CURRENT POTENTIAL OF A CIRCULAR ECONOMY WITH RESPECT TO THE REDUCTION OF PRIMARY RAW MATERIAL DEMAND

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Abstract

The dependency of the European Union on the imports of primary raw materials was one of the major drivers for the release of the circular economy strategy, in which resource input and waste, emissions, and energy leakage are minimised by closing material loops. As part of the shift towards a circular economy, proposals introducing new waste-management targets regarding reuse, recycling and landfilling have been made. In the study at hand, the potential impact of these new targets for packaging waste PW (and Municipal Solid Waste MSW) on the EU´s supply of four raw materials, namely Iron & Steel, Aluminum, Plastics and Paper & Board, has been assessed. Thereto the method of material flow analysis has been applied in order to evaluate current and potential future flows of secondary raw material. The results of the investigations indicate that for Iron & Steel and Paper & Board already today about 50% of the EU´s production is made out of secondary raw materials. For Aluminum (36%) and Plastics (10%) this share. however, is significantly lower. Implementing the higher recycling targets in accordance with the circular economy package would increase the domestic supply of secondary materials by between 0.6% (Iron & Steel) and 70% (Plastics). However, as already today significant amounts of recyclables (equivalent to more than 10% of the total domestic raw material consumption in the EU) are exported and thus not utilized by the European industry, it is questionable to what extent additional quantities of recyclables derived from post-consumer waste will substitute for primary raw materials. Quality constraints of the industry as well as production capacities for secondary raw materials in place might limit the domestic utilization of recyclables liberated by the Circular Economy Package. Hence, additional policy measures (e.g. targets for the share of secondary production) seem to be necessary to enhance the rate of secondary production within the European Union.

Introduction

The limited availability of many natural resources has become a growing concern in the last few decades. Continuous growth in global material turnover during the last century, which has resulted in enormous resource consumption, as well as recent increases in commodity prices are the main drivers of these concerns. In addition to existing efforts to intensify exploration for new deposits, proposals for higher efficiency in resource use and the recycling of materials have been put forward to overcome the potential danger of more pronounced material shortages.

Based on the “Raw Materials Initiative" (e.g. COM(2008)0699, COM (2011)0025, COM(2013) 442), which can be regarded as a strategic pillar for “boosting resource efficiency and recycling”, an EU action plan for a circular economy (COM/2015/0614 Circular Economy Package) was released in December

2015. It foresees a “transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized, which is seen as an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy.” Within the action plan for a circular economy, waste management plays a central role. Clear targets for the reduction and recycling of waste are proposed. For instance, by 2030 65% of the municipal waste generated is supposed to be recycled. For packaging waste an even more ambitious target has been scheduled (75% recycling by 2030). Furthermore, landfilling of all wastes is supposed to be reduced to 10% by 2030 and separately collected waste is completely banned from landfilling. All these measures should significantly contribute to the development of a sustainable and resource-efficient economy. This requires that additionally generated secondary resources be utilized by European industries. At present, however, significant amounts of waste-derived raw materials (including waste paper, scrap metals, or waste plastics) are exported out of the European Union, suggesting a surplus of secondary resources.

Hence, the aim of the present paper is to analyze the current flows of secondary resources for selected commodities within and out of the EU and to predict their future quantities in the case that the Circular Economy Package, and in particular its recycling targets for PW and MSW, are fully implemented. Besides a quantitative analysis, qualitative aspects of secondary resources and their impact on recycling and export are also discussed. The investigations focus on the following commodities*: Iron & Steel, Aluminum, Plastics*, and *Paper & Board.*

Material and Methods

Material Flow Analysis for the different commodities

In a first step, a material flow analysis MFA (according to Brunner and Rechberger, 2004) for each commodity has been conducted. Thereby a systematic assessment of all materials flows in the European Union has been undertaken. In particular, the following data have been collected for Paper & Board, Plastics, Iron & Steel, and Aluminum for the EU-28: *domestic production and consumption; net imports or exports of commodities via semis, finished products, End of Life EoL products (largely vehicles) and wastes; domestic waste production (divided into Municipal Solid Waste MSW, other wastes, production waste and processing or internal waste); material “losses” during production; net stock increase within the EU; final disposal or recycling of waste*. The MFA was conducted at a rather superficial level. The model used for the analysis of the commodity flows is present in Figure 1. It basically consists of four processes, namely *Raw Material Production*, *Manufacturing & Trade*, *Consumption*, and *Waste Management*. The spatial system boundary is the European Union (EU-28), whereby primary raw materials (regardless of whether they are extracted within or outside the EU) are considered as imports into the system. On the other hand, wastes (e.g. waste plastics, waste paper & board) thermally utilized or landfilled are accounted for as exports from the system, although the respective processes (e.g. Waste-to-Energy plants, landfills) are located within the European Union. For the temporal system boundary, one “average” year representative for the period 2013 to 2016 was chosen, as not all data were available for the same year. The “commodities flows” considered include *primary raw materials* demanded, *raw material* produced, *material losses* during raw material production, the *net import of semis and finished products*, *finished goods*, *production* or *manufacturing waste*, *Municipal Solid Waste MSW*, all *other wastes*, *net exports of recyclables* and *end of life products* (vehicles and electronic waste), as well as *wastes landfilled* or *incinerated*.

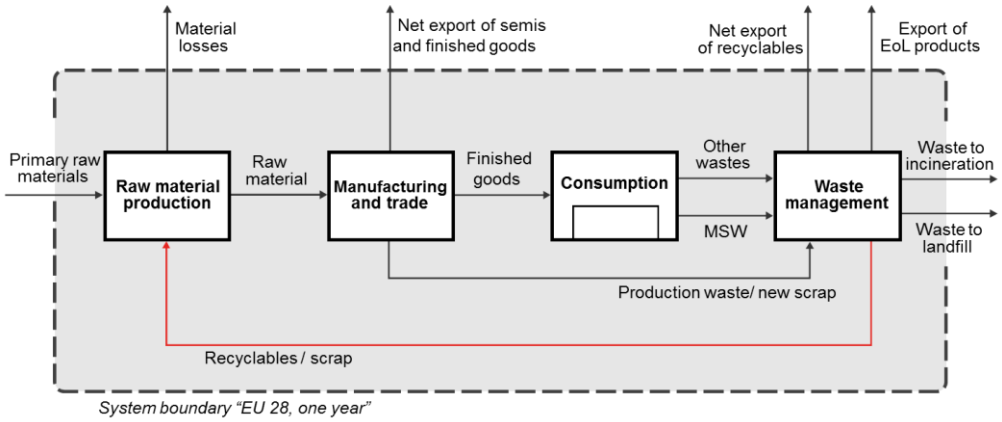

Figure 1 Material flow model for Iron & Steel, Aluminum, Plastics and Paper & Board for the EU-28

In a second step, the management of MSW and packaging waste with respect to the four commodities has been investigated in detail. This was done in order to evaluate the status quo and to assess the potential impact of the Circular Economy Package (namely increased recycling targets for packaging waste and MSW[1]) on the overall domestic supply of secondary resources. For the additionally provided secondary resources, two "extreme" scenarios are basically possible: One the hand, all additional quantities of recyclables and scrap might be utilized within the European Union. On the other hand, the entire amount of recyclables/scrap liberated by the implementation of a circular economy might be exported and thus not utilized by European industries. Based on historical data on the supply, utilization and export of recyclables, which of the two options (domestic utilization or export of recyclables) is likely to prevail is discussed.

Data collection

A wide range of different data sources was utilized to establish the material budgets for Iron & Steel, Aluminum, Plastics and Paper & Board of the EU-28.

For Paper & Board, data were derived from the Confederation of the European Paper Industry, which publishes statistics about production of pulp and paper and therefore utilized raw materials each year (CEPI, 2016). In addition, the data of the CEWPI statistics have been complemented and crosschecked with MFA figures recently published on paper recycling in the EU (Pivnenko et al., 2016).

For Plastics, most data used for the MFA (e.g. production, consumption, recycling, waste to landfill, waste to incineration) have been obtained from Plastics Europe (Plastics Europe, 2016). Information about the export of recyclable plastics was retrieved from a study recently conducted by Velis (2014). Furthermore, plastics exported via end of life products were assessed using data on the composition (plastics content) of vehicles and estimates about the (official and unofficial) exports of end of life EoL vehicles. For the latter a total number of approximately 5 million passenger cars was assumed according to Oeko-Institut e.V. (2016). The assignment of waste plastics to MSW and other wastes was accomplished in accordance with information provided by Van Eygen et al. (2017).

For European flows of Aluminum (including data about production, consumption, scrap generation) comprehensive data sets for recent years are provided by the European Aluminum Association (2016). Exports of Al scrap was obtained from the UN Comtrade database and exports via end of life products

[1] *For simplicity reasons it was assumed that recycling targets for packaging wastes are also applicable to similar materials present in MSW*

were estimated in analogy to plastic flows. Al flows via MSW were assessed using data on production statistics (Al used in packaging) and information provided by Buchner et al. (2015) and Warrings and Fellner (2017).

Information about Iron & Steel production and consumption as well as data on scrap generation were obtained from the European Steel Association Eurofer (Eurofer, 2017). In addition, the generation of internal (home) and production scrap was estimated using data (ratio between steel production and scrap generation) provided by Ghenda and Lüngen (2013) and Wang et al. (2007). Iron & Steel exported via end of life products (mainly due to end of life vehicles) were estimated in analogy to similar exports of plastics and aluminum. For the estimation of Iron & Steel present in MSW, the data of waste sorting analyses from different EU countries (Germany, Denmark, Austria, Croatia and Sweden) were used.

Results

Current and Future (Circular Economy) Material Flows

The results of the material flow analyses reveal that for Iron & Steel (share of secondary production SSP: 46.4%) and paper & board (SSP: 52.4%) secondary production is equally important as primary production. For aluminum, almost 37% of the sellable production originates from scrap. In contrast, only about 10% of the plastics produced in the EU are made out of secondary raw materials. In addition, it can be assumed that at present they only partly substitute for primary plastics since mixed-polymer re-granulates represent a significant share of the secondary plastics produced in the EU. These mix-polymer plastics are then used for products (e.g. roof tiles) which are usually not made out of plastics.

A significant share (between 42 and 47%) of the final consumption of commodities (except for paper & board) contributes to an increase in anthropogenic material stocks in the EU. The annual stock growth amounts, in absolute figures, to 55,000 kt for Iron & Steel, to 4,700 kt for aluminum and 22,000 kt for plastics. This observation demonstrates that even in a highly developed economy like the European Union, societies´ material flows are far from being balanced (input > output of materials), thereby limiting the overall potential of a circular economy to substitute primary resources. Furthermore, for all four commodities a significant export of recyclables / scrap is observable. Taking exports via end of life products (e.g., export of end of life vehicles) into consideration as well, the total "loss" of secondary resources for the European industry amounts to approximately 10% of the overall resource consumption for all four commodities.

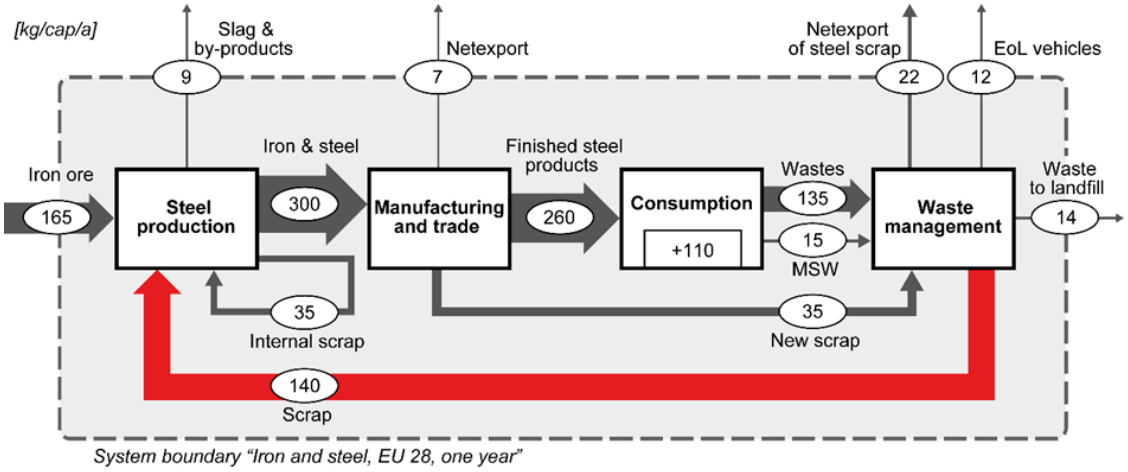

Figure 2 Annual Iron & Steel flows in the EU-28 (data given in kg/cap/a)

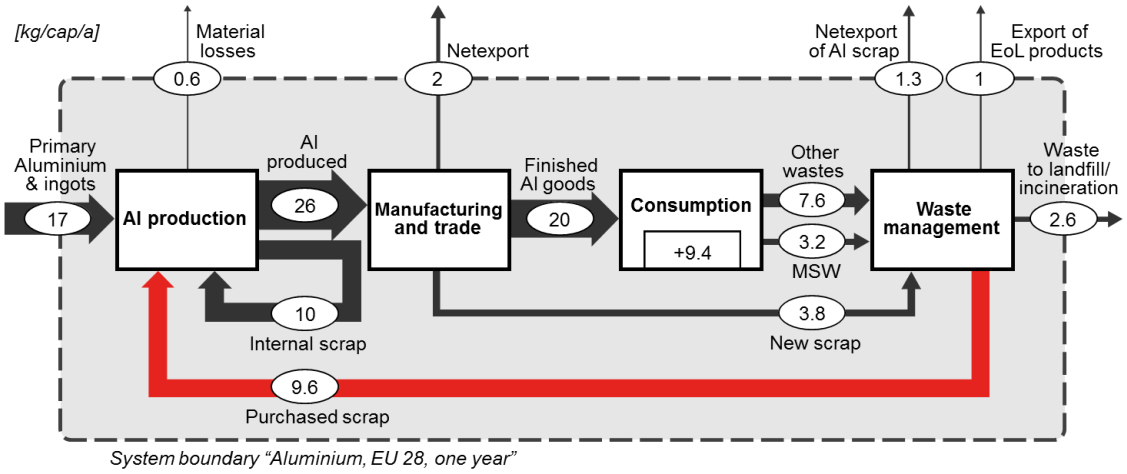

Figure 3 Annual Aluminum flows in the EU-28 (data given in kg/cap/a)

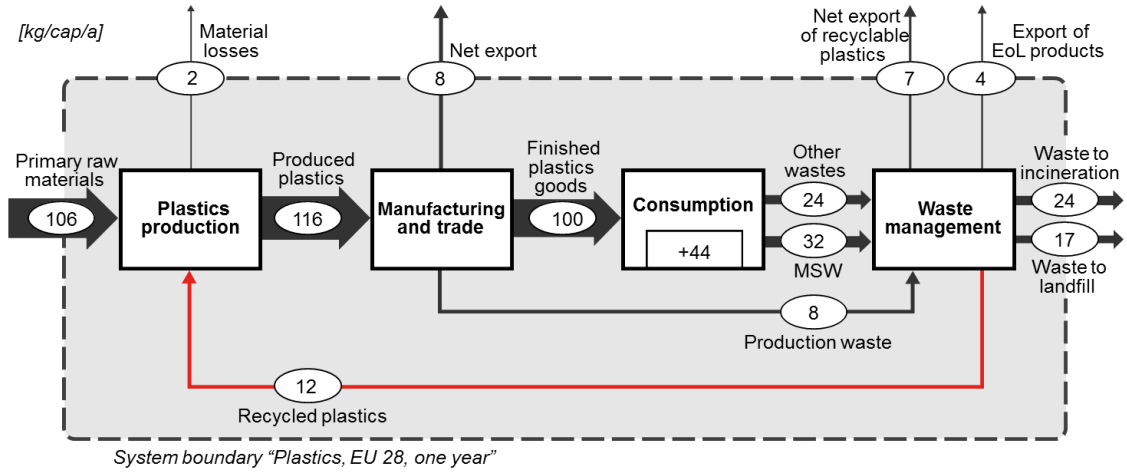

Figure 4 Annual Plastic flows in the EU-28 (data given in kg/cap/a)

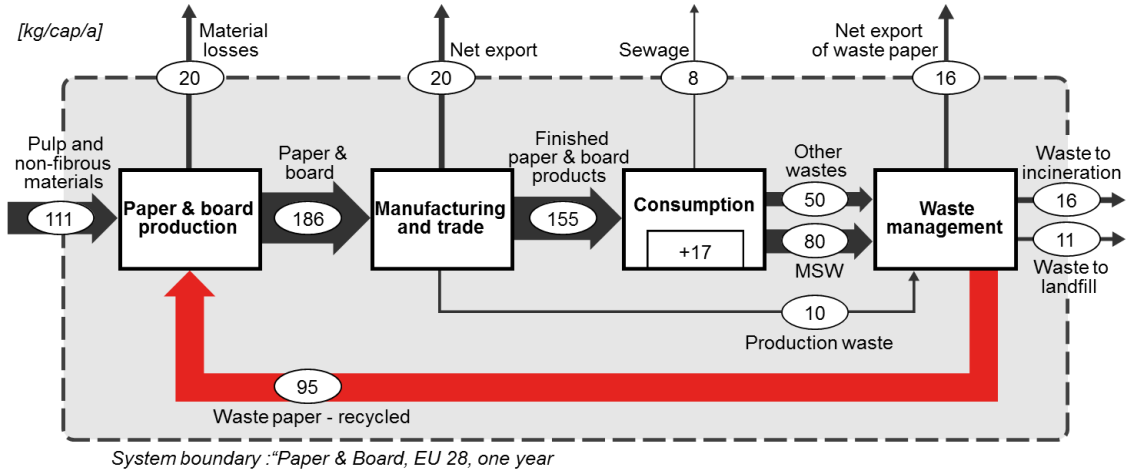

Figure 5 Annual Paper & Board flows in the EU-28 (data given in kg/cap/a)

Based on the current "commodity flows", the potential impact of implementing the circular economy package for MSW and packaging waste was assessed. Thereto it was assumed that the recycling targets proposed by the EU circular economy package are met and the thereby additionally recovered recyclables / scrap (in comparison to the status quo) are fed into the European recycling market.

In Table 2 the current status of the management of packaging waste and MSW with respect to the four

commodities is summarized. It is obvious that for Iron & Steel and as well as for Paper & Board current recycling rates are already close to target values proposed by the Circular Economy Package (85%), whereas for Aluminum (47% → 85%) and Plastics (23% → 55%) substantial improvements would be necessary to meet the targets. It needs to be noted that for simplicity reasons it was assumed that recycling targets proposed for packaging waste also apply to non-packaging materials present in MSW. Based on the necessary improvements (increase) of recycling rates and the quantities of materials present in packaging waste and MSW, the impact of the proposed circular economy in terms of additional quantities of recyclables / metal scrap was calculated.

Table 2 Quantities of recyclables derived from packaging waste and MSW (current status versus achievement of the Circular Economy targets for packaging waste and MSW)

	Unit	Iron & Steel	Aluminum	Plastics	Paper & Board
Total packaging waste & non packaging present in MSW	[kg/cap/a]	15	3.2	44	125
Current recycling rates (packaging & non packaging)#	*[%]*	*77.5%*	*47%*	*23%*	*83%*
Current quantities of recyclables derived from packaging waste and MSW	[kg/cap/a]	12	1,5	11	104
*Recycling targets (according to the Circular Economy Package CEP)**	*[%]*	*85%*	*85%*	*55%*	*85%*
Additional quantities of recyclables (implementation of CEP)	[kg/cap/a]	**1.1**	**1.2**	**13**	**2.5**

*# based on EUROSTAT data, * until 2030*

Iron & Steel

For Iron & Steel, the achievement of a recycling target of 85% would imply an additional amount of 1.1 kg of scrap per capita and year (or 550 kt/a for the EU-28). This represents about 0.6% of the EU´s total ferrous metal scrap generation. If the total amount of additional scrap were utilized by the European steel industry (no export of this additional scrap quantities), the share of secondary steel production would marginally increase by 0.4% to 47%.

Aluminum

For Aluminum, an achievement of the proposed recycling target of 85% would translate into an additional scrap quantity of 1.2 kg/cap/a (or in total 600 kt/a). This would increase the current quantities of Al scrap available (9.6 kg/cap/a) by 11%. In the case that all the additional quantities are utilized by European Al smelters, the share of secondary production (SSP) would theoretically increase by almost 5% to 41.5%. However, it is highly questionable whether such an increase in Al scrap supply could be absorbed by the European manufactures. It is more likely that these quantities would at least to some extent be exported for recycling, as was observed for iron scrap in the previous decade (see Figure 6). There higher shares of scrap in relation to the production volume, expressed as potential share of secondary production (light blue bars in Figure 6), did not translate into higher secondary production (dark blue bars in Figure 6). The “additional” quantities of Fe scrap could not be utilized by the European steel makers and were hence exported.

Figure 6 **Potential share (dark blue) and actual share (light blue) of secondary production for Iron & Steel (incl. home scrap) within the European Union for the period 2006 to 2016**

Plastics

For Plastics, current recycling rates (23%) would need to more than double to reach the target value of 55% proposed by the circular economy package. Such an increase would generate an additional quantity of recyclable plastics of almost 13 kg/cap/a (6,500 kt/a). In comparison to the status quo (19 kg/cap/a), this would increase the recyclable quantities by more than 65%. Considering that already today a significant share of plastics is exported for recycling (7 kg/cap/a), it might be questioned if huge amounts of additional quantities of recyclables will be utilized within the EU. In general, higher collection and sorting rates will most likely lower the quality of the recyclable plastics obtained, which further challenges the production of high quality re-granulates able to substitute primary polymers. It is more likely that the collected materials are down-cycled (e.g. mixed polymer re-granulate) or exported.

Paper & Board

Current recycling rates for paper & board (83%) are already very close to the target values proposed (85%). The improvements required would thus translate into an additional quantity of recyclable waste paper & board of only 2.5 kg/cap/a (equals 1,250 kt/a). This is about 2% of the waste paper quantity generated at present in the EU-28. Assuming that the total additional quantity of waste paper & board is domestically utilized, the share of secondary production would increase to 53.8% (+1.3%). Considering the recent changes in secondary production (the share rose constantly from 48% in 2005 to 52.5% in 2015), this moderate increase seems to be manageable by the European paper & board industry. Nonetheless, quality constraints, as highlighted by Pivnenko et al. (2016), might also limit the utilization of additional waste paper quantities for paper & board recycling.

Conclusions:

Based on the results of the study, the following conclusions can be drawn:

► The additional quantities of secondary materials induced by implementing the Circular Economy Package CEP for MSW and packaging waste would amount to

550 kt/a (1.1 kg/cap/a) for Iron & Steel (0.4% of EU production)

600 kt/a (1.2 kg/cap/a) for Aluminum (4.6% of EU production)

6,500 kt/a (13 kg/cap/a) for Plastics (11% of EU production)

1,250 kt/a (2.5 kg/cap/a) for Paper & Board (1.4% of EU production)

► The current rate of circularity for Iron & Steel and Paper & Board is already high, thus limiting the potential reductions of primary raw material demand induced by the CEP.

► Material stocks for Iron & Steel, Aluminum and Plastics are still growing at a significant rate, meaning that even a 100% recycling rate may only partly cover the material demand.

► At present there is a significant net export of scrap and recyclables for all four commodities, which might be explained by quality constraints of European manufactures.

► Increasing exports of recyclables might be expected if quantities of recyclables increase due to the CEP.

► There is a risk of down-cycling if only recycling quotas are targeted.

Recommendations:

► Additional policy measures, such as quotas for the share of secondary raw materials utilized in products in order to prevent/reduce exports of recyclables.

► Expansion of recycling quotas by qualitative aspects.

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