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CIRCULARITY OF PLASTICS PACKAGING AND ENVIRONMENTAL PERFORMANCE OF THEIR WASTE MANAGEMENT

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Introduction

The European Commission (EC), in its "action plan for the circular economy" and "strategy for plastics in a circular economy" communications (EC 2015, 2018), has named the circular economy in general and a responsible use of plastics in particular key in achieving increased resource efficiency as well as decreased environmental and human health damage. The proper management of waste plastics is thus crucial, especially from short-lived products such as packaging. To further encourage the (plastic packaging) waste management system in this direction, the EC has proposed a considerably increased recycling target (EPC 2018). However, formulating quantitative recycling targets without underlying data may prove to be counterproductive, as trade-offs within the waste management system might not be accounted for. It is therefore crucial to assess the environmental consequences of this increased target from a systems perspective.

A case study was thus carried out, where the waste management system of plastic packaging in Austria was assessed (with 2013 as the reference year). First, Material Flow Analysis (MFA) was used to quantify the flows of waste plastics in detail with respect to product types and polymers, and to identify if the current and future recycling targets are met and what improvement potentials exist. Second, Life Cycle Assessment (LCA) was used with the MFA results as a basis to evaluate the potential environmental impacts and benefits of plastic packaging waste management. Two alternative scenarios were built to explore the relationship between the recycling rate and the environmental performance of the waste management system, considering a wide range of impact categories to investigate whether burden shifting goes along with increasing the recycling rate.

Results

The results of the MFA for waste plastic packaging, subdivided by polymer, are displayed in Figure 1. About half of the total waste input, which amounted to 300,000 t/a or 35 kg/cap·a, was composed by small and large films, while one third consisted of small hollow bodies including PET bottles. The polymer composition was consequently dominated by LDPE (46%), PET (19%) and PP (14%). 34% of the waste was sent to mechanical recycling, after which 26% was recovered as regranulate, while 40% was treated in waste-to-energy plants and 33% was incinerated in the cement industry. The fact that 34% was sent to mechanical recycling means that the current recycling target of 22.5% was reached, but leaves large improvements needed to reach the

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recently increased targets of 50% and 55% by 2025 and 2030, respectively. Three product types, which represent 40% of the total waste mass, already (almost) reach the required increased target of 55 %: EPS large (68 %), films large (55 %) and PET bottles (54 %). However, the other categories are far away from the target, with required increases of 24 to 51 percentage points. For collection, efforts should be focused on the hollow bodies (except PET bottles) and others product types. Moreover, improving sorting of especially the small product types (films small and hollow bodies small) as well as the others has a large potential to increase the mass of plastic packaging sent to the recycling process. For a more detailed discussion on the waste plastic packaging flows in Austria, the reader is referred to Van Eygen et al. (2018a).

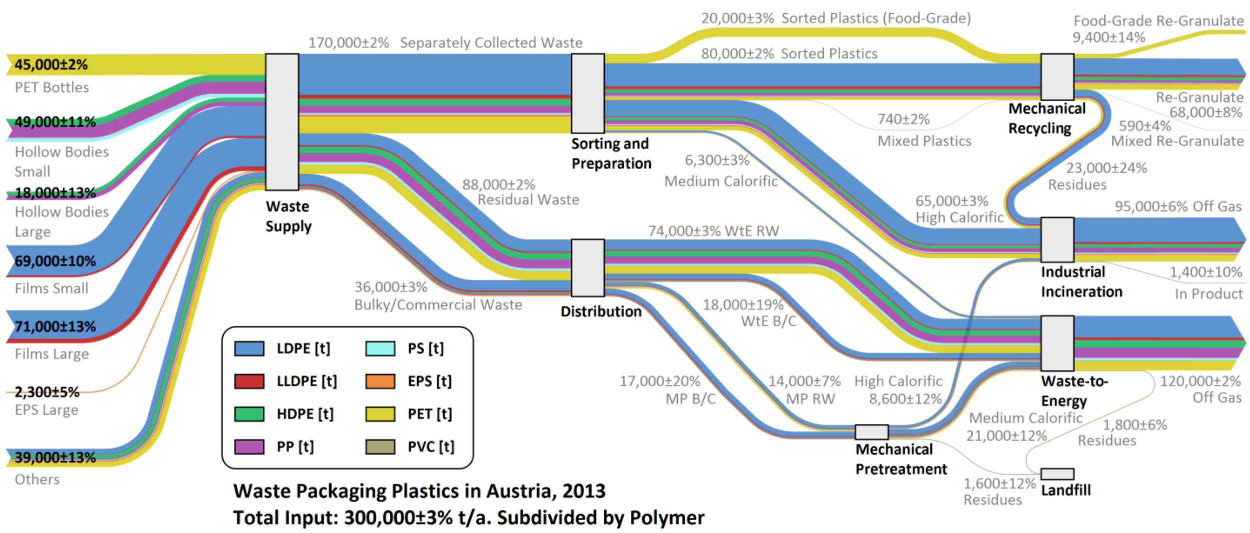

Figure 1 **Results of the MFA for the status quo of waste plastic packaging in Austria, subdivided by polymer (after Van Eygen et al. (2018a)).**

For the environmental assessment, the results for the status quo, as presented in Figure 2, show that for all 16 investigated impact categories, the waste management system achieves higher benefits, due to e.g. production of secondary materials and energy, than the impacts that are caused, resulting in net benefits. The exception is human toxicity (non-cancer), however, although here the tipping point between net impacts and benefits lies within one standard deviation. The benefits are achieved through a combination of all three major treatment options (mechanical recycling, waste-to-energy, industrial incineration), although their shares differ strongly regarding the various impact categories. Looking at the results for the treatment of the separately collected waste stream (58% of waste plastic packaging) compared to the material in the residual waste, it is clear that the former accounts for the majority of all achieved benefits across all impact categories, for instance 100% of global warming benefits, 87% for human toxicity (cancer), 78% for particulate matter emissions, 82% for ecotoxicity and 91% for mineral resources. For a more in depth discussion of the results of the status quo and the alternative scenarios, the reader is referred to Van Eygen et al. (2018b).

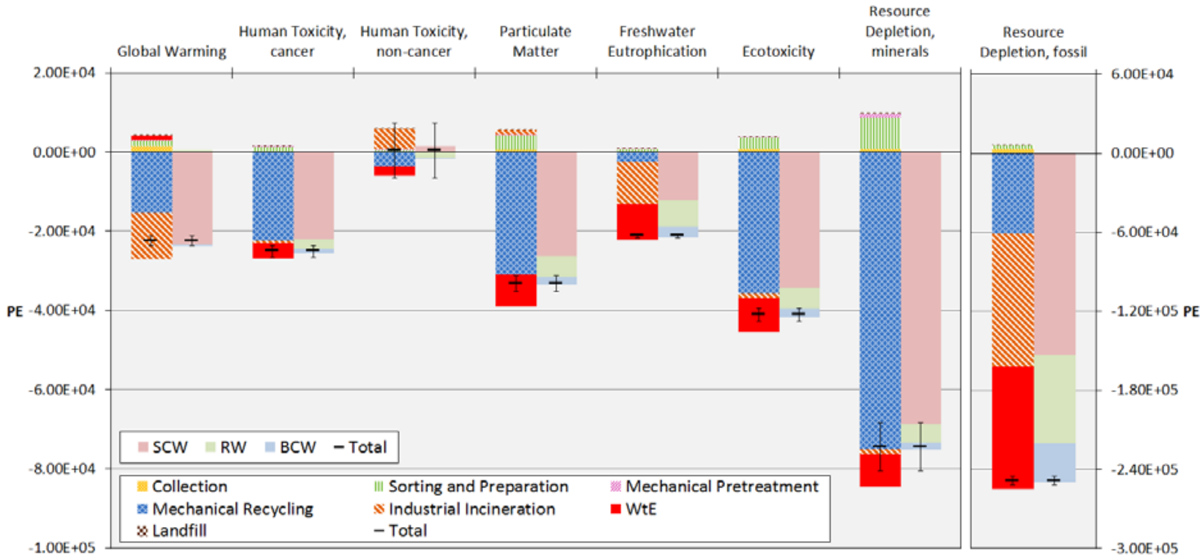

Figure 2 **Results for eight selected impact categories of the LCA for the status quo of waste plastic packaging in Austria, subdivided by treatment process and collection route (SCW: separately collected waste; RW: residual waste; BCW: bulky & commercial waste) (after Van Eygen et al. (2018b)).**

The two alternative scenarios represent a waste management system where about 60% of the waste is landfilled (based on the situation in 1994 in Austria) and 17% is sent to mechanical recycling ("Mainly disposal"), as well as a system which reaches the increased recycling target of 55% ("EU-target-SP"). The results of these scenarios in relation to the recycling rate are presented in Figure 3. Three types of relationships between the normalized results and the recycling rate can be observed (see Figure 4b and Figure S8 in the SI), as indicated by the stylized trend lines. An increasing marginal net benefit with respect to the recycling rate is recognized for human toxicity (non-cancer) due to the large net impacts of industrial incineration, the share of which increases strongly for the status quo but decreases again for the EU-target-SP scenario. On the other hand, eight impact categories (i.a. ecotoxicity, freshwater eutrophication and fossil resource depletion) display decreasing marginal benefits or even an absolute decrease in the net benefits when comparing the status quo and the EU-target-SP scenario, due to (a combination of) various reasons: the large net impact of landfilling in the mainly disposal scenario, the overall dominance of the incineration processes with respect to the net benefits, the large net impact of the sorting process, as well as the fact that mechanical recycling has a net impact itself. For the six remaining impact categories (i.a. global warming, human toxicity (cancer), particulate matter and mineral resource depletion), an approximately linear or slightly decreasing marginal benefit is apparent, generally due to the relative dominance of mechanical recycling in achieving the net benefits.

The alternative waste management scenarios thus indicate that for most impact categories increasing recycling rates lead to increased benefits. However, the marginal benefit decreases with increasing recycling rates for many impact categories, and for four impact categories the EU-target-SP scenario achieves lower net benefits than the status quo. This suggests that the environmentally optimal recycling rate is below 100% depending on the impact category. This is further reinforced by the fact that in the scenario for the EU target, no non-linear effects of e.g.

increasing separate collection on transport distances and sorting efficiency are included, which can potentially further decrease the benefits for this scenario. Therefore, future research should address these effects to create a sound basis for proposing recycling targets leading to an environmentally optimal outcome.

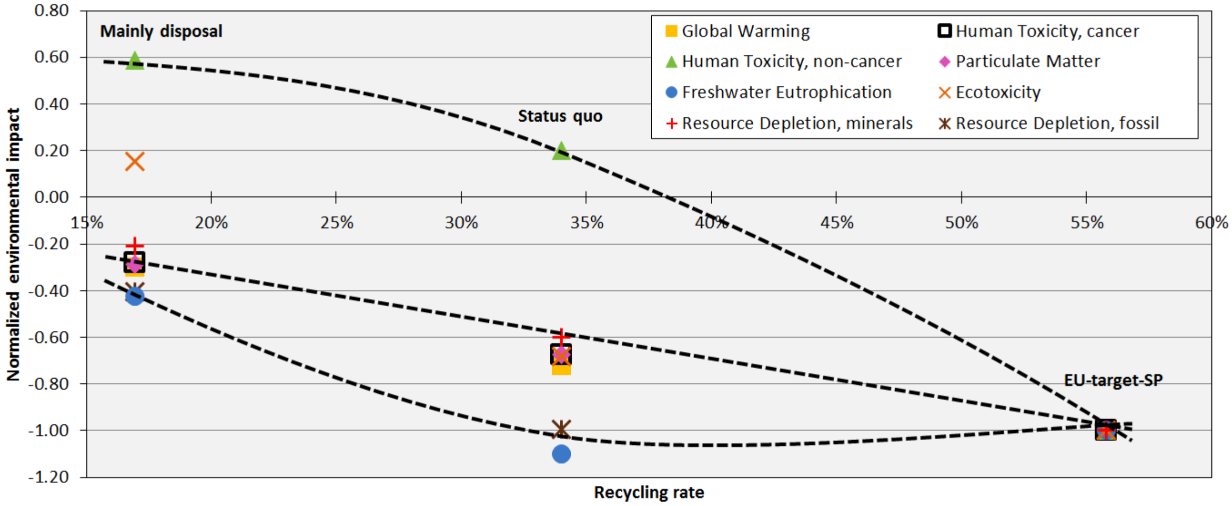

Figure 3 **Results for eight selected impact categories of the LCA for the status quo and two alternative scenarios in relation to the recycling rate. Three types of relationships between recycling rate and impact are observed, as indicated by the stylized trend lines (after Van Eygen et al. (2018b)).**

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