Additives in Plastic Manufacturing and Implications for Mechanical Recycling.

Pahola Thathiana Benavides, Ulises R. Gracida-Alvarez, Michael Wang

LCA and Technology Assessment Department, Energy Systems and Infrastructure Assessment Division, Argonne National Laboratory

Additives are widely used to improve the performance of plastic resins, enhance processability, and enable products to meet application-specific requirements. However, their contribution to plastics' life-cycle assessment (LCA) is often overlooked. Additionally, some additives are regulated due to health and toxicological concerns, which can restrict their use and hinder the recycling of plastic products. Minimizing additive loadings to the levels necessary for technical performance could therefore improve plastic recyclability. This study reviews the literature on common additives used in major plastic resins and discusses the results of an LCA of representative additives—such as plasticizers, flame retardants, stabilizers, scavengers, and pigments—by incorporating them into the formulations of PVC and PET products. Based on the current analysis, considering prevalence in plastics, typical loadings, environmental and health hazards, global production and consumption, and recycling implications, plasticizers, flame retardants, pigments, and stabilizers have been identified as the most consequential additive groups. The analysis aims to provide insights into environmental metrics such as greenhouse gas (GHG) emissions, fossil energy use, and water consumption in plastic formulations. Preliminary findings indicate that, compared with PVC without additives, certain additives increased product GHG emissions by roughly 0.3% to 25%. Across all cases, the additives' mass fraction had a greater influence on GHG outcomes than their inherent emission intensities. Additionally, a hypothetical analysis was conducted on the PET supply chain flows caused by hypothetical variations in material flow parameters. Preliminary results indicate that increasing the recycling rate of post-consumer PET bottles, along with their allocation for closed-loop (bottle-to-bottle) recycling, could raise the recycled content in mechanically recycled PET bottles by up to 12%, resulting in an 8% reduction in virgin PET consumption However, other variables, such as sorting yield, could be incorporated into the analysis to refine these findings. Overall, this study provides a framework for assessing the environmental impacts of plastic additives and their influence on product emission footprints. It also explores how variations in material flow factors and parameters—hypothetically affected by additive mass fractions—could alter material recovery for recycling.

Keywords: life-cycle assessment (LCA), plastics, additives, mechanical recycling.