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Regional approach of waste electrical and electronic equipment (WEEE) management in France

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ABSTRACT

Waste management regulation is generally impacted by Extended Producer Responsibility (EPR) implementation, such as Waste Electrical and Electronic Equipment (WEEE). The main goal of this article is to explicit the WEEE chain and flows using the material flow analysis (MFA) method and to contribute to the understanding of the EPR implementation in a specific case study by examining operational activities of WEEE regional and urban flows. A detailed case study of the EPR implementation for WEEE in the Midi-Pyrénées Region and the Toulouse's urban area was conducted. Based on a MFA of the WEEE chain, results give an insight into operational activities dealing with circulation of waste material. It reveals the main dysfunctions of this WEEE management system, including lack of involvement of local authorities and consumers, dispersion channels and a low recycling rate at the local level. The roles of recycling operators, social economy companies and EPR compliance are also important to recover more resources from waste and to close the recycling loop.

1. Introduction

Since the concept of urban metabolism was first introduced (Wolman, 1965), several studies have been conducted on this issue, as reviewed by Zhang (2013). Regional or urban metabolism refers to the exchange processes where regions or cities convert raw materials, energy, and water into the built environment, human biomass, and waste (Decker et al., 2000). The regional level can be chosen with respect to biophysical and political system definitions, even if socioeconomic statistics are not always updated or even available (Kennedy et al., 2011). The concept of regional metabolism analyses the relationship between material flows, environmental assessment, and social practices. The material flow analysis (MFA) method is often used to understand national metabolism, but also pollution from human or industrial activities at regional and urban scales (Fischer-Kowalski and Haberl, 2007). This tool examines the socio-ecological conditions that influence flows in order to support a basis for material flow management and dematerialization strategies (Barles, 2009). MFA also enables new understandings of material and energy flows within the city (Brunner, 2002; Broto et al., 2012) that can be integrated into policy making and land planning.

A MFA approach linked to agent analysis can be considered to study waste flow management because it offers the opportunity to investigate each waste path (Binder, 2007). We refer to the term "waste chain" as defined by Yuan et al. (2011): "a chain consisting of a series of waste management activities. Wastes pass through all activities of the chain in order and at each activity the volume of waste is minimized by various waste management activities".

Therefore, the WEEE chain is a system which involves different operators, activities and factors. A multi-scale analysis of waste chains is also relevant to understand waste flows and policy dysfunction (Berlin et al., 2008; D'Alisa et al., 2012), but further studies about the concept of proximity and the role of local activities are required (Barles, 2010). MFA is not only focused on the legislative framework but also on the "blind spots" of regional management systems (Binder et al., 2004).

MFA has proven to be useful in understanding pollution from human or industrial activities, i.e. to study the "Metabolism of Anthroposhere" (Baccini and Brunner, 1991), and can be applied at different scales according to the study's objectives (Binder et al., 2004; Erkman, 2004; Fischer-Kowalski et al., 2011). In order to perform the environmental assessment of a WEEE management system, Kiddee et al. (2013) presents an overview of several tools including MFA, LCA and Multi Criteria Analysis (MCA). This study shows that these approaches present different benefits but can be complementary to evaluate the

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system's environmental impact. Many studies have been conducted with a LCA approach (e.g. Hischier et al., 2005; Van Eygen et al., 2016), an input-output model (Leigh et al., 2012) or a characterization of WEEE flows at different scales (see for instance in Seattle (Lee et al., 2010), in China (Yang et al., 2008), in the U.S. (Kahhat et al., 2008), in Korea (Manomaivibool and Hong, 2014); in Denmark (Parajuly et al., 2017), in Switzerland (Duygan and Meylan, 2015), in Pakistan (Imran et al., 2017). Unlike the other tools, MFA aims to analyze material and energy flow throughout all the chain's steps, including treatment steps where waste fractions are either recovered into secondary materials or sent to final disposal. Even though many studies tackling WEEE systems and management exist (Ng et al., 2016), the approaches in specific regions or urban scales were not well studied and analyzed. The understanding of the WEEE chain is an important issue to reveal how local recycling systems contribute to the region's operations.

Therefore, the goal of this article is to contribute to the understanding of Extended Producer Responsibility (EPR) implementation, such as WEEE management, in regional and urban areas. Being fundamental to this study, the WEEE flows were considered in depth by examining the operational activities of recycling, collection, resource recovery, etc. Also based on the analysis of WEEE chain flows in the Midi-Pyrénées Region, the study intends to explore the potential of a regional approach in order to generate useful quantitative analysis for waste management.

2. WEEE management system in the Midi-Pyrénées region

WEEE includes a large family of devices such as TVs, computers, mobile phones, white goods (e.g. fridges, washing machines, dryers, etc.), home entertainment and stereo systems, toys, toasters, or kettles, which present an average lifespan of two to ten years and a mass of 0.1 kg to 45 kg (STEP, 2012). WEEE production is growing exponentially: between twenty and fifty million tons per year across the world and between 8.3 and 9.1 million tons per year in Europe alone (STEP, 2012). The end-of-life of WEEE is a global issue (Williams et al., 2008) given that these products contain hazardous materials (such as brominated flame retardants, chlorinated substances, polychlorinated biphenyls (PCB), refrigerant gas, cadmium, mercury, lead, and forty elements including metals). However, WEEE represents a significant source of valuable metal resources (Charles et al., 2017; Cucchiella et al., 2015; Vadoudi et al., 2015).

Collection and treatment of WEEE is regulated by European directives, (Directives 2002/96/CE and 2012/19/EU), the latter deems producers financially and logistically responsible for WEEE at the end-of-life stage (called the principle of Extended Producer Responsibility). Producers are required to organize and finance the take-back, treatment, and recycling of WEEE, in addition to meeting mass-based recycling and recovery targets (the financial flows are described in Fig. 1). This regulation framework is a part of a growing trend in EPR for waste which results in both economic and political incentives for waste recovery and green design (Lifset et al., 2013). EPR is a governmental instrument which "if applied appropriately, could substantially influence and change the way industry and society produce, use, and dispose of materials […] and could be one of the mechanisms by which circular economies can be realized" (Mayers et al., 2005, p171). This approach puts forward solutions for skills coordination, new links of proximity and new dynamics of the specific stakeholder systems.

2.1. The roles of national, regional and urban stakeholders

The French program's implementation is the result of the joint participation of various parties, including EPR compliance organizations, city and local governments, retailers, refurbishers, consumers, and collection, processing and recycling operators. Therefore, the roles of these stakeholders greatly influence and shape the current practice of the WEEE management system. In the following discussion, some insights concerning these roles and perspectives are provided.

1) EPR compliance and relations with French ministry and OCAD3E (coordinating center for WEEE management).

Four compliance schemes have been agreed by the French Ministry of the Environment, who sets the specification requirements. These four French EPR compliance organizations (Eco-Systèmes, ERP, Ecologic, Recylum) are created by original equipment manufacturers (OEMs) and brand owners, according to their professional association (for example, Eco-Systemes includes members of the Association of Manufacturers of Household EEE, the Federation of Commerce and Distribution and the Collective System of Industries of Multimedia and Electronics). These non-profit companies (called "eco-organisms" in France) aim at organizing and financing the take-back, treatment, and recycling of WEEE to meet mass-based recycling and recovery targets. They get visible fees (see Fig. 1) from the consumers through the retailers (Favot et al., 2017) and they provide financial support for local governments, refurbishers, and logistics and treatment operators. If they are certified by the French government, EPR compliance organizations do not operate in every region and urban area. They operate in a free market to provide the service of e-waste collection, transport and treatment, under the supervision of a coordinating center (called OCAD3E in French). Each country in the European Union (EU) is free to set up a compliance scheme (or schemes) for EPR implementation. As a result, the schemes can differ widely, depending on each country's organization and the status of companies. The coordination is sometimes very strict, if it supervises compliance schemes thoroughly and maintains the role of management regarding the conventions with local authorities.

2) Regional and local governments

Local governments, on a voluntary basis, establish a take back system to selectively collect household WEEE at container parks. Some municipalities do not want to be involved in the collection (because it is supposed to be the retailers' role). The municipalities receive compensation for their collection efforts by the French EPR compliance organizations. Municipalities are also required to provide campaigns to inform citizens about WEEE management and related disposal channels. They are not involved in the EPR governance, although these authorities have to establish and organize household and hazardous waste management plans.

3) Retailers

Retailers of EEE, as local stakeholders, are required to establish a take back system of WEEE brought back by consumers. They are equally obliged to promote WEEE recycling. Retailers are an excellent urban network for collecting wastes but it requires space in shops to handle WEEE.

4) Refurbishers (enterprises of social economy)

Stakeholders, as part of the reuse and reemployment sector, are also expected to contribute to WEEE management by recovering used appliances. They mostly consist of companies that contribute to the social economy of urban areas. They repair, reuse, and refurbish waste in order to sell second hand electric appliances to other consumers. It is quite difficult for them to maintain profitability.

5) Consumers

Consumers are responsible for returning their WEEE to the

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