Waste Management 72 (2018) 55–64

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Circular economy of plastic packaging: Current practice and perspectives in Austria

Emile Van Eygen *, David Laner, Johann Fellner

Christian Doppler Laboratory for Anthropogenic Resources, TU Wien, Karlsplatz 13/226, 1040 Vienna, Austria

A R T I C L E I N F O

Article history:
Received 27 June 2017
Revised 16 October 2017
Accepted 23 November 2017
Available online 28 November 2017

Keywords:
Resource management
Waste management
Recycling rate
Recycling target
MFA

A B S T R A C T

Plastics, especially from packaging, have gained increasing attention in waste management, driving many policy initiatives to improve the circularity of these materials in the economy to increase resource efficiency. In this context, the EU has proposed increasing targets to encourage the recycling of (plastic) packaging. To accurately calculate the recycling rates, detailed information on the flows of plastic packaging is needed. Therefore, the aim of this paper is to quantitatively and qualitatively investigate the waste management system for plastic packaging in Austria in 2013 using material flow analysis, taking into account the used product types and the polymer composition. The results show that 300,000 ± 3% t/a (35 kg/cap·a) of waste plastic packaging were produced, mainly composed of large and small films and small hollow bodies, including PET bottles. Correspondingly, the polymer composition of the waste stream was dominated by LDPE (46% ± 6%), PET (19% ± 4%) and PP (14% ± 6%). 58% ± 3% was collected separately, and regarding the final treatment, 26% ± 7% of the total waste stream was recovered as re-granulates, whereas the rest was thermally recovered in waste-to-energy plants (40% ± 3%) and the cement industry (33% ± 6%). The targets set by the EU and Austria were reached comfortably, although to reach the proposed future target major technological steps regarding collection and sorting will be needed. However, the current calculation point of the targets, i.e. on the input side of the recycling plant, is not deemed to be fully in line with the overall objective of the circular economy, namely to keep materials in the economy and prevent losses. It is therefore recommended that the targets be calculated with respect to the actual output of the recycling process, provided that the quality of the output products is maintained, to accurately assess the performance of the waste management system.

1. Introduction

Plastics are widely recognized to have an ever increasing importance in waste management. They have become one of the most used materials worldwide, are often used in products with short lifespans, and pose substantial environmental problems due to the accumulation in ecosystems when disposed of improperly (Barnes et al., 2009; Gregory, 2009; Jambeck et al., 2015; Teuten et al., 2009). Ever increasing attention for these negative aspects have stimulated policy initiatives to tackle these problems, especially for plastic packaging, as this is the main application of plastics and makes up the largest share in the post-consumer plastic waste stream (PlasticsEurope, 2015; Van Eygen et al., 2017; World Economic Forum et al., 2016). These initiatives focus on the consumption side, e.g. reductions or bans on lightweight plastic carrier bags (EPC, 2015; Ritch et al., 2009), as well as on the waste management side (Sakai et al., 2011). In case of the latter, the European Union (EU) has imposed a recycling target which currently requires 22.5% of waste plastic packaging to be recycled (EPC, 2004). This target is proposed to increase by 2025 towards 55% (EC, 2015a), further underlining the ambition to increase recycling and reduce landfilling of packaging wastes. This is part of the broader initiative to increase resource efficiency and reduce resource dependency (EC, 2011), and plastics are one of the five priority areas in the EU action plan for the circular economy (EC, 2015b).

This circular economy concept, which foresees a production and consumption system where materials are circulated as wastes are re-used, recycled and recovered, has been increasingly promoted by many governments and international organizations (EEA, 2014; Ellen MacArthur Foundation, 2013; Geissdoerfer et al., 2016; Ghisellini et al., 2016; Haas et al., 2015; Lieder and Rashid, 2016; Winans et al., 2017). To measure the progress towards a circular economy, many indicators can be calculated to quantify this performance (BIO Intelligence Service et al., 2012; Hashimoto and

* Corresponding author.
E-mail address: emile.van.eygen@tuwien.ac.at (E. Van Eygen).

https://doi.org/10.1016/j.wasman.2017.11.040
0956-053X/

Moriguchi, 2004; Haupt et al., 2016; Moriguchi, 2007). One of these indicators is the recycling rate, which is frequently used in policy documents (e.g. from the EU, see above) to quantify the amount of waste materials that is fed back into the economy. However, at which point in the waste management chain these rates are to be measured is part of ongoing discussions (EUWID, 2014). The general consensus for the EU targets seems to be to calculate the recycling rate at the gate of the recycling plant, i.e. the input to the recycling process, although this has not been clearly defined yet. This causes confusion, especially with regard to comparing the performance of different regions or countries, as it is not always clear how reported indicator values were calculated (Haupt et al., 2016).

For the calculation of these recycling rates and to draw the right conclusions on the overall environmental performance and potentially improve the system, detailed mapping of how materials move within the economy is needed (Hashimoto and Moriguchi, 2004; Preston, 2012). In the case of plastic packaging, it is of primary importance to gather information on the different polymers that constitute the waste stream, as these need to be separated in order to be recycled effectively. Furthermore, the environmental benefit achieved by recycling is different for each polymer: polyethylene terephthalate (PET) for example causes relatively high environmental impacts at primary production (Tabone et al., 2010) and has about half the heating value (Phyllis2, 2016) compared to the other major packaging polymers, making it all the more pertinent to increase high-quality mechanical recycling and avoid incineration for energy recovery. Furthermore, it is relevant to have information on the product types in the waste stream, as many collection systems and sorting processes are specific to certain product types.

Therefore, the aim of this paper is to quantitatively and qualitatively investigate the waste management system for plastic packaging in Austria with respect to polymer content and product types and 2013 as the reference year. Based on the results indicators on the performance of the system are calculated and compared with current and future policy targets. Furthermore, the potential for improvements throughout the system are identified, and the implications thereof for reaching future targets are analyzed.

2. Materials and methods

2.1. Material flow analysis

MFA is used to comprehensively assess the flows and stocks of materials through a certain system defined in space and time, thus connecting and quantifying sources, pathways and sinks of the material in question (Brunner and Rechberger, 2004). The software STAN 2.5 was used to perform the MFA calculations using a standardized method (Cencic and Rechberger, 2008). The material flows are calculated on different levels: total waste plastic packaging (i.e. goods) and the various constituting polymers (i.e. substances).

To assess the quality of the input data in describing the desired quantitative information, the uncertainties of these input data were quantified using the approach described by Laner et al. (2016). In this method, the data quality of each input data point is characterized qualitatively using five data quality indicators, which are presented in Table S-1 in the Supplementary data. The quantitative uncertainty value is subsequently derived based on coefficients of variation for each of the data quality indicator scores (as shown in Table S-2 in the Supplementary data), which are described by continuous characterizing functions (see Laner et al., 2016 for more details). This approach introduces two major aspects of subjectivity in the data uncertainty characterization. First, the indicator scores are assigned on more or less stringent criteria, and second, the quantitative uncertainty values for the various scores are estimated. Regarding the first aspect, although most evaluation criteria do not leave much room for interpretation, others are not that unambiguous, relying on the experience and tacit knowledge of the modeler. Concerning the second aspect, although the underlying mathematical functions allow the transparent and consistent characterization of the coefficients of variations within the method, the actual definition of these functions remains up to the modeler's choice (in the present study an exponential-type function is used, see Laner et al., 2016). As empirical data are usually not available as a basis for this choice, the estimates may differ from one MFA study to another. Therefore, although the approach builds on reproducible and internally consistent uncertainty estimates, comparisons of these estimates generated in different MFA studies should be done cautiously (Klinglmair et al., 2016; Laner et al., 2016). The estimated input uncertainties are subsequently propagated through the model using Gaussian error propagation (assuming normally distributed variables), whereas data reconciliation is used to resolve conflicts between input values. The material flow results are given as mean values and relative standard deviations of a normal distribution.

The system boundaries of the MFA are presented in Fig. 1, and are drawn to include all plastic packaging products from becoming waste in Austria until they are processed to provide secondary raw materials or energy, or are deposited on a landfill. The waste stream was subdivided into seven product categories, including PET bottles, small (<5 L) and large (≥5 L) hollow bodies, small (<1.5 m^2) and large (≥1.5 m^2) films, large EPS (≥0.1 kg), and other products. Only products fully composed of plastics are taken into account, so products made from material composites, such as food or drink cartons, are not considered. The quantification of the waste flows through the waste management system was performed separately for each of these seven product categories. On the polymer level, eight polymers were taken into account: low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE), polypropylene (PP), polystyrene (PS), expanded polystyrene (EPS), polyethylene terephthalate (PET), and polyvinyl chloride (PVC). These polymers account for 99% of all plastics used in packaging in Europe, according to PlasticsEurope (2015).

2.2. Description of the plastic packaging waste flows

Fig. 1 shows the MFA model that quantifies the flows of plastic packaging waste in Austria, and in the further description, the flow numbers from this model are indicated. The plastic packaging products are used in the seven aforementioned categories (F1.01 - F1.07). After becoming waste, the products are either collected separately (SCW; F2.01), or are disposed of in the municipal solid waste (MSW; F2.02) or in bulky and commercial wastes (BCW; F2.03).

The separately collected stream is sorted into 18 sorting fractions, based on polymer, product type and color, which are then sent for single-polymer mechanical recycling (F3.02). Part of the PET waste stream is used for the production of higher value food-grade re-granulate (F3.01), and is therefore included as a separate flow in the model. Furthermore, a mixed-plastics stream is sent for mechanical recycling into mixed-polymer re-granulate (F3.03), used for the production of items such as recycled plastic lumber (RPL), which is then used to substitute wood in e.g. outdoor furniture. Consequently, three types of mechanical recycling processes are taken into account in the model: single-polymer recycling to produce food-grade re-granulate (F4.01) as well as non-food-grade re-granulate (F4.02), and mixed-polymer recycling (F4.03).