Modeling material flows through plastic recycling chains

DOI:
10.26481/dis.20231204il

7.2 SCIENTIFIC IMPACTS AND CONTRIBUTIONS

Evidently, plastic is widely used in the economy and positively impacts humanity and society. However, plastic waste pollution causes adverse environmental impact and economic losses, hence, enabling a circular economy for plastic is crucial. Plastic recycling can be used as one of the solutions to deal with plastic waste pollution, in which plastic waste is collected for extensive sorting and recycling to allow the production of secondary materials. This thesis focuses on assessing potential improvements within the European plastic waste management systems. For this purpose, different methods are used, including material flow analysis (MFA) models in combination with other assessment tools such as cost-benefit analysis (CBA) and carbon footprint calculations. The results in this thesis could contribute to assessing potential improvements within the plastic waste recycling systems by providing thorough assessments on the fate of plastic waste throughout the recycling chains as well as the associated economic and environmental aspects, focusing on the European recycling chains (as case studies). Moreover, this thesis also provides insights into the attainment of recycling rates and recycled content targets in Europe.

In first instance, the presented results in this thesis could contribute to improve active participation from a broader group of stakeholders to enable a circular economy for plastic and material circularity. Our results for example show that consumers play a crucial role in determining the fate of plastic waste, especially in applying plastic separation at source (e.g., at households, schools, offices, etc.). Some plastic waste (e.g., plastic in electronic waste) can 'hibernate' for a relatively longer period of time in consumers' possession before being disposed of, which could delay material recycling and circulation from the waste products. Moreover, inefficient waste separation at source by the consumers could lead to plastic waste ending up in incineration facilities or landfills, in which plastic waste is not necessarily recycled back into the economy. Inefficient waste separation at source also impacts the performance of plastic recycling operations. For example, more residue is generated, which hampers the economic competitiveness of recycling plants as shown in Chapter 5. Indeed, the economic balance is affected because recyclers need to pay more for residual treatment and get less revenue from a lower recycled plastic quality. The environmental performance of plastic recycling is also affected, particularly from dealing with residual treatment, typically via incineration or landfill. Furthermore, when the waste contains more residue, a lower recycled plastic quality could be expected, limiting the potential use of the secondary materials (e.g., only suitable for less demanding applications such as trash bags). Hence, societal and behavioral changes could be detrimental to ensuring a successful and sustainable plastic waste management systems. This PhD thesis offers quantitative evidence for the role of stakeholders such as the consumers.

Furthermore, the results presented in this study emphasize (and could contribute) the urgent need to improve plastic waste compositional datasets. We need to gain more information on the waste feedstock compositions because it determines the extent to which recycling technology can deal with the waste and predict recycled plastic quality, which is important in plastic waste management. The collected plastic waste (from households, schools, offices, etc.) is typically contaminated with other non-plastic materials (e.g., paper, organic waste, etc.), partly because of inefficient separation at source by the consumers. Even after an elaborated sorting process at material recovery facilities, a considerable amount of non-plastic material can still be found, making recycling more challenging. With gained knowledge around waste compositions, the industry could choose the most appropriate sorting and recycling techniques to improve the waste streams, hence, plastic waste can be valorised into high-quality recycled materials (both from technical and economic perspectives). The prediction of plastic waste flows throughout plastic recycling chain and the quality of secondary materials could also be improved by gathering more realistic waste compositional data.

This thesis contributes to discussing plastic waste management from policy perspective. The presented case studies and results in this thesis could be used as the basis to formulate recycling targets based on quantitative projections. Policy makers could adopt the modeling approach or results to assess the impact of ambitious recycled content targets on the overall plastic recycling rate, and vice versa. With current market conditions, mechanical recycling is still used as the main plastic recycling option, however, new emerging recycling technologies like chemical and solvent-based recycling are expected to enter the European market in the near future. Hence, policymakers would need to revisit the European recycling strategies to ensure that these technologies positively contribute to increasing plastic recycling rates and provide recycled content. In this context, paying more attention to the nature of each recycling technique becomes imperative, for example, in the case of multi-output chemical recycling technologies. Pyrolysis and gasification technologies produce recycled polymers and valuable base chemicals but also fuels, which does not conform with 'recycling' definition in Europe. Thus, policymakers need to come up with a harmonized set of rules on how to quantify recycling rates for all recycling technologies in the near future (especially for the multi-output recycling process). Furthermore, with current legislation, the use of mechanically recycled plastic for contact-sensitive applications (e.g., food packaging) is limited partly because of concerns related to legacy chemicals. On the other hand, it is currently assumed that chemical and solvent-based recycling could produce virgin-like recycled plastic, which is expected to be the dominant technology to supply contact-sensitive applications and reach the recycled content targets. In this context, policymakers should ensure that legislation does not discriminate or aid certain recycling option(s). Lastly, this topic is especially relevant because the model results suggest that the recycling rates and recycled content targets could change considerably depending on the preferred recycling technologies used to deal with plastic waste.