Overview of the WEEE Directive and its implementation in the Nordic countries: national realisations and best practices

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ABSTRACT

Fast technical progress, new applications and electronic devices becoming a part of everyday life have led to the rapid growth of waste electrical and electronic equipment (WEEE). Due to hazardous substances but also burgeoning amounts of valuable materials contained in EEE, the European Union has implemented Directives related to electronics waste to reduce negative environmental and health impacts and to improve material recovery of valuable substances from WEEE. This paper provides an overview of the WEEE Directive and its implementation to the national legislations in Finland, Sweden and Norway and, further, describes how the nationwide WEEE recovery infrastructures in the Nordic countries have been built. The Nordic WEEE management systems are evaluated from the resource efficiency point of view and the best practises of the systems are also expressed. It can be said that the WEEE management systems as established in the Nordic countries have evidently advantages because the WEEE collection rates have exceeded 9 kg/inhab./year in all three countries since 2007 despite of their wide, sparsely populated areas. The Swedish and Norwegian experiences with the long history of WEEE recovery indicate that increasing consumer awareness leads to more environmentally sound behaviour and, thus, improves the recovery efficiency.

Keywords: *WEEE Directive, recovery network, collection, Finland, Sweden, Norway.*

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1 INTRODUCTION

Production and use of electronic and electrical equipment have significantly increased during the last three decades due to technological innovations, new applications of electrical and electronic devices and market

expansion into developing countries. Fast technological progress and EEE becoming a part of the everyday life have also led to the rapid growth of waste electrical and electronic equipment (WEEE). Due to the burgeoning amounts and the complex mixture of materials and hazardous substances contained in EEE, environmental and health impacts of WEEE has become an increased concern. The hazardous substances present in electronic equipment are not likely to be released during their regular use but pose hazards during inappropriate treatment methods and landfill disposal.

In the mid-1990s, more than 90% of WEEE was landfilled, incinerated or recovered without any pre-treatment and, therefore, a large proportion of hazardous substances found in the municipal waste stream came from WEEE. Already at that time, the amount of WEEE arising as waste was estimated to be at around 6 million tonnes in EU and the growth rate of WEEE was expected to be 3-5% per year, which was about three times higher than the growth rate of municipal waste of EU [1]. In the late 1990s, some of the European countries, such as Norway, Switzerland, the Netherlands and Sweden, began as forerunners to prepare national legislations regarding WEEE management to prevent the environmental problems caused by uncontrolled disposal of WEEE. Further, in order to adequately address the environmental problems associated with the treatment and disposal of WEEE and ensure the functioning of the internal markets, measures at the European Community level were prepared and introduced in June 2000 in a form of proposal {COM(2000)347} for two Directives.

Nowadays, WEEE is one of the largest growing waste streams globally. Development of new applications of EEE have led to a situation where a number of materials formerly no more than scientific curiosities have an important role in electronic and other future devices, resulting in a concern about their sufficiency and vulnerability of supply. As recycling is regarded as a solution to substitute primary resources and decrease environmental loading, the efficient recycling of electronic scrap has been rendered indispensable for a sustainable environment and the economic recovery of valuable material for reuse. Also comprehensive collection infrastructures and consumers' awareness have significant roles in achieving an efficient and environmentally conscious waste management of WEEE.

The aim of this paper is to provide an overview of the WEEE Directive and its implementation to the national legislations and, in addition, describe how the nationwide WEEE recovery infrastructures in Finland, Sweden and Norway have been built. Furthermore, realisations of the WEEE recovery networks are compared and collection efficiencies of the national systems are evaluated based on the EU statistics on amounts and sources of the collected WEEE. Finally, best practises of WEEE management in the Nordic countries are expressed.

This paper is based on personal professional experiences and academic research conducted over the last 10 years in Finland and Norway. The study is explorative in nature and it rests on a literature review and personal notifications from Finnish, Swedish and Norwegian real-life experiences. Notifications from various representatives of national authorities and the WEEE operators were conducted either through personal encounters in professional positions, e-mail enquires or personal interviews carried out during company visits, person-to-person discussions and in public events related to the topic of this work.

2 AN OVERVIEW OF THE EUROPEAN WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE) DIRECTIVE

2.1 Main principles included in the WEEE Directive

The Polluter Pays Principle (PPP), which makes responsible for environmental pollution those parties who are associated with the cause and are able to improve the situation, was launched by the Organisation for Economic Co-operation and Development (OECD) already in 1972. Nowadays, PPP is one of the fundamental principles of the European Community environmental policy and it encourages preventing and reducing pollution and, therefore, it has also been included in the RoHS (restriction of hazardous substances) and WEEE (Waste Electrical and Electronic Equipment) Directives. In the RoHS Directive, the requirement of substitution of hazardous substances for safer materials follows the principal idea of PPP for pollution prevention, while PPP is included in the WEEE Directive in a form of extended producer responsibility (EPR). EPR for the waste management phase of EEE was regulated in order to create an economic incentive for producers to move toward more environmentally sound design and manufacturing [2]. Therefore, the establishment of the WEEE Directive aimed at to encourage producers to consider the design and production of EEE in relation to the end-of-life (EOL) management; an approach that takes into account and facilitates their repair, possible upgrading, re-use, disassembly and recycling and, finally, the best methods of recovery and disposal.

The other fundamental principles built into the WEEE Directive are the principles of subsidiarity and proportionality. The purpose of subsidiarity is to ensure that powers are exercised as close to the citizen as possible. In the European Community context, subsidiarity protects the Member States' capacity to take decisions and actions, however, also authorises the intervention of the Community when the objectives cannot be achieved sufficiently by the Member States 'due to the scale and effects of the proposed action'. [3] The principle of proportionality, for one, introduces only obligations which are necessary to achieve, not the measures of the execution. In accordance with subsidiarity, national and regional conditions have to be taken into account when collection, treatment and financing systems for the management of WEEE are devised. Therefore, the WEEE Directive describes only the main principles of WEEE management and financing and, further, the establishment of principles at the Community level. In contrast, the modalities of the logistics and the organization of the take-back schemes are left to the choice of the Member States [1]. Further, in accordance with the proportionality principle, the minimum targets of 70 w% for recovery and 50 w% for re-use and recycling of WEEE are set in the Directive.

2.2 The initial WEEE Directive 2002/96/EC

The WEEE Directive 2002/96/EC was signed in January 27th, 2003 and put in effect in February 13th, 2003 by publishing in the Official Journal of the European Union. At the same time, also the Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment, RoHS (2002/95/EC) was introduced, to ban the use of six hazardous substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs)) in electrical and electronic equipment.

The principal purposes of the WEEE Directive 2002/96/EC are to prevent WEEE generation and, in addition, to improve the re-use, recycling and recovery of WEEE in place of disposal, to reduce the environmental and health impacts of WEEE. Further, it seeks to harmonize the Member States' national measures on the management of WEEE in order to avoid national approaches which may hamper the effectiveness of recycling policies and cause substantial disparities in the financial burden at the EU level. These objectives are considered to achieved by a wide range of measures required for operators involved in the life-cycle of EEE, including producers, consumers and, in particular, operators directly involved with the WEEE treatment. [2]

The Directive 2002/96/EC defines EEE as equipment that is dependent on electric current or electromagnetic field to work and equipment for the generation, transfer or measurement of such currents and fields. The voltage rating ranges 0-1000 V for AC and 0-1500 V for DC. The scope of the Directive includes practically all electrical and electronic equipment falling under the definition, excluding only equipment intended for military purposes such as arms and munitions [2]. Due to the extremely wide range of equipment, EEE is categorized in the Directive 2002/96/EC as can been seen in Table 1. Separate collection is the precondition to ensure specific treatment and recycling of WEEE. Therefore, according to the Directive 2002/96/EC, producers need to oversee the finance for the development of appropriate systems, so that returning of WEEE is reasonable painless and, moreover, free of charge for private persons. Further, a general collection target for the WEEE categories, 4 kg/inhab. per year, was provided and it had to be achieved by December 31st, 2006, at the latest.

Producers also had to set up appropriate systems in order to ensure improved treatment and re-use/recycling of WEEE. Certain requirements for treatment are prescribed in the Directive 2002/96/EC as targets for the re-use, recycling and recovery of WEEE. Treatment requirements, recovery rate up to 80% by an average weight and recycling rate up to 75% by an average weight per appliance, had to be realized also by December 31st, 2006. Specific recovery and recycling targets of different WEEE categories, as set in Directive 2002/96/EC, are presented in Table 1.

Table 1: The minimum targets of the European WEEE Directive 2002/96/EC [2].

	Category	**Recovery rate [w%]**	**Re-use & recycling rate [w%]**
1	Large household appliances	80	75
2	Small household appliances	70	50
3	IT and telecommunications equipment	75	65
4	Consumer equipment	75	65
5	Lighting equipment	70	50
6	Gas discharge lamps	-	80
7	Electrical and electronic tools	70	50
8	Toys, leisure and sports equipment	70	50
9	Monitoring and control instruments	70	50
10	Automatic disperser	80	75

In order to achieve high collection rates and to facilitate the recovery of WEEE, users of EEE and recyclers must be informed about their role in the recovery system of WEEE. Therefore, a labelling requirement for EEE put on the market after August 13th, 2005 to minimize the disposal of WEEE as unsorted municipal waste and requirements for producers to inform recycling operators about the material content of such equipment are indicated in the Directive 2002/96/EC. The symbol for marking EEE is shown in Fig. 1.

Figure 1. Symbol for the marking of EEE [2].

According to the Directive 2002/96/EC, within five years after the entry into force, experiences from the application of the Directive, especially regarding separate collection, treatment, recovery and financial systems, had to be reported and recasting of the Directive suggested, if appropriate. Simultaneously, the new mandatory targets for recovery, recycling and re-use of WEEE had to be established by December 31st, 2008 at the latest. [2] The time line of deadlines and important dates of the WEEE Directive 2002/96/EC illustrated is in Fig. 2.

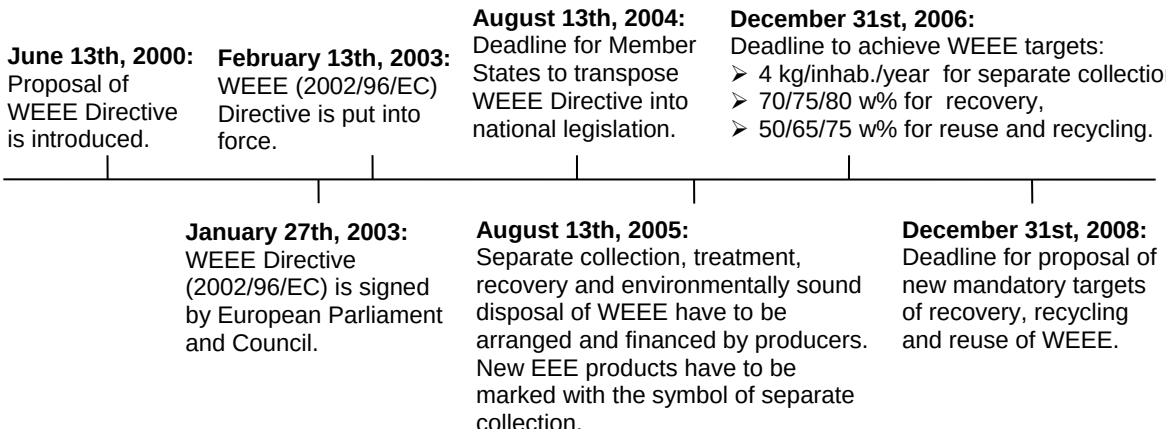

Figure 2. Time line of the implementation of the European WEEE Directive 2002/96/EC based on [2].

2.3 The recast Directive 2012/19/EU on WEEE

According to the impact assessment of the WEEE Directive done in 2008, experiences with the first years of implementation have indicated some technical, legal and administrative problems causing, among others, continuing environmental harm, low levels of innovation in waste collection and treatment as well as distortion of competition [4]. The WEEE Directive 2002/96/EC itself foresaw the possibility of revision based on the experiences of the application. In addition, it set out to propose new mandatory WEEE collection,

recovery and re-use/recycling targets by the end of 2008. The proposal of the recast WEEE Directive {COM(2008) 810 final} was introduced in December 3rd, 2008. After the revising process, the recast WEEE Directive 2012/19/EU was signed on July 4th, 2012. In consequence, the initial WEEE Directive with its successive amendments was revealed on February 15th, 2014.

The main tasks of revision were to increase separate collection and proper treatment by establishing a collection rate ambitious and appropriate for each Member State and fight illegal exports of e-waste disguised as "used equipment" by reversing the burden of proof on functionality for exporters. Further, lower administrative burdens in the internal market by simplifying registration and reporting requirements for new equipment placed on the market were also in target. [5] In the recast process, also the scope of the Directive has been clarified by defining categories of equipment as from private household (C2B) or from users other than private households (B2B). This is expected to result in positive environmental and economic impacts and clarity for producers by reducing free-riding on the market.

In the recast WEEE Directive, electrical and electronic devices have been re-categorized (see Table 2). According to the Directive 2012/19/EU, EEE categories follow the initial ones over to the transitional period from August 13th, 2012 to August 14th, 2018 with an extension of photovoltaic panels to the category 4. From August 15th, 2018 onward, the Directive applies to all EEE categorized as follows:

1. Temperature exchange equipment (e.g. refrigerators and heat pumps)
2. Screens, monitors and equipment containing screens having a surface greater than 100 cm^2
   (e.g. televisions, LCD photo frames)
3. Lamps (e.g. fluorescent lamps and LEDs)
4. Large equipment, any external dimension more than 50 cm
   (e.g. washing machines, photovoltaic panels and large medical devices)
5. Small equipment, no external dimension more than 50 cm
   (e.g. vacuum cleaners, smoke detectors and sport equipment)
6. Small IT and telecommunication equipment, no external dimension more than 50 cm
   (e.g. mobile phones, GPS and personal computers)

The more demanding and gradually evolved collection and recycling targets of WEEE are included in the recast Directive (Table 2). In the initial stage, over the first three years, the recovery, re-use and recycling target remained at the previous level. However, the scope of the recovery and recycling targets was extended to cover also medical devices (category 8) with the percentages of 70% for recovery and 50% for re-use and recycling. Moreover, a rate of separate collection of at least 4 kg/inhab./year of WEEE from private households, or the same amount of WEEE that was collected in the three preceding years, whichever is greater, have to be collected. [6] In the following stage, from three to seven years, all targets will be raised by 5% being from the lowest recycling rate of 55% for small household appliances up to recovery rate of 85% for large household appliances. Eventually, after the transitional period of seven years, new categories of WEEE will come into effect and, therefore, some changes for the targets may occur upward or downward due to re-categorization. In 2019, collection targets will be specific for each Member State; the minimum

collection rate shall be 65% of the average weight of EEE placed on the market in the three preceding years or, alternatively, 85% of WEEE generated [6].

Table 2: The minimum targets of recovery, re-use and recycling rates in the WEEE Directive 2012/19/EU [6].

Category		**Recovery/reuse & recycling target [%]** in period 1*	**Recovery/reuse & recycling target [%]** in period 2**	**Recovery/reuse & recycling target [%]** in period 3***
1	Large household appliances	80/75	85/80	
2	Small household appliances	70/50	75/55	
3	IT and telecommunications equipment	75/65	80/70	
4	Consumer equipment	75/65	80/70	
5a	Lighting equipment	70/50	75/55	
5b	Gas discharge lamps	-/80	-/80	
6	Electrical and electronic tools	70/50	75/55	
7	Toys, leisure and sports equipment	70/50	75/55	
8	Medical devices	70/50	75/55	
9	Monitoring and control instruments	70/50	75/55	
10	Automatic disperser	80/75	85/80	
1	Temperature exchange equipment			85/80
2	Screens and monitors			80/70
3	Lamps			-/80
4	Large equipment			85/80
5	Small equipment			75/55
6	Small IT and telecommunication equipment			75/55

*period 1: from August 13th, 2012 until August 14th, 2015

**period 2: from August 15th, 2015 until August 14th, 2018

***period 3: from August 15th, 2018 onward

To ensure that all WEEE is treated properly in the Member States, Directive 2012/19/EU requires that the European standardization organisations develop standards for recovery, recycling and preparing for re-use of WEEE by no later than February 14th, 2013. Further, the registration and reporting requirements of national registers to the Commission are harmonized in Directive 2012/19/EU for reducing unnecessary administrative burden between the Member States and EU and, as well, the minimum inspection requirements for the Member States are set in order to bridge the implementation gap. Further, minimum monitoring requirements for shipments of WEEE are enacted to strengthen the enforcement of the WEEE Directive [6]. The time line of deadlines and important dates of the WEEE Directive 2012/19/EU illustrated is in Fig. 3.

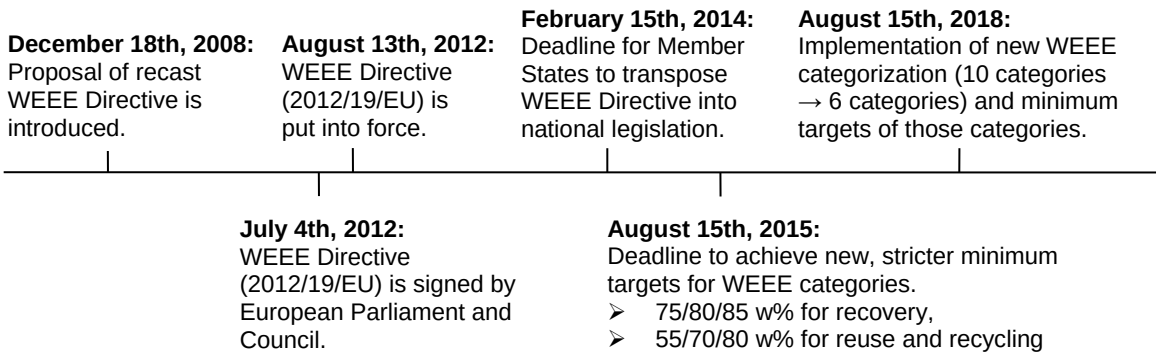

Figure 3. Time line of the implementation of the WEEE Directive 2012/19/EU based on [6].

3 CHARACTERISTICS OF THE NORDIC COUNTRIES

Finland, Sweden and Norway are relatively large and sparsely populated countries situated in Northern Europe, Table 3 summarizes their characteristics. As it can be seen from Fig. 4, population is strongly concentrated in the southern parts of these three countries. In Finland, the most populous area is the Helsinki Capital Region (cities of Helsinki, Espoo, Vantaa and Kauniainen) in the south coast of Finland with 1.1 million inhabitants, while Stockholm, the Swedish capital city in the east coast has a population of around 1.25 million. Also in Norway, the capital city Oslo in the south coast with more than 925,000 million inhabitants is the most densely populated area of the country. In addition to these populous capital city areas, there are 300-400 municipalities in each country, half of which have no more than 5000 residents.

Table 3: Demographics of Finland, Sweden and Norway compared to EU27 [7].

Country	Area [km^2]	Population [millions]	Pop. Density [inhab./km^2]
Finland	338,400	5.4	18
Sweden	450,300	9.5	21
Norway	324,000	5.0	16
EU27	4,324,800	500.3	114

Large unpopulated northern areas, long distances and a cold climate with long and snowy winters are typical characteristics of the Nordic countries. They have also much in common in the way of life, history, language, and social structure with high equality. Due to challenging weather conditions and high living standards, EEE has become an important part of Scandinavians' everyday life and, further, applications of information and communication technologies (ICT) are highly implemented in Nordic societies.

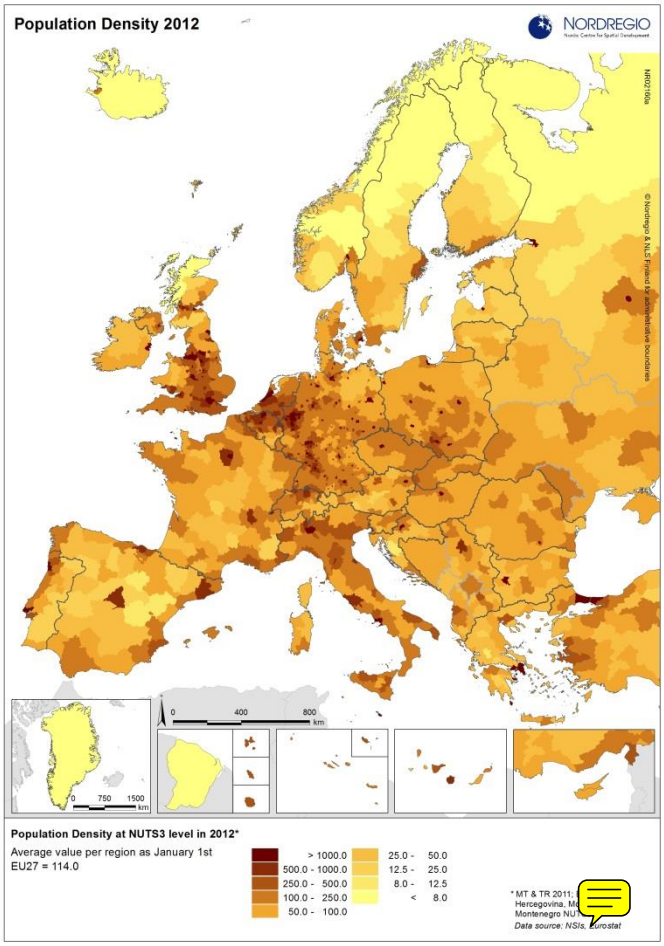

Figure 4. Population density in Europe in 2012 [8].

4 WEEE RECOVERY IN FINLAND

4.1 Legislative implementation

Prior to the implementation of the WEEE Directive, neither the legislative nor the operational preconditions to a nationwide, comprehensive separate collection and recovery system of WEEE existed in Finland. In order to harmonize Finnish waste legislation with the WEEE Directive, in June 2004 the Finnish Waste Act (1072/1993) was amended (452/2004) to include new clauses on producer responsibility. Moreover, governmental regulations of WEEE (852/2004) and RoHS (853/2004) were incorporated to the national legislation in September 2004. Later on, the Finnish Waste Act was reformed due to the implementation of the Waste Framework Directive (2008/98/EC) and incoherence caused by several amendments. No outstanding changes in producer responsibility on EEE were done at that time, however, roles and responsibilities of various actors were clarified and the mandate of the national inspecting and controlling authority was enhanced. The reformed Waste Act (646/2011) took effect on May 1st, 2012 with an exception of articles concerning producer responsibility, which entered into force on May 1st, 2013. More detailed legislative implementation of the WEEE Directive in Finland is presented by Ylä-Mella et al. [9].

In spite of the recent reform of the Waste Act, the Finnish Waste legislation is required to be revised due to adaption of the recast WEEE Directive (2012/19/EU) into the national law. Therefore, the amendment of the Finnish Waste Act (646/2011) has been passed in March 2014 and the revised Government Degree on WEEE will be issued later in 2014.

4.2 Finnish WEEE recovery infrastructure

The overwhelming majority of electronic devices sold on the Finnish market are imported and, therefore, the representatives of foreign and domestic producers may transfer responsibility over discarded electronics to a producers association. The producers association in turn appoints WEEE recovery companies to treat and recycle the collected waste. In Finland, electrical and electronic equipment producers and importing business have formed five producer co-operatives for the purpose of organizing collection and recycling of WEEE. FLIP ry (Finnish Lamp Importers and Producers Association), ICT-tuottajaosuuskunta (ICT Producer Co-operative) and SELT ry (Electrical and Electronics Equipment Producers' Association) have founded together an umbrella organization and service provider named Elker Ltd. SER-tuottajayhteisö ry, SERTY (The Association of Electric and Electronic Producers and Importers) and the ERP Finland (European Recycling Platform Finland) operate independently. Within the supply chain of WEEE, various tasks such as collection, transportation, sorting and disassembly of products, storage, selling of material fractions as well as reusable products and parts is conducted. The main stages of the WEEE recovery system in Finland are presented in Fig. 5.

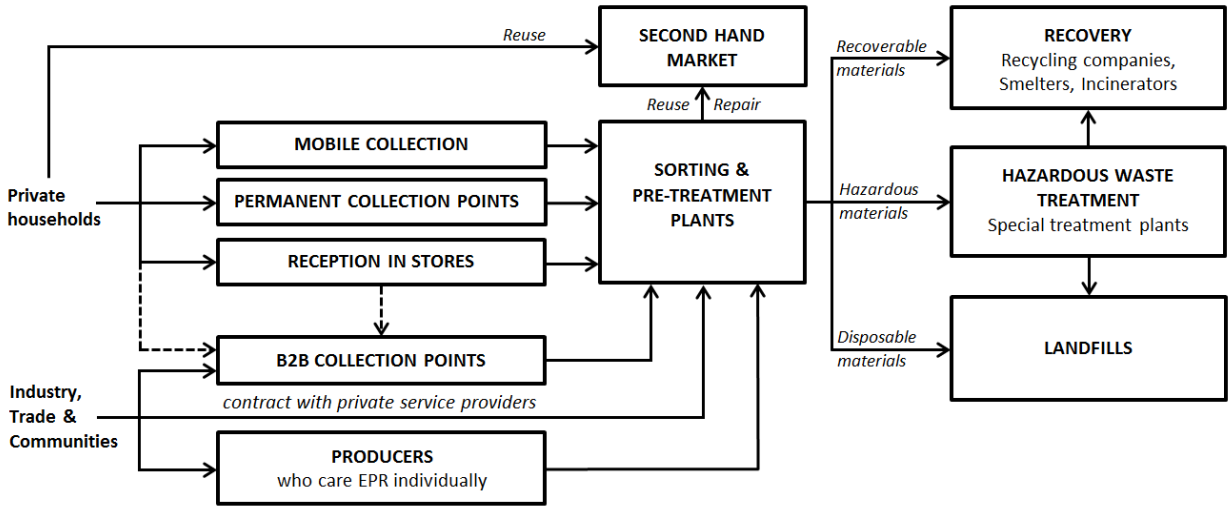

Figure 5. The main stages of the WEEE recovery system in Finland modified from [9].

In the building phase of the Finnish WEEE recovery system, two diverse structures of the supply chain were built. SERTY and NERA (current ERP Finland) had both their own centralized reverse supply chain, where WEEE was transported nationally from collection points to only a few treatment points. Elker, for one, promoted a nationwide decentralized logistics network with over 30 pre-treatment stations and several transport service providers. Logistics services were typically sourced from regional operators, such as from social enterprises or public institutions. Regional handling of WEEE included also the sorting of collected

WEEE into reusable and recoverable fractions. After the first operating years, producers associations have begun to collaborate more and, in consequence, SERTY and ERP Finland have also moved towards a more decentralised system with several regional contractors and, nowadays, most of the reception points are collectively financed by the producers associations.

Collection and transportation are generally the most expensive steps of the WEEE supply chain and, therefore, it is crucial to set up an efficient collection system [10, 11]. The collection of WEEE can be arranged in several different ways; however, the three most common ones are municipal sites, in store retailer take-back and producer take-back [12]. The collection methods generally used for WEEE are drop-off programs, pick-up programs and distance collection. In drop-off programs, consumers can return discarded devices to permanent collection centres, retailers or to containers located in the public places such as in the streets. Drop-off collection programs can also be implemented as temporary collection events. WEEE can also be collected from last users through pick-up programs or, distance collection, such as when WEEE is sent through postal services. [13]

In Finland, collection of WEEE is arranged mainly as a permanent collection; approximately 450 collection points existed around the country in 2011 [14]. Permanent collection points are, in most cases, provided by the municipality and, in some cases, by private companies or social enterprises. Private users and households can bring end-of-life products to the collection points free of charge. Non-private users, such as enterprises and institutes are, generally, not allowed to return WEEE to collection points but are, ordinarily, required to have an individual contract with regional operators to remove and take care of their electronic equipment.

However, a permanent collection system is not efficient in all cases, because e.g. the quantity of returned devices has to be checked and transported regularly [15]. Therefore, in the smallest or the most sparsely populated municipalities of Finland, the recovery of WEEE has been organized as a mobile collection once or twice a year. End-of-life EEE can also be returned to the retailers in association with buying a new one, a corresponding device. Further, since May 1st, 2013, small WEEE including lightning equipment (all dimensions no more than 25 cm) can be returned also with no purchase obligation to electronics shops larger than 200 m^2 or to grocery shops with the minimum area of 1000 m^2.

From the local collection points, WEEE is transported by private transportation providers contracted by producers associations to the regional sorting and pre-treatment stations situated in across the country. In the sorting plants, WEEE is separated for different product co-operatives, weighed and sorted into re-usable and not re-usable ones. Re-usable equipment or components are disassembled, stocked and delivered onwards. Further, the pre-treated recyclable devices and materials are delivered for treatment and material recovery mainly in Finland. Non-recyclable WEEE is stocked in the pre-treatment station until it is delivered to the final treatment plants or disposed. Data on the quantities of various WEEE fractions and operations performed in the sorting and pre-treatment stations are sent to the producers' co-operatives.

4.2.1 *Development of a nationwide recovery network: Case Elker Ltd.*

Elker Ltd. (www.elker.fi) is a non-profit service company established in 2004 by the Finnish producer organisations SELT Association, ICT Producer Co-operative, and FLIP Association. Elker Ltd. has been established as a company providing centralised services to manage practical affairs related to obligations set out in the EU's WEEE directive and to fulfil the corresponding obligations of the Finnish legislation. In 2005, approximately 550 member companies were joined to the producer associations of SELT, ICT and FLIP. The expansion of Elker Ltd. has been rapid in first years; in 2006 there were 700 member companies, while only three years later, in 2010, almost 1000 companies were members of Elker.

To fulfil the requirement of separate collection, Elker built up a nationwide collection network for WEEE. In the implementation phase of the WEEE Directive, the Finnish inspecting and controlling authority of WEEE, the Pirkanmaa Regional Environment Centre, set requirements for the extent and coverage of this network. In the case of Elker, at the minimum requirement, there were 340 permanent collection points in 235 municipalities. In addition to permanent collection, Elker had carried out mobile collection in municipalities without permanent collection points. By the end of 2006, Elker built the network of 390 permanent collection points in 250 of most populous municipalities. Further, mobile collection was carried out twice in the year. The management of permanent Elker collection points are provided chiefly by municipal waste companies and are typically located in the premises of the said companies. In case of mobile collection, Elker appoints the dates and places case-specifically with the municipality in question.

In the view of Elker, the main challenges of the development of the nationwide collection network were related to the smallest collection points, where the physical space of collection cages was limited and the amounts of returned WEEE varied substantially. Therefore, Elker has launched reception points for B2B WEEE, which are also open for private consumers with larger batches of WEEE. The other remarkable challenge has been the collection points outside the official network. In these unofficial collection points, only the most valuable WEEE is received, while WEEE with low or negative value remains the responsibility of producers associations. This unhealthy competition in WEEE collection and recovery resulted in increased operational costs and, further, decreased the cost-effectiveness of WEEE recovery network under producer responsibility.

4.2.2 *An example of a WEEE collection supported by a manufacturer: Case Nokia*

Regardless of numerous methods suitable for a WEEE collection, a large fraction of small end-of-use EEE do not still enter the WEEE recovery systems [16], but lie around not in use or, even worse, are disposed of in inappropriate ways such as with mixed waste [17-20]. The well-known Finnish mobile phone manufacturer, Nokia, has worked for several years to raise consumer awareness and improve the recycling behaviour of consumers. Nokia has, for instance, organized co-operation programs with telecom operators, retail companies, environmental non-governmental organizations (NGO's) and educational institutes, direct consumer campaigns and university events. In addition to permanent take back locations in almost 100 countries, Nokia has also developed alternative channels for consumers. [21]

In Finland, Nokia is taking part in maintaining collection points for the public to return old devices and reporting imported products and recycled waste flows to authorities as a member of the producer associations' service producer company, Elker Ltd. In addition to collection points at recycling centres, old devices may also be returned to the retailer when buying new ones or, alternatively, to an authorized service points or special collection bins (see Fig. 6) for proper end-of-life treatment. The take back bins are a visible collection method to raise awareness and suitable to use in closed or semi-closed communities such as in company premises; however, the use of bins may be challenging from a logistics point of view because bins need to be located in easily accessible and secure locations with an economically viable logistics solution to empty the bins regularly. [21]

Figure 6. A collection bin for mobile phones [21].

Another, one of the easiest and most convenient ways for consumers to return old mobile phones, batteries and accessories for recycling is to use pre-paid mail-back envelopes (see Fig. 7), in which end-users may drop off discarded devices in the nearest mailbox. The envelopes can be distributed to consumers through several ways; they can be mailed directly to the consumers, distributed in retail shops or included in the sales package of a new product. Further, prepaid postage and addresses can even be downloaded and printed from the internet. However, the method has also some drawbacks related mainly to economic inefficiency and logistics when large volumes are in question. [21]

Figure 7. A return envelope for mobile phones [21].

5 THE WEEE RECOVERY IN SWEDEN

5.1 National WEEE legislation

Sweden is one of the European forerunners in WEEE recovery. Sweden has implemented the law of producer responsibility for electrical and electronic producers in 2001 and launched an operational recycling system of WEEE in 2002. The WEEE Directive (2002/96/EC) has been implemented in the form of the ordinance of producer responsibility for electrical and electronic products (Swedish Code of Statutes 2005:209) issued on April 14th, 2005. Recently, the adaptation of the recast WEEE Directive (2012/19/EU) to the Swedish regulations has been initiated in 2012, and the work has continued through 2013. It is expected to be completed in 2014 accordingly to the transposition period of the Directive. [22]

5.2 Swedish WEEE recovery infrastructure

The Swedish system is recognized as one of the most effective WEEE recovery systems in the world not only due to the high amounts of WEEE per inhabitant collected annually (more than 16 kg/inhab./year since 2007 [7]), but also in terms of costs [23, 24]. In Sweden, two producers' responsibility organisations exist to service Swedish EEE producers and manufacturers and are responsible for the management of WEEE recycling. El-Kretsen, established in 2001, is owned by 20 business associations and runs on a not-for-profit basis. El-Kretsen has currently 1300 affiliated companies undertaking the agreement for electrical and electronic products and about 700 customers undertaking the agreement for batteries as defined in the Swedish laws SFS 2005:209, 210 and SFS 2008:834, when the charges paid by the affiliated members are based on their own costs. El-Kretsen collects a major proportion of Swedish WEEE as its total share of WEEE collection was around 80% in 2012. For household collection of WEEE, called 'Elretur', El- Kretsen makes contracts with municipalities and, in the case of business collection, with other collecting

organisations. In 2012, there were approximately 600 municipal recycling centres in operation for all WEEE categories and, further, almost 2000 collection stations for small electronics, batteries and lighting equipment existed in the Swedish municipalities. Household collection is organised in cooperation with Swedish municipal authorities. [22]

The other Swedish operator of WEEE, the Swedish Association of Recycling Electronics Products (EÅF), has provided WEEE collection points in the members' retail stores nationwide since 2008. In 2012, its share of collected WEEE in Sweden was around 20%. Basically, the EÅF system in parallel with the El-Kretsen's Elretur system; however, because all municipalities have not retail shops of EÅF, it has to pay a fee as other members of El-Kretsen for the part of its members' WEEE that is collected by El-Kretsen. [23] In addition to these nationwide municipal recycling centre and in-store retail collection systems, some trials of property-close source collection of WEEE are also provided in some Swedish city centres with good results [25-27].

In addition to networks of free collection for households, there are also around 550 private collection points for companies and organisations in 2012. Collection from organisations is partly organised in cooperation with municipal authorities and partly through directly contracted transporters. In addition, some collection services for certain types of product, such as light sources, are provided by El-Kretsen [22]. It is important to note that, in Sweden, the disposal services are free of charge also for business. This is due to using a return certificate, through which the party disposing of the object guarantees that the number of units returned corresponds with the undertaking's purchase of new equipment. [24]

At the recycling centres, products are sorted into the following seven categories [22]: 1) Assorted electrical goods, 2) televisions and monitors, 3) fridges and freezers, 4) large white goods, 5) lighting, 6) fluorescent tubes, and 7) portable batteries. After deposited at the collection points, WEEE is transported onwards to the recycling plants chosen by El-Kretsen, where the products are unloaded and registered before undergoing initial sorting and disassembly. Disassembly involves removing environmentally hazardous substances and components that require special processing. The main stages of the WEEE recovery system in Sweden are presented in Fig. 8.

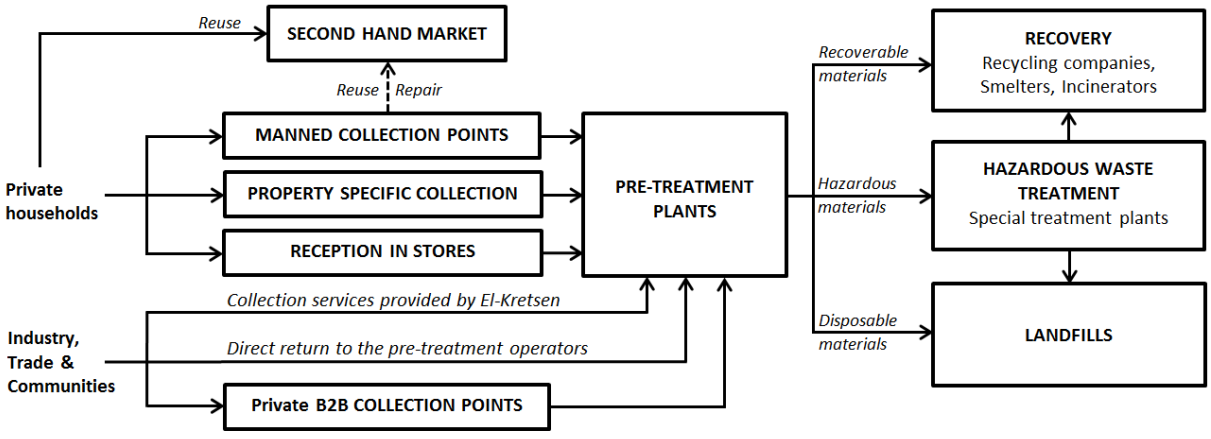

Figure 8. The main stages of the WEEE recovery system in Sweden based on [22, 24].

El-Kretsen makes contracts with transportation companies and treatment plants (a recycling service provider) based on five different categories: 1) assorted electrical and electronic goods, 2) large white goods, 3) fridges and freezers, 4) batteries, and 5) lightning. Depending on the segments, El-Kretsen has split Sweden into 1 to 14 different collection areas of various service providers based on volume, logistics costs and location of pre-processing. [22, 24] For instance, in 2012, there were five collection areas for fridges and freezers and ten areas for large white goods while a single collection area of lightning equipment was extended over the whole country. [22]

The procurement of recycling services is conducted through an open tender procedure. All tenders who met the environmental and quality requirements had an opportunity to take part in the procurement process. The transport procurement is implemented with the same manner, the transportation volume of a collecting area is divided between two to three transportation companies so that transportation routes are optimised. Each transport supplier is specialised to deal with a particular category and region. A web-based system was introduced already in 2007 to disseminate and cover information. Transporters have access to stock reports that the collection facilities have submitted. The transporters plan their shipments and use handheld computers to report back. The recyclers can then see when the transporters are planning to deliver electrical and electronic waste. The cash flow between El-Kretsen and a pre-treatment service provider is based on the material value. The treatment service provider “buys” the waste from El-Kretsen; although their pay from the products only if they get a profit. In the case of large white goods, television sets, when the value is negative; EL-Kretsen pays to the treatment service provider. [22, 24]

El-Kretsen has taken care of the WEEE recycling; and it is not involved with the re-use of remanufacture. Currently, there is no formal second hand market for the products collected through the ‘Elretur’ system [23]. However, the organisations responsible for collection points may take care of re-use when consumers return the product to a collection point [24]. Moreover, some recycling centres have also special containers, where visitors can place their discarded but functional electronics [23]. The basic feature of the Swedish system is the efficiency of materials flows through centralized recycling operations and optimised transportation. Large companies dominate the recycling business and, according to Lehtinen et al. [24], social enterprises have a very small role in recycling in Sweden; El-Kretsen supplied 5% of its volume from social companies, in order to show social responsibility.

6 THE WEEE RECOVERY IN NORWAY

6.1 National WEEE legislation

Norway has a long history in regulating WEEE. It was one of the first countries in the world that regulated WEEE in 1998 and, in addition, started to run the WEEE recovery system in 1999. Even though Norway is not an EU Member State, it is obliged to implement EU Directives in its national legislation by the EEA (European Economic Area) agreement. Therefore, the Norwegian legislation related to WEEE (Chapter 1 of the Waste Regulation) was revised to comply with the WEEE Directive in June 1st, 2006. At the same time, a national EEE-register, called EE-Registeret, owned by the Norwegian Environment Agency was established. The register comprises of an administrative and a web-based module, providing overview of all imports and

exports of EEE and WEEE from all producers and importers. The Norwegian WEEE legislation has also been amended; the latest amendment was implemented as recently as in August 22nd, 2013.

The current definition of WEEE in Norwegian legislation is broader than in EU. In addition to ten categories established according to the WEEE Directive 2002/96/EC, the Norwegian legislation includes also following four extra categories comprising WEEE mainly from industry and business:

11. Automatic machines for selling beverages, food, cash points and equipment delivering automatic products
12. Cables, wires
13. Electronic equipment (passenger and freight lifts, moving staircases, winches)
14. Mounted rigid equipment for heating, air-condition and ventilation.

6.2 Norwegian recovery infrastructure for WEEE

At this moment, five collectively financed take-back companies (Elretur AS, Elsirk AS, ERP Norge AS, RENAS AS and Eurovironment AS) are registered and authorized by the Norwegian Environment Agency. Two of these companies, Elretur and RENAS, are non-profit companies owned by the Electric and Electronic Industry and Business Sector and they have been in the business already more than 10 years. Elretur has concentrated of consumer WEEE (B2C) and RENAS on WEEE from industry (B2B). [28] Take-back companies are required to ensure free collection from enterprises, distributors and municipalities collecting WEEE and confirming that the collected WEEE is treated pursuant to the requirements of the Norwegian waste regulation. Further, collection and accepting WEEE should be in line with the geographical areas of Norway where member EEE-companies are located or have previously sold or supplied EEE. In addition, the proportion of the total collected WEEE has to be in a correspondence with the members' share of the total supply of goods. Currently, more than 4800 companies have joined to the collectively financed take-back companies while no individually financed take-back companies exist in Norway [29].

In the Norwegian WEEE system, WEEE collection is organized on a municipal level by inter-municipal waste companies or by stores. Material flows of WEEE in Norway are outlined in Fig. 9. Despite the good functionality of the system, resources in the WEEE are not yet utilized optimally in Norway because the most of treatment facilities are centred in near the capital Oslo in the southern part of the country causing long and demanding transportation conditions for WEEE. Therefore, some unexplored potential for new business and reverse chain management of WEEE still exists [28].

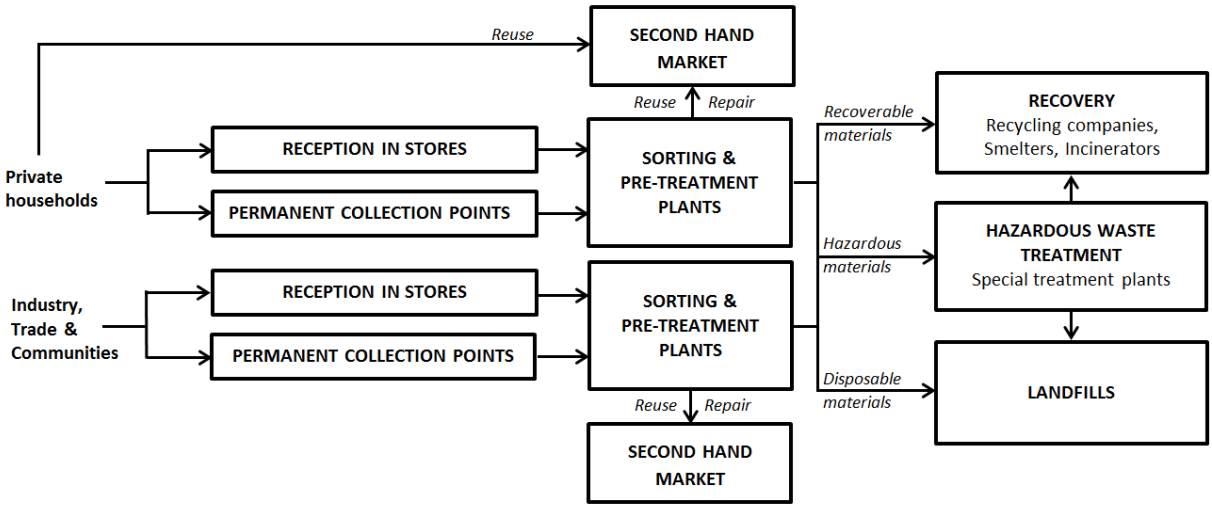

Figure 9. The main stages of the WEEE recovery system in Norway based on [28, 30].

7 COMPARATIVE ANALYSIS OF THE NORDIC WEEE RECOVERY SYSTEMS

7.1 Realisations of the WEEE recovery systems

As forerunners of WEEE management, the Swedish and Norwegian WEEE recovery systems were already in operation when the Finnish system was initiated as the consequence of the implementation of the WEEE Directive. In the planning phase of the Finnish WEEE recovery system, the Swedish and Norwegian systems were benchmarked by Finns to identify the factors of a successful and efficient WEEE recovery system. Therefore, the Nordic recovery systems have several similarities. In all three countries, for example, the WEEE management system is financed by a fee included in the price of EEE. Moreover, the producer responsibility has been launched through collective systems, where the representatives of foreign and domestic producers have transferred responsibility over discarded electronics to producers associations and onwards to service providers. Further, WEEE collection is mainly organized on a municipal level and municipalities have a significant role in arranging and maintaining several hundreds of permanent collection points around the countries.

In addition to similarities, there are also some fundamental differences in the Nordic recovery systems. The main difference between the Nordic systems occurs in the number of the organizations involved with WEEE management. In Finland and Norway, several collectively financed take-back companies manage the collection and recycling operations while only one organization (El-Kretsen) services all producers and manufacturers in Sweden. Therefore, the Finnish and Norwegian systems are regarded as more fragmental realisations. Another main difference is related to the recovery routes of WEEE. In the Finnish system, the recovery route depends on the brand but not the source (from private consumer or from business) and, therefore, all WEEE of a certain producer is treated at the same pre-treatment station notwithstanding the type of the WEEE. However, in the Norwegian case, WEEE collected from private consumers follows a different treatment route than those collected from business. The basic characteristics of the national WEEE recovery systems in the Nordic countries are overviewed in Table 4.

Table 4: The overview of national WEEE recovery systems in Finland, Sweden and Norway.

Characteristic	Finland	Sweden	Norway
Legislation:	Directive 2002/96/EC implemented in 2004, no exemptions. Finnish Waste Act revised in 2011 and amended in 2014 to comply with the Directive 2012/19/EU.	Law of producer responsibility for EE products into force 2001, revised in 2005 to comply with the Directive 2002/96/EC. Amended in 2014 to comply with the Directive 2012/19/EU.	Law of Scrapped EE Products into force 1998, amended in 2006 and 2013 to comply the requirements of the Directives 2002/96/EC and 2012/19/EU. The definition of WEEE broader than in EU.
Financing method:	Recycling fee included in the EEE prices.	Recycling fee included to the EEE prices.	Recycling fee included to the EEE prices.
Launch of the separate collection:	2004, in consequence of the WEEE Directive.	2002	1999
Operators:	5 PRO's formed in 2004: • FLIP ry • ICT-tuottajaosuuskunta • SELT ry • SERTY ry • ERP Finland ry (Elker Ltd. is founded by Flip, ICT and SELT)	2 collective take-back & financing systems: • El-Kretsen (municipal collection points and B2B collection) • EÅF (in-store collection)	5 collectively financed take-back companies: • Elretur AS (only C2B) • RENAS AS (only B2B) • Elsirk AS • ERP Norge AS • Eurovironment AS
Collected amounts of WEEE:	9.5 kg/inhab./year (in 2010)	17.2 kg/inhab./year (in 2010)	28.0 kg/inhab./year (22.0 kg/inhab./year in compliance with Directive 2002/96/EC) (in 2010).

7.2 Amounts of collected WEEE

Separate collection is a precondition to ensure specific treatment and recycling of WEEE. Therefore, according to the Directive 2002/96/EC, a separate collection, treatment, recovery and environmentally sound disposal of WEEE had to be arranged since August 13th, 2005. Further, a general collection target (4 kg/inhab./year) and treatment requirements, recovery and recycling rates (up to 80 and 75 w%) had to be realised by December 31st, 2006.

The setting up the WEEE recovery infrastructure in the Nordic countries has succeeded. Norway and Sweden are reckoned as global forerunners in WEEE management owing to a national WEEE legislation and operational recovery system even prior the EU legislation. In Finland, for one, the legislative basis has been enacted and a functional infrastructure has been built in a relatively short time accordingly the WEEE Directive 2002/96/EC. In all these countries, the collection requirement (4 kg/inhab./year) of the Directive has clearly been exceeded (see Fig. 10) and, in addition, good recovery percentages have been managed to achieve (see Table 5).

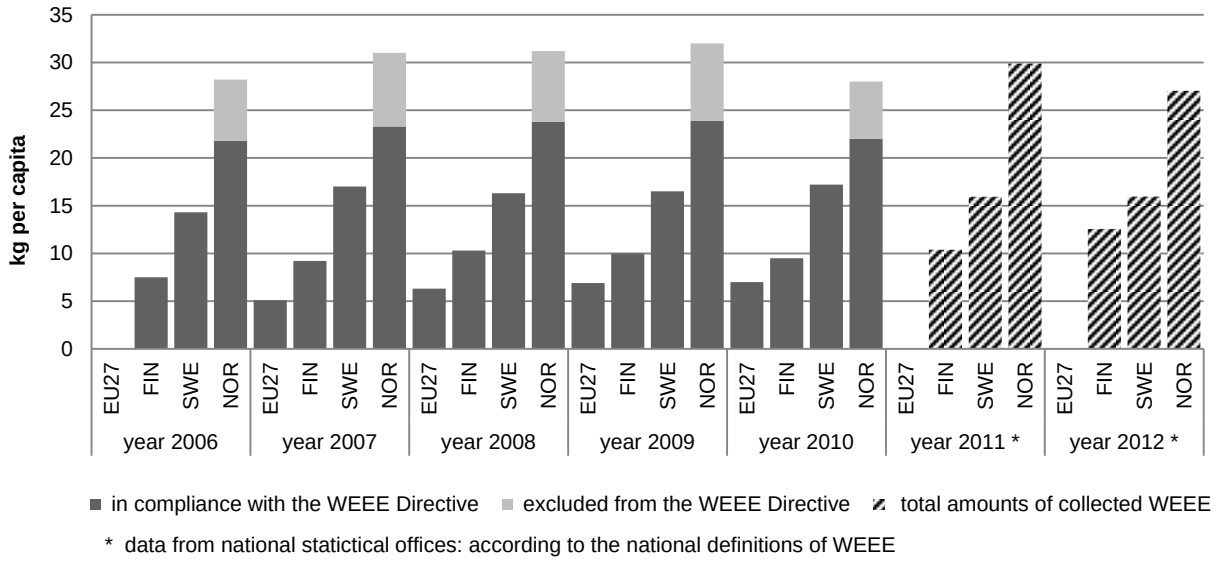

Figure 10. Amounts of collected WEEE per capita in Finland, Sweden and Norway in 2006-2012 compared to the average of EU 27 [7, 31-34].

As seen from Fig. 10, Norway has the highest amounts of collected WEEE per capita. Around a fifth of the collected WEEE in Norway consist of various automatic machines, cables and wires, as well as large electronic equipment for conveying people, commodities or air, which are included in the national legislation but excluded from WEEE Directive. Even if that portion is not taken into consideration when comparing the Nordic collection amounts of WEEE, Norway has still the most effective collection. When Swedish collection amounts are observed, it can be noticed that the collection level has been reached the steady annual level of 15 kg/capita in the course of years. As for Finland, the WEEE recovery network has not been set up until 2006 and, therefore, the collection amounts per capita still remains in the substantially lower level than in Norway and Sweden. However, based on the data from Statistics Finland, a clear improvement in the collection amounts occurred in the very recent years.

When the collection amounts of WEEE in the Nordic countries is considered as total tonnages, the highest quantities have been gathered up in Sweden. The annual tonnages of WEEE collected in Finland, Sweden and Norway in 2006-2012 are illustrated in Fig.11. Collected WEEE amounts have been categorized by the source and, in the case of Norway, also by the definition until 2010 accordingly the official EU statistics. Since 2011, only the total tonnages of collected WEEE are included in Fig. 11 because classified statistics of WEEE are not annually released by national authorities or WEEE operators.

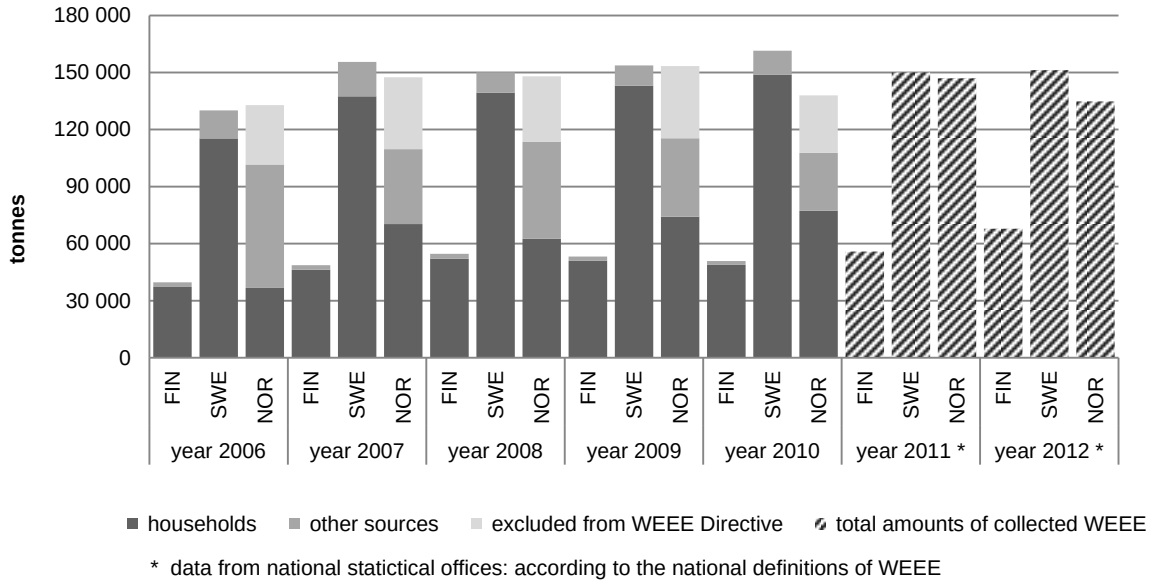

Figure 11. Amounts of collected WEEE from households and other sources in Finland, Sweden and Norway in 2006-2012 [7, 31-34].

Despite of the good annual WEEE collection and treatment rates in Nordic countries, the tendency of collected WEEE amounts has recently turn slightly down in Norway and Sweden, as seen from Fig. 10 and 11, while total tonnages of collected WEEE in Finland is still increasing. There is no certain reason to this phenomenon but it seems that the Norwegian and Swedish WEEE recovery systems have been reached a certain saturation point of collection efficiency while the Finnish system is still in its growing phase because of its young age. It is generally interpreted that the prolonged instability of the European and world economy has also weakened people's eagerness to replace functional devices by later models. Bernstad et al. [25], for ones, have suggested that the trend towards smaller and more light-weight electronic devices have also an impact on the decreasing tendency. Moreover, a Finnish study of Toppila [14] pointed out that leakage outside the official WEEE recovery system is also increased due to the continuously rising metal prices.

7.3 Compliance with recovery and recycling targets of the WEEE Directive

The first official data from Finnish producer registration system from 2006 were reported to the EU in June 2008. According to the EU statistics [7], a total of 39,678 tonnes or some 7.5 kg/pers./inh./year of WEEE were collected separately in Finland in the very first year after the implementation of the WEEE recovery system. Four years later, in 2010 (see Table 5), the total amount of collected WEEE in Finland had increased by around 30% to 50,867 tonnes or approximately 9.5 kg/pers./inh./year. Meanwhile, a total of 161,444 tonnes of WEEE (approximately 17.2 kg/inhab./year) were collected in Sweden and 107,767 tonnes (approximately 22 kg/inhab./year) in Norway in the compliance of WEEE Directive. [7] A compositional breakdowns and amounts of the collected WEEE in 2010 are represented in Table 5. According to the European statistics [7], the rate targets set down in the WEEE Directive for re-use, recycling and recovery of WEEE were fulfilled in every category. The total rates of recovery and recycling in Finland were increased from those in 2006, to 91.5% for recovery and 88.1% for material recycling, while the rate of re-use was more than halved, to 0.4%

in 2010. The total rates in Sweden and Norway were equivalent to that in Finland; 91.8% and 89.9% for recovery, and 83.8% and 81.1% for recycling, respectively. Further, re-use rates remained at 0.1% in Sweden and 0.4% in Norway.

According to official statistics of EU in 2010 [7], portions of WEEE categories follow fairly well to each other in Finland and Sweden while a compositional breakdown of WEEE collected in Norway differs substantially from them (see Table 5). In Norway, the amounts of collected large household appliances (40.9 w%) were lower than those in Sweden (46.7 w%) and especially in Finland (54.5 w%), and also the portion of collected consumer electronics (17.2 w%) remained substantially from that in Finland and Sweden (23.8 w% and 23.4 w%). However, portions of lightning equipment (7.2 w%) and EE tools (9.3 w%) were substantially higher in Norway as in Finland (1.9 w% and 0.5 w%) and Sweden (2.7 w% and 0.9 w%). Also monitoring and control instruments were collected tenfold in Norway compared to Finland and Sweden.

Divergent breakdown of Norwegian WEEE can be presumed to result from its origin; in Norway, a considerable amount of WEEE is collected from industry in comparison with Finland and Sweden. According to EU statistics [7], totally 30 529 tonnes or some 28.3% of B2B WEEE were collected in Norway in compliance with the WEEE Directive in 2010, while its proportion remained 7.8% (12,549 tonnes) in Sweden and less than 4% (2010 tonnes) in Finland. As a conclusion, it seems that specialised operators and parallel routes for WEEE only from private households or only from business improve the efficiency of the WEEE recovery system. On the other hand, the amounts of collected B2B WEEE in Sweden and Finland may remain at a lower level than in Norway because the WEEE Directive has been implemented to focus on WEEE only from private consumers and households. In consequence, all B2B WEEE, even if collected and treated in the compliance with the Directive, has not necessarily been reported to the official EU statistics due to lack of reporting obligations of Member States. Some uncertainty about EU statistics arises also from the possibility to mix B2C and B2B WEEE flows in the collection stage. For instance, not only companies and other representatives of business sector apply B2B collection points of Finnish WEEE recovery system; also private consumers and retailers are allowed to use these points to return larger batches of WEEE regardless of its origin.

Table 5: Amounts of collected WEEE and achieved recovery and recycling rates in Finland, Sweden and Norway in 2010 in compliance with the Directive 2002/96/EC [7].

	Categories		**Amount** [tonnes]	**Portion** [w%]	**Recovery/ target** [%]	**Re-use and recycling/target** [%]
Finland	1	Large household appliances	27,698	54.5	93/80	88/75
	2	Small household appliances	1320	2.6	84/70	82/50
	3	IT and telecom equipment	8034	15.8	92/75	92/65
	4	Consumer electronics	12,117	23.8	90/75	88/65
	5	Lightning equipment	961	1.9	91/70	86/50
	6	Electrical and electronic tools	276	0.5	94/70	98/50
	7	Toys, leisure and sports devices	99	0.2	84/70	82/50
	8	Medical devices	53	0.1	75/-	75/-
	9	Monitoring & control instruments	119	0.2	78/70	76/50
	10	Automatic dispensers	189	0.4	98/80	78/75
	Total / average		**50,867**	**100**	**91.5**	**88.5**
Sweden	1	Large household appliances	75,341	46.7	91/80	86/75
	2	Small household appliances	8959	5.6	91/70	74/50
	3	IT and telecom equipment	31,756	19.7	92/75	84/65
	4	Consumer electronics	37,809	23.4	94/75	82/65
	5	Lightning equipment	4396	2.7	94/70	93/50
	6	Electrical and electronic tools	1531	0.9	82/70	71/50
	7	Toys, leisure and sports devices	697	0.4	82/70	70/50
	8	Medical devices	519	0.3	92/-	86/-
	9	Monitoring & control instruments	91	0.1	92/70	82/50
	10	Automatic dispensers	345	0.2	73/80	68/75
	Total / average		**161,444**	**100**	**91.8**	**83.9**
Norway	1	Large household appliances	44,031	40.9	94/80	84/75
	2	Small household appliances	7,592	7.0	89/70	79/50
	3	IT and telecom equipment	16,496	15.3	87/75	79/65
	4	Consumer electronics	18,479	17.2	84/75	76/65
	5	Lightning equipment	7,760	7.2	90/70	86/50
	6	Electrical and electronic tools	10,009	9.3	88/70	85/50
	7	Toys, leisure and sports devices	479	0.4	81/70	74/50
	8	Medical devices	584	0.5	86/-	79/-
	9	Monitoring & control instruments	2,131	2.0	88/70	83/50
	10	Automatic dispensers	206	0.2	86/80	69/75
	Total / average		**107,767**	**100**	**89.9**	**81.5**

8 BEST PRACTICES OF THE NORDIC WEEE RECOVERY SYSTEMS

The primary goal of the European WEEE legislation is to prevent waste generation and to promote re-use, recycling and other forms of recovery of such waste. To fulfil the requirements of WEEE Directive related to WEEE recovery, comprehensive collection networks for WEEE have been built up in the Nordic countries. In addition to hundreds of permanent collection points situated in recycling centres and shops nationwide, more allocated options, such as property-close and mobile collection, have also been developed to ensure a reasonable opportunity to return discarded EEE appliances for recovery. At the quantitative point of view, the most effective recovery system has been built up in Norway as an annual collection amount reached 30 kg per capita at first time already in 2007 and, since then, it has steadily remained above 25 kg per capita despite of the trend towards smaller and more light-weight electronics

The key motives of the Nordic WEEE recovery systems are not only the national and EU legislation but also the market value of the materials contained in WEEE. However, long transportation distances, especially in the northernmost parts of the countries, bring challenges to managing the WEEE recovery systems effectively. The most competent recovery system at the material efficiency point of view is implemented in Sweden. In the Swedish system, there is no formal second hand market for the products collected through the system. Therefore, PROs are responsible only for the management of the WEEE recycling system, which can then be optimized from an efficient material flow point of view. The other key issue is the one dominant service provider for the whole country. By controlling the whole WEEE recovery chain, El-Kretsen is able to offer practical and cost-effective solutions and optimized transportation from collection points to the centralised treatment plants. Lee and Sundin [23] argued, that the standardised system at the national level provides also clear roles and an efficient way for all stakeholders to operate and, therefore, increases understanding and satisfaction amongst the stakeholders resulting in improved efficiency of the Swedish WEEE recovery system.

The WEEE legislation highlights that private consumers ought to be able to dispose of WEEE through the official system without any charge while the industry, educational institutes and communities may have to pay for the use of it. Currently, only small amounts of WEEE from industry (B2B WEEE) are reported as collected in compliance with the WEEE Directive in EU Member States, including Finland and Sweden. However, according to recent studies of Huisman et al. [35] and Peagam et al. [36], a remarkable amount of B2B WEEE is properly collected but still not reported due to organisations' practises to dispose their B2B WEEE through contractors or some informal arrangements. That means complementary recycling streams for B2B WEEE exist in parallel with the official WEEE recovery system in EU [35, 36]. The feature of the Norwegian system, where WEEE collected from private consumers follows a different treatment route than those collected from business, enables more flexibility to select optimal recovery routes and also promotes the re-use of B2B devices improving the efficiency of the recovery system. Further, as a non-member of EU, all EEE products imported and exported are recorded in Norway, which enables a better control of EEE and WEEE flows and more accurate calculations of WEEE amounts leaking outside the recovery system. Therefore, the Norwegian system as a whole can be managed more efficiently than the systems in Finland and Sweden.

Reasonable, nationwide returning possibilities of EOL devices and efficient management of WEEE recycling systems are still not enough for creating a sustainable WEEE recovery system; the level of consumers' understanding of the importance of separate WEEE collection and their behaviour regarding to returning EOL devices to collection points have also a significant influence on the effectiveness of WEEE recovery. Scandinavians are typically highly aware of environmental issues and, therefore, also willing to take advantage of established WEEE recovery systems. Therefore, it can be said that one of the biggest strengths of the WEEE recovery systems in the all three Nordic countries is a strong civic support of environmental protection.

9 CONCLUSIONS

The purpose of this paper was to provide a comprehensive overview of the European WEEE Directive and its implementation in the Nordic countries. The WEEE recovery systems in Finland, Sweden and Norway are evaluated from the point of resource efficiency to identify successful and efficient factors as well as the best practices. Based on this study, it can be concluded that the national implementations of the WEEE Directive and development of the WEEE recovery infrastructures have succeeded in the Nordic countries. In addition to Norway and Sweden as global forerunners of WEEE management, also Finland has enacted the legislative basis and has built the functional infrastructure successfully in a relatively short time after the implementation of the WEEE legislation in the EU. The collection requirements of the Directive (4 kg/inhab./year) have clearly been exceeded and good recovery percentages of WEEE have been achieve in all three countries. Since 2007, the WEEE collection rates in Finland, Sweden and Norway have exceeded 9 kg/inhab./year despite of their sparse populations, standing in the best third in the context of the European Union. Therefore, we believe the WEEE collection systems as established in the Nordic countries have evidently advantages, which can be considered by countries implementing national WEEE legislation or setting up WEEE collection networks.

In addition to the efficient management of WEEE recovery systems, the level of consumers' understanding of the importance of separate WEEE collection and their behaviour regarding to returning EOL devices to collection points have also a significant influence on the effectiveness of the WEEE recovery. Even though Swedish and Norwegian experiences with long history of WEEE recovery prove that raising consumer awareness leads to environmentally sound behaviour and improve WEEE recovery efficiency, more information and communication is still needed to fully realize the potential of WEEE recovery and to establish a sustainable WEEE recovery system.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

ACKNOWLEDGEMENTS

The financial support of the Thule Institute's Doctoral Program and the Centre of Northern Environmental Technology (NorTech Oulu) at the University of Oulu are gratefully acknowledged.

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