If it’s broken, fix it: how chemical recycling can fix the broken plastics cycle

Building a better working world

It's no secret that plastics are a part of almost everything we do in our lives, and that trend shows no sign of slowing down. US plastic production has been steadily increasing over the last 20 years and is expected to continue to grow 3.5% per year on average. Despite this growth, plastic recycling rates have largely leveled off in the US over the past decade, hovering at around 9%. The remaining 91% of plastics disposed of by consumers in the US either ends up in landfills or is combusted in waste-to-energy plants. Much is being done in the name of protecting the environment and reducing waste, but these efforts are increasingly proving to be futile. Analysts are curious about a new approach that addresses plastic recycling's massive gap between quality supply and rapidly growing demand that has yet to be bridged.

9%

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5%

While the recycling rates of PET and HDPE are at around 30%, less than 5% of PP and PS is recycled in the US.

Current state of post-consumer recycling

The current plastic recycling model starts with the consumer. Plastic waste either goes into a commingled recycling container and is processed at a material recovery facility (MRF) or into a garbage bin, where it is taken to a Mixed Waste Processing Facility, affectionately referred to as a "dirty" MRF. The objective of the MRF is to separate all of the different materials (paper/fibers, aluminum, glass, plastic, etc.) into minimally contaminated streams to be resold to product manufacturers. For plastics, there has been a concerted effort to reduce contamination rates using technologies such as optical sortation and artificial intelligence. However, while sorting technologies are constantly improving, they are also met with an increasing diversity of plastic types. Forty percent of plastic used in the US is used for product and food service use, which means that materials are often contaminated and vary considerably in plastic type, density and shape.

To better preserve packaged products, composite materials, such as laminates, are widely used. This only exacerbates the challenge of separating waste into single-material bales for traditional recycling.

Circularity of plastic has also been hurt by low crude oil prices in recent years, which makes virgin plastics considerably more cost-effective. Historically, plastic innovations have not been met with equal innovations of plastic recycling on the back end compared to other materials, such as aluminum and cardboard, which have considerably higher recovery rates. Ironically, many companies have also switched to thinner, less recyclable forms of plastic to market themselves as reducing their total plastic use.

However, the full story is a bit more nuanced. Over the last decade, MRFs have advanced their ability to sort polyethylene terephthalate (PET) and high-density polyethylene (HDPE), the two most recycled plastics. These plastics are then baled and sent to plastic reprocessing facilities, where they are cleaned for contaminants,

melted down and turned into plastic pellets for use in new products. This process of "mechanical" recycling is somewhat effective for these plastics because they are often thick and relatively uncontaminated, and they typically make up products that are bulky and easy to sort (think water bottles, milk jugs and detergent containers). In fact, PET and HDPE have recycling rates around 30%, triple the average plastic recycling rate. However, following China's "National Sword" Policy in 2017, the stricter quality requirement on baled recyclables and the price volatility of recyclable commodities reduced profitability of MRFs: the quantity of plastics recovered at US MRFs decreased with PET as the only exception.

For other plastics, the recycling story is even less encouraging. Plastics such as polypropylene (PP) and polystyrene (PS) are recycled at rates well under 5%. Very little post-consumer PVC is recycled due to the strict sorting requirements for recycling and concerns over emissions released in the process.

Recently, polylactic acid (PLA) plastics have surged in popularity due to their ability to be composted. However, these plastics require an industrial composting facility, and the actual composting rate of these plastics in the US is still unclear. Only 19% of the largest cities (representing 11% of the total US population) have composting programs that accept compostable plastics. Compostable plastics are also difficult to distinguish from other types of plastic and thus (1) are not accepted by many composting facilities and (2) can lead to increased contamination in mechanically recycled plastic streams. The end result is that, in 2018, the EPA estimated that over 26 million tons of plastic were sent to landfills in the US.

While there continues to be a struggle on the supply of quality recycled plastics, there is no shortage of demand for recycled content from consumer brands. CPG brands, such as Nestle, Procter & Gamble. Unilever and Anheuser-Busch, have steadily made commitments to increased recycled content in their products and packaging. In order to meet current recycled content goals, a recent study showed that the recycled plastic industry is projected to grow at a 35% per year rate through 2025 in order to keep up with current recycled content commitments from major brands. According to the 2021 Progress Report for the Global Commitment and Plastic Pact network, one of the challenges that brand owners face surrounds flexible packaging, which constitutes 18% of signatories' plastic packaging weight and is not recyclable at scale. With the limit on the waste management system and technical constraints, it is now becoming clear that mechanical recycling cannot fill this gap alone.

The failure of plastic recycling lies in the fact that current mechanical recycling processes cannot sort various plastic types into a suitable baled product and produce recycled polymers that meet the standards required by brand owners at a competitive price. Enter chemical recycling.

Chapter 1

Current state of chemical recycling production

Chemical recycling is the process of changing the chemical structure of plastic waste so that it is reduced to its basic building blocks. While mechanical recycling weakens the tensile strength of the resulting resin, chemical recycling can turn mixed or even contaminated plastics into pure monomers or polymers that are chemically identical to their virgin resin competitors. The chemical recycling field currently has dozens of technologies, but the three overarching processes of chemical recycling are purification, conversion and depolymerization:

Purification:

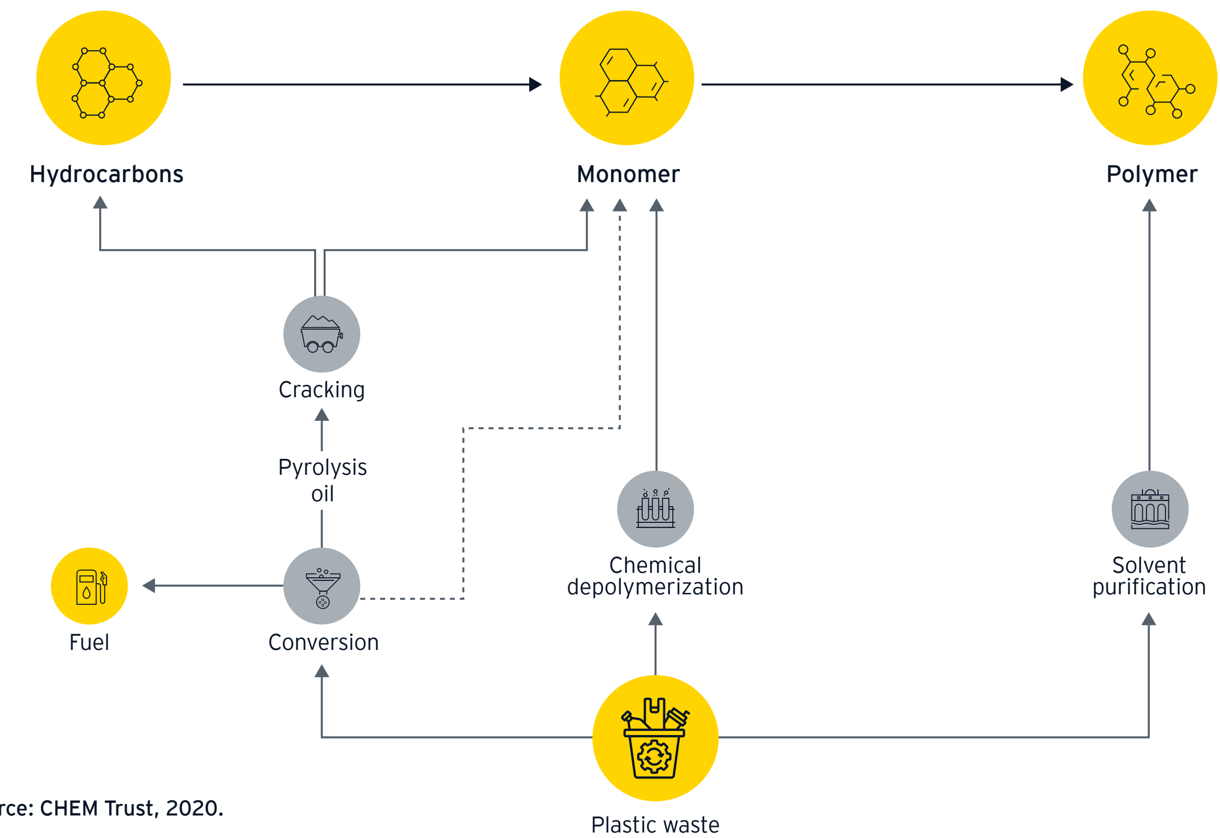
This is commonly viewed as the most "circular" chemical recycling technology, as it can process commonly landfilled plastics, such as PS, PP and PE, with the lowest energy input. It is also the least technically mature of the three.

Conversion:

This is the most developed technology and is unique from the other two technologies in that it can accept mixed plastics as feedstock. Studies show that some pyrolysis techniques may even produce a better product when a mix of plastics is used as feedstock, which is encouraging, given current plastic sorting limitations. It is also viewed as the least environmentally friendly form of chemical recycling, as it is more energy-intensive and returns plastics back to an "oil" state.

Depolymerization:

This method lies in between the other two technologies in terms of its maturity and energy input, but it is rather limited in application.



Source: CHEM Trust, 2020.

Each technology has its own benefits, downsides and particular plastics for which it is most useful. As a result, it is most helpful to think of these three technologies, along with mechanical recycling, as working in tandem to increase circularity instead of competing against each other. Further, it is generally accepted that, while chemical recycling alone wouldn't lead to a circular economy for plastics, a circular economy of plastics is difficult to envision without chemical recycling.

In the US, > 30 chemical recyclers exist, with only ten chemical recycling plants fully operational in all of North America as of 2021. The current operating capacity of chemical recyclers in the US is about 300,000 tons per year.[1] While operationally nascent, chemical recycling has already been receiving significant attention in the US in the form of investment. The American Chemistry Council reports that over $7b has been invested since 2017 and is consistently growing. Multiple chemical, energy, recycling and consumer good companies have announced plans to open chemical recycling facilities specifically within the US.

Conversion of plastics is currently the most popular technology because integrated oil companies can potentially perform the process using existing underutilized equipment and facilities. A recent investment into a chemical recycling plant, on the other hand, will utilize depolymerization technology. Pyrolysis, the most popular form of conversion, is expected to grow 14% per year for the next decade according to some industry predictions. In fact, the same companies that produce most US plastics and chemicals are poised to become leaders in chemical recycling in the coming years. When looking at the top plastic producers who have made recycled output goals in the US, several are targeting to have roughly 4% of their total resin output from recycled plastic (chemical or mechanical) in a time frame of five to 10 years.

Under the current market conditions and technological maturity, we estimated the cost of selected chemically recycled plastics, inclusive of regulatory savings against their respective virgin alternatives.

[1]EY Analysis

Chemical recycling cost estimate ($ per metric ton) — mixed plastics (top) and PET (bottom)

Source: EY Analysis, 2022.

Chapter 2

Factors affecting chemical recycling: drivers and detractors

Brand commitments

Demand for recycled plastics from consumer brands is one of the most obvious, but crucial, support mechanisms for chemical recycling. These brands play an important role in implementing a circular economy by providing materials that can ultimately be recycled and stimulating demand for chemically recycled plastics via minimum recycled content commitments. Such commitments are now imperative for businesses: across five global post-pandemic consumer segments, the EY Future Consumer Index shows that planet-first has steadily evolved into the largest segment.

The 25 largest consumer brands — both independently and through partnerships — publicly committed to packaging sustainability: 70% of these commitments plan for majority recyclable or biodegradable materials within the next decade, 40% include commitments to reduce plastic volume and nearly one-third incorporate provisions for minimum recycled content in packaging. Smaller brands will continue to face increasing pressure from stakeholders to meet similar commitments: multiple national retailers have committed to reducing plastic waste in their own brands and cite goals to reduce plastics use across the value chain.

For the chemical recycling industry, this means that a growth in demand is fairly predictable for the next decade. In fact, the few chemical recycling plants that are operational already have most of their future product committed to buyers who are desperate to get their hands on quality recycled feedstock. Moreover, additional brand commitments to support the infrastructure of the circular economy will enable higher-quality feedstock as chemical recycling facilities continue to scale.

Legislation

At the international level, the UN began drafting a resolution requiring action toward circular economies, which is expected to pass by 2024 and incorporates member nations' actions and scientific input.

In the US, several regulations could impact the growth of chemical recycling. As lawmakers continue to set recycled content minimums and consider utilizing extended producer responsibility laws for plastic packaging, the chemical recycling industry will grow just as the European industry did after the EU set such requirements. Thus far, California, Washington and New Jersey have already passed recycled content regulations similar to the EU for 2025 and 2030. Development within relevant agencies, such as the FDA's published guidelines on chemically recycled content use in food contact packaging, brings clarity to the brand owners, which mitigated the potential regulatory risks for brands and financial risks for investors.

Legislative support for chemical recycling may also take the form of a "carbon tax," which would narrow the cost advantage of virgin plastic over chemically recycled plastic due to decreased carbon emissions from the latter. Carbon taxation would help out chemical recycling from all directions because carbon emissions from the production, sale and landfilling of plastics will have a financial impact on producers, brands and waste managers.

Another support mechanism for chemical recycling is the proposed SEC guidance on mandatory reporting of direct (scopes 1 and 2) company emissions, as well as indirect (scope 3) emissions if deemed material. For consumer brands, plastic packaging can be a significant part of scope 3 emissions, and therefore will receive increased attention from investors should this guidance be implemented.

One large consideration continues to play out across the country: how to classify chemical recycling as an industry. Many states welcome the industry. Since 2017, 18 states have introduced regulations to classify chemical recycling plants as manufacturing facilities, not solid waste disposal centers. These laws are intended to support the development of chemical recycling by providing investors and operators with regulatory certainty as to which rules and regulations they must abide by, as well as which state and local incentives they are eligible for.

On the other hand, the recently proposed Break Free from Pollution Act, which seeks to increase the responsibility of consumer brands and plastic producers in improving recycling rates, excludes chemically recycled polymers from its definition of recycling goals. A recent report by the Natural Resources Defense Council studied currently operating chemical recycling plants in the US and found that they were recycling very little amounts of plastic while producing significant amounts of toxic pollutants in the process. The EPA is currently reviewing various chemical recycling technologies to guide future decision-making.

Regulatory pressures, such as plastic/carbon taxation, carbon credits and zero waste laws, need to be carefully followed as they are the most important contributor to ensuring the economic viability of chemical recycling.

Overall, the regulation of plastic waste — whether through subsidies, levies, mandates, incentives or extended producer responsibility — will be instrumental in the long-term success of recycled materials. Based upon our analysis, it will continue to drive up the cost of virgin plastics while reducing the bottom-line impact to sustainably oriented companies.

Tipping fees

Another growth factor for chemical recycling will come from the simple truth that the US, like most of the world, is running out of space for safely and conveniently disposing of municipal solid waste. As landfills continue to fill up, tipping fees for disposing of waste have increased at an average rate of 3.5% per year. Although landfill operators (who also act as waste collectors in many municipalities) stand to profit from increased plastic waste, these increased tipping fees will encourage plastic users and government agencies to find opportunities for circularity. Additionally, chemical recycling companies could potentially receive a discount on purchased feedstock so that waste sorters, municipalities and taxpayers can avoid these increased landfilling fees.

Scaling and sourcing

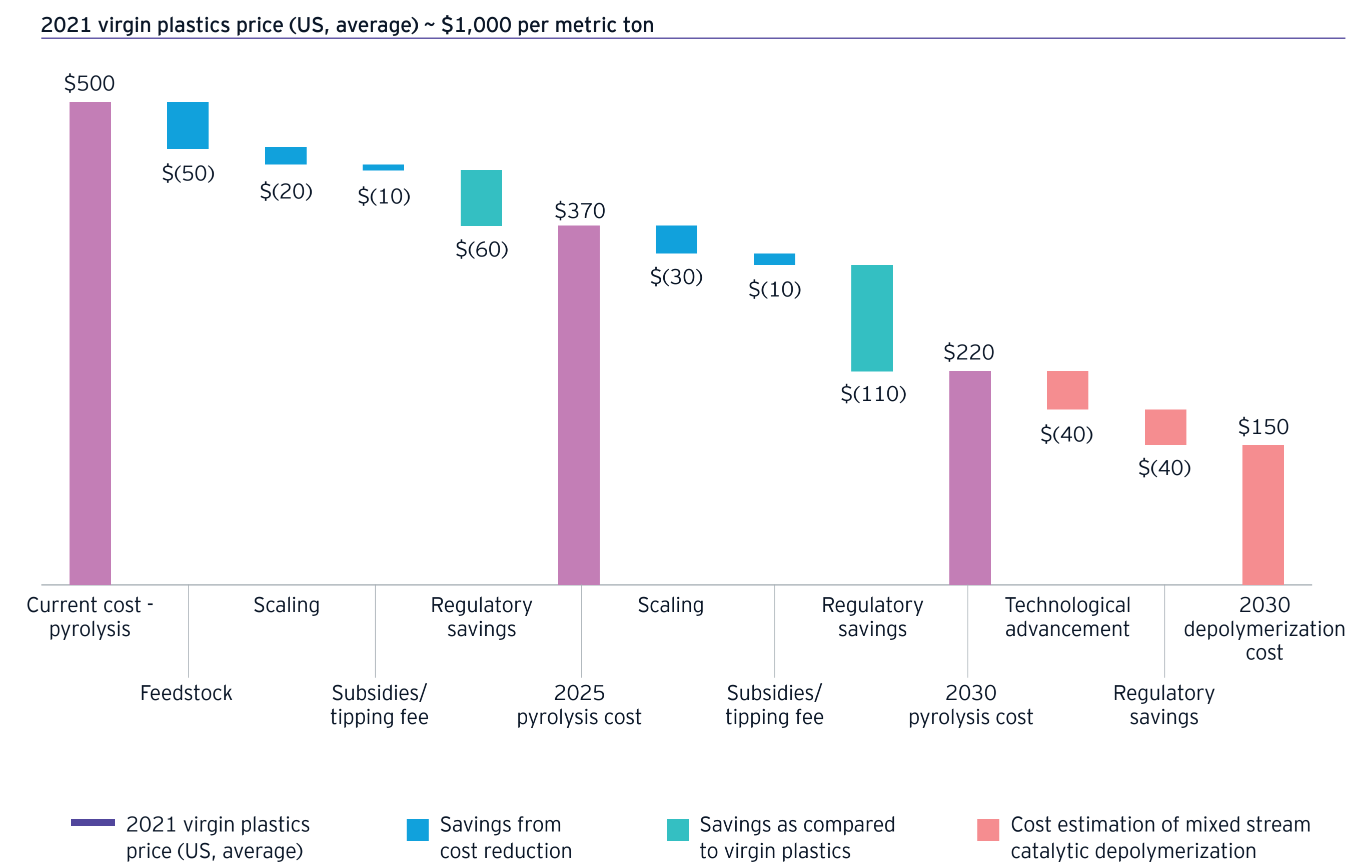
Once chemical companies start to operate at scale, we assume that the unit prices of chemically recycled plastic will continue to fall from 2021-2026 and beyond, as seen in other chemical processes' upscaling. The learnings from operations and marginal enhancements from iterations of technology also create savings. The pricing models were derived utilizing simple scaling formulas, but no specific assumptions could be made, given the nascency of the technologies used in mechanical recycling and the intellectual property.

Public perception

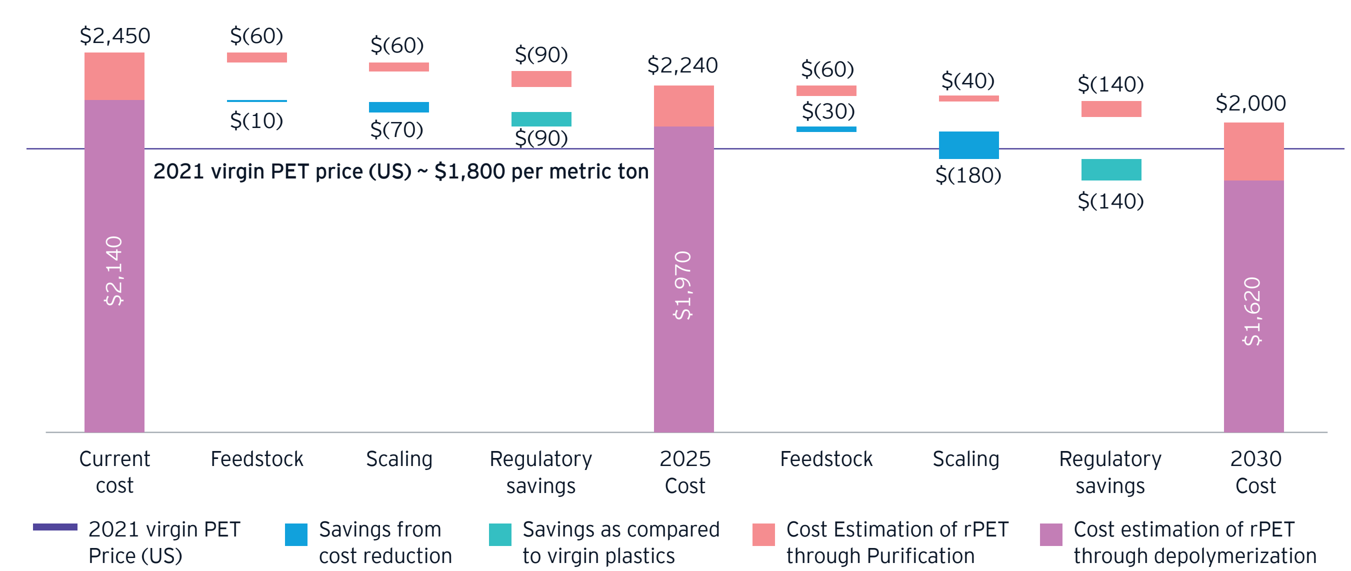
Current coverage of chemical recycling focuses on conversion. In its current form, conversion is energy-intensive, but it emits only half as much pollution per ton relative to energy conversion, while mechanical recycling fares far better. Further, conversion produces an oil, which causes part of it to be "downcycled" as opposed to recycled. Due to the increased potential for greenhouse gas emissions and association with downcycling for conversion technologies, many citizens and organizations have negative perceptions about chemical recycling. However, the status quo of mechanical recycling has led to just a 5%–6% plastics recycling rate. Chemical recycling, despite its shortcomings, has the potential to increase the plastics recycling rate significantly.

Overall, as chemical recycling technologies mature and economies of scale are realized, the processing cost for chemical recycling will decrease. In addition, regulatory developments are expected to add costs to virgin plastics and enhance waste plastic feedstock availability/affordability through investments toward waste management system. Therefore, we expect chemically recycled plastics to increasingly become an economical substitute for brand owners in the coming years.

Mixed stream:



PET through chemical recycling:



Source: EY Analysis, 2022.

Chapter 3

Now, next and beyond

Now (0 to 6 months)
In the short term, both plastic manufacturers and users should be realistic about the capacities and capabilities of chemical recycling. While there is growing momentum supporting various technologies, even the most economically feasible options will simply not be able to provide enough recycled plastic feedstock to meet brand owners' recycled content goals. Although mechanical recycling in the US is far from perfect, the reality is that current mechanical recycling capacity is around 60 times larger than chemical recycling and, as a result, needs to be a prime focus for companies trying to make changes now.

Plastic manufacturers should take advantage of the significant demand for recycled plastics by investing in pyrolysis technologies that can complement mechanical recycling systems. Pyrolysis has proven that it is ready to be used now. They should also engage with policymakers to ensure that support for chemical recycling is being heard from the industry perspective.

The first order of business for any resin user should be to establish concrete, quantifiable sustainable packaging commitments for 2025 or 2030 to match current industry practices. Plastic resin users should immediately start thinking not about if their product "can" be recycled, but if it "will" be recycled with current realistic recycling capabilities. In the current state of plastic recycling, this means redesigning products that will be recovered by MRFs and mechanically recycled. Conversations with waste companies should be initiated to discover the true end-of-life destination for sold plastics to demystify any assumptions.

Next (6–18 months)
In the medium term, resin manufacturers should look beyond pyrolysis and into depolymerization and purification technologies for their investment strategy. They should start to invest in grassroots facilities and become familiar with the positives and negatives of each emerging chemical recycling technology. They should also look to partner with waste management companies to develop improved MSW infrastructure to secure a steady supply of recycled plastics that may have been previously regarded as landfill.

Resin users should start marketing and selling products with pyrolysis-recycled plastics in the medium term. They should also begin to research emerging chemical recycling technologies beyond pyrolysis, such as depolymerization and purification. They should start investing in specific technologies to be able to prove their commitment to being more sustainable and reap the economic rewards. Resin users should consider outwardly supporting legislation that seeks to increase recycling rates through the inclusion of chemical recycling as legitimate plastic recycling.

To fulfill holistic ESG agendas, recyclers and brand owners alike should monitor and manage the potential environmental and social risks embedded in the processes at and around the chemical recycling facilities. As technologies mature and installed capacity grows, it is critical to ensure that the outputs are compliant with safety standards and that workers and local communities are not exposed to health and safety hazards. Technological and procedural upgrades should be promptly introduced should such risks emerge.

Those involved in the plastic value chain should also begin to implement digitization to maximize the value of chemical recycling. The availability of data in the plastics recovery process is currently extremely limited, and companies stand to benefit from increased connectivity and data collection. Additionally, the increase in diversity of plastic recycling options will require more mechanisms for tracking as the supply base grows considerably.

Overall, traceability of plastic molecules through the plastic cycle will be crucial in ensuring the growth, reliability and veracity of chemically recycled plastics.

Beyond (18 months+)
While companies have historically looked at technology as a "nice to have," the growth of chemical recycling over the next decade will offer opportunities far beyond ESG goals. It is now a business imperative that any consumer brand, plastic producer or waste collector take a serious look at how they can become involved with chemical recycling technologies to take advantage of the significant growth that will occur over the next decade. While involvement historically took the form of partnerships and donations, in the distant future, companies should be looking to further integrate their business strategy with chemical recycling by directly investing and financing chemical recycling technologies that align with their product portfolio.

The plastic recycling industry in the US is currently at a major crossroads. Historically, plastic recycling was viewed as a viable system that allowed companies to save both money and the planet by reusing the materials they put out into market. Over the last decade, however, the narrative on plastic recycling has been shifted to focus on how ineffective mechanical recycling really is at reusing a majority of the plastics disposed of in the US. The result has been increased costs to companies, consumers, taxpayers and the environment as a growing variety of plastics piles up in landfills across the country. Our analysis has shown that chemical recycling can be the missing piece to address this problem over the coming decade, regardless of the price of oil.

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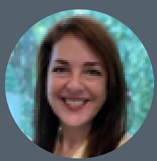

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