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Richter, Jessika Luth; Koppejan, Rob

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PO Box 117  
221 00 Lund  
+46 46-222 00 00

## Extended Producer Responsibility for Lamps in Nordic Countries: best practices and challenges in closing material loops

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Jessika Luth Richter<sup>a</sup>; Rob Koppejan<sup>b</sup>

<sup>a</sup> International Institute for Industrial Environmental Economics, Lund University, Tegnérsplassen 4, Lund, Sweden. [jessika.luth.richter@iiee.lu.se](mailto:jessika.luth.richter@iiee.lu.se)

<sup>b</sup> RKI Sustainable Solutions, Planketent 3 4471 SC Wolphaartsdijk, Netherlands. [rkoppejan@outlook.com](mailto:rkoppejan@outlook.com)

### *Corresponding author*

Jessika Luth Richter, International Institute for Industrial Environmental Economics, Lund University, Tegnérsplassen 4, Lund, Sweden. [jessika.luth.richter@iiee.lu.se](mailto:jessika.luth.richter@iiee.lu.se); +46 46 222 02 82

### Abstract

Extended producer responsibility (EPR) schemes are adopted not only to promote collection and recycling of waste products but also to close material loops and incentivise ecodesign. These outcomes are also part of creating a more circular economy. Evaluations of best practices can inform how to further optimise systems towards more ambitious collection, recycling and recovery of both hazardous and critical materials. Gas discharge lamps in particular are a key product category in this regard, considering both the presence of mercury and of rare earth materials in this waste stream. Nordic countries in particular are known for advanced collection and recycling systems and this article compares the EPR systems for gas discharge lamps. The EPR systems for lamps are evaluated using theory-based evaluation approaches to analyse both the performance of lamp EPR systems and challenges perceived by key stakeholders. The cases were constructed based on primary and secondary literature, statistical data, and interviews with stakeholders. The findings indicate that the collection and recycling performance is generally still high for gas discharge lamps in the Nordic countries, despite some differences in approach and structure of the EPR systems, but there remain opportunities for further improvement. In terms of EPR goals, there is evidence of improved waste management of these products as a result of the systems; however, there also remain significant challenges, particularly in terms of ecodesign incentives. The key factors for best practice are discussed, including aspects of the rule base, infrastructure, and operations. The particular characteristics of this waste category, including the rapidly changing technology, also pose challenges for EPR systems in the future.

**Keywords.** Extended producer responsibility, WEEE, gas discharge lamps, fluorescent lamps, collection, recycling, Nordic, circular economy

## 1. Introduction

Energy efficient lighting is an important part of addressing climate change and transitioning towards a green economy with electricity for lighting accounting for approximately 15% of global power consumption and 5% of worldwide greenhouse gas (GHG) emissions (UNEP, 2012). Energy efficient gas discharge lamps (also known as fluorescent or mercury lamps), and now increasingly LEDs, have been gradually replacing traditional incandescent lamps for the last few decades and this trend has accelerated recently due to the tightening of energy efficiency regulations in most regions of the world (see e.g. UNEP, 2014). In Europe for example, EU Commission Regulation EC No 244/, 2009 and EU Commission Regulation EC No 245/, 2009 introduced stricter energy efficiency requirements for lighting products and a similar approach has been adopted through energy efficiency regulations in the U.S. (UNEP, 2014). Lighting represents a key area for achieving the European Union (EU) goal to increase energy efficiency by 20% by 2020 and replacement of inefficient lighting by 2020 is expected to enable energy savings to power 11 million households a year (EU Commission, 2013). The 2009 regulations initiated a phase-out of incandescent lamps (EU Commission, 2014a) and resulted in an increase in gas discharge lamps in the EU general lighting market (accounting for an estimated 43% of units sold in 2011 and 2012 (McKinsey & Company, 2012)). A further increase of both gas discharge lamps and LEDs is expected with the phase out of halogen lamps (originally scheduled for 2016, but now delayed to 2018).

However, in transitioning to energy efficient lighting, an integrated policy approach must also consider end-of-life management of energy efficient lamps (UNEP, 2012). The WEEE Directive (EU 2002/96/EC and recently recast 2012/19/EU) has implemented extended producer responsibility (EPR) for such waste in EU member states and banned landfilling of WEEE covered by the legislation. Gas discharge lamps are covered under category 5 of the WEEE Directive. As a product group, they have special characteristics that make them particularly challenging for collection and recycling. They contain mercury that can be detrimental when released into the environment in large enough quantities (Wagner, 2011) or result in high mercury emissions when incinerated without adequate filter technology (Silveira & Chang, 2011). The fragility of lamps makes safe collection and transportation more complex to ensure the health of handlers (Kasser & Savi, 2013; Sander, Schilling, Wagner, & Günther, 2013). Avoiding this environmental harm from waste gas discharge lamps is a compelling reason for “collecting as much as possible and in a safe way (avoidance of breaking) and to treat them properly” (Huisman et al., 2008, p. 281). However, collection and recycling of gas discharge lamps represents relatively high cost compared to the value of the product (Philips Lighting, 2012) and the low or negative value of the recovered material from lamp waste (G. Lundholm, personal communication, 13 August 2014). While clearly it is of societal value to avoid

mercury contamination, this is a positive externality and moreover, it is a benefit difficult to quantify in economic terms<sup>1</sup>. As such, legislation, targets and other drivers are integral to incentivising end-of-life management (Huisman et al., 2008; (G. Lundholm, personal communication, 13 August 2014)). The high cost for lamps is tied to necessary recovery of hazardous materials increasing recycling costs, but also to challenges in collecting lamps. Lamps are lightweight, which means they are a small part of total WEEE and that filling trucks for optimal transportation can be an issue. Lamps are also dispersed in high quantities, geographically and between consumers and businesses. This necessitates the need for an extensive capillary network for collection.

The collection and recycling of gas discharge lamps can also create opportunities to recycle valuable materials. Waste gas discharge lamps contain rare earth elements (REE) in the phosphor layer, which is necessary for producing white light. Nearly all global supply of europium, 85.2% of terbium and 76.7% of yttrium is used for phosphors, and the majority of these are used for lighting applications (Moss et al., 2013; Tan, Li, & Zeng, 2014). Despite only using 7% of global REE by volume, due to the high level of purity needed for lighting applications, phosphors represent 32% of the value for rare earth applications (Binnemans et al., 2013; Schüler, Buchert, Liu, Dittrich, & Merz, 2011; U.S. Department of Energy, 2011). The EU Commission's report on Critical Raw Materials for the European Union (EU Commission, 2014b), considers the REE group as having the highest supply risk and REE have received increasing attention in the last few years with rising prices and concern about supply restrictions from China, where over 90% of production takes place (Binnemans et al., 2013; Bloomberg News, 2015). The presence of REE in only small amounts in waste products represents a challenge for recycling, but increased recycling has the potential to address supply risks (Binnemans et al., 2013; Rademaker, Kleijn, & Yang, 2013; Sprecher, Kleijn, & Kramer, 2014). However, currently less than 1% of REE is recycled and examples of closing this material loop are rare (Binnemans et al., 2013) but the experience in recycling REE from gas discharge lamps is promising (Dupont & Binnemans, 2015).

EPR systems for lamps have been in place in the EU under the WEEE Directive, but legislation has been present in some countries, like Norway, Sweden, and Austria, even longer. Academic literature has evaluated various aspects of WEEE systems in the EU, including the challenges for collecting small WEEE (Huisman et al., 2008; Khetriwal, Widmer, Kuehr, & Huisman, 2011; Melissen, 2006) However, there has been not been a comprehensive evaluation of the best practices and challenges for end-of-life management of gas discharge lamps specifically, despite this product stream having been acknowledged to be of particular relevance both for recovery of critical materials and for

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<sup>1</sup> Some studies, for example, Hylander & Goodsite (2006) have tried and estimated a cost of USD 2,500 to 1.1 million per kg Hg isolated from the biosphere depending on local factors quantity, nature of pollution, media, geography, technology used etc.

avoidance of mercury contamination. The literature that has addressed this waste stream has tended to focus on the set up of EPR systems for lamps in the EU in general (Wagner, 2011, 2013; Wagner, Toews, & Bouvier, 2013) or has emphasised recycling over collection aspects (Silveira & Chang, 2011). Very little is known about how EPR systems for lamps compare or differ from the structure and performance of the overall WEEE systems.

### 1.1 Research Aim

The research presented in this paper evaluates EPR systems for lamps in the Nordic countries of Denmark, Finland, Norway and Sweden<sup>2</sup>. The Nordic countries have been recognised for best practices in the area of end-of-life management of WEEE (Román, 2012; Ylä-Mella, et al., 2014a; Ylä-Mella, et al., 2014b) and as such also provide good cases for a deeper analysis of EPR for lamps in particular. Such analysis can provide further insight into how to address the unique challenges for this waste stream and the factors that potentially contribute to better attainment of EPR goals and a more circular economy for this key product category. EPR includes goals to conserve source materials by promoting better waste management, ecodesign, and closing material loops and such goals are also an integral part of a circular economy (EU Commission, 2014c). This article presents analyses of EPR systems for lamps in Nordic countries in relation to EPR goals and discusses the factors that contribute to well-functioning systems as well as challenges still to be addressed in further optimising such systems.

Section 2 describes the methodology used in this policy evaluation and comparative case study methodology. Section 3 presents the findings of the comparative case study and evaluation of the performance of the Nordic EPR systems in relation to the EPR outcomes. Section 4 discusses these findings and presents factors identified as influential to the success of the systems as well as remaining challenges.

## 2. Methodology

The research approach used embedded multiple cases in which multi-level perspectives were explored simultaneously (i.e. gas discharge lamps, country perspectives, key stakeholder groups, etc.) (Yin, 2003). Comparative analysis of multiple cases particularly suits research evaluating multiple holistic systems and allows comparison of factors influencing performance (Druckman, 2005). The framework for the initial comparison of the EPR systems for lamps was based on important elements of such systems identified by Murphy, Gregory, & Kirchain, (2012). Nordic countries are the focus cases in evaluating EPR systems for lamps because they have been described for their best practices

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<sup>2</sup> Iceland has been excluded in this research as its context as well as the implementation and experience thus far with WEEE systems has been quite different than other Nordic countries so far. It is expected to further develop and resemble other Nordic country systems in the future (Baxter et al., 2014).

in performance for WEEE in general, but they have not been examined in regard to gas discharge lamps. High performing systems can be studied to identify the common elements that could be the key to their effectiveness. It can also reveal context-specific or organisational differences that have or have not influenced effectiveness, as well as challenges perceived about the different systems from corresponding stakeholder groups in each system.

Policy evaluation, using multiple methods of inquiry to generate policy-relevant information that can be utilised to resolve policy problems (Dunn, 1981), framed this research. In terms of focus criteria, the WEEE legislation in regard to gas discharge lamps in the Nordic countries is evaluated primarily for its environmental effectiveness, a common criterion evaluating the policy in relation to its goals (Mickwitz, 2003; Vedung, 2008). While there is data related to collection and recycling rates, more comprehensive information about EPR systems for energy efficient waste lamps is still lacking. Moreover, the goals of the WEEE Directive and the legislation transposed in the member states refer to WEEE collection overall, with few product level specifications. A separate target for gas discharge lamps within the Directive is being investigated until August 2015 (Article 7.6). In such cases where the data or explicit goals may be lacking, the use of intervention theories can support the evaluation of the policy (Kautto & Similä, 2005; Manomaivibool, 2008).

The main policy interventions governing the end-of-life management of gas discharge lamps in the Nordic countries are based on the principle of EPR, defined as “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 entire life cycle of the product, and especially to take-back, recycling and final disposal of the product” (Lindhqvist, 2000, p. 154). Moreover, Lindhqvist (2000) argues that EPR entails different types of responsibilities: liability, physical, financial, and provision of information (i.e. informative) responsibilities. Policy mixes can vary in how these responsibilities are realised and distributed amongst actors but there are specific goals and outcomes of EPR that should be common to all EPR programmes. These have been outlined by Tojo (2004) and are shown below in relation to the WEEE Directive 2012/19/EU. While the WEEE Directive is the main focus of this article, it is also acknowledged that the Restriction on Hazardous Substances in EEE (RoHS) Directive is part of the EU’s EPR policy package (van Rossem, Tojo, & Lindhqvist, 2006a). The RoHS Directive’s influence on design for lamps is also discussed in section 3.3. The EU Ecodesign directive also has an indirect effect on EPR policies (OECD, 2014).

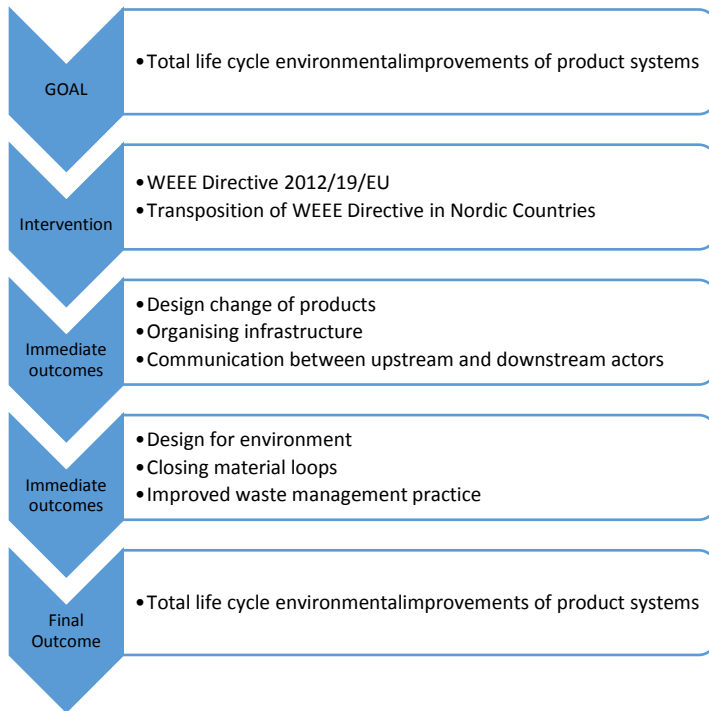


Figure 1. Simplified intervention theory for EPR programmes and specifically the WEEE Directive, based on Tojo (2004).

Theory based (also known as program theory/theory-driven) evaluation includes reconstruction of the intervention (program) theory to model how a policy is supposed to function (Bickman, 1987). Using an intervention theory as a basis for environmental evaluations focusses the evaluation in terms of scale and stakeholders (Mickwitz, 2003). Hansen and Vedung (2010) propose that an intervention theory consists of three elements: a situation theory concerning the context of the intervention; a causal theory concerning the implementation and outputs that lead to certain impacts of the intervention; and a normative theory concerning the envisioned outcomes of the intervention. This study includes these elements with the context, implementation and outcomes of the intervention all examined.

In addition, theory based evaluations are grounded in a stakeholder approach (Hansen & Vedung, 2010), but it is a recognised challenge that there can exist competing program theories (Dahler-Larsen, 2001). When dealing with more complex program evaluations, Hansen and Vedung (2010) suggest a “theory-based stakeholder evaluation” that elaborates upon a “raw” intervention theory with the perspectives of key stakeholders. Identifying key stakeholders stems from the intervention theory and from this the primary stakeholders crucial to its implementation and likely to have in-depth knowledge of the intervention are selected. The intervention theories from the perspective of these key stakeholders can then be reconstructed to identify similarities, differences, and disagreements (Hansen & Vedung, 2010) or the distinction between the “espoused theory” and the

“theory-in-use” (Friedman, 2001). The latter distinction is included in this paper while stakeholder perspectives of success factors and continuing challenges for EPR systems are discussed.

### 2.1 Data collection

Both the evaluation and cases used data collected from publicly available statistics from Eurostat, national authorities, and producer responsibility and municipal waste organisation reports. This data was supplemented and triangulated with peer-reviewed and grey literature as well as semi-structured interviews with key stakeholders and additional email correspondence (based on interview protocols). For each country case, similar stakeholders were interviewed with identical protocols. When possible, interviews were recorded and in person, though they were also conducted by telephone. Extensive notes were taken and when necessary, clarified again with the interviewed stakeholder via email correspondence. Lighting producers themselves were not interviewed as earlier research has examined EPR from the perspective of lamp and lighting sector producers (see Gottberg, et al., 2006). The focus of this study is instead on stakeholders downstream from producers involved in the practical implementation of the EPR systems for lamps. These stakeholders included managers of producer responsibility organisations (PROs) in each country dealing with lamp collection, lamp recyclers responsible for recycling lamps in Nordic countries, and managers of WEEE issues in national waste management associations representing municipalities and municipal waste management companies in each country. In addition, a few specific Nordic retailers and municipal waste management companies with initiatives for lamp collection were also interviewed. A list of organisations and representatives interviewed is included in the appendix as well as sample interview protocols. Where specific information from an interview is presented, the interviewed person is identified, but where there was general consensus amongst a group of interviewed stakeholders, the group is identified.

## 3. Findings and Analysis

It has been demonstrated and generally accepted that end-of-life management of WEEE is environmentally beneficial and benefits can be better realized through increased collection and recycling rates (Hischier, Wäger, & Gauglhofer, 2005; Khetriwal et al., 2011). In the first version of the WEEE directive collection rates differed widely between member states, with ten countries failing to meet the 4kg per capita target in 2010 but most exceeding and the Nordic countries well exceeding the target (EU Commission, 2013). Ylä-Mella et al. (2014a) and Román (2012) describe the performance of WEEE systems in the Nordic countries as exemplary, citing their high collection rates in Nordic countries (ranging from 8 kilograms/capita/year in Finland to over 20 kilograms/capita/year in Norway) despite low population densities and high transport distances, especially in the northern parts of Norway, Sweden, and Finland. Such per capita collection rates rank Nordic countries all in



the top five performing countries in Europe. Aside from system architecture, Ylä-Mella, et al. (2014a) attribute the success of the Nordic WEEE systems in part to high awareness of environmental issues among Nordic citizens and further argue that one of the strengths of the WEEE recovery systems in Nordic countries is the strong civic support of environmental protection and willingness to use the WEEE systems in place.

While this measure of performance has been consistent with historic WEEE Directive targets measuring performance in terms of kilograms per capita, the WEEE recast brings new targets which measure collection rates in comparison to product put on market in the previous three years. In the recast the target is 45% of the sales of products in the three preceding years with an increase to 65% by 2019 (or 85% of generated WEEE). This has implications for Nordic countries where there is a high level of EEE products put on the market, reflecting both the challenging climate conditions and high living standards that make EEE and information technology an important part of everyday life in Nordic societies (Ylä-Mella et al. 2014a). Despite this, according to Eurostat statistics, Denmark, Norway and Sweden remain in the top five performing countries and are already poised to meet the 45% collection target of previous three years EEE put on market, which is in place from 2016-2019. Sweden is already meeting the 65% target that will be in place from 2019. However, Finland, having collected only 36% in 2012 compared to the previous 3 years EEE put on market, still has improvements to make to meet this target. However, it has also been suggested that Finland's lower figures have more to do with collection reporting rather than actual collection being low (see Baxter et al., 2014). Another important change with the recast of the WEEE Directive has been the increased responsibility for retailers and this is examined in further detail in relation to the specific cases.

### 3.1 Comparing Nordic country cases

In our analysis, we compare the systems for gas discharge product group specifically, though of course the overall WEEE design has a large influence on how this waste category is collected. As described earlier, EPR consists of financial, informative, and physical responsibility for waste products and these responsibilities can be allocated differently in different systems. Table 1 below outlines the basic components and context of the WEEE systems for lamps in the Nordic countries.

Table 1 Comparison of EPR for lamp systems in Nordic countries

		Denmark	Finland	Norway	Sweden	
Context	Population 2013 (mil)	5.6	5.4	5.1	9.6	
	Area (km <sup>2</sup> )	43,094	338,424	385,178	449,964	
	WEEE/ lamp legislation beginning	2005 <sup>a</sup>	2004	1998	2001/2000	
System Architecture	Legislated responsibility <i>(italics responsibility in practice)</i>	Lamp scope legislation	Filament bulbs excluded <sup>b</sup>	Filament bulbs excluded <sup>b</sup>	All lamps covered	All lamps covered
		Physical responsibility	Producer/ Municipality <sup>c</sup>	Producer/ Municipality/ Retailer	Producer/ Municipality/ Retailer	Producer/ Municipality/ Retailer
		Informative responsibility	Producer/ Municipality	Municipality	Producer/Recycler/ Municipality/Retailer	Producer/ Municipality
		Financial Responsibility	Producer/ Municipality	Producer Municipality (part)	Producer Municipality (part)	Producer Municipality (part)
		Retailer take-back	Voluntary	1:1; 0:1 (≥ 1000m <sup>2</sup> grocery stores/ 200m <sup>2</sup> EEE)	All selling EEE	1:1; 0:1 (≥ 400m <sup>2</sup> EEE sales space)
	Recycling stations	Yes	Yes	Yes	Yes	
	Kerbside collection	Limited (2 municipalities)	Mobile collection a few times/year	Mobile collection a few times/year	1.5 million households	
	Permanent collection sites 2013	398	526 <sup>d</sup>	~2700	~2600	
	Main PROs dealing with lamps	LWF (lamp specific)	FLIP (lamp specific); Elker Oy	RENAS, Elretur	El Kretsen	
	Collection and recycling	Avg. tonnes Put on Market (POM) 2009-2011	1670	1926	3018	3 203
Collected tonnes 2012		706	850	890	2165	
% recycled of collected 2012		93%	90.1%	92.7%	100%	
2012 collected /avg. 2009-2011 POM		42%	44%	29%	68%	
Kg per Capita collection 2012		0.126	0.157	0.177	0.227	

Sources: Dansk Producent Ansvar, 2015; Elker Oy, 2014; El Kretsen, 2014; Elretur, 2014; Eurostat, 2014; RENAS, 2014; "Danish WEEE legislation", 2014, "Swedish WEEE legislation", 2014, "Norwegian WEEE legislation", 2015, "Finnish WEEE Legislation", 2014; personal communication with the following organisations: Dansk Affaldsforening; Avfall Sverige; Avfall Norge; JLY Finland (see interview information in Appendix A).

<sup>a</sup> Since 1998 the Danish Environmental Protection Act included a section about ecodesign for producers

<sup>b</sup> Inevitably some filament bulbs are collected and recycled with gas discharge and LED lamps

<sup>c</sup> Municipalities have responsibility for collection from households only, while producers are responsible only for collection from municipal collection to recycling (not from households directly)

<sup>d</sup> Does not include retailer collection locations which were implemented in 2013.

### 3.1.1 System Architecture

With the exception of Denmark, each Nordic country has transposed the WEEE Directive with the financial responsibility for collection, transportation, and treatment being the responsibility of producers. In Denmark, municipalities are currently financially responsible for collection of WEEE from households and cover this cost by fees charged to households. Physical responsibility has been extended to retailers in the recast of the legislation in Finland and Sweden and was already part of

the responsibility in Norway prior to the recast. In practice, municipalities in all Nordic countries are responsible for most of the household collection of WEEE, including gas discharge lamps. Municipal waste organisations and municipal stakeholders interviewed in these countries reported that financial compensation for municipal collection of WEEE did not cover the full costs of the services provided by the municipalities. The financial compensation in Sweden is negotiated as a contractual arrangement every few years between municipalities and the main producer responsibility organisation, El Kretsen. In Norway and Finland, contracts are negotiated between individual municipalities and individual PROs. As such, the individual arrangements often reflect the negotiating power of the municipality (i.e. in larger urban areas there are often other waste service providers who can compete with the municipalities and thus these municipalities often receive less compensation for their services than rural municipalities). In Denmark, though municipal waste organisations have requested financial compensation for collecting WEEE, they have so far been unsuccessful in this endeavour and do not foresee any changes in the near future due to a recent agreement between the government and industry regarding ecodesign (N. Remtoft, personal communication, 15 December 2014).

In all Nordic countries, producers are solely responsible for transport and treatment of the waste lamps collected by municipalities and retailers, though the exact details of the financial and physical responsibility for transport of lamps from retailers in Sweden remains to be seen with this aspect remaining vague in the recast legislation. The WEEE Directive specifies a target of 80% of collected gas discharge lamps to be recycled (Annex V) and specifies that treatment should include removal of mercury (Annex VII).

The duty to provide information to consumers about the WEEE system for lamps is distributed differently in the Nordic countries, with different emphasis on the roles of PROs, municipalities, and retailers. PROs interviewed generally felt that adequate information was being provided while municipal organisations were more likely to acknowledge that this was an area that could still be improved. While consumer knowledge about WEEE in general was perceived as high, there were different perceptions about consumer awareness of disposal requirements and environmental impact of waste discharge lamps in particular. In Sweden, lamps were specifically targeted in information campaigns by the main PRO (El Kretsen) and the national waste management association (Avfall Sverige). In Denmark, the provision of this information was seen to be more the responsibility of the lamp PRO, and it did run awareness campaigns every few years. In Norway, the national waste management association (Avfall Norge) began an awareness campaign for small WEEE, including lamps in 2014. In Finland there have not been lamp-specific campaigns, and better information

provision, particularly from retailers with new responsibilities under the recast, was seen as an area for improvement.

The organisation of PROs also differs between the Nordic countries. Lamp-specific PROs, like those found in Denmark and Finland, were initiated by the lamp producers who were aware that they were putting a product that contained a hazardous substance on the market and who wanted to ensure the hazards were managed properly at the end-of-life phase for these products and thus not jeopardise market acceptance of these products. Larger umbrella PROs run the risk of having decisions dominated by other waste streams and not ensuring the interests of lamp producers (J. Bielefeldt, personal communication, 26 August 2014). Examining the boards of larger PROs in Norway, it is the case that there is no representation by lighting producers or organisations on the boards of two largest PROs handling lamps and luminaries (see RENAS 2014; Elretur, 2014).

The competing nature of PROs in Norway has resulted in general issues with collection of WEEE with incidences of PROs refusing to collect from municipalities once they had reached their targets, requiring intervention from authorities. This situation has improved, but the lack of a clearinghouse structure in Norway remains a perceived challenge (E. Halaas, personal communication, 9 December 2014). Lamp-specific PROs and national waste management associations reported more cooperation than competition amongst the several PROs in Finland and Denmark and perceived this as strengths of the systems.

In Sweden, a representative of the lighting industry is present on the board of the largest PRO, El Kretsen, though the lighting association is only one of over twenty owning industry associations (El Kretsen, 2014). Environmental management of waste gas discharge lamps has also been given priority in Sweden the past few years by Swedish Environment Minister Lena Ek, who has pushed for increased collection of this waste stream from 2011 when meeting with El Kretsen and the national waste management association, Avfall Sverige, about improvements to lamp collection (Pehrson & Balksjö, 2011, 2012; von Schultz, 2013). This led to a pledge to increase lamp collection by 2 million pieces in 2013 and an information campaign focussed on lamps from households (Avfall Sverige, 2013). In response to this pressure for increased collection of lamps as well as other small WEEE, El Kretsen also initiated a project to make collection of lamps even more convenient with in-store "Collectors" ("Samlaren" in Swedish). The Collectors are closed cabinets positioned most often next to reverse vending machines for beverage packaging in grocery stores. The pilot program with them in Gothenburg, Sweden, was deemed a success. At 14-20 SEK/kg (1.5 Euro- 2.1 Euro/kg) the Collectors were found to be more expensive than other forms of collection but became more cost effective with time as consumers became more aware of this option and collection increased (El

Kretsen & Sörab, 2011). Collectors are currently being deployed first in major cities and increasingly in municipalities throughout southern Sweden where over 60 Collectors have been placed in grocery stores in 2014 and early 2015. The initiative is being led by municipal waste companies and is partially financed by producer compensation to municipalities for collection of WEEE. (A. Persson, personal communication, 9 September 2014).

### 3.1.2 Collection and Recycling Performance

The general WEEE system architectures in the Nordic countries are described as best examples and perform well in relation to the WEEE Directive goals (Román, 2012; Ylä-Mella et al., 2014a). The general architecture also encourages high performance in the category of gas discharge lamps with the Nordic countries among the top five in Europe in 2012 (figure 2) when measuring collection in terms of kilograms per capita.

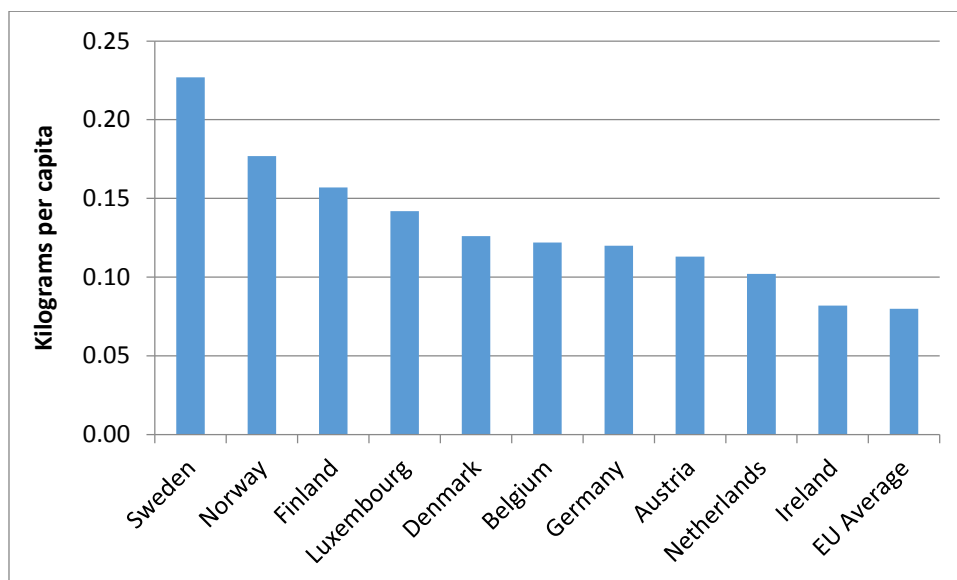
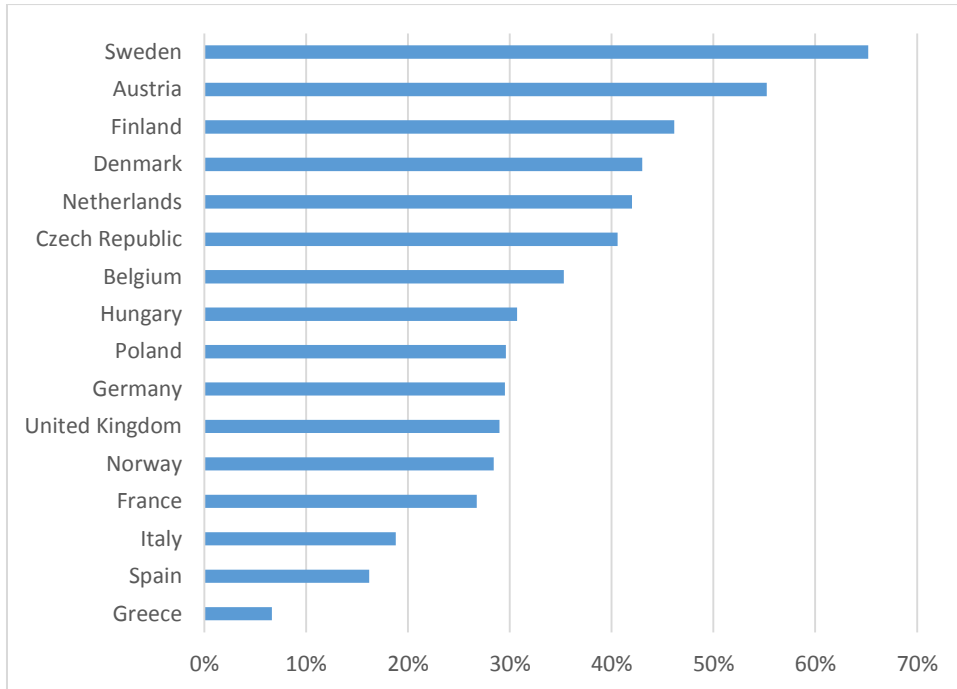


Figure 2. Top 10 performing European countries, kg per capita collection of gas discharge lamps. Source: Eurostat, 2014.

However, when considering the collection rate compared to the amount of gas discharge lamps put on market, a different situation is found. Nordic countries performed better than the overall EU average of 37% in 2012 (see table 1), with the exception of Norway. It should be noted that statistics for this product category are highly variable for countries with small amounts of gas discharge lamps recorded (for example, Eastern European countries). When countries with larger lighting markets are compared (figure 3), Sweden, Denmark and Finland show consistent collection rates that compare well with other countries and again indicate advantages to the WEEE systems in these countries. The same cannot be said for Norway, for which statistics indicate a consistently lower performance than the EU average. In terms of recycling, all four countries have high treatment rates for the collected lamps, exceeding the minimum 80% recycling in the WEEE Directive (see table 1). Additionally, all

Nordic countries comply with the requirement to remove the mercury in recycling process for gas discharge lamps.



*Figure 3. Collection % for countries with market over 1000 tonnes based on 2010-2012 average collection % of gas discharge lamps (GDLs) compared to put on market 2007-2011 based on Eurostat (2014). Note: Netherlands data estimated based on 2012 (tonnes) Eurostat (2014) put on market data and Huisman et al. (2012) estimates of per capita lamps put on market 2010. Collection % from 3 years (2010-2012) were averaged to account for higher variability when looking at this product category. Note that GDL data in practice often contains LEDs and other light sources and can be deemed an estimate only.*

In the absence of specific information about a possible target for the collection of lamps under the WEEE Directive, it is difficult to gauge how Nordic countries will perform if one is introduced after the review in 2015. In relative terms to other countries though, it can be anticipated that Nordic countries are well-positioned to meet such a target, though Norway may need to improve if the target takes into account put on market data for collection rather than weight per capita. However, regardless of any specific targets, increasing the collection and recycling of gas discharge lamps results in environmental benefits that should make continuous improvement of collection and recycling a goal.

### 3.2 EPR Outcomes for Energy Efficient Lamps in Nordic Countries

In general, EPR interventions should produce three intermediate outcomes that lead to the policy goal of total life cycle environmental improvements of product systems (figure 1 and Tojo, 2004): 1) design for environment, 2) closing material loops and 3) improved waste management practice. The performance of the Nordic EPR systems for lamps is considered in light of these outcomes.

### 3.2.1 Design for environment

Interestingly, gas discharge lamps are one of the only EEE product categories whose lifespan has increased in recent years (Bakker, Wang, Huisman, & den Hollander, 2014). Additionally, levels of mercury in gas discharge lamps have also decreased and LED technology now becoming more competitive can eliminate mercury altogether in new energy efficient lamps. These developments have significant implications for the end-of-life impact of energy efficient lighting products. In some cases, such developments are likely also to have been motivated by other EPR-related legislation, for example the Restriction on Hazardous Substances (RoHS) Directive which limits mercury content. In other cases factors beyond EPR are likely also influential, for example, the Ecodesign Directive phasing out less efficient light sources, competitive technology development, company culture, etc.

Earlier research by Gottberg, et al. (2006) explored the impact of EPR legislation in the lighting sector, including several Swedish producers, and found little evidence of ecodesign in response to the financial responsibility of EPR. Despite initial concerns by lighting producers about the costs of EPR legislation being higher than relative to the product price (Philips Lighting, 2012), lighting products are also characterized by inelastic demand that has allowed producers to more easily pass on compliance costs to consumers. The cost of EPR compliance depends at which point this cost is being considered. EPR compliance costs have been found in some cases to be a small percentage in relation to total product costs and in others quite high. Despite the wide range, Gottberg, et al (2006) argued that the cost of EPR was a small economic driver for ecodesign changes in relation to other product requirements. In all Nordic systems, undifferentiated fees (fixed in Sweden, but by market share in the other countries) are faced by all producers and this also gives little financial incentive or comparative advantage for improving products. For example, there is no differentiation among the producer responsibility organisations in the fees charged for LEDs in comparison to gas discharge lamps, despite the presence of mercury only in the latter. One challenge to doing this is the reality that LEDs and gas discharge lamps in Nordic countries are collected, transported, and treated together so they incur the same costs, though it is unclear whether LEDs, if separated, could be recycled in a more cost efficient process. LEDs do not contain mercury, but do contain some hazardous materials such as lead (see Lim, Kang, Ogunseitan, & Schoenung, 2013). Another concern with differentiation expressed by PROs interviewed is that if LEDs were differentiated that treatment for gas discharge lamps would be left underfinanced.

In their research Gottberg, et al. (2006) consider EPR mainly as an economic instrument and only the financial responsibility as a motivation for product design improvements. However, EPR is also about information flows between consumers, recyclers, and producers. Interviewed producer responsibility organisations and recyclers for lamps reported different levels of communication with producers

about the end-of-life attributes of their products. In cases where the recycler or producer organisation had information to provide in this regard, it was reported that the contacts with the producers were generally not in the design department, which was often located in another country. Such anecdotal evidence indicates a possible prerequisite for design change may be missing; namely, communication between upstream and downstream participants may not be taking place in a way that facilitates relevant information from downstream reaching those working with producers who have an influence over design decisions. However, even if this information does reach product designers, its usefulness may be limited due to the (increasingly) long life of lighting products. Indeed, other drivers including market competition and company culture were found to also be able to explain design improvements in the lighting sector and causation to EPR legislation alone could not be established (Gottberg, et al., 2006). This is not surprising given the challenges for design incentives for lamps and these are further discussed in section 4.2.

### 3.2.2 Closing material loops

In theory, almost all the material from gas discharge lamps can be recycled and some components even re-used, for example the glass tubes if using an end-cut method (Nordic Recycling, 2014) or phosphor coating if reused by the same type of lamp and manufacturer (Binnemans et al., 2013). Table 2 illustrates the possible end uses or disposal options for fraction from gas discharge recycling processes; however the actual end use of fractions is highly context specific.

Table 2. Fractions and end uses from waste gas discharge lamps

<b>Fractions</b>	<b>Approximate part (compact fluorescent – fluorescent tube)</b>	<b>End use / disposal</b>
<i>Aluminium / other metals</i>	18-30%	Reused or recycled
<i>Mix of plastic and metal</i>	20%	Recycling; energy recovery; landfill
<i>Glass</i>	45%-80%	Reused for fluorescent tubes; lamp glass; glazing; glass wool insulation; fusion agent with black copper foundry; abrasive sand for cleaning, under layer for asphalt; sand replacement; silicon substitute, landfill cover
<i>Rare earth powder, also containing mercury and small glass particles</i>	2-3%	Separated and reused as mercury or phosphors in new lamps, separated and recycled after rare earth processing; powder and Hg landfilled as hazardous waste

Sources: Nordic Recycling, 2014; WEEE Forum, 2011



In practice, materials from the recycling process in Nordic countries are not used again in the production of new lamps. Currently, most waste lamps in Nordic countries are shredded together in a wet process (as opposed to the end cut method, for example) (Nordic Recycling, 2014). In Finland, collected lamps are recycled at one location in Finland (Ekokem, 2014). PROs in Norway and Sweden (and at the time of writing, also Denmark) send waste lamps to be recycled in one location in central Sweden. While this arrangement helps to increase economies of scale in treatment, the recycler faces challenges in returning glass and other materials long distances to lamp manufacturers and this is part of the reason these materials are not recycled in a closed loop.

It is also difficult to transport the glass fractions long distances to glass recyclers in Sweden and Europe as the cost for the transportation will decrease profit. For this reason, much of the glass is currently used as construction material in landfill cover; though higher level alternative uses are being actively sought (G. Lundholm, personal communication, 26 October 2014). The lamp PRO (LWF) in Denmark had been sending crushed lamps for recycling in Germany where more fractions could be used for new lamps, but the recycler has since closed, forcing it to use the same recycler as PROs in Norway and Sweden (but in a new tender process at the time of writing). In Finland the glass fraction is delivered to a nearby glass recycler who can use it to produce foam glass, as well as glass powder (Uusioaines Oy, 2014).

Other fractions, such as the metal, are easily sold and used by local metal recyclers. The small fraction of plastics is generally incinerated in the Nordic countries. In many EU countries the mercury containing phosphor layer is landfilled or stored in salt mines rather than recycled (Solvay, 2014). Solvay Rhodia in France began the first commercial scale recycling of lamp phosphors, separating rare earth oxides for use in new phosphor powders in 2011 (Walter, 2011). It buys fractions from recyclers based on the amount of rare earth material and deducting for the amount of mercury, glass, and other impurities. The recycling process used for Swedish, Danish, and Norwegian lamps produces a phosphor fraction of high enough quality that it can be sold for this recycling. Though not at a large profit, this further recycling also avoids the cost of hazardous landfill. This is made possible both by the recycling process and the scale of the centralised treatment. By contrast the Finnish recyclers have studied the use of phosphor but it is currently produced in such small quantities, and in a less useful form, that it does not make sense to recycle the phosphors (J. Koskinen, 29 January 2015, personal communication).

### 3.2.3 Improved waste management practice

The collection and recycling of gas discharge lamps represents a significant improvement in waste management practice compared to a situation where there is no legislation or policy for collection

and recycling. Even before EPR legislation, the mercury present in gas discharge lamps did make them a concern in countries like Sweden. Voluntary programs for collection and recycling were set up in Sweden, mainly for business end-users (who were the majority of the users in the early stages of the technology). Between 1993 and 1998 the collection rates for gas discharge lamps in Sweden was roughly estimated between 10-25% and this was perceived as inadequate in light of the risks of mercury emissions associated with the waste products (Kemikalieinspektionen, 1998). OECD countries with some waste legislation or voluntary programs, but lacking mandatory EPR legislation, also have very low collection and recycling rates of lamps. For example, it is estimated that 95% of fluorescent lamps in Australia are landfilled (Lighting Council Australia, 2014), while Canada, Japan, and Mexico are estimated to collect and recycle less than 10% of waste lamps (EU Commission, 2008). The United States has some, mainly state level, legislation for management of waste lamps, focussed on end user (primarily business) responsibility. However, enforcement is low and the collection and recycling rate is estimated around 23% (Silveira & Chang, 2011).

EPR systems in Nordic countries continue to evolve, with Finland and Sweden using the recast to include new retailer take back options for consumers. Increasing the collection of small WEEE in particular requires increasing attention to factors which influence recycling behaviour, for example motivation, convenience and capacity and the available recycling infrastructure can influence all three of these (Melissen, 2006; Wagner, 2013). Using more retailers to take back waste lamps regardless of purchase (prior, retailers were required to take back a product if an equivalent product was purchased) is a way to further increase the number of convenient return options for household consumers. Such retailer take-back has been successful at the municipal level in the U.S. (where other recycling options for households are not provided), achieving recycling rates of over 36% from near 0% previously (Wagner et al., 2013). However, because of the existence of established and better known recycling centres in municipalities in Nordic countries, the impact of retailer take back is anticipated by some stakeholders to have a small, but still positive, impact on collection of lamps. In Denmark and Sweden there was also evidence of municipalities collecting waste lamps through kerbside collection for detached households through plastic bags or boxes attached to the top of kerbside recycling bins. While this type of kerbside collection is relatively new and effectiveness has yet to be fully assessed, the initiatives represent attempts to further optimise collection of this waste stream. Another form of kerbside collection, collection small bins in apartment complexes, has been more established in these countries, as is mobile collection from households a few times year.

There were mixed views on whether more market oversight was necessary or whether enforcement was adequate in all countries. In the Nordic countries market enforcement is undertaken by typically

small authorities (in terms of resources devoted to enforcement of WEEE legislation) and takes the form primarily of guidance about rules and response in the cases of complaints. Interviewed stakeholders perceived that high levels of cooperation amongst PROs and municipalities were part of why general WEEE systems performed well in the Nordic countries. While there were some concerns about free-riders in the systems, this was not perceived to be a major inhibitor of the function of the system, but rather an area where the system could still be optimised, but requiring greater resources than currently available.

## 4. Best practices and remaining challenges

### 4.1 Factors in best practice

In contrast to other waste streams, lamps are small, meaning they can be easily disposed of in residual waste, and represent a net cost to collect and recycle, meaning there is no natural economic incentive in absence of legislation (Huisman et al., 2008). Mandatory EPR legislation for lamps is it appears key for higher collection and recycling of this product group. However, the fact that collection and recycling rates in the EU member states and even amongst the Nordic countries also vary indicates that having the legislation, or a rule base, itself is not enough for excellent collection and recycling rates. From the analysis of the Nordic systems, we identified several common factors that contribute to excellence in operational performance (figure 4).

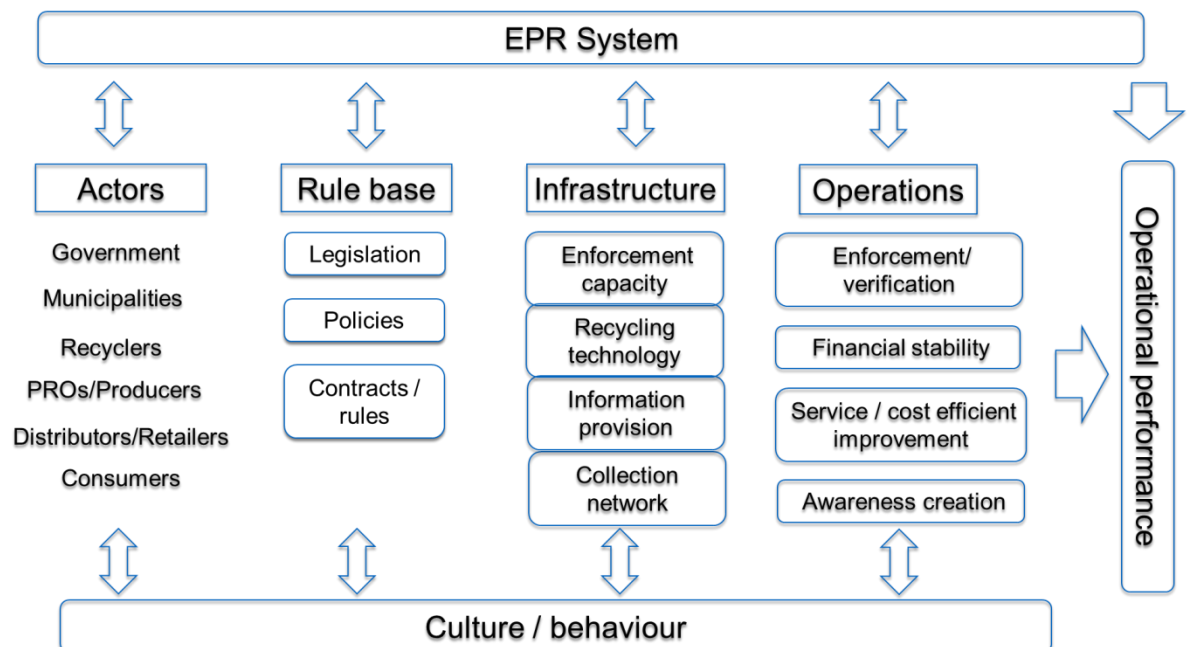


Figure 4. Common factors contributing to excellence in operation performance of an EPR system.

Building on a robust and transparent rule base, the system infrastructure is also essential. Enforcement of the rules needs to be adequate to allow focus on continuous improvement rather

than incentivising a focus on lowest costs by avoiding compliance. As is seen in the Nordic cases, the strength and resources devoted to the authorities can be fewer in a situation with high compliance and cooperation. Such voluntary action on the part of actors is key, particularly in areas where the rule base is vague. For example, sound financial management is stipulated by the WEEE Directive (Article 12) but how producers and PROs incorporate end-of-life costs is still open to interpretation (Article 12.6 invites the Commission to report “on the possibility of developing criteria to incorporate the real end-of-life costs into the financing of WEEE by producers...”). With the requirement for a financial guarantee waived in most Nordic countries with the participation in a collective scheme (i.e. a PRO with a sufficient number of members to guarantee financing), the financial stability of the collection system rests upon the financial management of these PROs. Whether the arrangements are adequate remains to be seen and tested with more experience. The recycling technology used in the Nordic countries ensures significant mercury emissions are avoided. In addition, despite being small markets on their own, the high level of collection and recycling of these lamps in Nordic countries, the recycling technology to produce powder fractions, and the development of Solvay Rhodia’s capacity to utilise these powders, has made recycling of rare earths from waste lamps a reality. In view of the criticality of rare earths (Koninklijke Philips Electronics N.V., 2011; Moss et al., 2013), this development in closing the rare earth loop from lamps is a significant contribution to a more circular economy in the EU.

Information provision ensures that key actors in the EPR system architecture know their role. It is also the basis for continually improving the system. In Nordic countries, a variety of actors engage with information provision to consumers through a variety of media. While the high collection rates could be indicative of the effectiveness of information campaigns, this is unclear in the case of Norway. The high visibility of waste lamps in the media due to the attention of the Minister for the Environment in Sweden may have been just as effective as the subsequent information campaign from the PROs and waste management organisations. The actual level of awareness and responding behaviour of households in the Nordic countries remains an area for further study.

In terms of the collection system in place in the Nordic countries, it can be seen that there has been a concerted effort to provide multiple means of taking back products and this continues to evolve with retailer-takeback and kerbside collection. Such options further increase the convenience of services offered to households, which in turn are particularly key aspects for optimising collection systems for small WEEE like lamps (Melissen, 2006; Wagner, 2013).

## 4.2 Remaining challenges

The experience with EPR systems in the Nordic countries reveals well-performing systems, however, with the exception of Sweden, not as dominant as for WEEE in general. The general collection of lamps compared to some other categories of WEEE is consistent with the challenges identified with lamp and small WEEE collection in general. Small WEEE is more easily disposed into other waste streams, and there is some evidence of this still happening, particularly in the general glass recycling and residual waste (see e.g. El Kretsen & Sörab, 2011; Elretur, 2012; Pehrson & Balksjö, 2012). However, the small documented amounts in these streams indicate that knowledge is still missing about how consumers deal with lamps at the end-of-life (for example, they are also small enough to be stored and not ending up in any waste stream for several years). This was noted as a continuing challenge by interviewed stakeholders in all four countries.

Obtaining accurate and useful data for measuring and comparing collection rates remains a significant challenge. Producers are required in some countries to report based on amounts (C. Andersson, personal communication, 13 May 2015), which are then converted into kilograms for reporting at the EU level, which in turn leaves room for error and inconsistency. This is particularly the case regarding put on market data, which also utilize the combined nomenclature (CN) codes used for trading and customs. For lighting products these codes are quite general (Wang, Huisman, Baldé, & Stevels, 2012) and do not align with WEEE product categories. It does not help that lighting technology is also changing at a rapid pace, faster than codes which explains why LEDs can be classified under different CN codes and with which the distinction between lamps and luminaires becomes less obvious (LightingEurope, 2014). With this complexity comes the risk that put on market data can be multiplied through double-counting or codes used erroneously. Additionally, lag times resulting from consumers delaying disposal of waste lamp products could affect the collection data. Also, as lifetimes of lamp products have extended, the three year average from put on market may not be the most relevant measure of collection effectiveness. It has been proposed that at least 6 years is a more accurate measure of the historic collection rate (European Lighting Companies' Federation, 2003). Even if this change was made, it would be a few more years before there is adequate data to measure this robustly (Sander et al., 2013).

Despite the reasons for making collection and recycling of gas lamps a priority, there is still the risk that this product category receives less emphasis in the overall WEEE system with targets still based on the overall weight of collected WEEE. There is some evidence from Denmark and Finland that the presence of lamp-specific PRO may ensure that lamps are adequately emphasised. However, the case of Sweden demonstrates that the emphasis on this product category can also be made by other stakeholders (in that case, the Minister for the Environment) and in fact this may be even more

effective in motivating collection. The effectiveness of recent education campaigns in Norway to raise awareness of small WEEE collection, in which lamps are given special emphasis, still has to be gauged, but thus far having neither lamp specific PROs nor a particular emphasis on collection of lamps from other influential stakeholders may help explain the significant difference in performance between this category compared to WEEE collection overall in that country. Interviewed stakeholders also indicated that there was still room for raising the level of consumer awareness about gas discharge lamps to include not only disposal options, but the benefits of recycling these products for the environment and closing valuable material loops.

Further optimisation of materials in closing the loop and improving design requires communication between (the right) upstream and downstream actors. The problems with EPR systems incentivising design change are not unique to lamps, but an overall acknowledged challenge for WEEE systems in general (Huisman, 2013; Kalimo et al., 2012; Lifset, Atasu, & Tojo, 2013; Van Rossem, Lindhqvist, & Tojo, 2006b). However, there are challenges also unique to lamps due to the increasingly prolonged life of lighting products. Unlike many other categories of WEEE products in which turnover of products becomes shorter and shorter, new energy saving lamp products have an average lifespan of 8500 hours for a CFL and 25000 hours for LEDs (U.S. Department of Energy, 2012), which can correspond from a few years to several decades depending on actual use<sup>3</sup>. The lighting industry has used an average of six years (European Lighting Companies' Federation, 2003), but even this means communicating information to upstream producers as information from actual recycling is often too late to be relevant for the current design of lighting products. Product designers then must be incentivised to design with end-of-life management in mind without empirical knowledge of that management. The challenge of providing such incentives is compounded by the fact that consumers of lighting products do not necessarily respond to environmental design and reward such efforts. Despite new standards and more efficient lighting options available, the least expensive and least environmentally beneficial lighting products continue to dominate the market in Europe (Bennich, Soenen, Scholand, & Borg, 2014). In light of these challenges, it may well be that EPR, while part of the means to communicate and incentivise consideration of end-of-life management at the design stage, is not sufficient to overcome the other influences on design. These barriers may need to be addressed through more direct tools to influence ecodesign.

The development of new technology such as LEDs and more integrated products in lighting is increasing in its pace and market penetration (McKinsey & Company, 2012). Such technologies bring

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<sup>3</sup> 8.500 is an average but it should be noted that the use varies significantly. In a professional situation the product would typically be used more intensely than home use, but the users also typically purchase different specifications of lamps (i.e. 6000 hour CFLs versus a 15,000 hour LFLs). So this could result in a majority of fluorescent lamps being disposed around 6000 hours, but with a long tail extending decades.

a new set of challenges for WEEE system for lamps. It is unknown whether the smaller amounts of rare earth material (in addition to other critical materials like Gallium and Indium) will have the same potential for recycling as the gas discharge lamps. The longer lifetimes of these products may also result in less waste material overall to be collected and recovered. The best ways to deal with hazardous materials as LEDs become the dominant lamp type in the waste streams remains a question as to the best recycling techniques for integrated LED products. The long life of these products and the rapid development of the products may mean that they are disposed before their end-of-life, in which case opportunities for reuse of some components may become possible. Prevention of waste and product design for recycling, one of the key aims of EPR is still a challenge for lamps, and consideration of the new technology will be key to further advancing a circular economy.

## 5. Conclusion

Collection and recycling of gas discharge lamps should be a priority in a circular economy, in consideration of both the avoided environmental harm of mercury emissions and the potential for recycling of valuable materials. Nordic countries perform well in the collection and recycling of gas discharge lamps compared to other EU countries, and this performance can be attributed to robust system architectures, as a result of the rule base but also other factors. There is evidence that the systems continue to improve in terms of convenience and in closing material loops, with the recycling of rare earths from lamp phosphors a notable development. However, challenges remain to further optimise the systems, particularly in terms of meeting EPR goals for better design and in light of rapidly changing technology.

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## Appendix A. List of Interviewed Stakeholders

	Name	Organization, position	Stakeholder Group	Interview date
Denmark	Jan Bielefeldt	Lyskildebranchens WEEE Forening (LWF), Administrative Director	Producer Responsibility Organisation (lamps)	In person interview - 26 August 2014
	Jonas Engberg	Ikea, Sustainability Manager Denmark	Retailer	In person interview - 26 August 2014
	Hardy Mikkelsen	Reno Djurs, Environmental Manager	Municipal Waste Organisation	Phone interview – 4 December 2015
	Lotte Wammen Rahbek	Forsyning Helsingør , Waste planner	Municipal Waste Organisation	In person interview – 15 December 2014
	Niels Remtoft	Dansk Affaldsforening, Special Consultant	National Waste Management Association	In person interview – 15 December 2014
Finland	Senja Forsman	SOK Grocery Chain Management, Compliance Manager	Retailer	Phone interview - 4 December 2014
	Timo Hämäläinen	Finnish Solid Waste Association, Development Manager	National Waste Management Association	Phone interview - 19 December 2014
	Jorma Koskinen	Ekokem, Sales Group Manager	Recycler	Email correspondence – 29 January 2015
	Jesse Mether	Rautakesko Ltd, Sustainability Manager	Retailer	Email correspondence – 19 December 2014
	Perrti Raunamaa	FLIP, Administrative Director	Producer Responsibility Organisation (lamps)	Phone interview - 8 December 2014
	Tuomas Räsänen	Elker Oy, Chief Operations Officer	Producer Responsibility Organisation	Email correspondence - 22 January 2015
Norway	Ellen Halaas	Avfall Norge, Adviser for framework and law collection, sorting and recycling	National Waste Management Association	Phone interview – 9 December 2014
	Guro Kjørsvik Husby	El Retur, Information Officer	Producer Responsibility Organisation	Email correspondence – 24 November 2014 and 8 January 2015

	Bjørn Thon	RENAS, Administrative Director	Producer Responsibility Organisation	Phone interview – 30 January 2015
Sweden	Carina Andersson	IKEA of Sweden, Product Laws & Standard specialist - Producer Responsibility	Producer	Email correspondence 13 and 15 May 2015
	Jessica Christiansen	Avfall Sverige, Education Manager /Controller Technical Advisor WEEE	National Waste Management Association	In person interview - 16 December 2014
	Jonas Carlehed	IKEA, Sustainability Manager Sweden	Retailer	Phone interview - 30 January 2015
	Lars Eklund	Natursvardsverket (Swedish EPA), Advisor Environmental Enforcement	Government authority	Phone interview - 2 December 2014
	Göran Lundholm	Nordic Recycling, General Manager	Recycler	In person interview - 13 August 2014; phone interview - 27 October 2014
	Dolores Öhman	Hässleholm Miljö, Head of Waste Collection and Customer Service	Municipal Waste Organisation	In person interview - 3 September 2014
	Anders Persson	SYSAV, CEO	Municipal Waste Organisation	In person interview - 9 September 2014
	Mårten Sundin	El-Kretsen AB, Marketing Manager	Producer Responsibility Organisation	In person interview - 5 December 2014
	Hans Standar	Svensk GlasÅtervinning AB, CEO	Glass recycler	Phone interview – 4 December 2014
	Joseph Tapper	Elektronikåtervinning i Sverige, CEO	Producer Responsibility Organisation	In person interview - 5 December 2015
<b>Additional correspondence</b>	SERTY (Finland), ERP (Denmark)	Producer Responsibility Organisations	Email correspondence	

## Appendix B: Sample interview protocol for producer responsibility organisations

1. In other countries there are different situations regarding a separate PRO for lamps. What are the advantages and disadvantages having a PRO focussed solely on lamps? What else distinguishes [organisation] from other PROs operating in [country]?
2. How does the general WEEE system affect the take back of lamps? Would you characterise the system as competitive or cooperative for collection between the PROs?
3. What do you find to be the particular challenges to take back of lighting products? For example, collection, transport and recycling for lamps have been described as very expensive compared to other WEEE categories but the costs are different in each country context. What are the main cost factors and how is [organisation] working to make the system as cost efficient as possible?
4. There are statistics from Eurostat regarding recycling in [country]. The collection rates vary depending on how you count, for example historically versus same year as well as how you divide product categories. How does [organisation] measure collection and recycling effectiveness for lamps and are there challenges to collecting good information (e.g. from producers)?
5. How does your organisation communicate with other stakeholders like producers, producer responsibility organisations and government authorities - is there a specific forum for this?
6. Is there any information or communication with producers regarding the end-of-life/recyclability of products? How do the producers respond?
7. Do you have information about how recycled fractions from collected and treated products are used? Is there interest/action on using these fractions in particular ways (e.g. in lighting products)?
8. Do you differentiate fees in any way depending on the product? Is there likely to be any differentiation between CFL and LEDs in the near future?
9. How are producers active in the system through your PRO?
10. The EU is considering a separate target for gas discharge lamps. What is your organisation's view about this?
11. In the media in some countries, it has been highlighted that there are still lamps ending up in incineration and glass recycling. Is it an issue in [country]?
12. Transporting hazardous waste such as lamps could pose risks from mercury for waste handlers. Is handling mercury-containing waste products or broken lamps an issue in [country]?
13. There is the website and some material from [organisation], are there any other ways [organisation] is working with education and information to raise awareness about WEEE recycling?
14. Are there strengths or weaknesses you perceive to the [country] WEEE system compared to other Nordic countries?
15. Nordic countries are often cited as the best practitioners of WEEE recycling - what do you think are the main factors in success?
16. Improving collection and recycling is a continuous challenge, what do you think are the main areas that still need significant improvement? Is there more that can be done with critical materials recovery for instance?



## Appendix C: Sample interview protocol for national waste management associations

1. What are the main issues in producer responsibility for WEEE where your organisation is involved on the member's behalf?
2. How does your organisation communicate with other stakeholders like producers, producer responsibility organisations and government authorities - is there a specific forum for this?
3. Are there any issues with working with the relationship between municipalities and PROs in [country]? Is it a contract or other agreement on how the responsibility is allocated and managed for collection points and collection?
4. Would you characterise the system as competitive or cooperative for collection between the PROs?
5. Transporting hazardous waste such as lamps could pose risks from mercury for waste handlers. Is handling mercury-containing waste products or broken lamps an issue in [country]?
6. From [organisation] reports there are still some lamps found in residual waste. Are these and other small electronic waste perceived as a particular problem?
7. How are municipalities and/or your organisation working with increasing collection of lamps and other small WEEE? Are there any pilot projects or innovative examples to further optimise the WEEE system in this respect?
8. There is the website and some material from [organisation], is there more [organisation] is doing to educate about hazardous waste like gas discharge lamps?
9. The EU is considering a separate target for gas discharge lamps. What is your organisation's view about this?
10. Are there strengths or weaknesses you perceive to the [country] WEEE system compared to other Nordic countries?
11. Nordic countries are often cited as the best practitioners of WEEE recycling - what do you think are the main factors in success?
12. Improving collection and recycling is a continuous challenge, what do you think are the main areas that still need significant improvement?