

# INDUSTRY'S PLASTICS RECYCLING BET

Companies are spending billions on chemical recycling methods. But environmentalists don't think it will solve the plastic waste problem

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Coming soon to dairy aisles around Europe: the circular economy in miniature.

In 2022, Mondelēz International intends to start packaging its Philadelphia brand cream cheese in tubs made from chemically recycled plastics. The packaging maker Berry Global will mold the containers. Petrochemical giant Sabic will supply the polypropylene. And the start-up Plastic Energy will produce feedstock for that polypropylene from postconsumer plastics at a plant it is constructing on Sabic's site in Geleen, the Netherlands.

"You cannot achieve a circular economy on your own. A circular economy requires partnering up- and downstream," says Robert Flores, vice president of sustainability at Berry, for which the project is its first in chemical recycling. "And obviously, as such a well-known global company, Mondelēz International was an ideal partner to launch this material with."

Mondelēz isn't the only multinational firm promising high-profile business to start-ups, some of which haven't even built their first recycling plants yet. Food, beverage, and consumer product companies—under fire to do something about

mounting plastic waste—are clamoring to set up relationships like this. They have embraced chemical recycling as a means of incorporating renewable content without the performance compromises common with current recycling methods. Seeing a market, recycling companies will spend billions of dollars on recycling projects in the US and Europe in the 2020s.

But that very embrace makes environmentalists suspicious. They contend that the plastics industry is using chemical recycling to appear to be doing something about plastic waste without addressing the core problem—overdependence on

## In brief

**Chemical companies and major consumer brands are betting that chemical recycling**—mainly pyrolysis and depolymerization—will help them achieve ambitious recycling targets. They will invest billions in new projects over the coming decade. Environmentalists, however, are skeptical. They think chemical recycling is a smoke screen for keeping business as usual, for not much of an environmental improvement. And they doubt the projects will get off the ground. Using less plastic, they say, is the best option. But industry maintains it is on the threshold of proving the technology.



plastics. Chemical recycling, environmentalists say, isn't as circular as industry claims. And as a means of disposing of plastics, the method won't scale up fast enough to make much of a dent in the plastics that are piling up.

## A growing crisis

Waste is a perennial issue for the plastics industry, but recent years have brought a sense of urgency. Plastic debris in the ocean—and images of sea creatures tangled in plastic—has woken up the public. University of Georgia chemical engineer Jenna Jambeck attached a number to the problem in 2015: 8 million metric tons (t) of plastic waste is dumped into oceans every year. A study by Stephanie B. Borrelle, a research fellow at the Society on Conservation Biology, and others, published last month in *Science*, increased the estimate to between 19 million and 23 million t per year, and those figures could swell to 53 million t by 2030.

China's National Sword policy, which blocked imports of plastics collected curbside in the US and Europe when it was enacted in 2018, tipped the plastics problem into crisis. Waste piled up locally. But perhaps more importantly, it put an end to the "out of sight, out of mind" practice of sending trash overseas. For the first time, the US and Europe had to care about what happened to its plastics.

Consumer product companies feel the pressure and are promising to dramatically increase their use of recycled resins. Last October, Unilever vowed to cut its consumption—about 700,000 t per year—of virgin plastic in half by 2025, in part by incorporating 175,000 t of recycled resin in its packaging. It used only 5,000 t at the time of the announcement.

Regulators have been pushing industry too. In July, the European Union passed a tax of €0.80 (\$0.94) per kilogram on non-recycled plastic packaging, to be enforced starting next year.

But plastics industry experts don't think companies can meet their goals through conventional mechanical recycling alone.

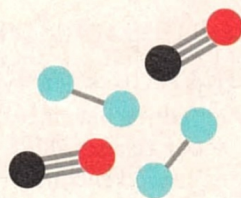
Mechanical recycling—which involves collecting, sorting, and washing post-consumer plastics—has its limitations. It's almost impossible to eliminate the intermingling of different kinds of polymers, particularly when they are melded in multilayer flexible packaging. Furthermore, repeated melting degrades polymers, limiting the number of times they can be recycled. For these reasons, mechanically recycled polymer doesn't perform as well as virgin polymer and is usually unsuited

# THE 5 LEADING PLASTICS RECYCLING METHODS



## ► Mechanical

The most common recycling method starts with plastics collected at the curb. After being sorted, plastics are sent to recyclers that wash, shred, and pelletize them for reuse. For the most part, only polyethylene terephthalate (PET) and high-density polyethylene are recycled, because they are available in sufficient volumes. Other plastics typically get sent to landfills. Moreover, given the levels of contamination—by foreign matter and other plastics—as well as polymer degradation over time, mechanically recycled plastics are often "down-cycled" and can't be used in applications like food packaging. Largely because of the shortcomings of mechanical recycling, the US plastics recycling rate sits below 9%, according to the US Environmental Protection Agency.



## ► Gasification

Plastics and other municipal waste, such as textiles and paper, are gasified under low-oxygen conditions to form a mixture of carbon monoxide and hydrogen. This synthesis gas can be a raw material for chemical production. For instance, Enerkem's gasification facility in Edmonton, Alberta, makes ethanol. Gasification plants are expensive. Making the process economical is a challenge and has led to project cancellations and failures.

## ► Pyrolysis

Under oxygen-free conditions and temperatures above 400 °C, plastics are broken down into smaller hydrocarbons, such as diesel and naphtha, which can be the starting point for new plastics. Among the technology's proponents is Plastic Energy, which is working with Sabic to develop pyrolysis facilities in Europe. Agilyx uses it to break down polystyrene into styrene for repolymerization. An appeal of the process is that it can process mixed plastic waste. Critics say turning plastics into fuel isn't really recycling. They also point to the energy intensity of the process.



## ► Depolymerization

Processes like methanolysis and hydrolysis break down PET into building blocks such as dimethyl terephthalate and ethylene glycol. These monomers can be condensed again into PET that has properties indistinguishable from those of the original. Loop Industries and Eastman Chemical are already building plants using this technology, which has generated interest from consumer product companies hungry for recycled content to incorporate into their packaging. A drawback for developers is that PET is already widely recycled by mechanical recycling.



## ► Solvent-based processes

Solvent processes don't break down polymers with chemical reactions but rather dissolve them so impurities can be filtered out and the polymers reconstituted. The result is nearly equivalent to virgin polymers. Practitioners include Polystyvert, which is working on polystyrene, and Pure-Cycle Technologies, which is developing a polypropylene technology invented by Procter & Gamble.



to package food. A mechanically recycled polymer might work perfectly well in a detergent bottle, but it wouldn't be appropriate for a yogurt tub.

Chemical recycling doesn't have these limitations. In one major process, pyrolysis, high temperatures break down polymer chains to make hydrocarbons such as diesel, kerosene, waxes, and naphtha. The process can manage multilayer packaging and other mixed plastics. Chemical makers—like Sabic, with its program in the Netherlands—aim to use naphtha as feedstock for new polymers.

The other main process, depolymerization, breaks down polymers into their precursors. A few companies are advancing projects to recover dimethyl terephthalate and ethylene glycol from polyethylene terephthalate (PET). These molecules are combined into new PET again. Mechanical recycling rates for PET bottles are already relatively high, but depolymerization can tackle products like PET fiber that are difficult to recycle mechanically.

Chemical recycling's appeal to the plastics industry is its ability to turn plastic waste that cannot otherwise be recycled into high-quality polymers.

Ron Cotterman is the vice president of innovation and sustainability at Sealed Air, a company famous for Bubble Wrap but also a big player in medical and food packaging. "These are highly regulated industries that require materials to meet food and safety requirements," he says. "It is very difficult to get mechanically recycled resins that would meet those."

Berry's Flores agrees. "There's insufficient volumes of recycled polypropylene that is suitable for food contact today," he says. "We really need advanced recycling to get greater and greater volumes of recycled content suitable for food contact."

Sealed Air aims to incorporate 50% recycled content in its products by 2025 and is thus investing in Plastic Energy. The motivation, Cotterman says, is for Sealed Air to secure resin for itself down the road by giving the nascent industry a push. "We saw a gap," he says. "Our resin suppliers appear to be moving in that direction; our customers and retailers are indicating their goals. But the ability to close that loop was ultimately limited by the infrastructure."

Owing to the push from industry, global revenues from plastics recycling—and chemical recycling, especially—is set to expand by about 30% annually over the coming decade, according to Michael Dent, a consultant who tracks plastics sustainability with IDTechEx. Plastics recycling will grow from \$48 billion in revenues today to \$162 billion by 2030. Chemical recycling



**Brightmark is testing equipment at its plastics pyrolysis plant in Ashley, Indiana.**

processes—nearly nonexistent in 2020—will make up about a third of plastics recycling by then.

## A deep skepticism

But while industry plans ambitious chemical recycling projects, environmentalists have been formulating a broad critique of the practice. A better alternative, they say, is reducing the amount of plastics produced to begin with.

Environmentalists argue that the plastics industry is insincere about its promotion of chemical recycling. They accuse the industry of trying to placate criticism so it can go on flooding the world with plastics. To them, chemical recycling is a classic greenwashing scheme.

In a report released in July called *All Talk and No Recycling: An Investigation of the U.S. "Chemical Recycling" Industry*, the environmental group Global Alliance for

Incinerator Alternatives (GAIA) alleges that the plastics and fossil fuel industries are promoting chemical recycling "as the silver bullet to solve the plastic crisis." A recent Greenpeace report refers to "the fantasy of chemical recycling."

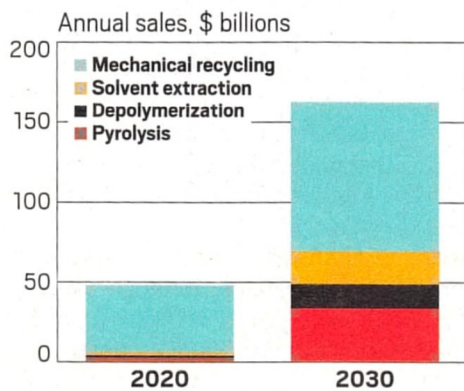
Ivy Schlegel, a senior research specialist at Greenpeace and an author of the report, says chemical recycling is convenient for consumer product companies looking to meet their environmental pledges. "I think for a lot of the fast-moving consumer goods companies, their concern is just maintaining their business model," she says. "And from what we can tell of their business model, we suspect a lot of it relies on increasing the amount of disposable packaging, but just being able to call it recyclable, and not resolving the core issue."

Chemical recycling, Schlegel says, is "largely a marketing term that is designed to really confuse people into accepting technology that is not proven to be a solution."

Craig Cookson, senior director of recycling and recovery at the American Chemistry Council (ACC), an industry group, counters that the best evidence of the industry's sincerity is the consumer product companies lining up to use recycled resins and the chemical companies investing to make them. "Consumers want their packaging to be recycled and to have recycled content in their packaging," he says. "So in a lot of ways, the stars are aligned."

Environmentalists focus their criticism on pyrolysis, which so far is used mostly to make fuels. "I think we can objectively say that it is actually not recycling because you are converting the plastic into oil, but then you are just burning it," says

## Big jump Global revenues from plastics recycling is set to grow prodigiously this coming decade.



Source: IDTechEx.



Denise Patel, GAIA's US program director.

"We really need to be moving towards more circular systems that are going to lead to lower emissions, lower energy use and not just adding to the overall climate pollution on our planet," Patel says.

The ACC's Cookson says pyrolysis, even if it is just used to make diesel that will fuel a truck, is better than throwing plastics away. "We're getting another use out of those plastics and keeping them out of the landfill and displacing a fossil fuel—a virgin fossil resource that would be used—by keeping the molecules in play," he says.

Additionally, chemical companies like Sabic, BASF, Dow, Ineos, and Lyondell-Basell Industries all aspire to use pyrolysis to make naphtha that they can process into plastics again. "By 2030, our ambition is to produce and market 2 million t of recycled and renewable-based polymers annually," says Jim Seward, LyondellBasell's senior vice president of R&D, technology, and sustainability. The company is piloting its own catalyst-assisted pyrolysis process in Italy.

Environmentalists also maintain that chemical recycling—pyrolysis in particular—consumes a lot of energy. For example, GAIA investigated environmental disclosures from Agilyx's joint venture in Tigard, Oregon, which uses pyrolysis to crack polystyrene into styrene. The group found that Agilyx's process emitted 3.2 kg of carbon dioxide for every 1 kg of styrene it produced in 2019.

The catalog of studies on chemical recycling's carbon intensity is small but growing. Many are sponsored by industry. Broadly, they point to environmental benefits of making plastics and fuels with chemical recycling compared with conventional production of plastics.

For instance, Agilyx says its process is half as greenhouse gas intensive as the conventional route. Loop Industries claims that its method of depolymerizing PET and making new PET saves more than 2 kg of CO<sub>2</sub> for every 1 kg of PET compared with the fossil fuel route.

Third-party studies come to similar conclusions. An often-cited 2017 study from Argonne National Laboratory found that low-sulfur diesel derived from plastic waste was 14% less greenhouse gas intensive than conventional diesel. In 2018, the Dutch think tank CE Delft stated that depolymerization saves 1.5 t of CO<sub>2</sub> per 1.0 t of plastic recycled versus making new virgin materials.

And in July, the consulting group Sphera Solutions completed a life-cycle analysis of BASF's ChemCycling program, which aims to use pyrolysis-derived feedstock to produce plastics. The study, commissioned

by BASF, projects greenhouse gas benefits if ChemCycling is used instead of incinerating plastics to generate electricity. Environmentalists claim a lack of transparency in such analyses and question the yardstick by which the processes are measured. "While industry claims that PTF [plastics to fuel] has a lower carbon footprint compared to conventional fossil fuels, such claims either lack independent verification or are based on incomplete, partial life-cycle assessment (LCA) models," GAIA's report says.

Ultimately, GAIA's objection is to plastic itself rather than how it is recycled or disposed of. "Industry oftentimes will say that plastics to fuel and chemical recycling is actually reducing the carbon footprint, but it's not accounting for all of the carbon that went up to producing that piece of plastic in the first place," GAIA's Patel says. "We really need to look at the life cycle beginning from the extraction point."

Even if chemical recycling projects can beat fossil fuel-based production

regulations forcing industry to use recycled plastics will help, he notes.

Environmentalists also question whether chemical recycling will keep up with the expansion of the plastics industry. In its *All Talk* report, GAIA points out that the ACC says firms have invested nearly \$5 billion in chemical and other advanced recycling projects. At the same time, the ACC boasts of \$200 billion in chemical projects related to shale gas. "The investment in the expansion of new plastic production dwarfs that invested in 'chemical recycling,' and reveals where the priorities of the industry truly lie," the report says.

## A massive opportunity

The companies boosting plastic recycling see the size of the plastic waste problem, and the big commitments of consumer product companies, as opportunities. Agilyx CEO Tim Stedman says his firm would need to build more than



Agilyx's plant in Tigard, Oregon

environmentally, they might not beat it economically. Given the time it will take oil prices to recover from today's COVID-19-depressed lows, IDTechEx's Dent says, the point at which pyrolysis can compete with virgin feedstocks on price is "quite a few years away."

Proponents of chemical recycling are betting that consumer goods companies will pay more for products that help them meet their sustainability pledges. Such a green premium has "been one of the stumbling blocks for green technologies over the past 20 to 30 years," Dent says. Time and again, consumers have demonstrated that they don't want to pay much more for environmentally friendly products. But

20 plants with 100 t per day of capacity to meet a target of 30% recycled content in polystyrene packaging in North America and Europe, which half the market has already committed to. "There is a significant requirement for a massive step-up in recycling, of which chemical recycling is really the thing that gets you to the higher percentages," he says.

In some cases, consumer product companies' targets for recycled content might have been too ambitious, Berry's Flores acknowledges. "There is actually not currently enough out there to meet all those goals, quite frankly," he says.

Despite the demand, environmentalists say the first chemical recycling projects

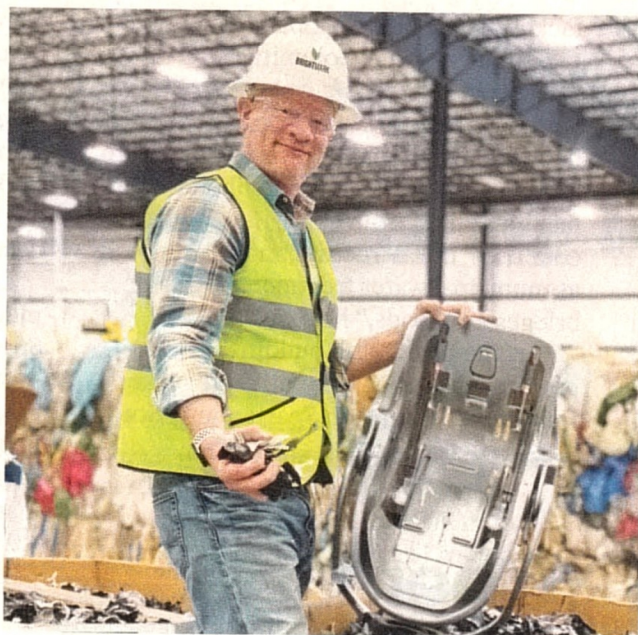


are having difficulty getting off the ground. *Deception by the Numbers*, the Greenpeace report released last month, analyzed the 52 projects that make up the \$4.8 billion investment figure cited by the ACC. In Greenpeace's estimation, a third of the projects are not likely to be viable.

Greenpeace evaluated publicly available information about the projects, listing as questionable and unlikely those subject to delays or public opposition. It also looked at whether project backers had notable past failures or haven't provided many details.

Into those categories Greenpeace put Agilyx's project to make jet fuel from plastics in Trainer, Pennsylvania; Brightmark's plans to build several plants beyond the pyrolysis plant it is building in Ashley, Indiana; and Eastman Chemical's plastics gasification project in Kingsport, Tennessee.

Greenpeace's Schlegel says using chemical recycling to meet recycled content targets is a misdirection, one that will waste time when industry should instead be looking at reducing the amount of plastic waste to begin with. "If that's the direction they're headed and chemical recycling is



**Brightmark CEO Bob Powell inspects postconsumer plastics that have arrived at the company's plant in Ashley, Indiana.**

the only way to get there, then the viability of these chemical recycling technologies should be of extreme concern to them," she says. Instead, Schlegel says, companies ought to focus on new models, like delivering goods in refillable containers.

In its report, GAIA examined 37 pro-

posed chemical recycling projects in the US and publicly available data about them. The group found that only 11 have reached the pilot stage or are under construction, and only 3 are operating.

Agilyx's Stedman acknowledges that the burgeoning chemical recycling industry needs to show results. "We've got to start moving further forward and proving the doubters wrong through demonstration—not by saying but by doing," he says.

Last month, Agilyx signed up the big polystyrene firm Americas Styrenics as a partner for a facility it plans to build in Channahon, Illinois, to process 100 t per day of polystyrene waste. They haven't set a date to complete the plant. Agilyx's technology is also being considered for a joint venture between Ineos and Trinseo to build a similar plant in France.

Like Agilyx, other companies have compiled long to-do lists, but they still are only building their first big projects.

Brightmark's \$260 million pyrolysis plant in Ashley, Indiana, which will take in 100,000 t per year of mixed plastic waste and turn out naphtha, diesel, and industrial waxes, is about 80% complete, accord-



ing to CEO Bob Powell. The company plans to have it ready early next year.

Brightmark's ambitions are enormous. It aims to process 8.4 million t of plastics per year by 2024. To get there, it plans to simultaneously build several plants, each with 400,000 t or more of processing capacity and costing as much as \$1 billion. They are targeted for the Texas region, the Northeast, and the Southeast. Powell says Brightmark will announce specific sites later this year. "Doing these on a one-off basis is not going to allow us to

tackle the problems globally," he says.

Similarly, Daniel Solomita, CEO of Loop Industries, has big plans for his company's PET depolymerization process. He hopes to install one "in every country" to recycle polyester resins and fibers. "Our facilities will become a basic part of the countries' infrastructure, in the same way as municipal water treatment plants or bridges and roads," he says.

But the firm is still building its first project, a joint venture with PET maker Indorama Ventures in Spartanburg, South

Carolina, that will be able to process 40,000 t per year of postconsumer PET. The partnership already has commitments from the likes of PepsiCo, Coca-Cola, and Danone to buy over half the plant's output. Loop had been targeting a start-up date of the third quarter of 2021 but now expects a delay of up to 6 months due to COVID-19.

Last month, Loop also inked an agreement with the waste management firm Suez to build a plant in Europe by 2023.

A company a little different from, and possibly ahead of, the start-ups is Eastman, which is dusting off a process it used a generation ago. It has been able to use existing manufacturing infrastructure, and even existing product lines, to advance its effort.

Eastman announced two chemical recycling initiatives last year, and both are already operating. In one, the company uses mixed plastics to supplement the coal feedstock for its gasification plant in Kingsport. Eastman uses the resulting carbon monoxide and hydrogen for acetyl-based products such as cellulose acetate.

The company started running materials such as old carpet through the plant last November. Eastman is using the plant's output to make cellulose acetate with 40% recycled content.

Early this year, Eastman also started using glycolysis to break down PET into dimethyl terephthalate and ethylene glycol. Production so far is modest. The firm will roll out a larger plant, with more efficient methanolysis technology, by the end of 2022, according to Scott Ballard, the firm's vice president of specialty plastics.

Eastman is using the dimethyl terephthalate to make Tritan Renew, a tough specialty polyester. It has signed up Nalgene as a customer to make reusable water bottles, which, Ballard points out, will replace many PET bottles over their lifetimes. The combination of the recycled resins with a container that itself will eliminate single-use bottles, he says, makes for "pretty dramatic sustainability."

In the 1980s and 1990s, when it was still a part of Eastman Kodak, Eastman operated a methanolysis plant to break down used polyester like X-ray film and turn it into new film products. "There are people on the project today that actually operated that plant at the time," Ballard says.

The previous effort, perhaps ahead of its time, was shut down, Ballard says. "The market just wasn't ready for it."

But consumers, brand owners, and governments see plastics differently today. "Things have finally changed," he says. "People are fully aware of the waste crisis, and they're demanding something be done about it." ■