related. The company focuses on hazardous substances, weight, recycling and disposal, and Lifetime reliability (Philips 2012b).

On the issue of hazardous substances several processes have been initiated (strategy IIIa). With regards to a phase out PVC and BFRs the company sees several challenges connected to technical, safety or regulatory standards. Nevertheless, it committed itself to phase out these substances in all new consumer products placed on the market after January 2011 (Philips 2012a). There is currently no information available whether this target has been reached. The company's latest sustainability report merely states that it continues to work on voluntarily phase-out of PVC and BFRs (Philips 2012b). Philips' hazardous substance policy also includes the phase-out of the six most common phthalates and antimony compounds for consumer products. Arsenic has been restricted since 2008, and beryllium is partly phased out (Philips 2012a). To ensure that suppliers follow these policies the company obliged them to its Restricted Substances List (Philips 2008). Compliance is controlled by regular audits of first and second tier suppliers as well as by sample screenings of incoming products and components (Wong 2008). In addition, Philips developed with industry partners the BOMcheck platform, which allows checking supplier information, such as the bill of materials (BOM) and compliance declarations, in a standardised way (Philips 2012a). Greenpeace (2011a) attests the company an average performance on hazardous substances. The organisation criticises the lack of a timeline for overcoming the exemptions on beryllium as well as the lack of a clarification why other types of phthalates beyond the six specified are not scheduled for elimination (Greenpeace 2011a).

Philips' focus on recycling and disposal includes design for recyclability and the use of recycled materials. Recyclability is benchmarked via several indicators, such as types of plastics and markings, types of connections, and disassembly time (strategy IV), as well as material recycling efficiency (strategy Vb) (Boks and Stevels 2003). Performance on these issues has been improved in some green flagship products (Philips 2012b). However, there is no further information available if and how these aspects are considered systematically in the development process of non-flagship products. The use of recycled materials (strategy VII) is advanced more systematically. As part of the company's Eco Vision 5 metrics, the amount of recycled material per product is measured for the whole consumer electronics product range (Philips 2011). Philips targets to double the amount of recycled materials by 2015 compared to a 2009 baseline of 7500 tons. In 2011, the total amount of recycled materials was determined at some 10,000 tons (Philips 2012b).

Philips states to work towards improving lifetime reliability (strategy Ia) (Philips 2012b), but it does not further specify what this means. Some green flagship products, particularly in the lighting sector, have a reported longer lifetime (Philips 2012c). Greenpeace (2011a, 14) remarks

[70] Personal Interview wit Eelco Smit, Senior Manager Sustainability at Philips Consumer Lifestyle, on April 16th 2012.

that "Philips needs to publicly disclose the length of warranty and spare parts availability for its main product lines [... and] show some innovative measures that increase lifespan and durability of whole product systems, rather than only individual parts." Similarly, Philips has reduced the weight of a number of green flagship products, but does not disclose further information on the subject.

4.5.4 Indications of EPR affecting the company's eco-design activities

a) Financial feedback loop

There are indications that financial EPR feedback positively influences eco-design at Philips, especially when transferred timely in a system with differentiated fees. The company's sustainability manager notes: "At Philips we try to push things anyway, but even for us a cost argument makes it easier and can speed up developments. [...] If you can make environmental improvements and save costs at the same time then everyone will go with you"[71] This indicates that financial feedback supports an environmental position within the company and is used to justify costly investments for eco-design innovations.

However, the company's sustainability manager also sees limits to financial incentives. He notes that the influence of product design on recyclability is small considering how the recycling process works nowadays. Only certain small parts would have to disconnect swiftly and the choice of plastics does not have a big monetary impact.[72]

The company concentrates its efforts to reduce end-of-life costs particularly on tendering and negotiating contracts with schemes that reflect the correct recycling costs. Because collection costs are a much bigger cost factor than recycling costs, efforts are made to find the most efficient collection system. Design changes are not considered to have a significant impact on costs as they take very long to materialize and recycling costs are generally low for most products. Philips reports that except for TVs all of its products have a positive recycling value due to the currently high prices of resources.

b) Informational feedback loop

On a project basis Philips has discussions with recyclers to improve recyclability issues. The interviewee explains that informational feedback from these discussions is reflected in the company's recyclability strategy. "Design for recyclability is moving away from guidelines and standards with do's and don'ts to a materials approach: combinations of materials that don't work well, e.g. copper and aluminium, should be separated, because when they are smelted together it's only possible to recover one of the two. So we try to improve these guidelines and for this you need to work together with recyclers."[73]

Philips' decentralised takeback organisation may lengthen the communicative distance from takeback experiences to potential design inputs. However, the company also maintains direct contact to recyclers at higher levels. Moreover, there is a general concern for an easy flow of information between company departments. All Philips employees are explicitly invited to submit

[71] Ibid.
[72] Ibid.
[73] Ibid.

ideas and contribute to the definition of new business models. Employee inputs are further encouraged by an internal sustainability competition (Sherwin 2004). In this way, takeback staff can directly contribute to eco-design improvements.

c) Material feedback loop

Philips aims to use more recycled plastics in its production and realised that it needs to work together with recyclers to improve current recycling practices. This approach can be interpreted as sign for material feedback relating to its responsibility for end-of-life matters. However, in Philips' case it is interestingly not material feedback promoting eco-design, but rather the company aiming to improve the material outputs of recycling due to its eco-design activities.

d) Assessment of the WEEE Directive and obstacles faced

Philips' sustainability manager states that the WEEE Directive has raised awareness of end-of-life issues across the industry. "Now every company does something with design for recyclability." However, he says that EPR does currently not go beyond that. "It did not incur really big changes as there is no return on investments. [...] Maybe it will work in the future if we can get IPR to work." With regards to Philips, the interviewee says that since EPR there is more awareness among staff, particularly in financing and engineering divisions. Furthermore, the increased general societal awareness would make it easier to run respective Design for Recycling projects.

4.6. Sony

4.6.1 Company profile

Sony is headquartered in Tokyo, Japan and one of the largest electronics manufacturers worldwide. Its manufactured consumer products include mobile phones, laptops, video and audio entertainment devices, digital imaging products and medical equipment. In 2011, the company employed 162,700 people and had a sales volume of 65.3 billion € (Sony 2012a). Until 2012, Sony marketed mobile phones through a joint venture with the Swedish telecommunications company Ericsson. In February 2012, Sony acquired Ericsson's share and incorporated mobile phone production under its own brand (Sony 2012c). The company's global market share in this segment was estimated 1.9 % in the first quarter of 2012, which makes Sony the ninth largest manufacturer of mobile phones (Gartner Inc. 2012b).

4.6.2 Takeback and EPR compliance

a) Organisation

Sony's takeback organisation in Europe has both centralised and decentralised elements. Coordinative tasks are located at the company's European Environmental Department, which is directly linked to Sony's environmental headquarters in Tokyo. The implementation of takeback systems is managed by a joint team of European and local staff. This collaborative structure shall create synergies on a European level while drawing on local understanding and capabilities in national contexts. The team receives support by other departments of the company, for instance from legal experts, to cope with the specific challenges provided by the WEEE Directive and its national transpositions.[74]

b) Individual approaches

Sony publicly voices support for the principle of Individual Producer Responsibility, but does not run any individual takeback programmes in Europe. Furthermore, no supplementary activities such as recycling days or trade-ins are reported. In its Japanese home market, Sony runs an extensive individual takeback programme for PCs and televisions, which are treated individually in the company's own recycling plants. This system, however, could not be simply transferred to the European context, which covers a much larger product scope.[76]

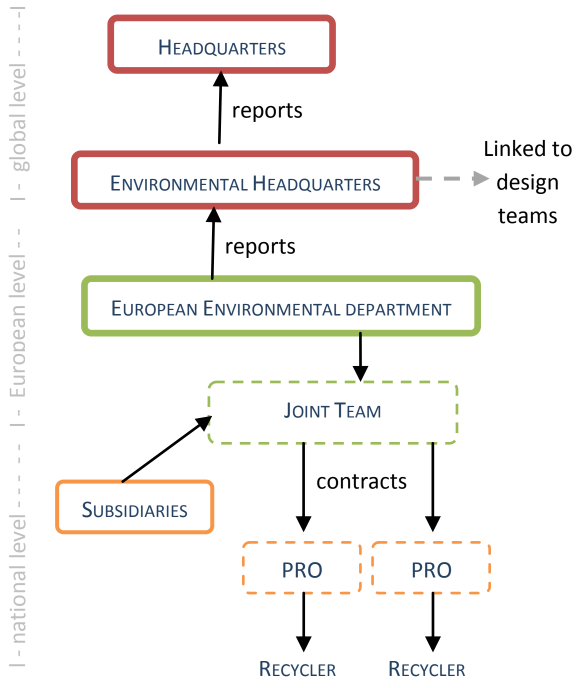

Figure 11: Takeback Organisation at Sony [75]

c) Collective approaches

Sony engaged with other producers (HP, Braun, and Electrolux) to establish an own PRO (European Recycling Platform) rather than simply joining the schemes that were being set up following the example of already existing monopolistic national schemes in countries that had EPR legislation prior to the WEEE Directive. Sony made this step for similar reasons as HP. According to the company representative, the European Recycling Platform promised both financial and organisational advantages. Considerable price differences charged by existing schemes lead to the conviction that more competition on the WEEE market would lead to lower end-of-life costs. Another major reason for setting up a competitive scheme was to gain more control over the system, which allows Sony to validate the performance of the schemes. Sony requires its PROs to perform audits and periodic on-site checks of recyclers to ensure high treatment standards (Sony 2011a). Despite some initial opposition by existing schemes and some other producers who feared that PRO competition would overcomplicate the situation and increase administrative efforts, the European Recycling Platform was a success and now operates in 12 countries. Sony is a member in 11 countries and provides a list of PROs it joined in other countries (Sony 2011a).

Sony has no specific preference how producer contributions to a scheme should be allocated. The company principally agrees with a market-share allocation. Cross-subsidisation due to mixed collection groups is considered to be unavoidable in practice. Sony's representative points out that there is not only cross-subsidisation between different kinds of products, but also between products of the same type. More narrowly defined collection groups, however, could entail other problems. "You cannot simply make collection groups for different subtypes of products, for

[74] Personal interview with Frans Loen, Environmental Manager at Sony, on April 24th 2012.
[75] Please note: This figure has been compiled by the author of this thesis based on the information available to him and has not been officially confirmed by Sony.
[76] Personal interview with Frans Loen, Environmental Manager at Sony, on April 24th 2012.

example one category for CRT TVs and one for newer LED TVs. Because allocation is based on current market share, then the producer who is the last to market CRT TVs would have to finance all the take-back of waste CRTs."[77]

d) Stance on hybrid systems

Although Sony is generally opposed to fixed fees as they are difficult to determine and may lead to higher prices than flexible contributions, the company is principally positive about the introduction of differentiated fees if these reward environmentally preferable design, such as in France. However, the interviewee remarks that a system with differentiated fees needs to stay simple and can include only a very limited number of criteria. More specific criteria would be too complicated and could entail diffuse incentives. While seeing its limitations, the company's representative considers hybrid systems an interesting initial step towards IPR, as it provides, albeit simple, incentives for individual manufacturers to make desirable design choices.[78]

e) Closed-loop initiatives

Sony is concerned about increasing resource scarcity. The development of closed-loop systems is seen as one possible way to address such problems. However, Sony does not run own direct closed-loop programmes. The company's representative points out that "we need a circular economy in society at large, not necessarily a closed loop at Sony."[79] The company strives to increase the amount of recycled materials used in products. The disclosure of data on this aspect (see below) shows that Sony is actively and transparently working towards improvement on closing material loops.

f) Quantitative reporting

Sony provides comparatively extensive data on its takeback and recycling performance. The company reports that in 2010 it financed the costs of recycling of around 74,000 tons of WEEE in Europe, which constitutes almost half of the 164,000 tons of WEEE handled by Sony globally. Furthermore, the company reports that in the same year 1.19 million tons of products have been shipped (Sony 2011a). From this, a global takeback rate of approximately 14 % can be calculated.

With regards to closing material loops, Sony reports on the share of reused and recycled materials among the materials used in its overall production. The rate lies currently at 8 %. The target is to increase it to 12 % by 2015. The figure, however, does not only refer to electronic devices, but also includes packaging materials (Sony 2011a).

Of all companies investigated in this thesis, only Sony explicitly connects takeback and closed-loop data in its public reporting. The company developed a 'Resource Index' to measure the ratio of input materials compared to recovered materials. On the recovery side, the volume of recycled materials used in products and the volume of collected WEEE are added up. This is subtracted from the total amount of materials used, which comprises the amount of resources used in

[77] Ibid.
[78] Ibid.
[79] Ibid.

products and the amount of waste produced at manufacturing sites.[80] The resulting Resource Index gives an indication on Sony's demand of virgin materials. In 2010, the result was 0.94 million tons, which constitutes a reduction of 3 % compared to 2009. Sony states to continue working towards reducing this figure (Sony 2011a).

The Resource Index has some inconsistencies. Sony equals the amount of collected WEEE with the volume of resources recovered from end-of-life products, which is not entirely correct due to wear and unavoidable losses in the recycling process. Moreover, adding the volume of recycled materials used in products to the amount of collected WEEE may lead to double counting. If Sony uses a recycled material recovered from its own amount of collected WEEE, this material would be counted twice. Nevertheless, Sony is ahead of its competitors by transparently reporting on these aspects. The Resource Index shows that Sony is aware of this issue and is actively working towards improvement.

4.6.3 Eco-design

a) Company's eco-design approach

Sony enacted its Global Environmental Policy in 1993 and has launched a variety of environmental activities since. In 1998 the company began to commit to mid-term targets, which laid out a measurable and goal-oriented approach to environmental improvements (Sony 2011a). The targets are revised every few years and encompass Sony's worldwide operations. Green Management 2015, the current set of mid-term targets, was adopted in 2010 and includes several eco-design goals (Sony 2011b). In the same year, the company formulated its Road to Zero strategy, a global environmental plan by which the company strives to achieve a zero environmental footprint throughout the lifecycle of its products and business activities by 2050 (Sony 2011a). Hereby, the company focuses on four areas: curbing climate change, conserving resources, promoting biodiversity and controlling chemical substances. Sony aligns its mid-term targets accordingly, in order to gradually approach the goal of its Road to Zero strategy.

Sony's global operations are structured into various business groups, which formulate own annual targets in line with the company's Green Management strategy. Progress towards achieving these targets is regularly reviewed and reported to the headquarters. To "ensure employees achieve a level of competence that enables them to perform their assigned duties while taking environmental concerns into consideration" they are regularly provided with environmental information and respective training programmes (Sony 2011a, 122). Through the Green Management programme eco-design is approached comprehensively, as targets cover Sony's complete product range. However, the company also aims to develop environmental flagship products in each business category (Sony 2011a).

b) Integration of eco-design into product development

Sony introduced a formalised process of implementing eco-design improvements. The company's individual business groups formulate annual design targets reflecting the specific challenges with regards to their products. The envisioned changes are implemented in a plan-do-check-act

[80] The formula of the resource index is: RI = (Waste landfilled from sites + Product resource input) – (Volume of reused and recycled materials + Volume of resources recovered from end-of-life management). For further information see: Sony 2011a.

process. Lifecycle analyses are conducted to identify priorities for product improvement with regards to reducing CO2 emissions. For specific product groups, such as televisions, the company has developed guidelines summarising crucial points for consideration to increase the product's recyclability. Sony states that it has incorporated these guidelines into the product planning and design stage (Sony 2011a).

c) Adopted eco-design strategies with end-of-life relevance

Sony adopted several eco-design strategies to improve product end-of-life management. Particular emphasis is placed on the minimisation of resource use (strategy II), which is a cornerstone of the company's Road to Zero programme. Sony states that it identified certain key resources for which it strives to achieve zero usage of virgin materials. It is, however, not comprehensively disclosed to which specific resources this refers. Until 2015, the company aims to reduce its use of virgin oil-based plastics by 5% and reduce the average mass per product by 10% against a 2008 level. Furthermore Sony continues to research on low impact materials such as bio-plastics, which it uses already in a number of flagship products (strategy IIIb). To substitute virgin materials, Sony intends to increase the use of recycled materials (strategy VII). While the target to increase the share of recycled materials used in products by 4% covers the whole product range, Sony primarily focuses on flagship products to achieve this goal. (Sony 2011a)

Another cornerstone of Sony's Road to Zero programme is the elimination of hazardous substances (strategy IIIa). The company compiled a document on "Management Regulations for Environment-related Substances to be Controlled which are included in Parts and Materials" (Sony 2012b), which is used to communicate substance restrictions and requirements to suppliers, and serves as a basis for internal inspections and measurements. To control the use of substances, Sony applies the JGPSSI[81] survey response tool, which compiles information on declarable substances, such as mass contained in parts, purpose of use, or sites where used (Sony 2011a). Furthermore, the company maintains a database called Green Books to support suppliers finding materials that are compliant with its substance regulations. The regulations restrict the use of PVC and BFRs, and prohibit beryllium oxide. The company intends to ban the use of four types of phthalates in certain product components (Sony 2011a). Greenpeace (2011a), however, is critical on the company's efforts to phase out hazardous substances. The NGO notes that there are many exemptions from Sony's ban on PVC, that not all types of BFRs and phthalates are restricted, and that antimony is not covered at all.

Sony states that it will "step up efforts to design products that are easy to recycle" (Sony 2011a, 130). However, it appears that these efforts mainly concentrate on specific product groups, such as televisions. For these products, Sony intends to facilitate disassembly by marking the position of screws indicating the number of screws as well as by labelling materials and flame retardants used in plastic parts (strategy IV) (Sony 2011a). Furthermore, the company wants to ensure that its products are long-lasting and reliable (strategy Ia). For this purpose, the company established a Quality Reliability Lab in 2009, which conducts research on technologies like adhesives and anticorrosives, and efforts to eliminate software vulnerability. Furthermore, Sony runs global

[81] Japan Green Procurement Survey Standardization Initiative

repair and service operations, which it currently strives to improve in terms of distribution and repair times and fees. (Sony 2011a)

4.6.4 Indications of EPR affecting the company's eco-design activities

a) **Financial feedback loop**

Although Sony's environmental manager reports that the financial implications of end-of-life management are significant for the company there is only limited evidence that financial feedback from end-of-life management has promoted respective eco-design activities. The interviewee describes that there are principally two ways in which Sony can reduce its end-of life costs. First, by optimising compliance to make sure that the costs are not higher than they need to; and second, by manufacturing products that are easy to recycle and rely on respective materials. However, he concedes that so far more progress has been achieved with regards to ensuring competition on the WEEE market (establishment of the European Recycling Platform) than with regards to the feedback mechanism between the costs of takeback compliance and design changes. Reaping the benefits from design changes is more complex and other external factors, such as market prices for raw materials, influence end-of-life costs. The interviewee further explains that optimising compliance is an important condition for eco-design incentives. Being able to exert some control over the schemes increases the likelihood of benefiting financially from the appropriate design changes. This mechanism is considered possible in competitive schemes, and to some extent in schemes with differentiated fees.[82]

b) **Informational feedback loop**

There is indication for informational feedback from end-of-life management. In Europe, Sony's takeback department receives direct feedback from recyclers, which ultimately reaches designers via headquarters. In Japan, there is direct contact between recyclers and designers due to Sony's active engagement with a recycling plant. The company's representative notes that through regular informational exchange with recyclers learning effects have occurred. Some of this information has been compiled into design guidelines.[83] Furthermore, the company organises employee tours to recycling plants to increase respective knowledge and awareness among its designers and managers (Sony 2011a). However, the interviewee sees informational feedback impaired in collective schemes. "A complication in Europe is that we're allocated a certain share of the WEEE of one group, which may contain products from us, our competitors, from producers that don't exist anymore, and products that we may not even sell. So it's difficult to learn directly from that." [84]

Internally, information from takeback management is reported to the company's environmental headquarters in Tokyo. Some product development groups based in Europe are directly provided with information. In the end, various sorts of information (takeback, legal, market) are reflected in design guidelines.[85] Internal communication of environmental issues is also supported by a special e-learning platform available to employees (Sony 2011a).

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[82] Personal interview with Frans Loen, Environmental Manager at Sony, on April 24th 2012.
[83] Ibid.
[84] Ibid.
[85] Ibid.

c) Material feedback loop

To a limited extent Sony experiences material feedback from end-of-life management. While Sony does not run any direct closed-loop programme, it explicitly connects end-of-life management with its ambition to foster indirectly closed material loops. To reach the target to improve on its 'Resource Index', the company needs to work on both increasing recyclability in product design and incorporating recycled materials into its products.

d) Assessment of the WEEE Directive and obstacles faced

Sony's representative draws a largely positive résumé of the WEEE Directive. He concludes that the directive achieved a high awareness of end-of-life issues among the industry. "My impression is that, amongst other developments, the directive made producers change the way they are thinking about their responsibility. The old thinking was: develop a product, make it, sell it, and then forget about it. Taking responsibility for recycling the products was just not part of the mindset, other actors were taking care of that. Now it's totally different, we consider end-of-life as a part of our responsibility, and beyond that we find end-of-life management can help us to get access to resources." He further describes that an evolution took place "from not thinking about the end-of-life stage, to actively taking responsibility, ensuring the quality of it and seeing it also as a reputational issue." In addition, learning effects have occurred. "Producers now understand better the effects of their products and the influence on the costs of recycling".[86]

However, the interviewee also notes some critical points. While more end-of-life products are now collected and recycled in a more systematic way, the legislation and in particular its weak enforcement by national authorities is failing with regards to fighting illegal exports. Sony's representative notes that calculations of collection results do not reflect other actors in the field who handle a large share of WEEE outside of producer schemes. "If a society is serious about achieving high collection results of electronic waste and about having that waste treated at a high environmental standard, it must ensure that all actors handling WEEE are held responsible and accountable under this legislation".[87]

[86] Ibid.

[87] Ibid.

5. Comparative Analysis

5.1. Takeback and EPR compliance

The case studies show that producers have adopted different approaches of managing takeback and complying with the provisions of the WEEE Directive. Differences are found with regards to all analysed aspects.

5.1.1 Organisation of takeback

Among the analysed companies various ways of organising takeback activities have been found.[88] While there are several individual variances, two basic types can be identified. HP's, Dell's, and to a lesser extent also Nokia's takeback activities are organised centrally. In these companies, takeback activities are managed and implemented at a regional (European) level. National subsidiaries may be consulted, but decisions are made by a central takeback team. The advantage of this approach is that the companies can set out a uniform European approach to ensure an effective management. LG and Philips, by contrast, hand over large shares of responsibility to their national sales subsidiaries, which make decisions on schemes and takeback implementation. The advantage here is that the approaches are based on local understanding and can be better tailored to differing contexts. Furthermore, national subsidiaries are more involved in takeback issues what creates a higher awareness at these levels for end-of-life issues. However, a potential disadvantage is that national sales subsidiaries primarily look at takeback from a legal compliance perspective rather than from an environmental point of view. It can be speculated that the topic would reach more prominence and relevance in internal company decisions, if represented by a powerful and responsible environmental department.

The differences in organisation can affect the way information is channelled within companies and thus the efficacy of informational feedback from end-of-life management. This is discussed in the respective section below.

5.1.2 Individual and collective approaches

None of the examined EEE producers relies fully on an individual responsibility scheme to comply with their takeback obligations in Europe. All producers engage in collective approaches to ensure their compliance with the WEEE Directive. The interviewees argued that individual collection and logistics are considered too expensive as well as that individual collection by different producers would be complicated and inconvenient for consumers and therefore negatively affect collection rates. A later sorting of jointly collected WEEE is not considered a feasible option either, as this would involve disproportional labour costs. Some indicated that this may change if in future technical solutions for sorting by automated identification technology can be established.

However, some producers run voluntary individual takeback schemes in addition to their collective engagement. Particularly Dell's comprehensive scheme stands out. The company offers a global pick-up service for both private and business customers. The scheme operates

[88] It can be assumed that the variances relate to general differences in the organisational structure of businesses. It is known that companies in the electronics sector show different degrees of hierarchy (c.f. Daft 2009). However, this connection could not be examined in more detail in this thesis.

successfully and demonstrates that individual systems can work. HP, Nokia and LG run voluntary programmes in Europe, too. However, there are some limitations in comparison to Dell's scheme. HP offers its service exclusively to business customers. Nokia and LG offer consumers to take back products at specified collection points instead of offering pick-up or mailback of discarded products. Particularly the low number of collection points offered by LG appears too low to provide for a viable alternative for consumers to discard of old electronic devices.

While all producers engage in collective schemes to fulfil their end-of-life obligations, their compliance strategies differ to some extent. While many producers awaited early developments and joined existing PROs, Sony and HP decided to form an own responsibility organisation. With this step they intended to cut-down the costs of the schemes by establishing a competitive market and to gain more control on the schemes.

All producers have largely similar criteria on which they base their decisions for or against joining specific PROs. Next to the costs of a scheme, its capabilities, service quality and treatment standards are important. Some companies have a preference on the mechanisms in which costs are allocated in a scheme. HP and Sony object fixed product fees, on the grounds that they are too static and often do not reflect the true treatment costs. Philips, on the other hand supports these fees, arguing that they ensure a reliable funding of WEEE treatment and de-incentivize illegal exports. Most producers, however, do not attach importance to this aspect and do not state any preference. Allocation by market-share is generally accepted as a fair and efficient basis for calculation and none of the interviewees mentions support for return-share allocation. This contradicts the position of scholars who dismiss cost allocation based on market-share due to the long time span between product sale and product disposal.

In collective schemes products with low end-of-life costs may subsidise products that are more difficult to treat. While a few interviewees recognise a problem in that and strive to solve this issue by differentiated fees, most consider cross-subsidisation as unavoidable and find that its consequences are of little relevance by arguing that most products would have comparable end-of-life costs.

5.1.3 Producer positions on differentiated fees

Hybrid systems based on differentiated fees find approval and dismissal among the interviewees. The responsible managers from Nokia, LG and Philips consider differentiated fees as a practical way of implementing IPR. Especially the fact that differentiated fees provide immediate feedback to product design is noted as an advantage compared to CPR and also to fully individual systems, where feedback can be impaired by the long time span between product development and the costs they create at their end-of-life stage. However, there are also sceptical views on differentiated fees. Dell's takeback manager points out that differentiated fees can always only reflect a limited set of eco-design criteria. Diverging schemes with differentiated fees in different countries would result in confusion rather than in clear incentives. HP and Sony point to the difficulty of calculating these fees. Since the fees are calculated ex-ante, they represent merely an estimation of the true treatment costs.

5.1.4 Closed-loop initiatives

Producers have not started to initiate closed-loop programmes on a large scale. Among the six examined companies, only one initiative to close material loops directly could be found. HP uses materials recovered from old printer cartridges to manufacture new ones. Although there are currently no plans to expand the programme to discarded hardware products, HP's initiative can be considered current best-practice in the industry.

With regards to indirectly closed material loops producers show more activity. All examined companies aim to increase the use of recycled materials in their production. However, often these activities seem unrelated to companies' takeback and recycling activities. Only two companies make a connection to their own takeback activities. Sony developed an indicator that takes both sides into account to measure progress, and Philips explicitly involves with recyclers to work towards their target of increasing recycled content.

5.1.5 Quantitative reporting

All producers disclose some quantitative data on their takeback efforts. Table 7 gives an overview of the reported figures. However, a comparison is difficult considering the heterogeneity of what the reported figures refer to. Some producers report about the volume of WEEE handled through individual schemes whereas others include also the shares handled on their behalf in collective schemes. Some companies provide numbers specifically on the European context while others only provide global data. Furthermore, it is difficult to compare the takeback volume of a company producing only light products, such as mobile phones, to the volume of a company selling PCs or industrial server parks. Hence, it would be interesting to know how much each producer takes back in relation to the total volume of products it sells. Yet, only HP and Sony are transparent with regards to this aspect. HP reports that the amount of parts and materials recovered through its activities comprise 16 % of HP's relevant hardware sales worldwide. Sony's reported data reveals a global takeback rate of 14 %. All other producers do not provide data in relation to their product sales, even though this is a core indicator in the guidelines of the Global Reporting Initiative (GRI 2011).

	Sales Volume (in billion €)	**Takeback volume in individual schemes** (in tons)	**Total takeback volume** individual plus collective (in tons)	**Relative takeback volume** (% of product volume)	**Use of recycled materials** (in tons)	**Relative use of recycled materials** (% of product volume)
Dell	50.9	375,500 globally	-	-	3300 (only plastics)	-
HP	104.2	150,000 globally	-	16 %	-	-
LG	40.1	-	198,984 globally; 148,284 in Europe	-	2014 (only plastics)	11 % of all plastics
Nokia	38.7	661 globally	-	-	-	-
Philips	22.6	-	35,000 globally	-	10,000	-
Sony	65.3	-	164,000 globally; 74,000 in Europe	14 %	-	8 %

Table 7: Reported figures of takeback and the use of recycled materials[89]

[89] All data refers to the respective last year for which information is available.

5.2. Eco-design

5.2.1 Approaches to eco-design and integration into product development

In the 1990s most companies began embracing environmental issues and formulating respective environmental policies. While early measures mainly related to pollution and energy issues at manufacturing sites, the focus gradually shifted to products. Today, eco-design is a highly relevant topic for all examined producers. Many producers structurally integrated eco-design into their product development process.

In principal, two forms of implementing eco-design can be distinguished. Companies may focus on developing environmental flagship products with cutting-edge environmental qualities, or work towards comprehensive, but incremental improvements for their entire product line. The first approach is particularly practiced by LG and Philips. Both companies have developed benchmarking systems to classify their products and set targets to increase the amount of highly ranked products. Nokia and HP, on the other hand, appear to place more emphasis on the second approach. The two companies put designated environmental managers or product stewards in charge of promoting eco-design for each new product development. However, there is no clear-cut separation between the two strategies. All examined companies market certain showcase models with advanced environmental features, as well as have environmental standards that apply to their whole product range.

All companies use lifecycle analyses to examine the environmental impact of their products. However, these analyses are usually in the context of carbon emissions. To incorporate end-of-life considerations into the product development process several producers developed specific tools and, such as Nokia's 'Recycling Assessment Tool', HP's 'Recyclability Assessment Tool', and LG's ATROiD. According to Boks and Stevels (2003), the application of customised tools implies that these producers have a high level of maturity with regards to eco-design and the respective environmental issues.

5.2.2 Adopted eco-design strategies with end-of-life relevance

The case studies revealed that all producers undertake eco-design activities in order to reduce the impact of their products at end-of-life stage. However the specific strategies adopted vary between producers. Table 8 below gives an overview of the pursued strategies. It is also displayed whether respective efforts appear to cover the entire product range or concentrate on certain flagship products. This should not be misunderstood, however, as an evaluation of the performance of producers on the listed strategies. The available data does not allow conclusions on how effectively and far reaching companies pursue these strategies.

	Eco-Design Strategy	*Dell*	*HP*	*LG*	*Nokia*	*Philips*	*Sony*
I.	Design for Longevity						
	c) Durability					light green	dark green
	d) Upgradability	dark green					
II.	Reduction of Material Use		light green	light green			dark green
III.	Use of Low-Impact Materials						
	a) Phase out of hazardous substances	light green	light green	dark green	dark green	dark green	dark green
	b) Use of renewable materials				dark green		light green
IV.	Design for Disassembly	dark green	dark green	dark green	dark green	light green	light green
V.	Design for Recyclability (DfR)						
	c) Enhanced use of easily recyclable materials				dark green		
	d) Reducing material diversity		light green			light green	
VI.	Design for Reuse	dark green					
VII.	Use of Recycled Materials	light green	light green	dark green	light green	dark green	light green

Table 8: Adopted eco-design strategies

dark green	Strategy adopted comprehensively, covers the whole or a large extent of the product range, measured and documented quantitatively, structurally integrated into product development process
light green	Strategy envisioned; declaration of intent; applied to certain pilot products; unclear scope.
white	No indication that strategy is currently pursued; based on the available data.

Some eco-design strategies are more common than others. In particular, strategies that promise to reduce WEEE treatment costs are popular (III and IV). All six producers conduct measures to phase-out hazardous substances and to facilitate disassembly. Furthermore, all producers strive to increase their use of recycled materials. By contrast, strategies to reduce the volume are less common. Only half of the examined producers, respectively, carry out measures to improve longevity of products or aim at reducing the amount of materials used. Finally, strategies that promise to increase the amount of recovered materials are the least relevant. Design for Recyclability is still pursued by three producers, whereas Design for Reuse is only considered by one.

5.3. Indications of EPR affecting the company's eco-design activities

5.3.1 Financial feedback loop

There is indication that in some companies, financial feedback from end-of-life management helps to promote eco-design activities. LG and Nokia developed tools to estimate the end-of-life costs of new product designs and try to optimise this parameter. Also Dell states to take end-of-life costs into account in its product development process. Philips' environmental manager reports that financial feedback provides a monetary argument, which helps to justify envisioned design changes internally. However, companies also point to certain limits. Financial feedback is impaired by uncertainties resulting from the long time gap between product sale and disposal. During this time recycling facilities may develop and make certain design changes irrelevant. Furthermore, it is reported that with currently applied recycling technologies that rely to a large extent on shredding the room for design changes to reduce end-of-life costs is limited. Furthermore, in collective systems financial feedback is distorted by cross-subsidisation between different product groups. Nevertheless, also companies without comprehensive individual programmes (LG, Philips) appear to experience financial feedback from end-of life management.

5.3.2 Informational feedback loop

Informational feedback from end-of-life management influences eco-design practices in nearly all analysed cases. Many interviewees confirmed that learning effects occurred. There is a considerable exchange of information between recyclers and producers. Takeback departments are in regular contact with recyclers. Internally, producers pass over relevant information to design teams or formulate appropriate design guidelines. How effectively these internal channels function depends in part on the structural organisation of takeback management. When takeback management is allocated at high levels (usually in centralised approaches) information is more likely to reach product development teams or strategic managers. If information from end-of-life management is passed over via several departments until it reaches design teams it is likely to fizzle out. In some cases (Dell, Nokia, Philips, HP) product designer also engage directly with recyclers in discussion or collaborative projects. This naturally provides for strong informational feedback.

Companies that maintain individual takeback schemes can be assumed to experience more direct informational feedback. Even though they contract third party recyclers rather than setting up recycling facilities themselves, they are usually involved in the recycling process. Similar to respective efforts in supply-chain management, producers carry out site visits and audits to ensure that vendors meet the company's environmental standards of the company.

5.3.3 Material feedback loop

There is hardly any indication that EPR established a material feedback loop. While all companies aim to increase their use of recycled materials, hardly any company pointedly connect takeback issues to this topic. An exception is Sony's effort to link in its reporting aspects of end-of-life management with data on its use of virgin and recycled materials. Even producers with comparably advanced individual schemes do not treat the collected WEEE themselves, but hand it over to third party recyclers. While it would be conceivable that the producers make agreements to retrieve the recovered materials for their own production, they show no interest in doing so. Instead, the materials are sold at secondary markets.

5.3.4 Influence of feedback loops on the application of eco-design strategies

In summary, the case studies reveal that in practice EPR established a strong informational feedback loop, a medium financial feedback loop, and a weak material feedback loop. When this finding is compared to the results of the analysis of eco-design strategies pursued by producers, the model provided in section 2.4.2 can be confirmed to a large extent. Of course, as explained before, the influence of other factors does not allow establishing causal relationships between the presence of a feedback loop and the application of a specific eco-design strategy. Nevertheless, some general aspects can be noted. According to the model, the strong presence of informational feedback particularly promotes strategies that reduce the treatment costs of WEEE. This is confirmed by the case studies. Strategy III (use of low-impact materials) and strategy IV (design for disassembly) are pursued by all examined producers. Furthermore, the model suggests that informational and financial feedback promote strategies that increase the amount of recovered materials and components. This is, however, not fully confirmed by the case studies. Strategy V (design for recyclability) is pursued by three and strategy VI (design for reuse) by only one producer. One reason for this might be that these strategies also relate to material feedback, which was not established to the necessary extent. The model further suggests that financial feedback promotes strategies that reduce the volumes of WEEE. Strategy I (design for longevity) and strategy II (reducing material diversity) are each pursued by half of the producers. This is in line with the finding that financial feedback has been established to a medium extent. The model appears to be flawed, however, with respect to strategy VII (use of recycled materials). This strategy is pursued by all producers, yet, contrary to what the model suggests, hardly any indication for material feedback was found. It appears that the motivation for this specific eco-design strategy is unrelated to EPR.

5.3.5 Producer assessment of the WEEE Directive and faced obstacles

The majority of the interviewed company representatives draw a positive conclusion of the WEEE Directive. Most interviewees note that it contributed to a shifting mindset. It raised awareness of end-of-life issues both internally among staff as well as externally among society. Furthermore, offering product takeback and taking responsibility for end-of-life products has evolved into a reputational issue and provides companies the opportunity to foster brand value and gain competitive edge. Interestingly, several companies notice that the directive caused changes among producers 'in general' while asserting that it did not incur many changes for themselves. This biased perception likely relates to the sensitivity bias discussed in the section 3.4.4.

However, the interviewees also point out some drawbacks of the directive. A commonly expressed criticism is that the directive would focus too narrowly on producers and fail to take other involved actors into account. The interviewees point to several other stakeholders, including commercial actors who recycle WEEE for profit, as well as consumers and in the case of mobile phones also network operators. Furthermore, the heterogeneous transposition of the directive in the member states creates an administrative burden. Some producers criticise that some countries oblige then to join single national PROs, which reduce compliance options and the degree to which producers can exercise control over end-of-life management.

6. Conclusions

6.1. Findings

The aim of this study was to cast light on how ICT producers cope with the EPR principle as enacted by the WEEE Directive and which eco-design activities they undertake. It is hoped that the findings of this study can enrich the debate on whether or not EPR promotes eco-design with empirical insights. In order to answer the general research question, four sub-questions were formulated, which are discussed in the following.

The first sub-question asked *in which ways do producers comply with EPR requirements and manage product takeback and to what extent do they differ?* The WEEE Directive principally provides for two ways of EPR compliance. Producers can either choose to organise product takeback and recycling on their own, or join up with other producers in collective schemes. In the EPR literature a discussion arose about the advantages and disadvantages of these two approaches. While one side emphasises the feasibility and cost-effectiveness of collective schemes, the other argues that individual approaches provide for stronger and more direct feedback on product design. The case studies have shown that all examined producers rely on collective systems to fulfil their legislative responsibilities and established a largely similar set of criteria that they expect from such a scheme. The producers pay particular attention to the capabilities of a scheme to handle the expected amounts of WEEE and fulfil certain treatment standards. Also the costs of a scheme play a role in the decision for or against a scheme. Moreover, some producers place emphasis on being able to choose between different schemes and exerting some control over the process. Notably, HP and Sony decided to initiate an own collective scheme for these reasons. In addition to their collective efforts, some producers run voluntary individual schemes, which offer product takeback to private or business customers. These schemes collect discarded products either at specific collection sites, by mail, or through direct pickup at home. As reason for these supplementary individual activities producers mainly cite corporate social responsibility and increasing customer satisfaction by offering additional services. Among the examined cases, Dell's scheme is particularly advanced in terms of scope and performance and can currently be considered best-practice in the industry. With regards to hybrid schemes, which promise to combine the advantages of individual and collective approaches, the examined producers express divergent views. Half of the sample considers hybrid schemes as a viable approach to provide for strict design incentives, the other half criticise this approach for being simplistic and based on mere estimations.

The second sub-question was: *Which eco-design strategies can facilitate product end-of-life management or reduce end-of-life costs and to what extent are these strategies applied by producers in practice?* From the literature, seven eco-design strategies with end-of-life relevance could be identified: Design for Longevity (I), Reduction of Material Use (II), Use of Low-Impact Materials (III), Design for Disassembly (IV), Design for Recyclability (V), Design for Reuse (VI), and Use of Recycled Materials (VII). These strategies can affect end-of-life management in different ways. The first two promise to reduce the overall volume of WEEE, the third and fourth can reduce the treatment and recycling costs of discarded products, the fifth and sixth promise to increase the amount of recovered materials, and the seventh strategy increases the demand of recycled materials, which increases the attractiveness of undertaking recycling efforts. The empirical investigation has shown that the examined producers are generally considerably active with regards to eco-design. All companies committed themselves to environmental product improvements and pursue various eco-design strategies. Producers display particular interest in measures to reduce the amount of WEEE and increase the demand of recycled materials. Measures to reduce the costs of treatment are less prominent and measures to increase the amount of recycled materials are the least relevant.

The third sub-question was in the essential focus this thesis: *In which ways can EPR (potentially) influence eco-design and to what extent can this be observed in practice?* This thesis identified three feedback loops from end-of-life management to the production phase by which EPR can potentially influence eco-design. First, it can establish a financial feedback loop, which transfers the cost and profits of end-of-life management to producers. This is considered to provide a financial incentive for producers to make appropriate changes to their product design. Moreover, EPR can initiate an informational feedback loop, which channels informational exchange between recyclers and producers or product developers. This can raise awareness and result in learning effects and thus improve product design. Finally, EPR can establish a material feedback loop, if reclaimed materials or product components can be used for new production or remanufacturing. This can help to close material loops and set path for a circular economy. The examined cases provide indications that to some extent these feedback loops were established and had the expected effects. Informational feedback was found to have the strongest influence. Nearly all cases demonstrate that the application of eco-design benefited from the exchange of information between producers and recyclers. Many companies established direct communication channels between their product developers and recyclers. However, one drawback of informational feedback is the gap between the point in time when a product is developed and the point when it is finally recycled, which may result in the exchange of outdated information. Financial feedback was found to have some influence, too. However, the same drawback as in the case of informational feedback applies, which causes significant uncertainties with regards to the provision of financial incentives. Thus, financial feedback appears unlikely to promote eco-design where it has not been on the agenda already. But there is indication, that it can be the tipping point for decisions favouring eco-design and strengthen the position of environmental advocates within companies. With respect to material feedback loops hardly any indications were found.

Regardless of the type of feedback, it has been noticed that different organisational setups influence to what extent EPR feedback is forwarded within companies to product developers. In some cases there is no direct communication between takeback teams and product development teams. When takeback management is allocated at high levels (usually in centralised approaches) information is more likely to reach product development teams or strategic managers. If information from end-of-life management is passed over via several departments until it reaches design teams it is likely to fizzle out. End-of-life feedback is then communicated only indirectly via the company headquarters, but has no direct influence. Available EPR literature does not pay enough attention to this and tends to treat companies as a black box which would straightforwardly transform feedback and incentives into design outputs.

The fourth sub-question asked *which chances and obstacles do producers see with regards to EPR?* All producers unanimously voice support for the principle and state to accept their responsibility. Moreover, chances are seen with regards to corporate social responsibility and customer retention. Undertaking proactive takeback activities is an opportunity for companies to foster a green image and offering advanced services to their customers. Especially from business customers such services are increasingly requested. Several interviewees acknowledged that EPR raised awareness for end-of-life issues and their consideration at the product design phase. Yet, there are also certain drawbacks perceived. Some interviewees criticise that the WEEE Directive would focus too much on producers and fail to take other actors involved in end-of-life management into account. The activities of third parties who take back and recycle WEEE for profit are not properly reflected in the collection and recycling data. Another problem is seen with regards to current recycling practices. Many recyclers rely on shredding technology, which makes producers efforts to improve disassembly obsolete.

The fifth sub-question was: *To what extent does EPR set path for a circular economy with closed material loops?* In the examined cases EPR has hardly established any closed material loops. Currently, producers do not appear interested in retrieving the recovered materials from their takeback activities for their own production. Instead, the materials are sold at secondary markets, where they are considered to be distributed the most efficiently. While all companies undertake efforts to increase their use of recycled materials and thus foster indirectly closed material loops, only two producers of the sample explicitly make a connection between these efforts and their own takeback activities. This suggests that EPR as currently implemented does not have much influence with regards to closed-material loops.

6.2. Discussion of the results

6.2.1 The influence of EPR on eco-design

The findings of this thesis suggest that EPR, as implemented in the WEEE Directive, positively affects eco-design. This corresponds to the first of the three views identified in the literature. Contrary to the assertion of some scholars (e.g. Gottberg et al. 2006; Sachs 2006) that EPR does not have any significant influence on product design, this thesis presents several indications for established feedback loops from end-of-life management back to producers and eventually to product development. And contrary to the view that EPR is only effective in individual schemes (e.g. Dempsey et al. 2010; Lifset and Lindhqvist 2008; van Rossem 2008), it has been found that also in collective schemes EPR feedback loops had some effect. Moreover, this study points to some problems of IPR, which are discussed further below.

In general, it appears that the discussion on EPR has so far focused too narrowly on financial incentives. Informational effects were found to have a more significant impact. Furthermore, the case studies suggest that, perhaps more than through direct feedback loops, EPR promotes eco-design through several mediate effects. EPR has put e-waste on the agenda of producers. It raised company managers' and other staff's awareness of end-of-life aspects and the consequences of product design. Even though end-of-life cost reduction strategies often focus on organisational issues, such as optimising contracts, companies have started or intensified research about e-waste, resources, and recycling issues. The case studies show that learning effects have occurred and a new mindset has taken root. Beyond that, e-waste has become a reputational issue. The general public now perceives producers responsible for WEEE, which turns the topic into an important CSR concern for companies. This often motivates responsible end-of-life management and eco-design independent from any direct benefits.

It is clear that whether or not companies embrace determined eco-design activities does not entirely depend on whether EPR provides them with adequate incentives to do so. As mentioned before, eco-design is influenced by many factors, financial and non-financial ones. However, it has been shown that EPR has influence on producer's decisions on eco-design. The concept realises several advantages connected to innovative market-based policy approaches. EPR has institutionalised end-of-life issues into the daily operations of producers. It strengthens an environmental position within companies. Thereby even small financial arguments can be enough to tip the scales towards decisions in favour of eco-design. As the case studies show, large multinationals in the electronics sector have accepted their responsibility and undertake meaningful efforts with respect to eco-design. Public and corporate awareness of these issues has grown. It can be assumed that in this way eco-design is approached from many more angles than if producers would only work towards compliance with mandatory specifications. Nonetheless, market based and conventional command and control policies are not mutually exclusive. The combination of EPR policies with mandatory requirements (as for instance set out in the EU REACH, RoHs and Ecodesign Directives) is likely to provide for optimal policy effectiveness.

6.2.2 The ideal EPR system?

The academic discussion of EPR is characterised by the dispute whether producers have to fulfil their responsibility individually (IPR) or if they may do so collectively (CPR). This thesis suggests that collective systems provide sufficient feedback to promote eco-design. The common assumption that only IPR would provide meaningful eco-design incentives needs to be refined. Producers mainly rely on collective schemes because the pre-treatment costs of end-of-life management (collection, transport, etc.) outweigh the costs for the actual treatment of WEEE. In any individual scheme, the costs for either individual collection or for sorting would be disproportionally higher. As it can already be seen in collective schemes, producers focus their cost reduction strategies on the primary cost burdens and try to improve their contracts primarily in terms of efficient logistics and advantageous scheme set-ups rather than creating a direct link between end-of-life costs and eco-design. Furthermore, also in IPR systems the problem of uncertainty about the return of investments in eco-design continues to exist due to the long time gap between product development and disposal. This casts doubt on the argument that the financial incentives in full IPR systems would be significantly higher than in collective systems. Moreover, the case studies show that also companies without comprehensive individual programmes (such as LG or Philips) experience financial and other feedback from end-of life management. In addition, the discussed mediate effects are also realised in collective schemes.

Furthermore, the case studies question the assumption of some scholars that individual financial responsibility can be implemented in collective systems through differentiated fees. The examined producers take opposing stances on these hybrid schemes. Some producers expect that they can provide useful incentives. A particular advantage is that differentiated fees bridge the time gap between product development and disposal. However, to be effective hybrid schemes would require a homogenous fee system in all European countries. The inconsistent transposition of the Directive in the European member states casts doubt that this could be achieved.

Ideally, EPR regulation allows competition between different collective and individual systems. Many producers express concern over mandatory national schemes, where they are not able to exert any control over the process. This takes responsibility away from producers rather than putting them in charge of end-of-life management as intended by the EPR principle. Furthermore, scheme variation pays reference to altering company and country contexts. The coexistence of individual and collective schemes allows producers to be proactive and offer advanced services to customers while acknowledging at the same time that collective systems are currently more efficient in terms of collection and logistics and thus better suited to handle the large volumes of mixed-up WEEE. Experiences with different variations of producer schemes as well as developments in sorting technology may eventually lead to a situation where individual systems become more efficient than collective ones. Then, it can be assumed that companies with advanced eco-design products will leave collective systems and fully rely on their own schemes to avoid subsidising competitors with less advanced products.

6.2.3 Limitations of this study and further research need:

In the light of the early stage of research on the subject, this thesis adopted a qualitative multiple case study approach. This approach provided sufficient room for the explorative examination of producer activities while at the same time allowing for some degree of generalisation. However, as discussed, the examined sample of six producers is subject to a positive selection bias. It can be assumed that the producers who declined participation at this study are generally less advanced in terms of takeback and eco-design. Furthermore, this thesis could only consider a limited scope. The focus was placed on large multinational corporations in the ICT sector. The analysis did not take account of small and medium enterprises or of producers of other product groups. In addition, the thesis focused on EPR as implemented in European countries by the WEEE Directive. Different legislative provisions, such as in Japan, China, or the USA, can bring about other practical forms of EPR and may lead to other conclusions about the concept.

Thus, the relevance of the findings presented here needs to be confirmed by further studies, which differ from this thesis in terms of scope or methodology. Interesting insights can be expected from a wider quantitative approach that includes more (different) cases, as well as from the detailed analysis of one specific case. Beyond this study, more empirical insights need to be collected on the efficacy of EPR and the systems it creates. Particularly interesting would be an attempt to evaluate the influence of EPR versus other influences on eco-design. It is hoped that the contribution of this thesis to the discussion of EPR can provide a sound basis for such further research efforts.

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8. Appendix

Generic Interview Guideline

Please note that the questions below represent a generic outline of the interviews. For each case, the questions were adapted to previously available information and were occasionally altered in the course of the interview. The questions in italic were designed to probe into further details and only asked where needed.

Background information

- Could you provide me with a brief description of your functions at your company?
- *[Responsible for which countries?]*
- Since when do you work for your company?

Product Takeback at your company

- Did you already work at your company when the issue of product takeback appeared on the agenda for the first time?
- *[When was that? When did the first related activities start?]*
- Could you describe me how product takeback is organised within your company? Which departments are involved and how are responsibilities distributed? *(~in Europe)*
- How do you manage B2B WEEE?
- In Europe you manage WEEE Takeback in Producer Responsibility Organisations. By which criteria do you choose a PRO, in countries where you have a choice?
- Can you tell me on which factors the fee that you have to pay to these PROs depends?
- *[weight/amount of products; return-share or market-share? Average fee on the basis of all collected products of a specific kind?]*
- Do you consider this cost arrangement fair?

End-of-life costs

- In which ways does your company attempt to reduce the costs related to product end-of-life management?
- You mentioned that you / the PRO manage(s) WEEE recycling in collaboration with other producers. Under these circumstances, it might be the case a producer with products for which treatment is relatively inexpensive subsidises other producers with high treatment costs. Is this description correct?
- *[Do you consider freeriding as an issue here?]*

IPR

- Your company states to support IPR. Yet, as I understood it, as far as Europe is concerned you joined (a) collective scheme(s). What are the reasons that you did not set up an individual scheme?

Involvement with recycling

- Is your company in any way involved with the final recycling and treatment of WEEE?
- *[Are you in contact with the recycling facilities? Do you receive feedback from them?]*

- What happens to the materials that have been regained from WEEE?

- *[secondary market? Or could they be used by your company for new products? Do you reuse certain product components?]*

Extended Producer Responsibility in general

- Do you think producers are the right addressees for WEEE?
- *[Why?]*
- Would you say the Directive has caused many changes for your company?
- *[Could you describe me what has changed? Did any organisational changes within the company occur?]*
- By implementing the principle of EPR, policymakers intend to promote environmentally conscious product design. Does the WEEE Directive, in your view, achieve this goal?
- *[benefits over the whole lifecycle? If not, which obstacles do you see?]*
- Does your company receive any useful feedback from end-of-life management?
- *[In which ways? Which kind of feedback? Is there any other feedback that comes to your mind?]*

Eco-design

Definition: an approach to product design that systematically integrates environmental aspects and aim at improving the environmental performance of products throughout the whole lifecycle.

- Could you briefly describe me your company's eco-design strategy? Which aspects do you focus on?
- *[Are there any specific goals that you pursue? Do you pursue a certain long-term goal? Do eco-design goals sometimes conflict with other design goals? Which are more important?]*
- Do you remember or know about the beginnings of eco-design at your company? When did your company start to integrate the design aspect in its general sustainability activities?
- Can you tell me which departments at your company are involved with eco-design?
- *[How are responsibilities distributed?]*
- How is eco-design integrated into the general process of product development?
- Do you focus on any particular stage of the products' lifecycle?
- *[Do you see any conflicts between improvements of different lifecycle stages? Do you try to reduce EOL costs by a specific product design?]*
- Could you describe me, which specific design changes you focus on?
- Do you use design support tools to improve product end-of life?
- Would you say that your activities regarding product takeback and eco-design are linked in an ideal way?
- *[Do you see something that could be improved?]*

Closed-loops

- A popular concept the discourse on sustainable development is the idea of a circular economy with closed material loops. What do you think of this vision?
- [*Do you consider it realistic?]*