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High-quality collection and disposal of WEEE: Environmental impacts and resultant issues

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ABSTRACT

Life cycle assessment of the collection, transport and recycling of various types of waste electrical and electronic equipment (WEEE) in Norway shows that small amounts of critical materials (refrigerants, precious/trace metals) are vital for the overall environmental accounts of the value chains. High-quality recycling ensures that materials and energy are effectively recovered from WEEE. This recovery means that responsible waste handling confers net environmental benefits in terms of global warming potential (GWP), for all types of WEEE analysed. For refrigeration equipment, the potential reduction of GWP by high-quality recycling is so large as to be of national significance. For all waste types, the magnitude of the net benefit from recovering materials and energy exceeds the negative consequences of irresponsible disposal. One outcome of this may be widespread misunderstanding of the need for recycling. Furthermore, framing public communication on recycling in terms of avoiding negative consequences, as is essentially universal, may not convey an appropriate message. The issue is particularly important where the consumer regards products as relatively disposable and environmentally benign, and/or where the "null option" of retaining the product at end-of-life is especially prevalent. The paper highlights the implications of all these issues for policy-makers, waste collectors and recyclers, and consumers.

1. Introduction

The collection, recycling and treatment of waste electrical and electronic equipment (WEEE) has in recent years come into increasing focus as an important element of national and international waste and environmental management strategies. WEEE is recognised as a rapidly growing waste stream, in terms of its overall volume but also in terms of its environmental significance. Scandinavian territories have been at the forefront of developments, with high collection rates and well-developed systems for waste handling and treatment (see Ylä-Mella et al., 2014). Widespread collection and recycling of WEEE offers considerable environmental advantage compared to other disposal options. Two main factors are identified:

- WEEE contains many elements that result in direct environmental impacts if disposed of improperly – they contribute to global warming, and some are toxic/hazardous.
- Recycling of WEEE leads to the recovery of valuable metals, plastics and other components. This brings obvious economic advantages, but also environmental benefits where recovered materials obviate the need for production of virgin materials. Even where material recovery is not possible or practical, energy recovery as part of a well-managed incineration process recovers some of the environmental burden of treatment.

Both policy-makers and consumers generally focus much more on the first of these than the second. *Avoiding negative consequences* is arguably the bedrock of mainstream discourse on the environment. This is wholly unsurprising, not least since legislation and regulation of activity in the environmental perspective is framed almost entirely in terms of avoiding negative consequences. The two principal European directives relating to WEEE, namely the revised WEEE Directive (2012) and the RoHS or Restriction on the Use of Hazardous Substances in Electrical and Electronic Equipment Directive (2011), are both framed in this fashion. Furthermore, at the macro (global political) scale, avoiding negatives *is* the ostensible purpose of environmental activity – the Kyoto Protocol (1997) for limiting the negative effects of greenhouse gases being a widely recognised example. The paper shows how avoiding negatives (direct environmental impacts) is most important for some, but not all, WEEE product groups and end-of-life

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value chains. The policy and practical implications of this finding are explored. Both recyclers and consumers have significant roles to play, and hence both policy and public communication instruments are vital.

As in many other European countries, Norwegian WEEE collection and recycling is almost entirely driven by the concept of Extended Producer Responsibility (EPR) which requires those putting items on the market to be ultimately responsible for their end-of-life treatment (Sander et al., 2007). EPR is implemented via a number of governmentally approved companies for the take-back, treatment and processing of WEEE. These companies are membership organisations, funded by subscriptions from technology producers and importers. Elretur AS is one of the biggest such organisations in Norway. It is responsible for tens of thousands of tonnes per year of WEEE from a network of several thousand collection points nationwide. Norway is a large country, with a sparse, widely separated population outside the major cities. National WEEE regulations (Milkødirektoratet, 2013) include a responsibility on approved companies to collect from all parts of the country. This poses considerable challenges in terms of costs, logistical efficiency and consequent emissions. Optimising these parts of the value chain is a distinct field of research in itself, which is not considered in detail here.

Examination of the environmental burdens and benefits of WEEE recycling via the Life Cycle Assessment (LCA) approach has become fairly prevalent in the past decade or so. Studies have included overall examinations of WEEE recycling value chains in particular countries or regions, such as Japan (Menikpura et al., 2014), Switzerland (Hischier et al., 2005; Wäger et al., 2011) and Lombardia in Italy (Biganzoli et al., 2015). Others include examinations of particular product groups in detail, such as refrigerators (Xiao et al., 2015) and fluorescent lamps (Tan et al., 2015). Studies vary considerably in range and scope – the part of the value chain that is studied in detail, the range of environmental indicators considered, the level of detail in the description of treatment and recycling, the level of data in inventory data, and so on.

1.1. Waste management

Many studies focus on the WEEE value chain as a whole – incorporating raw materials extraction, manufacturing, transport, use and disposal. Studies focusing on end-of-life are relatively rare, moreover they often focus on waste management as it is intended to happen. For example, products are assumed to be subjected to high-quality recycling that yields a net environmental credit to the overall value chain via avoided materials or energy production (Xiao et al., 2015 provides a typical example). Such a perspective is captured in our "best practice" recycling scenarios described below.

However, the reality is that recycling may not proceed exactly as intended in best practice. Here, we provide a novel focus on waste management activities by presenting disposal scenarios that are realistic yet non-optimal. Crucially, we highlight the relative responsibility of different actors in the value chain, eventually showing that the primary focus should be on different actors for different product groups. Specifically, optimal treatment of mobile phones depends primarily on consumer action, whereas for the other product groups, the actions of recyclers and processors are likely to be most important for the overall environmental account of the value chain.

The work presented in this paper concerns environmentally responsible collection, treatment and disposal of WEEE, with specific reference to the activities of Elretur, whose responsibilities extend along the value chain. From Elretur's standpoint, the work serves the following purposes:

- Analysing the take-back and recycling value chain to identify, document and communicate the environmental burdens and benefits therein.
- Identifying those parts of the value chain which impact most on the environment.
- Highlighting activities which need particular attention to ensure good overall environmental stewardship of the waste.

2. Material and methods

The study uses Life Cycle Assessment (LCA) – see for example, EU-European Commission (2010) – a standardised approach to systematically assessing the life cycle environmental impacts of products. As per the relevant ISO standards 14040 and 14044, there are distinct phases in the assessment – goal and scope definition, inventory analysis and impact assessment, each coupled with an interpretation stage. LCA is applied specifically here to the waste treatment parts of the value chain, following relevant European Commission guidelines (Simone and Rana, 2011).

This study focuses on three specific types of electronic waste – refrigerators, LCD screens and mobile telephones, considered separately. The goal and scope of the study was to calculate selected life cycle environmental impacts of the specific products along the parts of the value chain highlighted in Fig. 1, with a view to addressing the issues listed above with respect to Elretur's operations and public activity/communication. The functional unit for the study was the waste treatment of one typically-sized device in each of the product groups. More precisely, it was treatment of a mass of waste equal in mass to a typical device in each group. These masses were taken from Elretur's own data as 51 kg for refrigerators, 20 kg for LCD-TVs and 140 g for mobile phones, with the latter consisting of a 115 g phone plus a 25 g battery.

The collection, distribution and processing system for Norwegian WEEE operated by Elretur is highly complicated – owing to geographic factors, coupled with quite different treatment pathways for different types of WEEE. The system is broadly hub-and-spoke in nature. Elretur's responsibility for the waste begins at the collection sites across the country. These include municipal waste sites, electronics dealerships and others. Earlier parts of the extended value chain relate directly to consumer behaviour and hence the factors that influence if, when and how end-of-life WEEE reaches the initial collection site. This represents a substantial research area in its own right, and is not considered here.

Waste is classified in one of six product groups at the collection points. It is collected, with greatly varying frequency depending on location, and shipped to one of about 12 regional reception centres. Some types of waste demand a pre-treatment step, for example the removal of batteries from mobile phones. In some other cases, depending on waste type and location, pre-treatment consists of an intermediate reception/holding step, where waste from a number of locations is collated before onward transport. Then, depending on waste type, it is transported to treatment or recycling locations – most in Scandinavia, with some elsewhere in Europe and further afield.

Fig. 1 shows the system boundaries of the study and highlights the parts of the extended value chain in specific focus here. There are three transport stages from collection to treatment. Very detailed information was available on transport – over 8000 lines of data captured the collection and onward transport arrangements from every site in the country. This was combined with GIS data for distances between collection/treatment locations to compute accurate national weighted-average transport distances for every waste type at every stage of the chain. Further data enabled the modes of transport (road, rail or sea) to be identified and hence accurate computations made of the emissions and environmental impacts arising from transport.

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