Analysis of Concerns RE: Advanced Recycling

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December 16, 2019

Professor Marco Castaldi's Earth Engineering Center at The City College of New York (EEC|CCNY) has conducted sponsored research projects for The American Chemistry Council (ACC) and is currently researching gasification technologies for ACC. EEC|CCNY conducts unbiased research for the purpose of knowledge generation and educational dissemination and adheres to strict academic research standards.

Policymakers are reviewing proposals to minimize plastic waste and litter. One option includes supporting multiple, relatively new technologies that repurpose used plastics into new products, including new plastics, industrial products and transportation fuels.

First and foremost it must be understood that traditional mechanical recycling will not by itself achieve the time-restricted goals set by most municipalities and environmental organizations. A recent study[1] demonstrates that in an ideal scenario where a municipal recycling center receives an uncontaminated polypropylene (PP) and high-density polyethylene (HDPE) stream, the best recycling rate will be 73%. This still leaves nearly 83,000 tons of plastics that must be managed without sending it to a landfill. Furthermore, consider New York City, which has one of the best curbside collection and citizen participation rates in the United States for plastic recovery. Despite this, the city only achieves a recycling rate of 48% of plastic placed in the blue bins[2] [3]. These are just two examples of recent studies which clearly indicate mechanical recycling cannot be expected to manage all the plastics which enter the waste stream. To meet the ambitious targets ahead of us, all possible processes and technologies must be considered to ensure end-of-life plastics are not disposed in landfills.

Technologies that break down used plastics into their chemical building blocks to create new products are broadly referred to as "advanced recycling" or "chemical recycling," and complement current mechanical recycling efforts. In addition to creating new products, advanced recycling technologies keep these plastic materials circulating within the existing infrastructure and economy. The process of breaking down the plastics into their building blocks is basically reversing the assembly process. This can help to decontaminate some plastics making the recycling of them more valuable.

There has been much public discourse about the promise, merit and drawbacks of advanced recycling – however, it can only be fully understood through careful analysis of the results from scientific studies. Some organizations are concerned that the promise of advanced recycling is a myth and may actually exacerbate environmental impacts. The body of knowledge and evidence developed by engineers, scientists and practitioners demonstrates that these concerns not well-founded.

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[1] Sharma, D. K., Bapat, S., Brandes, W. F., Rice, E., & Castaldi, M. J. (2019). Technical feasibility of zero waste for paper and plastic wastes. *Waste and Biomass Valorization*, *10*(5), 1355-1363

[2] NYC Department of Sanitation. 2017b. SubSort Data: City and Boroughs. New York: NYC Department of Sanitation. https://www1.nyc.gov/assets/dsny/site/resources/reports/waste-characterization.

[3] NYS Department of Environmental Conservation. 2018. Recyclables Handling & Recovery Facility Annual Report: Sunset Park Material Recovery Facility (2017). New York: DEC. ftp://ftp.dec.ny.gov/dshm/SWMF/.

Let's review those concerns…

First, it's important not to make broad assumptions about advanced recycling technologies, processes, costs, efficiencies and environmental profiles. Each technology is different and has advantages and challenges just as mechanical recycling does. What is important to keep in mind is that the ultimate goal is to ensure that plastics are properly collected and managed after they have gone through their useful life. In addition, advanced recycling technologies have the added bonus of creating valuable products, while simultaneously displacing the need for virgin materials.

Concern. Advanced recycling is an "industry greenwash term."

This is not true. Greenwashing refers to efforts to obscure environmental realities by painting a misleading picture. The term advanced recycling is an attempt to categorize and describe the otherwise complicated processes. Advanced recycling encompasses multiple technologies that divert plastic from the landfill and instead breaks it down into its chemical building blocks to create new products.

The terms "advanced recycling and recovery," "transformational technologies" and "chemical recycling," are interchangeable. All of these terms help differentiate advanced recycling from the more widely known recycling processes that employ mechanical technologies to recycle used plastics.

Concern. Advanced recycling should be called different terms depending on the process and resulting product(s).

Maybe. As noted above, the term encompasses many technologies that remove plastics from the waste and litter streams to create new products. "Advanced recycling" includes multiple *similar* processes. But each advanced recycling company publicly characterizes their specific process by types of used plastics, technologies, and resulting products. Closed Loop Partners highlights the multiple, innovative solutions that transform used plastics into renewed materials. Unfortunately, most of the general public does not have the background, interest, or time to explore the technical differences of these processes; therefore the term "advanced recycling" helps to differentiate these processes from mechanical, thermal, and other processes.

Concern: Converting used plastics into fuel damages the environment.

This is incorrect. First, remember that converting plastics to fuel is just one of the processes defined by advanced recycling. Second, plastics contain an inherent energy content, and capturing that energy -- when these used plastics would otherwise be sent to landfill -- **IS** environmentally beneficial compared to the alternative. Transforming used plastics into valuable fuels for airplanes, trucks, heating and other purposes not only reduces the amount of plastics that would be sent landfill, but also reduces the need to extract virgin fuels. Effectively, this process takes back the inherent energy that was used to make the product and repurposes it in a beneficial use.

Concern: Chemically recycling plastics into fuels is the same as incineration.

This is not correct – incineration refers to destroying waste materials by burning, without any provision for recovering energy or materials. This is a separate process and **DOES NOT** fall under the umbrella of advanced recycling. Advanced recycling converts used plastic into a variety of useful materials:

(1) feedstocks for new plastics which can be utilized in a multitude of plastic applications including new packaging (foodservice);
(2) chemicals, such as methanol that becomes windshield wiper fluid;
(3) valuable products such as wax that can be utilized in various applications like roofing and candles; and
(4) consumer/commercial transportation fuels for jets, diesel trucks, heating units, etc.

Concern: Converting used plastics into fuel shouldn't be considered "climate friendly".

Disagree. Currently the transportation sector relies on fuels made from crude oil and natural gas. Converting plastic to fuel allows the energy captured in the original petroleum and natural gas hydrocarbons to have two uses: the plastic product and then fuel. Converting used plastics into valuable transportation fuels reduces the need to extract natural resources to create "virgin" fuels and avoids the associated environmental impacts. In other words, chemically recycling used plastics displaces the need for virgin fuels and reduces climate impacts.

Concern: Advanced recycling facilities create environmental emissions.

This is true, but the concern is often used in a misleading context. All processes yield environmental emissions. All facilities – not only manufacturing facilities, but also restaurants, factories, homes, hospitals, government offices – create environmental emissions. In fact home heating systems that use wood as their fuel are a source of major pollution in the Northwest U.S.[4]

Advanced recycling is a manufacturing process: raw materials (used plastics) are processed to make new products (plastics, chemicals, fuels, etc.). Like all manufacturing processes, there is a potential for emissions, so the process must be monitored and controlled to ensure emissions are below the US EPA and state regulatory limits. These processes are monitored not only by the manufacturer, but also by state and federal levels.

Interestingly, emissions from facilities that use a common advanced recycling technology (pyrolysis) were typically found to be lower compared to many industrial and commercial facilities, such as food manufacturing, hospitals, and universities. Pyrolysis results in a non-hazardous byproduct that can be managed similarly to other solid waste, resulting in waste reduction of approximately 90 percent.

Another important consideration about advanced recycling is that it allows for avoidance of emissions that would be generated if new plastic material or fuels needed to be manufactured from extraction of natural resources.

[4] Gaston, Cassandra J., et al. "Online molecular characterization of fine particulate matter in Port Angeles, WA: Evidence for a major impact from residential wood smoke." *Atmospheric environment* 138 (2016): 99-107.

Concern: Traditional mechanical recycling is environmentally better than advanced recycling.

Mechanical and advanced recycling are complementary approaches that have different inputs and outputs, and they cannot be compared without considering the whole picture, including what comprises the incoming plastic steam. For example, mechanical recycling works well for specific resins and forms like bottles and containers, and it's well-suited to produce plastics for new durable uses such as pipe, railroad ties, and pallets. However, some plastics are difficult to sort and impossible to process in today's mechanical recycling facilities. If those streams are processed through a mechanical recycling facility, huge amounts of waste are generated at the end of the process, and this would typically be landfilled. Advanced recycling offers an alternative for these waste streams and offers a second life for the plastic as a renewed useful end product.

It is also more challenging to use mechanically recycled plastics in food-contact applications and packaging, whereas advanced recycling allows for added purification making waste plastics suitable for food-contact. Therefore, both mechanical recycling and advanced recycling have a unique use-case depending on the plastic waste stream and the output needed.

Concern: Repolymerization is "technically challenging and uneconomical."

Repolymerization is one way to describe a type of advanced recycling, and it's exactly what it sounds like. Take a used polymer (a type of plastic), use an advanced recycling process to break it down into its chemical building blocks (monomers), and then build it back into a polymer: re-polymer-ization. It's basically like making virgin plastics from petrochemicals, but instead of using petrochemicals as the feedstock, chemical recyclers use "waste" plastics as the feedstock. This simultaneously reduces the use of petrochemicals and diverts used plastics from the environment.

Challenging? Yes, but challenges are normal for any business. The more important question: is it economical? Yes, it is with the right business model that marries three important elements (1) an unused waste stream of used plastics (2) a suitable technology and (3) ready demand from end markets. The first two elements exist. The third element is rapidly developing as today's business climate demands materials made from recycled content to help meet sustainability goals. Mechanical recycling will allow for a portion of that demand to be met, but not all. Remaking plastics from used plastics (repolymerization) will help businesses to meet their recycled content goals and to reduce their dependence on virgin material.

Concern: Advanced recycling technologies and businesses are too "immature" to handle today's plastic waste.

Every business (including recycling) requires many things to mature: adequate capital, readily available raw materials, proven technologies, robust end markets, etc. Today's advanced recycling businesses vary in their maturity, but all have demonstrated practical viability. There are quite a few examples of advanced recycling technologies that have been deployed economically in various industrial processes, including the production of industrial waxes, and more processes continue to come on line to meet the growing demands of consumers and businesses for solutions to divert plastics from our oceans and landfills.

Even as more and more advanced recycling technologies reach maturity, advanced recycling facilities will not handle <u>all</u> of the world's plastic waste. Thankfully, they won't need to. Advanced recycling is

complementary to mechanical recycling. Ongoing and emerging advances in mechanical recycling are capturing more types of post-use plastics, and advanced recycling is poised to capture other streams of waste plastics that are not mechanically recycled today due to myriad aspects.

Recent studies have demonstrated great opportunities for advanced recycling, both at home and abroad. For example, a **2019 report** by the Closed Loop Partners, an organization that invests in the development of the circular economy, found there is tremendous demand for the products of advanced recycling. So, while many advanced recycling companies are young, they are maturing quickly as the growth in demand for their outputs continues.

The combination of mechanical and advanced recycling will help lead to a circular economy for plastics, in which used plastics are repurposed rather than disposed, which keeps plastics out of the environment and harnesses their inherent value to create new products.

Concern: Many large companies that produce or use plastics are only promoting advanced recycling to distract attention from the growing amount of plastics production.

The amount of plastics produced is a direct result of demand by businesses and consumers. There is no distracting from that reality. Companies that make or use plastics realize that they must be proactive in helping create solutions for plastics once they have served their useful purpose, and these companies also realize that mechanical recycling is useful but obviously cannot handle all the plastic waste. So, these companies promote advanced recycling to complement existing mechanical recycling efforts. Furthermore, these companies possess the requisite experience and background to effectively develop robust and reliable advanced recycling processes.

Plastic manufacturers produce materials to meet customers' demands. They can easily produce plastics from virgin feedstocks or renewed plastic feedstocks that result from advanced recycling. Many of these manufacturers have committed to increase the amount of recycled plastics they use, to meet *their* customers' demands and sustainability pledges. They realize that to meet these pledges in the very short timeline promised, a huge amount of additional recycled material needs to quickly emerge. Advanced recycling will help to provide that feedstock from materials that would otherwise land somewhere in our environment.

Concern: Advanced recycling should not receive public incentives.

Public incentives help catalyze the quick development of processes and technologies that would otherwise take years to develop and mature. Consumers, manufacturers, recyclers and NGOs agree that plastic waste in the environment is a huge problem. The question is how to tackle that problem quickly and effectively without inducing unintended environmental harm.

Advanced recycling effectively diverts plastics from landfills and the environment and creates new and valuable products that displace virgin materials. These technologies reduce greenhouse gas emissions, contributing to efforts to combat climate change. However, like all businesses, advanced recycling cannot develop quickly without the right amount of initial capital investment. Advanced recycling companies can also create jobs and bring tax revenues to communities by building a thriving economy around extracting value from a resource which would otherwise simply end in a landfill or our oceans. It is absolutely logical to explore public policies and incentives that encourage these technologies to develop more quickly.