Incorporating Agile Life Cycle Assessment (LCA) and Machine Learning to predict environmental impacts for Chemical Recycling of State-wise Landfill Plastic Waste

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The increasing consumption of fossil-based plastics and the current linear approach combined with inefficient plastic waste handling are the main reasons behind the accumulation of plastic waste. The conventional way of disposing of plastic is through landfilling. About 86% of the plastic waste was landfilled in 2019; over the years, a significant fraction of plastics have been deposited in landfills. National Renewable Energy Laboratory (NREL) and the United States Environmental Protection Agency (US EPA) estimate the figure to be around 32.2 to 44 million metric tons with an average market value of $7.5 billion. Therefore, shifting towards a circular plastic economy through developing new recycling techniques is imperative. Chemical recycling of plastic, a promising solution, has the potential to fully utilize the waste by producing plastic monomers as well as high-value chemicals. LCA and other indices help determine whether chemical recycling is a viable alternative to current waste management plastic. In this study, we present an agile modeling framework that predicts greenhouse gas (GHG) emissions based on a given product distribution to evaluate energy demand and environmental implications of the chemical recycling of plastics. A data-driven machine-learned model was developed using the published literature data on oil yields by chemical recycling of plastic waste. Predicted oil yields from the machine-learned model at different reaction conditions and plastic waste fractions were then used as the main product yield for the LCA model. The study assesses the chemical recycling of plastic waste landfilled annually for each US state, considering different plastic types and conversion temperatures. This study elucidates the influence of varying waste composition, temperature, and utilities specific to each US state. We identify that GHG emissions can vary up to 3-fold among US states, even when using the same recycling process. GHG emissions significantly depend on the state-specific grid characteristics and plastic waste composition; for example, waste with higher LDPE/PS fractions and lower HDPE/PP fractions have lower emissions than waste with comparatively high HDPE fractions. Depending on the primary sources for electricity generation for a specific state, we can also identify suitable state-specific co-product handling pathways (e.g., fuel gas-to-electricity vs fuel gas sold directly as an energy product).

Topic: 1. Building a Sustainable Circular Economy for Materials & Products

Topic: 2. The Role of Circularity in a Resource-Constrained World