Engineering Alternative Technologies (EAT) Plastic

This review was written based the Engineering Alternative Technologies (EAT) Plastics Workshop held on October 13-14, 2020 on a virtual platform. The conference was supported by the United Engineering Foundation (UEF).

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Plastics are currently used extensively in various industries, including clothing, cosmetics, tires, containers, and more. It is predicted that if current production and treatment methods of plastic continue, by 2050, 26 billion tons of plastic would have been produced[i]. Over 99% of plastics are produced from chemicals sourced from fossil fuels, and it is expected that if current trends continue, plastic production will account for 20% of oil consumption in 2050[ii]. Additionally, every year, 8 million metric tons of plastics enter our ocean on top of the estimated 150 million metric tons that currently circulate our marine environments[iii]. The large amount of plastics produced coupled with the potential for negative environmental effects increases the demand for more efficient waste management, remediation technologies, and recycling systems for plastic waste. Plastics themselves contribute to approximately 10% of discarded waste and plastic is cited as one of the biggest challenges in waste management. It is not surprising that plastic issue regain popularity in the media in the recent years.

New Advancements in Circular Economy for Waste Plastic

There are currently seven different categories of plastics recognized by the Resin Identification Code (RIC), each with unique properties that present a unique challenge for recycling efforts. Plastics such as polyethylene, polypropylene, and polystyrene are among the most commonly produced plastics worldwide[iv]. The high variety of plastics in waste streams create the need to sort plastics into their respective RIC category for mechanical recycling to ensure feedstock consistency. However, challenges such as contamination from food, various additives, and other sources further complicate the mechanical recycling process. A complementary recycling practice is chemical recycling, which can be used for mixed plastic waste streams and converts the waste plastics into feedstock for the chemical industry. Thermal processes for advanced recycling include pyrolysis, gasification, combustion, and incineration. With some of these processes, particularly gasification, the waste collection footprint of the intermediates must also be considered prior to implementation. Creating a circular economy also requires a qualitative framework which assesses the footprint of various recycling strategies, focusing on key issues such as leakage and litter[v].

The liquefaction of plastics is one strategy being studied for treating various waste plastics, and involves converting the plastic polymers into a liquid chemical product through the process of thermal degradation. Waste polymers can even be converted to fuel using methods such as thermal cracking, flow cracking, catalytic cracking, and pyrolysis to achieve the conversion[vi]. Chen *et al.* have used supercritical water for the liquefaction of propylene into oil, resulting in a product that has the potential to be used as a gasoline feedstock with most of the liquid components had the same boiling point range as naphtha[vii].

Reuse and Recycle Waste Plastic

As we have seen so far, promising new technologies have the potential to accelerate the rate of recycling. However, there are several economic factors that will influence recycling practices. The price of recycled materials must be competitive with virgin plastics in order to incentivize the production and purchase of recycled materials. Additionally, tipping fees, or the costs of municipalities to pay to dispose plastics in a landfill, may de-incentivize recycling if too low[viii]. Recycling plastics on a large scale will also involve investment in infrastructure, whether it is made by companies or through policy and legislation. In order to increase the amount of plastic recycled, it may also be important to consider re-shaping the current domestic recycling system. For instance, since 1992, China has imported 106 million metric tons of waste plastic making up 45.1% of cumulative imports. However, recent regulation banning the importation of most plastics is expected to create 111 metric tons of displaced waste plastic by 2030[ix]. Recycling capabilities in the US may have to change even to maintain the rate of recycling in past years.

Funding education about plastic recycling is also vital to developing not only novel technologies, but impactful consumer habits. Consumer perception of plastic products will also largely influence industry decisions. The packaging sector often utilizes single-use plastics for many of its products, which has been the focus of campaigns against plastics in the past[x]. Therefore, in this case, investments in compostable and recycled materials may have long-term economic benefits.

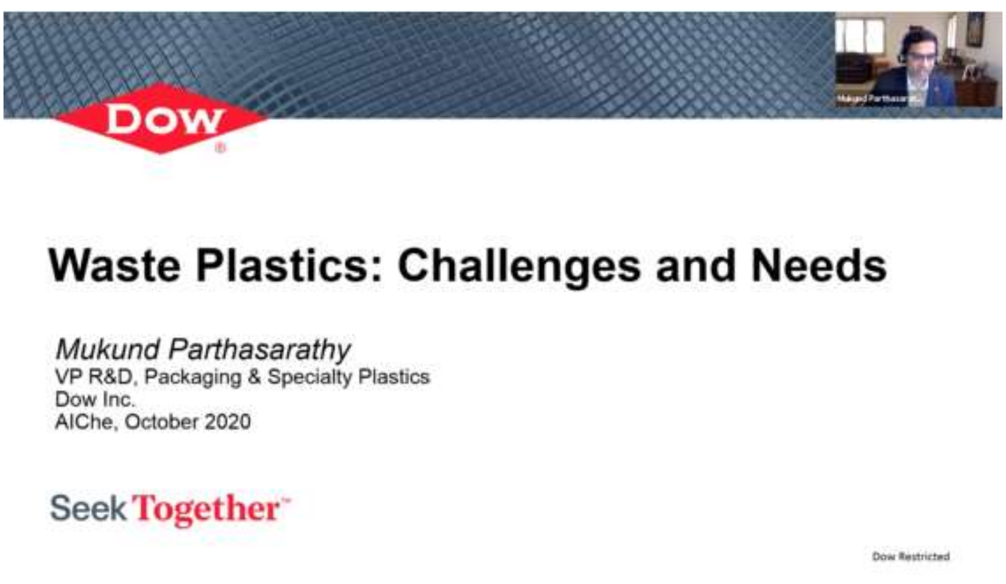
What we learn from these presentations is that sustainability is complex—it takes collaboration with various stakeholders, the need for innovative and scalable technologies, the development of new materials, and an effective recycle value chain. There is a need to consider the environmental benefit of new technologies, as well as market factors, policy, and consumer opinion. Additionally, new technologies have to be scalable, with the ability to be implemented within current recycling infrastructure.

Role of Industry and Government to Advance the Field

To recognize new technologies and innovations in the field, we have included a summary of the work of several of our speakers, working in academia, industry, and government to help solve issues associated with waste plastic.

Michael Maggio, Inclusive Waste Recycling Consortium (iWrc): The iWrc is an organization which helps waste picking cooperatives improve their social fingerprint, especially those in developing countries. They cover issues such as health and safety, hours, and protections against child labor while simultaneously developing improvement plans and optimizing the recycling processes. Michael gave a talk about cleaning up wastepicking in Brazil, where much of the waste sorting was done manually by workers. Advancing the health and well-being of workers and connecting the wastepicking cooperatives with companies that purchase ethically sourced materials was a success for iWrc.

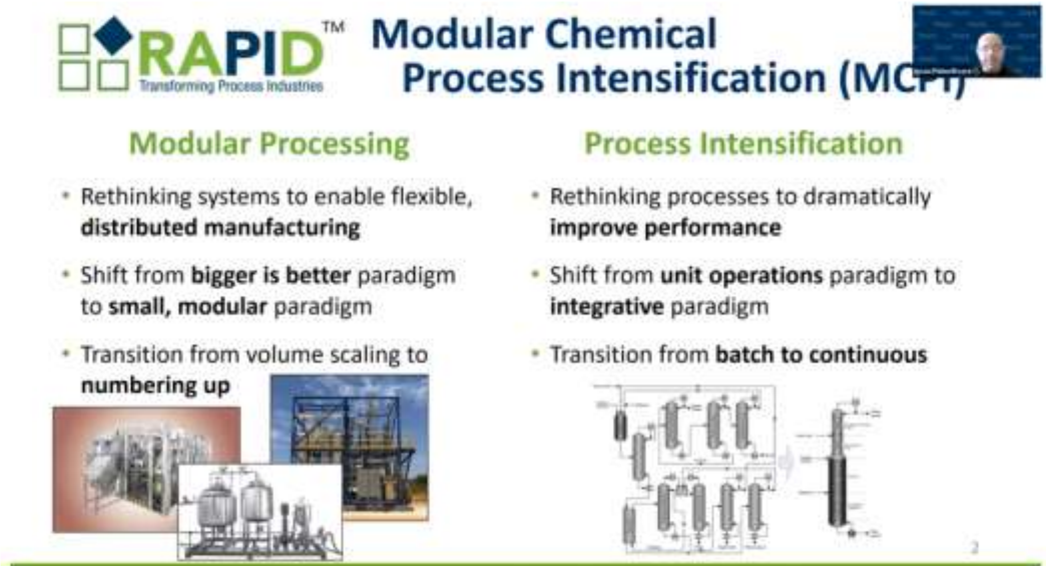
Mukund Parthasarathy, Dow Inc.: Dow is a founding member of the Alliance to End Plastic Waste, which is one of the topics Mukund addressed in his talk. The organization commits more than $1 billion to its mission, in order to develop solutions to manage plastic waste. The alliance currently has nearly 30 companies, all in various locations throughout the world.



James Tour, Rice University: James presented an upcycling system that can be run with mixed waste streams that are not prewashed. The carbon sources are placed between two electrodes and flashed, converting the waste material into graphene. Graphene has many different applications, being used in paint, bone composites, concrete, and many more. Therefore, the plastic waste can be converted into a high value product through a process with a relatively low cost.

Susan Thoman, Compost Manufacturing Alliance: The CMA works to provide a standard for compostable materials by performing tests to ensure these materials disintegrate within the production cycle. Failure to meet this standard can negatively affect the bottom line of composters by increasing the cost to facility owners. It is also beneficial for composters to receive food scraps and other high value organic feedstock for their compost facilities. Therefore, materials that are compostable as well as bring in such feedstocks have the most value for composters. Considering the economic impacts of composting brings us one step closer to expanding this practice across various industries.

Ignaci Palou-Rivera, RAPID Manufacturing Institute Technology: The RAPID Institute is funded by the Department of Energy, and is focused on process intensification and modular processes in order to build systems that are less energy intensive. RAPID has partnered with several universities to develop new technologies related to waste plastics, including Iowa State University and the University of Delaware.



Lucas Ellis, DOE BOTTLE: In October 2020, the Department of Energy has invested $27 million in plastics recycling R&D, including the Bio-Optimized Technology to Keep Thermoplastics out of Landfills and the Environment (BOTTLE). The BOTTLE is a consortium that conducts R&D in areas such as catalytic/bio catalytic recycling strategies that are energy efficient, scalable, and cost-effective for upcycling, as well as designing new materials that will be easily recyclable.

Jeff Cernohous, Interfacial Solutions and Interfacial Consultants: Interfacial accelerates the development of novel technologies, including high performance composite substrates for transportation, building, and other uses. Interfacial also develops technology that would allow for the utilization and incorporation of post-consumer recycled materials whenever possible.

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