Design for Recycling of e-products

The incentives under the Swedish Extended Producer Responsibility

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Abstract

The aim of this paper is to explore the incentives under the Swedish Extended Producer Responsibility that currently affect the design of electric and electronic products. Through tracing the incentives faced by different actors connected to e-waste we conclude that the incentives for promoting design for recycling are weak for each and every one of them. Foremost, we argue that this is the result of the diffusion of return on investments that appears in the collectively arranged system. Our analysis show that the product design choices upstream give rise to technological externalities in the recycling stage downstream. In turn, these create loss in social welfare both due to resource efficiency loss and entailed environmental externalities. We further discuss possible solutions to minimize this loss but acknowledge the difficulty in determining what would bring a more socially efficient outcome.

JEL Classification: Q53 · Q58
Key Words: extended producer responsibility, design for recycling, technological externality, waste management

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“Waste is the result of inadequate thinking.”

– Jeffrey K. Seadon

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Purpose

Electric and electronic products (e-products) often contain many valuable materials. Given the steady increase in the waste stream of this product category, there would be much to gain for society if valuable components could be recovered at the recycling stage. Since upstream design decisions, particularly the way of assembling different components, have great impact on the degree of recyclability, the design stage is of great interest for this purpose. In fact, encouraging "design for recycling" was one of the reasons for inventing and introducing the so-called Extended Producer Responsibility (EPR).

This paper investigates the impact of the current EPR regulation on upstream product design decisions. Using the approach of environmental economics we map the incentive structure that has evolved practically in Sweden, discuss how strong the incentives are for design for recycling and what effect this has on social welfare. Our paper thus contributes to the on-going policy discussion of the effectiveness of EPR in promoting design incorporating environmental concerns.

Background

As the total amount of waste in society has grown, the broad concept of waste management has been widely discussed and gotten interest from scholars and decision-makers alike. Considering the huge amounts of waste generated around the world, an efficient recycling system could potentially have considerable value for society—if we manage to make it efficient. Capabilities of recovering and reusing materials that have already been extracted once allows saving costs of extracting new virgin materials, both in terms of resource usage and environmental damage.

In obtaining an overall efficient waste system, there are many aspects of consideration: waste prevention, waste collection, recycling (in terms of materials or energy), and safe, minimized use of landfills. Waste prevention is one aspect that has gotten much focus by the European Union (EU), as for instance demonstrated by the obligation on all member states to develop a waste prevention programme, completed by December 2013 (The Swedish Environmental Protection Agency 2012).

Despite the attempts to reduce the amounts of waste, however, the trend currently points in another direction. The Swedish Environmental Protection Agency (SEPA) reports that if today's rate of waste growth continues, Sweden will double its quantities by 2030 (The Swedish

Environmental Protection Agency 2012). The product category increasing most rapidly is electric and electronic waste (e-waste). Not only is there a positive trend in number of e-products in households, but we also tend to use our products more intensively and replace them more often, following the fast advancement of technology (Lundstedt 2011). Another tendency is that e-products are getting more difficult to repair, which results in consumers choosing to buy new equipment instead of extending the life of their old products (Öhrlund, 2013).

When it comes to collection of e-waste, Sweden can parade with high rates. Compared to the target set for the EU of 4 kg per person per year, Sweden reached 17,2 kg in 2010 (although we should remember that is not only connected to a well established collection system, but also a high rate of consumption) (Jonsson et al. 2012). However, while high collection rates help preventing the environmental damage of products ending up in nature, one could question the system's effectiveness if the collected products are not efficiently recycled in the end. Society should find itself in a position adequate to ask: Given the capabilities we have, do we make sufficiently good use of the waste we generate?

In fact, recent studies have started questioning the very notion of waste. Instead of talking about a product life cycle from cradle to grave (with the landfills being cemeteries), some authors advocate a product life cycle as one from cradle to cradle and launch concepts such as zero-waste systems (e.g. Braungart, McDonough 2002, El Haggar 2007).

This is easier said than done. Different products have quite different characteristics as waste, containing different amounts of extractable value and embodying varying complexity. Common across product categories though, is that the design determines the degree of recyclability in its decisions of materials and ways of assembly. Whether two components are soldered, screwed or melted together make a big difference in the required efforts, techniques and costs at the recycling stage. Several business studies have advocated the importance of designing for assembly as well as disassembly and an integration of recycling considerations into product design. Not only is this promoted for the environmental cause but also for the economical benefits for individual companies (e.g. Boothroyd, Alting 1992, Kriwet, Seliger & Zussman 1994). However, most often, the actors carrying out the design decisions are not the same as the ones facing the task of recycling. The properties of products are decided by companies upstream but cause challenges for companies downstream, sometimes several years later.

Many economists have addressed the issue of organizing recycling systems efficiently and reaching a social optimum of consumption and waste disposal. Several of these take on a hypothetical approach to the subject, creating models to find a first-best[1] optimum. Economists have concluded that this social optimum could be obtained by having a system with a unit-based fee where households pay a certain price for every recyclable item that they dispose. This price would have to vary to reflect each item's full social cost, which includes costs such as external environmental costs as well as the cost of recycling the item (Calcott, Walls 2000). This structure would send the "right" signals both of how to consume and dispose, and we would reach a social optimum (Fullerton, Wu 1998).[2] It is also acknowledged, however, that in the real world setting, this first-best social optimum may not be attainable, since the transaction costs of the unit-based fee may simply be "prohibitively high" (Calcott, Walls 2000).

The collection and recycling of various different product categories in Sweden and Europe has seen the intervention by governments using the EPR legislation. In Sweden, the EPR legislation covers several different product categories, namely packaging, waste paper, batteries, tires, cars, radioactive products, pharmaceuticals and e-products. The specific design of the EPR varies between countries, but the concept is simply to make producers of certain products physically and financially responsible for the collection and recycling of their e-products. The term was officially coined in 1990 with the aim of "decreasing the total environmental impact from a product" (Lindhqvist 2000) and it created much controversy and excitement, "reshaping the conceptions of available environmental policy instruments" (Lindhqvist, Lifset 1997). At the heart of the visionary concept, was the desire for dynamic, on-going incentives to take environmental concerns into consideration when designing products covered by the legislation (Lifset, Lindhqvist 2008).

Indeed, the EPR embodies various distinctive features that are generally considered to generate an effective policy: it focuses on prevention instead of end-of-pipe solutions, it seeks to reduce the overall environmental impact of products rather than addressing point sources, it does not work

[1] "First-best" referring to a system where all optimum conditions are fulfilled simultaneously (Lipsey, Lancaster 1956).

[2] More detailed discussions have gone into whether the recycling should be organized through disposal fees or deposit-refund systems, and it has been argued that a deposit-refund system would have the advantage of discouraging illegal dumping (Fullerton, Kinnaman 1995). The problem is that often when modelling out these systems the studies assume that recycling markets function perfectly or not at all. Calcott and Walls (2005) have commented this tendency, arguing that the truth lies somewhere in between and that policies must be made with this in consideration. Through explicitly modelling the transaction cost that come with the current recycling markets, they find that a combination of disposal fees and a deposit-refund system was necessary to bring about the optimal level of waste, recycling and environmentally friendly design.

through specific prescriptions but via the provision of incentives and it delegates the responsibility to the manufacturers themselves (Tojo 2004).

The EPR has now been in force approximately ten years in Sweden, EU and some other parts of the world. Despite the promising traits, it has been argued by many that it does in fact not send the appropriate signals back upstream, or at least that they are not as strong as intended to be (e.g. Calcott, Walls 2000, Lifset, Lindhqvist 2008, Walls 2003, Glachant 2004, Atasu, Subramanian 2012). In light of this, several case studies have been conducted, investigating the effects on certain products and regions with varying results in determining EPR's effectiveness (e.g. Tojo 2004, Driedger 2001, Hage 2007, Manomaivibool, Vassanadumrongdee 2011, Gui et al. 2013, Mayers, France & Cowell 2005).

Scope and research method

We contribute to the discussion of the effect of EPR on design decisions by looking into the Swedish case, with the explicit focus on e-products. Instead of conducting an interview-based case study, we take on a helicopter perspective, tracing the incentives faced by different actors connected to e-waste.

In contrast to the broader economic literature on "design for environment" (e.g. Calcott, Walls 2000) that concerns the incorporation of all environmental issues on product design and manufacturing decisions (Fiksel 1996), we narrow the scope to solely treat design for recycling. We use this term to refer not just to design that makes e-products *recyclable*, but design that is *smart* from a recycling point of view, enabling society to profit from the value embodied in discarded e-products (Kriwet, Seliger & Zussman 1994). The reason we specifically address EPR in the area of e-products is because it is a product category of growing volume, high complexity and with a composition of valuable materials.

To structure our investigation, we have formulated two research questions. Namely:

1. What are the financial incentives for design for recycling brought by the Extended Producer Responsibility (EPR)?

2. Do these produce a social optimum of design and recycling of e-products?

The research has been executed by looking into both the legislative regulation and its practical arrangement as chosen by the Swedish actors. The investigation itself has been conducted through tracing, by logic, the incentives implicated by this practical arrangement. Complementary information has been provided from qualitative interviews with different actors involved in e-products' value chain. Having mapped the incentives, we use the broad economic theories of externalities and social welfare to discuss our findings. We assume that the reader is familiar with these economic theories and we will not spend time on explaining them in detail. They are quite simplistic and straightforward in nature, but become powerful tools in analysing and discussing our research questions in a structured and rational manner.

There are, however, some limitations of scope that we want to point out.

First, as explained, the legislation related to e-products varies across the world's nations, also within the EU. Even though the member countries are within the jurisdiction of EU, all nations implement the directives in their own restricted choosing. We limit our scope in this paper to investigating the Swedish legislation and its consequent incentives, but believe that our findings can be found interesting also in other national contexts.

Second, we focus our paper on consumer goods rather than products on the business-to-business market. The reason for this is that the business-to-consumer goods market faces bigger challenges in arranging its EPR since there is a big gap between producer and user and thus makes for a more interesting case.

Third, we will not try to quantify any possible current deviation from a social optimum, nor its entailed cost. There is an apparent difficulty in assessing such a cost, since we can by no means relate the whole cost of recycling e-products to the deviation. Instead we must somehow find a dividing line between what should be related to the deviation and what should not—and doing this in a just fashion is far from a straightforward case.

Fourth, and perhaps most important, there are several different approaches to analysing and discussing the economy and environment. As explained, we take on our research questions using the lenses of classical environmental economics, as demonstrated for instance by our focus on financial incentives and our discussion on different forms of externalities and socially efficient outcomes. The fundamental assumption that lies in the background is that the value of the environment derives from the value held by us as people (for example because we claim that there is much value embodied in e-products since the components have a positive market value). The reader should know that this is not the only possible way of thinking. In contrast, the school of ecological economics uses a biophysical view of value, where one instead measures value in terms of embodied energy content (Kolstad 2000). Here, financial incentives created by markets will generally not be a mechanism that mediates products' value. We do not believe that any of these two approaches is any more right than the other. Presumably, they may both provide interesting findings and valuable food for thought.

Introducing e-product characteristics and the EPR

We will now look more into the characteristics of e-products, both in terms of their life cycle, the involved actors and the features of the products themselves. We also explain the EPR legislation more thoroughly and distinguish between the legislative form and its practical arrangement of fulfilment in Sweden.

E-products – useful but complex

Without doubt, e-products have a high value to society. They unquestionably enhance productivity in businesses and add much value to private consumers. The category has a huge span ranging from large household appliances like washing machines, air-conditioners and refrigerators to laptops, cell phones, coffee machines, televisions, lighting equipment, medical devices and so on. During recent decades, the use of e-products has proliferated (Widmer et al. 2005). It is estimated that 20 to 50 million tonnes of e-waste is generated each and every year globally and it is not only growing, but is also the category of waste that is currently growing the fastest (Lundstedt 2011). What makes e-products particularly interesting from a recycling point of view is that they contain many components, such as different kinds of precious metals and plastics, that provide high benefits if they can be disassembled and reused (Widmer et al. 2005). Their positive market value

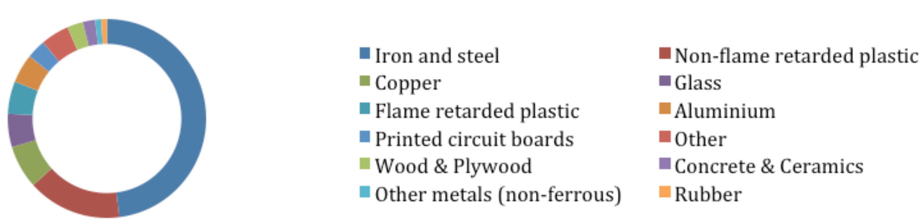

Figure 1. *The material composition of e-waste in terms of weight, according to the European Topic Centre on Resource and Waste Management (Widmer et al. 2005).*

is clearly demonstrated not least in many developing countries like China, Nigeria and Ghana where poor people engage in disassembly of e-products in the search for these valuable components to be able to provide some personal income (Lundstedt 2011).[3]

The life cycle of an e-product is similar to that of most consumer goods and it is shown in the model below.

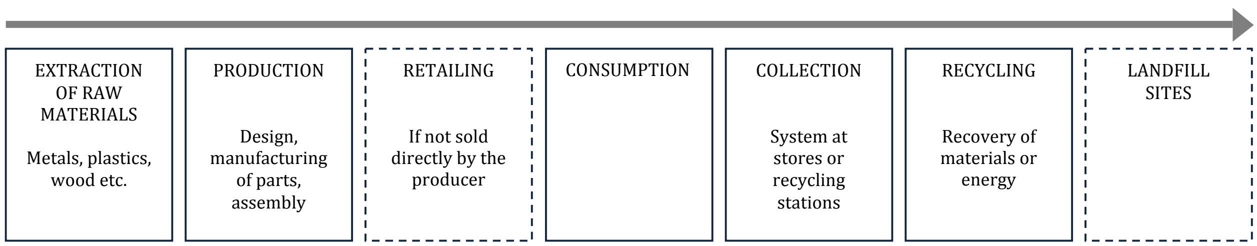

Figure 2. *The life cycle of e-products.*

The *extraction* phase is a diverse one, reflecting the variety of materials in e-products. Widmer et al. (2005) claims that e-products contain more than 1000 different substances and Figure 1 above gives an idea of how complex the products are compared to many other consumer goods. The raw materials of e-products are extracted through mining, felling, oil drilling and so on, accompanied by high costs both in terms of resources and negative environmental effects.

At the *production* phase, design decisions are made, parts are manufactured and assembly is carried out. A single product can be composed of hundreds of different parts and each one of these are designed by a different team that chooses the best kind of material for that part's own purpose. The assembly is done through welding, melting, mechanical bolts, casting or other convenient procedures. The designer firm generally does not care about disassembly in their design, because the buyer does not care (Fullerton, Wu 1998). Overall, there seems to be a trend that e-products are "associated with an increasing product complexity, an increasing diversity of the embodied materials, and a decreasing recyclability due to the substitution of metal by plastic" (Glachant 2004). For instance, Öhrlund (2013) highlights the problem that the new generation of laptops are increasingly moulded to entities instead of separate materials, considerably complicating later disassembly.

[3] As is regularly reported in newspapers, much of the world's e-waste is exported, most often illegally, to different developing countries. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal is a UN convention that entered into force in 1992 to work preventively against this stream of "toxic waste", but there still is large volumes of e-waste crossing borders (Lundstedt 2011).

Subsequently, the ready product is put on the market, either directly by the producer or through a *retailer* such as El-Giganten, Siba or others. The consumer then buys the product and uses it during a certain amount of time. After *consumption*, the e-product supposedly finds its way to a *collection* station where it can be discarded for free by the former consumer.

It is then time for the *recycling* phase. Compared to other product categories that are also collected and recycled, such as paper bags or plastic bottles, the complexity of e-products makes them difficult to handle at the end of their lives. The recycling phase itself is indeed more complicated than it seems and consists of many different activities. The first ones are normally manual dismantling and sorting, followed by mechanical shredding and separation and tailored recycling for the different kinds of materials, incineration and/or landfill (Lundstedt 2011).

Since many of the components in e-products are hazardous, there is an environmental risk of releasing them during the process of recycling. The United Nations Environmental Programme has distinguished the environmental damage that may occur during the recycling into the three categories, namely: primary, secondary and tertiary emissions (Schluep et al. 2009). The primary emissions include hazardous substances contained in the e-waste itself that may enter the environment if not taken care of in an appropriate manner. The secondary emissions refer to the hazardous reaction of products that arise from the handling of e-waste (e.g. incineration) and the tertiary ones are the hazardous substances or reagents that are used as inputs in the recycling processes. These emissions constitute a risk for both human health and the environment. The effects are often inevitable but are better controlled in facilities that are designed for the purpose of both recovering valuable materials *and* recycling the other parts (Lundstedt 2011).

Since recycling is becoming ever more difficult the actors are getting more specialized and

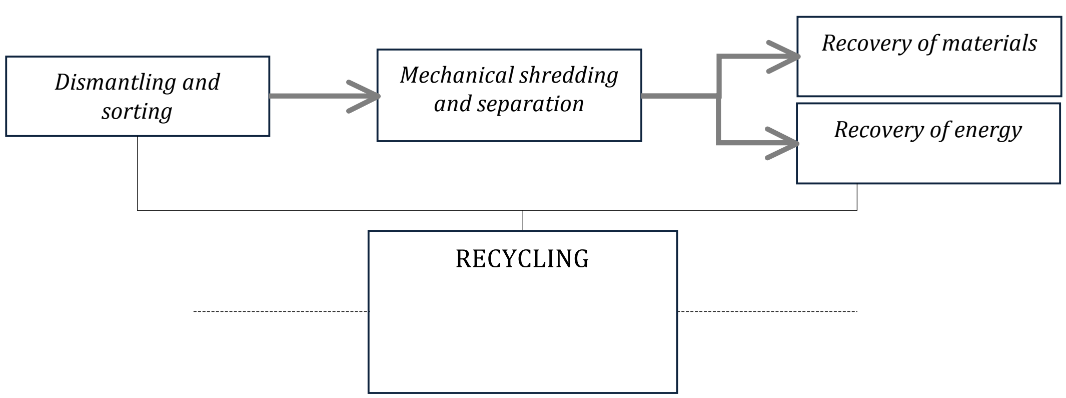

Figure 3. *The different stages of recycling, often done by several companies.*

there might be one firm dismantling the products, another one making preparatory treatment and a third one processing the material and sorting it either to recovered material or to landfill sites. This part of the chain is a place of tough competition. In order to win business and gain a competitive edge, the recyclers need to steadily evolve their techniques and recycling methods in order to handle the new products that arrive at their sites (Öhrlund, 2013).

Earlier, the producer and retailer were cut out of the chain as soon as a consumer bought the product. The firm had served its part and was not involved in how the product was used and what happened to it afterwards. But since EPR came into force the responsibility does not end there. Nowadays, as soon as the product has served its time, the producer has the financial and physical responsibility to take care of the waste and for instance make sure it does not end up in nature.

The EPR legislation in Sweden

A producer responsibility ordinance on e-products came into force in Sweden in 2001, and in 2002 the EU passed a directive regulating the matter in all member countries. Sweden incorporated the Directive 2002/96/EC of the European Parliament and of the Council (January 2003) on Waste Electrical and Electronic Equipment (WEEE Directive) concerning extended producer responsibility for e-products into Swedish law through the decree "Förordning om producentansvar för elektriska och elektroniska produkter" (SFS 2005:209). This is now ruling force.[4] EPR has many aims and the first listed in the directive is to minimize the waste attributable to e-products by improving their whole life cycle and engaging all actors involved in it. Additionally, in Article 4 in the new Directive 2012/19/EU, it stands to read:

> *Member States shall [...] encourage cooperation between producers and recyclers and measures to promote the design and production of EEE, notably in view of facilitating re-use, dismantling and recovery of WEEE, its components and materials.*

The Swedish regulation puts responsibility on the so-called producers, but legally this term refers to any actor that has sold the e-products on the Swedish market, regardless of whether the company itself has produced them (SFS 2005:209). In other words, retailers such as El-Giganten,

[4] After a recast of the directive, it is currently under investigation by the SEPA, though, whether the latest recast of the Directive requires new modifications in the Swedish law.

Siba and others, also obey under the EPR (one may think of them as the producer of the subsequent waste, rather than the products themselves).

According to the EPR, producers are both physically and financially responsible for their generated waste. The physical responsibility means that the producers have to provide suitable collection points for the consumers and then make sure that the products are transported, pre-processed, reused or recycled in terms of material or energy. The financial responsibility entails that the producers will get no compensation for this end-of-life treatment and also has to ensure that there are funds available for this fulfilment even if the producer goes out of business (SFS 2005:209).

The legislation itself, however, does not establish whether the responsibility has to be fulfilled in an individual manner or if the actors can arrange a collective effort to comply with it. This decision has thus been left for the producers themselves.

The practical arrangement of EPR in Sweden

Most European countries have set up a collective system to fulfil the EPR requirements (Glachant 2004). Commonly, this means producers pay a fee to so-called producer responsibility organizations (PROs) to ensure the management of collection and recycling.

In Sweden, the majority of business-to-consumer producers and retailers collaborate through the non-profit company *El-kretsen*, while a smaller proportion use the non-profit association *Elektronikåtervinning i Sverige*. These two PROs administer the whole producer responsibility on behalf of their member companies. In practice, this means that they provide collection points for consumers nationwide where consumers can discard the products for free (sometimes in their retailer stores, but more often at larger recycling stations in collaboration with municipalities), take care of the transportation of collected waste and hand it over to recyclers. Depending on whether the products have a positive or a negative net value (the net value being the value of components that can be successfully recovered minus recycling costs), the PROs either get paid or pay for the hand over (Öhrlund, 2013).

The collectively arranged system is financed by producers and retailers paying member fees to their respective organization. The fees are based on each company's current market share calculated in kilograms of e-products sold in the Swedish market place (Öhrlund, 2013) and it is thus not directly linked to the individual firm's products' waste management costs. When calculating the fees, the e-product market is not treated as a whole, but divided into ten different product categories as presented by the EPR legislation (see Table 1). This allows for a more fair distribution of costs, but still means that the individual firm does not pay a fee equivalent to what it costs to recycle its own products. In addition, the system implies that the fee is neither linked to the amount of waste that the individual firm has actually caused that year. A newly entered producer will pay for a part of e-waste collected even if its products have not yet reached any collection points. For example, this means that a current producer of environmentally friendly refrigerators will have to pay for the waste management of old Freon refrigerators (Öhrlund, 2013).

Category	Examples of waste
1. Large household appliance	Washing machines, dryers, refrigerators, air-conditioners etc.
2. Small household appliances	Vacuum cleaners, coffee machines, irons, toasters etc.
3. IT and telecom. equipment	PCs, Laptops, cell phones, telephones, copiers, printers, etc.
4. Consumer electronics	Televisions, VCR/DVD/CD players, Hi-Fi sets, Radios etc.
5. Lighting equipment	Luminaries 0.7, fluorescent tubes, sodium lamps etc.
	(Except: bulbs and halogen bulbs)
6. Electrical and electronic tools	Drills, Electric saws, sewing machines, lawn mowers etc.
	(Except: large stationary tools/machines)
7. Toys, leisure and sports equipment	Electric train sets, coin slot machines, treadmills etc.
8. Medical devices	
9. Monitoring and control equipment	Smoke detectors, industrial controlling systems etc.
10. Automatic dispensers	Cash dispensers, vending machines etc.

Table 1. *E-waste categories used by the European Union.*

Incentives induced by the EPR system

The specific chosen arrangement of fulfilling the EPR legislation in Sweden shapes the incentives faced by the actors involved in an e-product's life.

There are several different actors relevant in the life cycle of an e-product and the ones we choose to look into here are the consumers, PROs, retailers, recyclers and producers. As already stated, the EPR legislation does not distinguish between actual producers and retailers of e-products, giving them just as much responsibility at the late stages of the e-products' life cycle. Nevertheless, we will distinguish between them here since the producers directly decide the design of the e-products, while the retailers do not.

Furthermore, the reason that we do not only look into the incentives faced by producers themselves (but in consumers, PROs, retailers and recyclers as well) is that we are interested in whether the other actors face incentives to try to influence the producers' design (as, for example, the consumers do in the theoretical first-best optimum mentioned in the introduction).

We will start by looking into the actors with an indirect link to the design choices and conclude with the producers themselves.

Consumers have no reason to care

The consumers of e-products take many different things into account when buying their products. They place demands such as functionality, durability and aesthetics since it directly affects the benefits and costs associated with the e-product. But for the consumer there is no reason to have recyclability as a criterion of consideration. In the current setting, they can discard e-products for free just by dropping them off at a collection station. Since they do not have to take on any costs during the recycling phase, there is no incentive for the consumer to demand easily recyclable products (Fullerton, Wu 1998). If we instead consider a system where households pay a disposal fee based on degree of recyclability when discarding their e-products, the criteria of recyclability would be on the agenda when consumers evaluate what to purchase. This, in turn, would work as a mechanism for companies to produce design for recycling (Calcott, Walls 2005) but under the current EPR system, this is not the case.

PROs always even out

The PROs El-Kretsen and Elektronikåtervinning i Sverige are both non-profit organizations. The member fees are designed explicitly to cover their costs and thus they will get paid no matter how high they are since the member companies are obliged by law to handle the e-waste. Since this is the case, the organizations themselves have no incentives to lower the costs of neither collection nor recycling. The member companies (the Swedish producers and retailers), on the other hand, do have an interest in monitoring the costs and finding ways to reduce these. They will be considered below.

Retailers are potentially powerful

The EPR legislation puts retailers on par with the producers and thus they share the same responsibility. But there is one important difference: the retailers do not actually design the e-products that they put on the market. This does not mean that they have no power over the degree of recyclability of their products. The retailers have a wide variety to choose from when deciding their product range and may well select with design for recycling as a consideration. Under the assumption that they want to maximize their profit, the retailers would want to minimize the cost put upon them by the EPR and choose products accordingly. Their cost caused by the EPR however, is only marginally decided by their own choice of products, since they share the cost together with the whole sector on the Swedish market. This means that the benefit (i.e. cost savings) of a design for recycling will gain all actors, not only the firm who sold it. The incentive to have design for recycling high on the agenda is therefore significantly weakened.

Recyclers have much to win

The recyclers find themselves at the end of the e-product's life cycle. They have no responsibility under the EPR legislation, but profit from it since the directive secures business for them. However, it is a tough industry. It is capital intensive and requires continuous investments to be able to respond to the technological progress of e-products. In other words, recyclers need to be adaptive to the characteristics that the e-products have obtained upstream.

This makes the recyclers' operational costs highly influenced by the design of e-products. The design determines both how easily the products can be dismantled and processed and, consequently, how much of the materials that can be successfully recovered and resold.

In this regard, market prices for secondary materials are also crucial. For example, as long as copper prices are high, many e-products that are difficult and costly to dismantle and recycle will still be worthwhile because the return on investment will be positive. If the market goes down, the recovery costs of the copper will be larger than the income that the recycler can make and thus recycling would not be profitable for that same product. Taking this to the bigger picture, if the e-products would be easier to recycle, more products would be worth the costs of recovery. Adding on to this, if the market price for copper stays high and e-products are easier and thus less costly to recycle, the recyclers will get higher margins on the copper they recover and resell.

Because of this, the recyclers have incentives to collaborate with producers and promote design for recycling. Through collaboration, recyclers would have the opportunity of directing design towards products that do not need heavy investment in new processing techniques. Having information of product characteristics when the product is developed, would also allow for the recyclers to plan better in advance for ways to recycle it. That enables them to be proactive and invest in accurate research and have recycling capabilities in place when the products are discarded, rather than having continuous surprises to handle (Sjölin, 2013). All this would help them increasing their margins since fixed costs could be reduced.

However, the incentives for the individual recycling company to promote design for recycling are weakened because of the diffusion of returns on such a collaboration. This may be the reason explaining why Ordoñez and Rahe (2013) have found almost no interaction between recyclers and designers. If a recycler collaborates with a producer in developing design for recycling, the benefits of this design will profit all the recyclers where this particular device ultimately ends up. Thus, the recycler either has to find a way of making sure that this particular design is only channelled towards his/her company (which in itself probably would incur large costs). Or, the cost savings of the design would have to be immensely larger than the cost of developing the design, in order for it to be profitable for the individual recycler.

Producers do not profit from design for recycling

Producers have something that the other actors do not: the direct power over the design decision. These decisions are based on a variety of considerations, ranging from production efficiency to available technology and characteristics valued by the customers. Assuming that the producers want to maximize their profit, they will want to minimize the cost of the EPR, given that net profits are not affected negatively (for example if a certain design increasing recyclability would increase other costs even more).

As we know, in the current setting, companies do not pay the recycling cost of their own products, but collectively share the total cost of handling e-waste based on their current market share. This means that the cost savings at the recycling stage of a particular design for recycling will be reaped by all actors, not only the firm who introduced it. In other words, a company that invests in developing design for recycling, will bear the whole cost of developing it, but only get part of its return.

In order for investments in design for recycling to have a positive value for a given company, the return on investment needs not only to be larger than the cost—as in the general case of an investment—but larger with at least *a factor of the inverse of the company's market share*. To illustrate this, for a company that has the market share of a tenth, the return on the investment has to be larger than ten times the cost, for it to be profitable for the individual company. We say *larger than* ten times not only because the company will want a yield of return larger than zero, but also because it is likely the recyclers will gain a part of the benefits. For instance when costs of dismantling go down, the distribution of the yield between the producers and retailers on the one hand, and the recyclers on the other, will highly depend on the degree and nature of competition in the recycling business. If there is price competition among the recyclers, most of the return will go to the producers and retailers since the recyclers will try to squeeze their margins in order to win business. If there instead is little competition or competition in form of other parameters (such as brand loyalty or quality) the recyclers will be able to take a larger part.

Having mapped out the financial incentives for each actor we see that none of them are faced with powerful incentives to promote or execute design for recycling. Let us now look into the implications of this.

Implications of the currently weak incentives

Now we want to see whether the incentives enhance social welfare or not. We begin by defining what a social optimum is and *what* social optimum we are referring to in this case. This analysis then leads on to a discussion about externalities and their effects on social welfare.

Discussing the social optimum

It is familiar to any economist that what is beneficial for an individual actor in an economy is not always the same as what is most favourable for the society as a whole. For example, a producer will decide on output in order to maximize its profit even though this might cause costs to society in the form of pollution, over fishing or other problems.

This paper uses the approach of environmental economics, and therefore we define something to be socially optimal the same way it is usually done within mainstream economics. A social optimum is when the societal marginal benefit equals the societal marginal cost. The referral to society means that we do not only include the individual company, but sum up all actors' marginal benefit and marginal cost to an aggregate level. More specifically, the marginal benefit includes all aspects that affect society positively whereas the marginal cost represents the full social cost, including both direct cost and indirect costs, such as environmental issues. When the marginal cost is greater than the benefit, an act—whatever it is—is not worth pursuing. On the other hand, when the marginal benefit exceeds the cost, there is room for improvement that leaves everyone better off, at least potentially (Kolstad 2000). The reason that a social optimum is of interest is because this is where society reaches an efficient allocation and use of resources, thereby enhancing aggregate social welfare.

In theory, a social optimum is always worth pursuing. In practice however, there are countless deviations from social optimums and it does not make sense to dedicate significant resources to correct the ones that in fact do not entail a big loss to society. For it to be interesting, there should be significant gains in addressing the deviation.

The specific social optimum of interest here is the social optimum of design for recycling, that is when all investments in design for recycling having a marginal benefit greater than its marginal cost are undertaken (while investments with marginal benefits less than its marginal cost are not). As a simple example, assume that a certain change in design makes dismantling easier and enables more precious metals to be successfully withdrawn at the product's end-of-life. Add, that this change of design is worth 100 € for the recyclers. Let us assume that there is a cost of this change for the producer, which can be in the form of development costs or as a "loss" in other features. As long as this cost is less than 100 €, the change of design is socially beneficial.

As this "loss" suggests, a social optimum is always a matter of trade-offs. A producer of e-products does not have unlimited resources and there are many different aspects to take into account when designing the products. Some of them are determined by what the buyer uses as evaluation criteria, others stem from what makes production efficient. It is worth underlining that a social optimum of design for recycling is not a scenario where recyclability crowds out other criteria. There is much social benefit also in features such as functionality and user friendliness and this has to be weighed against the social benefit of recyclability.

In summary, a social optimum of design for recycling is reached when all the investments with an aggregate positive net benefit (like in the example above) are exhausted and the investments with aggregate negative net benefits (for example because development costs are too high) are left unexploited.

The hindrance of technological externalities

When looking into the incentives facing the respective actors under the EPR, it is clear that this system diffuses the return on investment of a design for recycling away from the investing company. On a general account, the Swedish EPR system results in the design decisions of one producer influencing the costs both of other producers, retailers and recyclers, which in turn have large implications for the profitability or non-profitability of investments. In economic terms, this is a clear example of a market failure termed technological externality (Nicolli, Johnstone & Söderholm 2012). An externality is defined as:

> *[...] when one agent's production function enters the production function or utility function of another agent, without there being any permission or compensation.*
>
> (Kolstad 2000, p. 91).

In this case, the design decisions of the producers of the e-products enter the cost functions of the other companies, without there being any permission or compensation among the actors. Nicolli, Johnstone and Söderholm (2012) calls this phenomenon a "missing market" for product characteristics since it is currently not possible for a producer to trade the characteristics related to recyclability.

One of the consequences of this is that today much innovation is happening among the recyclers to find new ways to take care of e-waste. This is of course the rational course of action for a given recycling company that wants to get business and make profit.[5] It is also desirable for society that there is innovation effort spent on finding new ways to enhance recycling capabilities. But there is no efficiency in this activity if instead less costly changes can be made already at the design phase, in fact reducing the innovation effort needed to take care of today's products. From society's point of view, today's practical setting risks becoming an exercise of chasing ones own tail (Nicolli, Johnstone & Söderholm 2012). To illustrate this, let us imagine that a producer of

5 Even if we do not take into account the environmental regulations and costs of putting products on a landfill.

vacuum insulated refrigerators would need to recycle the very same products after the consumers' disposal. If there in no current machinery of processing that can handle vacuum insulation without exploding to pieces, would the producer keep the current design under these circumstances? The important aspect is that *if* the producer decided to keep it, that would be because they in parallel found a way to recycle them and when crunching the numbers, found that the product is *still* profitable to introduce to the market. On the contrary, if the recycling stage becomes too expensive, the product would never be introduced. Going back to the real world, however, the product would be introduced irrespective of this, because the calculation is never made.

What we can make out of this is fairly straightforward: in the current setting, efficiency is lost because the design of e-products made upstream cause technological problems and unnecessary costs downstream. To address this technological externality and internalise it in the process of design decisions would thus result in a higher level of aggregate welfare.

The environmental externalities connected

Externalities are often discussed on the subject of the environment. Many readers may indeed be surprised by the fact that we so far have not yet mentioned the term environmental externalities.

As was stated earlier in the text, in order to reach a social optimum, every item should have a price reflecting its full social cost (Calcott, Walls 2000). This full social cost contains various different costs, many of them in the form of environmental externalities. These are everything from the environmental damage of extracting, transporting and processing the materials, of transporting and collecting the products and of dismantling and processing at the waste management stage.

We will not try to quantify nor describe in detail the full social cost here. Instead, we want to point out that there are apparent environmental external benefits connected to investments in design for recycling. The authors Nicolli, Johnstone and Söderholm (2012) note that "the [technological] externality should be addressed, irrespective of environmental concerns". We argue that while internalising the technological externality can be justified based only on efficiency concerns, there are *also* environmental reasons for doing this. By addressing (only) the technological externality, one in fact addresses part of the environmental costs as well. This mainly has two reasons.

First, there are several environmental costs that occur during the recycling stage itself, described by the first, second and third tertiary emissions presented earlier. The problems concerning these kinds of phenomena are primarily a problem in case of inappropriate waste management, especially during so-called “backyard recycling”, which is common in many developing countries (Lundstedt 2011). Because of low wages and weak institutions there is a worldwide problem of illegal waste shipping to developing countries today and the Swedish market is also part of this (Lundstedt 2011). Nevertheless, even when e-waste is recycled within our borders, negative environmental effects cannot be avoided because they also occur in the high-tech waste management facilities (Lundstedt 2011). Addressing the technological externality and making e-products more easily recycled, would thus also have the result of targeting environmental externalities. Easier dismantling would ensure that not as many materials are incinerated together but instead successfully recovered and sold, enabling their reuse and an extended life cycle. Neither would, as many reagents be needed when trying to extract the different materials, limiting their environmental damage.

Second, and even more salient, are the environmental costs during extraction and initial refinement that will be saved upon by targeting the technological externality. More efficient recycling will bring about better access to secondary materials and create more material loops. It is not unreasonable to believe that this particular social benefit in addressing the technological externality is quite considerable.

Summarizing the gains distribution

As we have explained, the practical applications of the EPR result in several efficiency losses due to externalities.

The graph below clearly demonstrates two interesting features resulting from the practical application of EPR in Sweden. On the one hand, there is the diffusion of the return on investment in design for recycling as a consequence of the collective fulfilment of the EPR legislation. The private producer’s gain on a given design is a function of that producer’s market share. Given that a producer does not have a monopoly on the market, it means that the return on investment in design for recycling is diffused among other actors in the same market. The important consequence of this is that investments that in themselves have a positive return, do not always have this for a given company. It also means that the category for which these investments will

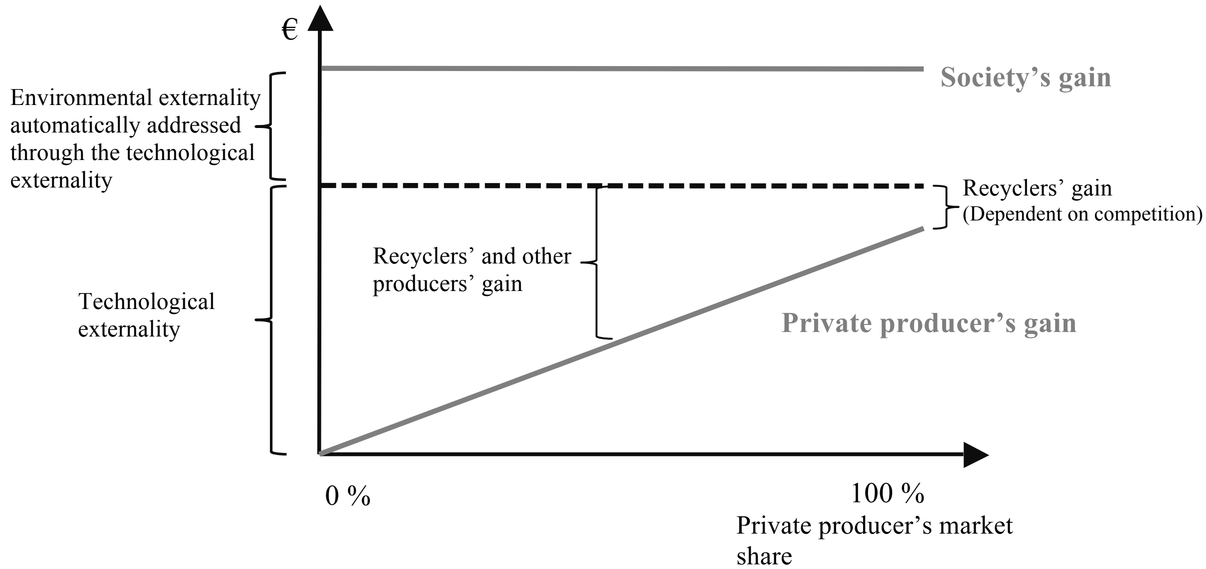

Figure 4. *The gain of investing in design for the private producer compared to society. It is clear that the individual firm's benefits are not equal to those of society. Source: authors.*

practically never be worthwhile is the companies that have the smallest market share. Considering that small companies are generally thought to be more agile and innovative, this might be a huge loss for society.

We also see that society's gain of a particular investment in design for recycling will *always* be higher than any private gain. This is because the environmental benefits that an investment entails cannot be assigned to a specific company, but profits society on an aggregate level.

Rethinking EPR – modify or replace?

In order to work towards a social optimum of design for recycling, classical economics dictates that there needs to be a closing of the gap between the private producer's and society's gain. If they are aligned, the business acumen of companies, while profiting individual businesses, will profit society at the same time, enhancing social welfare.

This sounds very straightforward, but has showed to be more difficult and more accompanied with trade-offs than first appears.

One way of inducing the right incentives would be for every producer to not only be legally responsible for its own products, but also have to do so individually *in practice*. If every producer were to collect its own discarded e-products, for example in its own stores, transport these to recyclers and pay the price of recycling its very own items, then much stronger incentives appear to design in order to lower the costs of recycling. This is because the return on investment will be gained directly by the investment company. A current example is drawn from Japan. There, one category of producers have gone so far as to vertically integrate the act of recycling by setting up their own recycling plants in order to increase the rate of recycling and reuse (Tojo 2004).

This very version of EPR is in the literature called "Individual Producer Responsibility" (IPR). It was discussed during the development of the WEEE directive and, not surprisingly, companies good at design for recycling were among the promoters for IPR (Glachant 2004). In recent years, there have been discussions comparing the IPR and the collective producer responsibility (CPR), under which label Sweden's system could be placed. There is agreement that CPR generally creates weaker incentives for design for recycling than IPR and that the diffusion of returns of design investments enables manufacturers to free ride on others' design choices (Tojo 2004, Atasu, Subramanian 2012), clearly demonstrated in our paper as well.

The problem is that while IPR would produce stronger incentives for design for recycling, it comes with high costs. For instance, the benefits of economy of scale in collection, administration and transportation when grouping the efforts, are removed. Concerns have been raised that an IPR system would duplicate the end-of-life infrastructure and increase transportations (Tojo 2004), something that counteracts social efficiency. Problems of who is to be responsible for the so-called orphan products (old products and products belonging to bankrupt companies) also surface (Tojo 2004). While companies are obliged under the current Swedish legislation to always secure financial means for their fulfilment of EPR if they go out of business, it is quite unlikely that a company would also practically arrange a satisfactory collection system ten to fifteen years after closedown.

A more interesting solution is to have a collective system of collection and transportation where producers can profit from economies of scale, but introduce a marking of products so that the companies bear their own recycling costs. There have in fact been examples of similar systems. Atasu and Subramanian (2012) call these the label of "brand identification" or "brand counting". For example, before the WEEE directive was implemented, Dutch producers of information and technology communication products organized their producer responsibility with individual financing, enabling to charge each producer for its own transportation and recycling costs (Glachant 2004). Generally, though, there has been a practical barrier of how to cost-efficiently sort out and identify the different companies' products in the mixed waste streams. But a recent article shows that this could be done using Radio Frequency Identification (RDI) (O'Connell et al. 2013). By identifying the producer at the recycling stage this way, the recycling costs charged to the individual producer could be based on its products recyclability instead of the firm's market share. Thus, the costs or benefits of design choices would actually be channelled back to the investing company through increased or decreased recycling costs. In other words, the return on investment in design for recycling will benefit the investing firm directly. And most importantly, since the system provides a net profit to the companies, many investments in design for recycling that are profitable for society and foregone today would be undertaken.

This system would also have the problem of orphan products, but now it would not be physical, only financial. A possible solution to this is for all the actors to share the costs of these orphan products. The year that the marking system is put in place, this category would make up a hundred per cent of the recycled items. If the cost is shared based on market share, this means that the financial implication the first year would be one of no change. But after this, the proportion would decrease steadily (if perhaps never entirely reach zero) and each and every company's recycling costs would gradually converge to the cost of recycling their own products.

It is noteworthy to point out that even though such a marking system would internalise the full social costs associated with collection, recycling and disposal, it still has its limitations. It would still not encourage *all* the investments in design for recycling that are socially profitable. The reason for this is that there are two different categories of investments that have a positive social net value. The first category is products that have benefits at the recycling stage that are significant enough to make an investment profitable for the producers. Such an example was given earlier, where a certain design may give cost savings worth 100 € at the recycling stage, and has a cost (of development or "loss" in other features) that is worth less than 100 €. Such an investment will have financial incentives under a marking system. The other category is the one where investments are profitable for society as a whole, but not for the individual company. Think of a design that is worth 80 € at the recycling stage, has the cost of 90 € for the producer, but entails further benefits to society of 40 € due to the indirect addressing of environmental externalities. This category of investments will still not be undertaken even if marking would be introduced.

A marking system would of course incur costs, both at its phase of implementation and while up and running. These costs therefore have to be related to the benefit it would provide society in terms of enhanced design for recycling. Without any quantification at our disposal on either aspect, we cannot say whether social welfare is in fact better off with today's system or with introducing a marking system. Potentially, the current EPR system, despite its shown shortcomings, could constitute a second-best optimum given the complications of orphan products and the costs of the marking system itself.[6] It is fully plausible that this is indeed the case of many product categories under the EPR policy such as paper packaging, plastic bottles and so on. The lesser complexity and embodied value in these product categories may mean that the possible benefits of a marking system might not be that significant and thus not outweigh the costs that come with it. But given the significant value embodied in e-products and that a marking system both would both internalise the technological externality and decrease external environmental costs, it does seem like it could have a net benefit for society, potentially quite a significant one. Although marking would not ensure that all investments profitable for society would be undertaken, it would still encourage it far more than the current system. Perhaps society would benefit from treating e-products differently than other product categories under EPR, implementing a marking system for this specific category? Since we do not have the qualifications needed to answer this question with certainty, we will here settle with the question itself.

If a modification of the current EPR system—or indeed a whole new policy—would increase social welfare, there is another apparent hindrance: that of scale. A change taken place only in the Swedish market will probably have very little effect on the parameters of design. Only small producers who rely mainly on the Swedish market would have any incentives to make changes in design, and many producers of e-products are large international companies. It might further complicate that companies who make e-products could have their designers in the North America, production in Asia and supply several markets throughout the world. A policy change would be needed at least on the level of EU, and preferably worldwide, to have the desired effects and the inertia in such a project is of course significant.

One may, however, question whether the only—or even most efficient—way of encouraging design for recycling is through policy changes at all. Promoting a new way of looking at business models may perhaps have an even more powerful effect? If there is economy for society as a whole to encourage a more circular economy where materials continues to loop instead of being dumped,

[6] ”Second-best” referring to when not all optimum conditions can be realized, and alternations are necessary in other optimum conditions to maximize social welfare given the restricted situation (Lipsey, Lancaster 1956).

there might also be profit in this for the individual company. Some companies have started to realize the benefits entailed. Vodafone, for example, has launched a new business model where customers lease phones and every year or so swap this for what is new and hot on the market (Vodafone Limited 2013). The deal is that the consumer never owns the phone, so instead of discarding it after a year the consumer hands it back to the company. This allows Vodafone to either directly reuse components or to sell the products to a recycler—which would not even need a marking system—and in the end profit from the value embodied in it. Companies discovering the profitability in such business systems would perhaps be a more efficient way for society to benefit from the value in discarded e-products.

Concluding remarks

This paper has explained that one of the hindrances in the way of promoting design for recycling in Sweden is in fact the practical arrangement of EPR itself. It should of course be remembered that the framework still has other achievements and therefore has great value. Notably, it counteracts the negative environmental externalities of dumping waste in nature and ensures a collection system and the financial means to run it. But due to the technological externalities that the Swedish EPR system gives rise to, many investments in design for recycling having a net profit are not undertaken, with the consequence that social welfare is far from maximized.

It should be pointed out that the problem of technological externalities is likely apparent with all product categories under the EPR where the costs are shared based on other parameters than the individual recycling costs. But what is particularly interesting in the case of e-products is that the losses to society are probably higher and thus more important to address, since it is a product category containing many valuable components. Additionally, many other product categories covered by the EPR are made of renewable materials, such as paper packaging, whereas e-products rely on several finite resources such as copper and steel. Even though it is quite possible that EPR provides a second-best optimum for other product categories, it is nonetheless also quite plausible that for e-products, it does not.

In the future, we hope for continued research and discussions on the organization and practical conditions of EPR. Since our paper join to the history of literature finding that EPR creates weak incentives upstream, it would be intriguing to see attempts to quantify, or at least theoretically model, the losses for society, to get an idea of the scale of the problem, even if it is challenging.

Research continuing to investigate the challenge of how to best equal private producer's and society's benefit on investments in design for recycling would also be rewarding. If a marking system could be put in place, allowing the yield of such investments to be channelled back to the investing company, other difficulties may still arise. For instance, the difficulty of how to estimate revenues and costs that depend on future processing techniques and occur only first when the product is discarded—which could either happen a year or more than a decade from now—may still stand in the way for investments in design for recycling.

Finally, as stated, policy might not even be the only or best way forward, but perhaps circular business models and ways of encouraging these is a better solution. Interdisciplinary work bringing together management, business strategy, economics and ecology has the potential both to complicate the picture further but also to provide a more holistic perspective. Something that has a better chance of inventing more effective and carefully thought out public interventions and business development, enhancing social welfare.

References

Books, articles and reports (including electronic sources)

Atasu, A. & Subramanian, R. 2012, "Extended producer responsibility for e-waste: Individual or collective producer responsibility?", *Production and Operations Management,* vol. 21, no. 6, pp. 1042-1059.

Boothroyd, G. & Alting, L. 1992, "Design for Assembly and Disassembly", *CIRP Annals - Manufacturing Technology,* vol. 41, no. 2, pp. 625-636.

Braungart, M. & McDonough, W. 2002, *Cradle to cradle: Remaking the way we make things,* First edn, North Point Press, New York.

Calcott, P. & Walls, M. 2005, "Waste, recycling, and "Design for Environment": Roles for markets and policy instruments", *Resource and Energy Economics,* vol. 27, no. 4, pp. 287-305.

Calcott, P. & Walls, M. 2000, "The economics of waste: Can downstream waste disposal policies encourage upstream "design for environment"?", *American Economic Review,* vol. 90, no. 2, pp. 233-237.

Driedger, R.J. 2001, "From Cradle to Grave: Extended Producer Responsibility for Household Hazardous Wastes in British Columbia", *Journal of Industrial Ecology,* vol. 5, no. 2, pp. 89-102.

El Haggar, S. 2007, *Sustainable Industrial Design and Waste Management,* Academic Press, Kidlington.

Fiksel, J. (ed) 1996, *Design for environment: Creating eco-efficient products and processes*, McGraw-Hill, New York.

Fullerton, D. & Kinnaman, T.C. 1995, "Garbage, recycling, and illicit burning or dumping", *Journal of Environmental Economics and Management,* vol. 29, no. 1, pp. 78-91.

Fullerton, D. & Wu, W. 1998, "Policies for green design", *Journal of Environmental Economics and Management,* vol. 36, no. 2, pp. 131-148.

Glachant, M. 2004, "Changing Product Characteristics to Reduce Waste Generation" in *Addressing the Economics of Waste* OECD, Paris, pp. 181-203.

Gui, L., Atasu, A., Ergun, Ö. & Toktay, L.B. 2013, "Implementing Extended Producer Responsibility Legislation", *Journal of Industrial Ecology,* vol. 17, no. 2, pp. 262-276.

Hage, O. 2007, "The Swedish producer responsibility for paper packaging: An effective waste management policy?", *Resources, Conservation and Recycling,* vol. 51, no. 2, pp. 314-344.

Jonsson, C., Agren, S., Stenmarck, A., Dunso, O., Edborg, P., Frane, A., Jensen, C., Johansson, M., Sundqvist, J. & Nystrom, A. 2012, *Avfall i Sverige 2010,* The Swedish Environmental Protection Agency, Bromma.

Kolstad, C.D. 2000, *Environmental economics,* First edn, Oxford University Press, Oxford.

Kriwet, A., Seliger, G. & Zussman, E. 1994, "Integration of Recycling Considerations into Product Design — A System Approach" in *Information and Collaboration Models of Integration* , ed. S.Y. Nof, Kulwer Academic Publishers, Dordrecht, pp. 27-42.

Lifset, R. & Lindhqvist, T. 2008, "Producer Responsibility at a Turning Point?", *Journal of Industrial Ecology,* vol. 12, no. 2, pp. 144-147.

Lindhqvist, T. 2000, *Extended Producer Responsibility in Cleaner Production*, The International Institute for Industrial Environmental Economics, Lund University.

Lindhqvist, T. & Lifset, R. 1997, "What's in a Name: Producer or Product Responsibility?", *Journal of Industrial Ecology,* vol. 1, no. 2, pp. 6-7.

Lipsey, R.G. & Lancaster, K. 1956, "The general theory of second best", *Review of Economic Studies,* vol. 24, no. 1, pp. 11-32.

Lundstedt, S. 2011, *Recycling and disposal of electronic waste - Health hazards and environmental impacts*, The Swedish Environmental Protection Agency, Bromma.

Manomaivibool, P. & Vassanadumrongdee, S. 2011, "Extended Producer Responsibility in Thailand", *Journal of Industrial Ecology,* vol. 15, no. 2, pp. 185-205.

Mayers, C.K., France, C.M. & Cowell, S.J. 2005, "Extended Producer Responsibility for Waste Electronics: An Example of Printer Recycling in the United Kingdom", *Journal of Industrial Ecology,* vol. 9, no. 3, pp. 169-189.

Nicolli, F., Johnstone, N. & Söderholm, P. 2012, "Resolving failures in recycling markets: The role of technological innovation", *Environmental Economics and Policy Studies,* vol. 14, no. 3, pp. 261-288.

O'Connell, M., Hickey, S., Besiou, M., Fitzpatrick, C. & Van Wassenhove, L.N. 2013, "Feasibility of Using Radio Frequency Identification to Facilitate Individual Producer Responsibility for

Waste Electrical and Electronic Equipment", *Journal of Industrial Ecology,* vol. 17, no. 2, pp. 213-223.

Ordoñez, I. & Rahe, U. 2013, "Collaboration between design and waste management: Can it help close the material loop?", *Resources, Conservation and Recycling,* vol. 72, pp. 108-117.

Schluep, M., Hagelueken, C., Kuehr, R., Magalini, F., Maurer, C., Meskers, C., Mueller, E. & Wang, F. 2009, *Recycling - From e-waste to resources,* United Nations Environment Programme, Berlin.

The Swedish Environmental Protection Agency 2012, *From waste management to resource efficiency: Sweden's Waste Plan 2012–2017,* The Swedish Environmental Protection Agency, Bromma.

Tojo, N. 2004, *Extended Producer Responsibility as a Driver for Design Change - Utopia or Reality?*, The International Institute for Industrial Environmental Economics, Lund University.

Vodafone Limited 2013, 5/15/2013-last update*, Vodafone Red Hot - Phone Leasing* [Homepage of Vodafone Limited], [Online]. Available: http://www.vodafone.co.uk/shop/pay-monthly/vodafone-red-hot/index.htm?cid=rdr-9094-01 [2013, 5/15].

Walls, M. 2003, *The Role of Economics in Extended Producer Responsibility: Making Policy Choices and Setting Policy Goal*s, Discussion Paper 03-11 edn, Resources for the Future, Washington, D.C.

Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M. & Böni, H. 2005, "Global perspectives on e-waste", *Environmental Impact Assessment Review,* vol. 25, no. 5, pp. 436-458.

Legislation

Directive 2002/96/EC of 13 February 2003 on waste electrical and electronic equipment [2003], OJ L37/24

SFS 2005:209. Förordning om producentansvar för elektriska och elektroniska produkter. Stockholm: Svensk författningssamling; 2005

Personal Communication

Öhrlund, Isak. 2013. *The organization of EPR in Sweden.* Interviewed by Karin Bratt and My Hedlin. [Personal meeting] Stockholm 3/8/2013.

Sjölin, Sverker. 2013. *Stena Metall AB.* Interviewed by Karin Bratt. [Telephone communication] Stockholm 5/8/2013.