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Resource savings by urban mining: The case of desktop and laptop computers in Belgium

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ABSTRACT

Waste electrical and electronic equipment (WEEE) has become increasingly important over the last years. Additionally, the European Union recognizes the growing importance of raw materials, and the crucial role of recycling. In this study the performance of WEEE recycling was assessed for the case of desktop and laptop computers in Belgium in 2013. The analysis was performed in four steps. First, the recycling chain is analyzed through material flow analysis (MFA) at the level of specific materials. Second, an indicator is calculated, which quantifies the effectively recycled weight ratios of the specific materials. Third, a second indicator expresses the recycling efficiency of so-called critical raw materials. Finally, the natural resource consumption of the recycling scheme in a life cycle perspective is calculated using the Cumulative Exergy Extraction from the Natural Environment (CEENE) method, and is benchmarked with a landfill scenario. Overall, the results show that base metals such as ferrous metals, aluminium and copper are recycled to a large extent, but that for precious metals improvements still can be made. The input of criticality (arising from the incoming mass, as well as the individual criticality value of the assessed material) mainly comes from base metals, resulting in a high recovery performance of raw materials criticality. Finally, the natural resource consumption of the recycling scenario is much smaller than in case of landfilling the WEEE: 80 and 87% less resource consumption is achieved for desktops and laptops respectively, hence saving significant primary raw materials.

1. Introduction

Waste electrical and electronic equipment (WEEE) is one of the fastest growing waste streams, in amounts as well as in importance. The use of electrical and electronic equipment (EEE) has grown rapidly in recent decades, and furthermore, due to ongoing technological innovations, lifespans decrease and consumer demand increases continuously. This in turn gives rise to increasing WEEE quantities being disposed of by the users (Wang et al., 2013; Widmer et al., 2005).

Because of the complex composition of electronic appliances, recycling has a twofold purpose. WEEE must be seen as a dangerous waste stream, which, if not treated properly, can cause severe environmental and human health damage (Tsydenova and Bengtsson, 2011). On the other hand, the many materials that constitute WEEE are an enormous resource potential. Printed circuit boards (PCBs) for example can contain more than ten times the concentration of precious metals, compared to the respective metal ores (Betts, 2008). The sustainable management of this waste stream is thus important to prevent the loss of these materials and to mitigate the growing shortage of resources (Hagelüken and Meskers, 2008).

The European Commission recognizes this, as they defined waste as one of the key resources to lower the dependence on imports of raw materials (European Commission, 2011). Indeed, raw material resources are crucial for the economy, but very little primary production occurs within Europe, so their availability is coming increasingly under pressure. An assessment of the economic criticality was therefore made, based on the economic importance and supply risk of 54 non-energy and non-agricultural raw materials, resulting in 20 raw materials being identified as critical (European Commission, 2014).

To enhance the recovery, the European Union (EU) adopted the WEEE Directive in 2002 to improve the collection, which is a major bottleneck (Bernstad et al., 2011), and subsequently the efficiency of the total recycling chain for WEEE. The WEEE Directive has been

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recast in 2012. Here, collection targets are defined, and starting in 2016, these will no longer be defined as a fixed amount per inhabitant (currently 4 kg/cap), but as at least 45% of the average amount of EEE put on the market (POM) in the three preceding years. From 2019 onwards, this will increase to at least 65% of EEE, or alternatively 85% of WEEE produced. The directive also subdivides the WEEE in different categories, and defines recycling and recovery targets for each of the categories of WEEE collected, based on mass (European Parliament and Council, 2012).

The choice of the directive for a focus on overall mass means that the recyclers can concentrate on the materials which are present in large amounts in the waste stream, such as ferrous metals or plastics, to achieve the imposed targets. In this situation, materials existing in small quantities, like precious metals, can potentially be neglected despite their obvious environmental and economic relevance. However, their primary production causes large environmental impacts, and recycling these materials could therefore achieve a large avoided burden per unit of mass, as well as keep (critical) raw materials within the (European) economic system. It is consequently suggested to base the targets not on overall mass, but on the recycling of individual materials, to improve the benefits achieved through recycling (Bigum et al., 2012; Huisman et al., 2008).

These aspects call for detailed data to be collected on two levels. On the micro-level, material composition data for all components of the WEEE and on the efficiency of the recycling operations should be established. Furthermore, to comply with the targets from the WEEE directive, data on the macro-level, quantifying the amount of WEEE that is generated and collected nationally, should be available. Combining these two levels allows estimating the total valorized resource potential of the waste stream in a country.

In this paper, the performance of the WEEE recycling chain in Belgium is assessed. As IT equipment is especially rich in valuable and critical materials (such as platinum group metals (Cui and Zhang, 2008) and rare earth elements (Binnemans et al., 2013)), the recycling of a desktop and a laptop computer, as carried out in 2013, is selected as a case. The assessment is performed in four steps. First, the recycling is analyzed through material flow analysis (MFA) at the level of specific materials to obtain an overview of the flows. Second, an indicator is calculated, which quantifies the effectively recycled weight ratios of these specific materials, which is linked with the WEEE Directive targets. Third, a second indicator expresses the recycling efficiency in terms of recovery of critical raw materials, in order to address the current strong policy focus on these materials. Finally, to go beyond the simple mass-based focus, the natural resource consumption of the recycling scheme in a life cycle perspective is calculated and benchmarked with a non-recycling scenario. The non-recycling scenario consists of landfilling the waste flow under study and the supply of the very same Basket of Products (BoP) offered by the recycling scheme, but starting from primary natural resources. The natural resource savings in a life cycle perspective are accounted for by the Cumulative Exergy Extraction from the Natural Environment method (CEENE), which quantifies the natural resource consumption in thermodynamic units.

2. Materials and methods

2.1. Description of the recycling chain

The WEEE recycling chain generally comprises three major steps: collection and sorting, dismantling and mechanical separation (primary treatment), and end-processing (see Fig. 1). Information on the two first steps in the chain was gathered in collaboration with Recupel and Galloo respectively.

In the first step, the discarded electrical and electronic appliances are collected and sorted. In Belgium, this is managed by the producer responsibility organization Recupel. Collected WEEE is first checked, and equipment that can be reused is repaired, refurbished or cleaned. The rest is divided into five fractions: cooling and freezing appliances, big white goods, television screens and monitors, gas discharge lamps, and other appliances (OVE). IT equipment is part of the latter OVE fraction (Huisman and Baldé, 2013; Els Verberckmoes, Recupel Treatment Manager, personal communication).

The contribution of reuse to resource savings can be either positive or negative. The efficient reuse of discarded products can contribute to significant resource savings when replacing the

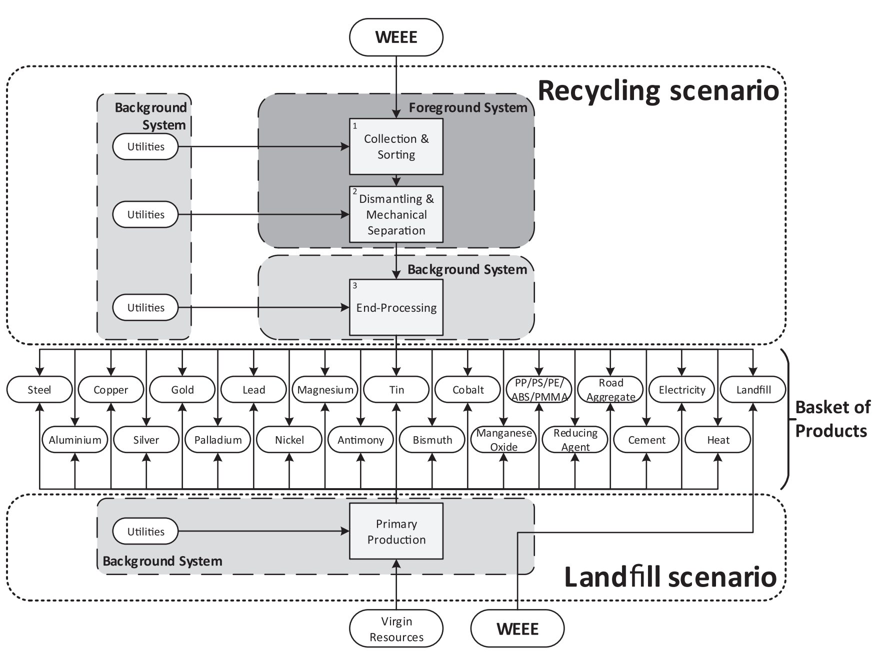

Fig. 1. Overview of the recycling chain and presentation of the system boundaries. The recycling scenario provides a Basket of Products (BoP) from secondary resources and is benchmarked with a landfill scenario where the waste is landfilled and where the BoP is to be provided from virgin resources through primary production.