Chemical Recycling of Plastic Waste in Practice: Assessment of Technologies and Economics

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Plastics are extremely valuable to our society and are widely used across industries such as food, beverage, textile, healthcare, automotive, aerospace, construction, agriculture, oil. The low density, water resistance, and moldability of plastics render plastic packaging crucial for food safety, storage, and distribution. The use of polymers as electrical insulators enabled the transportation of electrical energy. Polymer membranes are used for water desalination, fuel cells, and blood purification. Healthcare applications of polymers extend to drug delivery, implants, dental fillings, artificial hips, blood bags, and medical devices. The critical importance of plastics is currently evident in the widespread use of face-shields as a protection method against coronavirus.

The global production of plastics, accumulative from 1950 to 2017, is 8.3 billion metric tons, with 6.3 billion tons accumulative waste generated, of which only 9% has been recycled, 12% incinerated, with the remaining 79% landfilled or placed in the environment. By 2050, the accumulative waste generated is projected to about 26 billion tons if production and waste management were to continue with the current trends. The United States plastic production was 35.4 million tons in 2017, of which only 8.4% was recycled. The great majority of plastic waste (75.8%) was landfilled, and 15.8% was used for combustion with energy recovery. The discarded plastics pose a long-term environmental challenge. For example, at the current rate of plastics production and disposal, by 2050 the mass of plastics in the ocean is projected to exceed that of fish.

Mechanical recycling is the method used to recycle about 95% of plastic waste today. It involves sorting, shredding, heating, and remolding of the plastics. However, this technology works well only for homogeneous and non-contaminated plastic waste, and for easily identifiable objects such as bottles and containers made of PET and PE. Mechanical recycling generally degrades the polymers. Mechanical recycling fails completely for objects comprising more than one types of plastic, e.g., multilayer packaging, which typically end up in landfills.

Chemical recycling can offer a solution in recycling many of the plastics which mechanical recycling fails to process. Chemical recycling involves the deconstruction of polymers by chemical processes to monomers for conversion back into polymers or to molecular intermediates that can be used as fuel or feedstock by the chemical industry. A well-known chemical recycling technology is pyrolysis, which is used to transform plastics into fuel/oil or other by-products by reducing long polymer chains into shorter hydrocarbons through rapid heating in the absence of oxygen. The common inputs are rigid and film plastics while the operating conditions involve high temperature (350–650 °C) and high pressure (0.3-4.0 MPa) which are energy-intensive.

A number of chemical recycling technologies are being developed, and the processes are being tailored to handle specific feedstocks and/or produce desirable products. In this project we assess companies (big and small) that are involved in the chemical recycling of plastic waste: information is organized on the company size and ownership/investment, their technology and/or key innovations, the feedstocks and product(s), the current scale of operation (lab, pilot plant, large-scale), and their business model. Further, in this project we evaluate the economics of chemical recycling with a specific interest on plastic-to-oil conversion.

The techno-economic assessment of plastic waste conversion to oil/fuel goes through various stages: material input validation, process design, processing capacity adjustment, estimation of capital expenditures (capex) and operational expenditures (opex). The objective is to analyse technologies under development in terms of costs, profitability, uncertainty, and limitations in order to evaluate whether they are feasible to be deployed in the market, and at what scale. Studies on the plastic-to-fuel/oil economic feasibility have revealed that, in most cases, the process is limited by scale, and scales of about 10,000 kg/h or 100,000 tons/year or higher have been reported to be economically feasible and appealing to investors. However, factors such as limited feedstock availability and competition in feedstock with other plastic recycling technologies can hinder the economic feasibility. Optimization of operating parameters may improve the economic performance.

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