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Analysis of end-of-life treatments of commercial refrigerating appliances: Bridging product and waste policies

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ABSTRACT

This paper analyses the relationships between product design and end-of-life treatment, but also between product and waste policies, based on a relevant case study. Commercial refrigerating appliance is a suitable case study due to its recent inclusions in the scope of two important European pieces of legislation, the Waste of Electric and Electronic Equipment Directive and the Ecodesign Directive. Commercial refrigerating appliances are business to business products with several peculiarities such as: customized design, high range of dimensions, content of complex electronic components and parts difficult to treat and recycle. The method used for the analysis: formalization, through literature review and survey of recycling plants, of treatments applied to the studied waste product; investigation of problems and difficulties in the recycling plants; identification of possible product-related improvement strategies; definition of workable product design options. For the analysis of actual recycling practices, data has been gathered through interviews with four European recyclers, and by consulting manufacturers and other experts of these products. Several potential design options to improve the recyclability of these products are identified and discussed, such as the design for dismantling of some key components, the restriction of some blowing agents and the labeling of insulation foams. The article finally shows how the enforcement of these design features, in particular through mandatory product policies such as the Ecodesign Directive, could facilitate their end-of-life treatment and hence ease the compliance with the waste legislation.

1. Introduction

Cooling and freezing appliances represent one of the most relevant categories of Waste of Electric and Electronic Equipment (WEEE). In terms of waste flow, they account for about 17.8% of total WEEE produced in the European Union (EU) (Huisman et al., 2008) and thus the corresponding environmental impacts. Research done in the past showed that most of the environmental impact of these appliances was due to the use of refrigerants as chlorofluorocarbon (CFCs) and hydrochlorofluorocarbons (HCFCs) (Molina, 1996). These substances have been identified as ozone-depleting substances by the Montreal Protocol on Substances that Deplete the Ozone Layer since 1987 (UNEP, 1987). In addition, the EU adopted the Regulation 2037/2000, which required Member States to remove those substances from all types of refrigeration equipment before any end-of-life (EoL) treatment (EU, 2000).

The evolution of refrigerators has increased their complexity in their composition, with the consequence of having products more difficult and less economically attractive to recycle (Allwood et al., 2011). Refrigerators can contain several other hazardous substances as: mercury (in switches and lamps), lead and cadmium (in batteries, capacitors and other electronic components). They contain also various valuable materials including base metals, plastics, scarce and precious metals.

As result of all these facts, various types of refrigerating appliances have entered within the scope of the waste legislation. Household cooling and freezing appliances (including refrigerators, freezers and air conditioning units) have been regulated by the WEEE Directive since 2002 (EU, 2002). Thanks to the enforcement of this policy, the recycling of household refrigerating appliance has been well established in the EU. Refrigerators, as Electrical and Electronic Equipment (EEE),[1] also fall within the scope of the "Restriction of Hazardous Substances" (RoHS) Directive regulating the content of various hazardous substances (EU, 2011).

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[1] Electrical and electronic equipment (EEE) means equipment which is dependent on electric currents or electromagnetic fields in order to work properly (Europena Union EU, 2012).

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Apart from vending machines, included in the "automatic dispenser" category, other product groups different from household refrigerating appliances were not clearly included in the WEEE Directive (EU, 2002). As noticed by Huisman et al. (2008) the reference to 'household' in the headings of some waste categories of the WEEE Directive indicates that 'non-household' appliances are excluded from the scope. As a consequence, the recycling of some categories of cooling appliances, as large Commercial Refrigerating Appliances (CRA),[2] has been developed differently by Member States of the EU. With the objective of harmonizing EoL treatments of WEEE across the EU, the recast of the WEEE Directive (EU, 2012) clearly stated that, starting from 15 August 2018, all the categories of EEE will fall within the scope of the Directive. This would include all the types of CRA as refrigerated display cabinets, beverage coolers and ice cream freezers.

1.1. Scope of the research

Changes in the waste policies such as the enlargement of the scope of the WEEE to new product groups, have generated in the past important impacts at various level additional burdens for local authorities, producers and recyclers (Huisman et al., 2006); additional costs for consumers (Gottberg et al., 2006); unexpected environmental and social impacts in developing countries due to waste shipment (Nnorom and Osibanjo, 2008); and increased traffic due to waste transport (Barba-Gutierrez et al., 2008). The enforcement of waste policies can be strengthened by synergies with other policies. The article 4 of the WEEE Directive encourages the "cooperation between producers and recyclers and measures to promote the design and production of EEE, notably in view of facilitating re-use, dismantling and recovery of WEEE, its components and materials" (EU, 2012). The application of strategies for ecodesign and, in particular, 'design for recycling', can allow the appropriateness of the future products with the EoL treatment processes (Ardente et al., 2003; Mathieux et al., 2008; Ardente et al., 2014). On such purpose, the European Ecodesign Directive (EU, 2009) represents a useful policy instrument to set some minimum requirements of the products, for example to exclude from the market products with insufficient recyclability performances. Meanwhile, considering that the enforcement of specific waste policies (as the WEEE and the RoHS Directives for the EEE) can also have the effect of encouraging innovation and product improvement among manufacturers (Mathieux et al., 2001; Lepochat et al., 2007), there is also a need to analyse the CRA product group with the aim to propose potential products' improvement for a more efficient recycling.

In this context, CRA is a good example on how its inclusion within the scope of the WEEE Directive could pose serious problems to recyclers in the near future. In fact, CRA not properly designed could hamper the compliance with minimum targets and requirements, as those set by the WEEE legislation.[3]

Even though many studies analyse the recyclability of household fridges and their treatment (see e.g. (Huisman et al., 2007; Deng et al., 2008; Sansotera et al., 2013)), little information is currently available about the EoL of CRA. In some cases, its EoL is assumed to be the same than for household appliances (BioIS, 2007). However, the structural and technical functionalities of CRA are considerably different from that of household cooling and freezing appliances. Among CRA there is a great disparity on design as they are frequently customized to specific needs of the clients in supermarkets or vending areas. Some of them have large dimensions (up to 7 m^2 of total display area and up to 10 m^3 of volume) and use some specific materials, as for example glass for the doors and large amount of insulation materials (up to 30 kg in large appliances). CRA can use remote refrigerating circuits, as for example the supermarket display cabinets. CRA can also contain specific components (e.g. electronics, controllers, lighting systems, locks, reinforced frames, anti-intrusion systems). Overall, the variability in the design and structure can cause some problems at the recycling plants, because recyclers are not aware about the product composition and cannot easily locate and extract certain components. Some CRA are also difficult to be collected, transported and handled due to their large dimensions at EoL. On the other hand, large dimensions can prevent this waste from uncontrolled disposal outside the regular collection channels, as largely occurring for small electronic appliances (Darby and Obara, 2005).

1.2. Aims of the article

This article aims to analyze the potential synergies between product and waste policies based on a relevant case study. Due to its recent inclusion in the scope of the WEEE Directive and in the work-plan of the Ecodesign Directive, CRA appears to be a suitable product group to analyze such synergies. In particular, the paper has the objective to analyse and better formalize the actual EoL of CRA in the EU, with particular focus to the pre-processing and recycling treatments in Europe. Another objective is to identify potential design improvements for CRA, based on a better knowledge of their EoL treatment. This paper is organized in eight sections. It starts with the description of the method for the analysis (Section 2). Then, it continues with a review of scientific and technical literature about EoL for CRA (Section 3), and a survey of actual recycling practices in the EU (Section 4). Section 5 analyses a number of criticalities of the CRA for their EoL treatments, based on the previously collected evidences. The article follows by discussing some products' improvement opportunities (in Section 6), and the discussion of the method and results (Section 7). Section 8 summarizes the main findings.

2. Method for the analysis

A detailed analysis has been performed to better understand the EoL processes for CRA in Europe and to identify current products criticalities, i.e. when the waste products are not fully adapted to recycling processes. The initial data collection has been carried out through three different data sources: literature review, survey of European recyclers and communications with experts.

The first source of the data collection consisted in developing an exhaustive literature review about CRA and other product groups with similar characteristics (e.g. household refrigeration appliances).

The second source was to conduct interviews and visits to several European recyclers. Four recycling plants, located in Italy, Germany and two in Spain, were contacted.[4] The selection of the plants was based on the discussion with a major European WEEE collection and recovery organization: this organization qualified these four recyclers as 'representative' for the EU geographical context in terms of treatments adopted for the processing of waste CRA. The questionnaire used during the interviews (see Box 1) included three sets of questions for the: (1) general understanding of the company and its representativeness in the national and European

[2] Commercial refrigerating appliances are here understood as the group of various refrigerating devices which store food and beverages for merchandising purposes.

[3] The WEEE Directive establishes obligation to treat certain components and the achievement of minimum recycling and recovery rates.

[4] According to communications from the recyclers, the four plants together treat yearly around 0.9×10^6 [kg] of waste CRA; moreover, the annual CRA flows in these plants range from 1% to 10% of their total WEEE input flows.