CLIMATE TRANSFORMED

Tackling Industrial Plastic Recycling

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Tackling Industrial Plastic Recycling

Jodie Morgan is the CEO of Nexus Circular, an advanced recycling company that accelerates plastic recycling.
Tim Stedman is the CEO of Agilyx, a company that provides integrated solution for plastic recycling, including both a chemical recycling technology and feedstock processing expertise.

Summary

To claim success in developing a circular economy for plastic, billions of kilograms of hard-to-recycle plastics must be transformed into reusable circular materials. We chat with several companies driving this goal and discuss the enormity of the logistical and technological challenges in tackling plastic waste. **Watch the full session here**.

Key takeaways

- The US recycles 9% of plastics, and Europe slightly more, but either way, there is a long way to go to address the 400 million tonnes of waste produced yearly. Significant innovation is required to capture this above-ground hydrocarbon and reutilize it.
- Mechanical processing is well suited for rigid plastics such as PET and high-density polyethylene, about 22% of the plastic waste available. However, about 60% of available plastic is better suited to chemical recycling, including low-density polyethylenes such as grocery and garbage bags. In addition, film-based plastics, polystyrene, and polypropylene are well-suited to chemical processing.
- Different types of chemical recycling aim to take materials back to virgin products and take very distressed waste to produce food and pharmaceutical-grade applications. Mechanical recycling is the first port of call in plastic recycling, but molecules are gradually downcycled and then need chemical recycling to bring them back up to high-end uses.
- Existing recycling centers may touch as much as 10% or 15% of available plastic waste. To make drastic improvements, we must consider how different plastics within waste streams can be used as recipe elements provided as feedstock to companies like ExxonMobil.
- Eventually, advanced recycling will commoditize, and then it will be all about access to the cheapest feedstock, but we are a long way from doing so.

Paul's observations

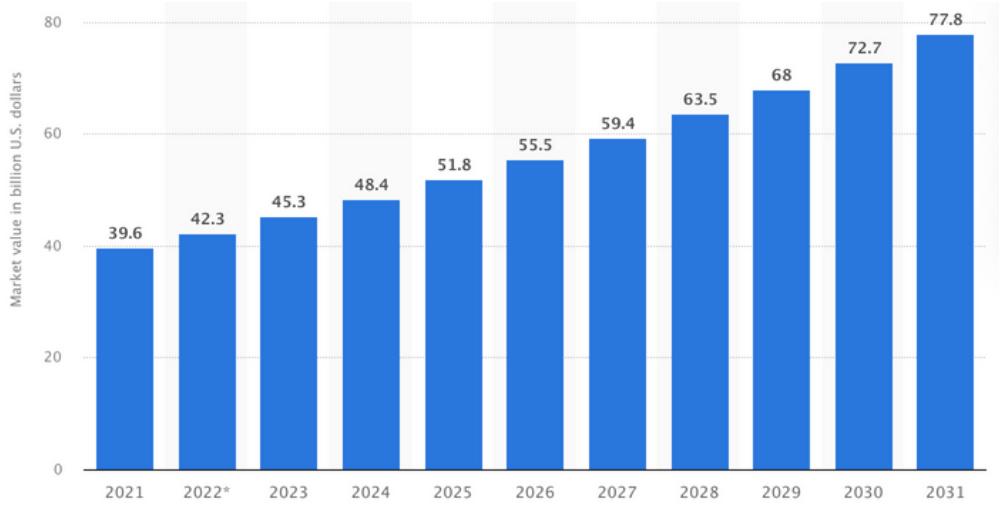
When addressing the sustainability of the global economy, plastic recycling is front and center in the eyes of consumers and government alike. Most completely underappreciate the complexity and the structural impediments required to get recycling rates above 10%. For advanced recycling companies like Nexus Circular and Agylix, two major structural headwinds revolve around access to feedstocks and the localization required for economically viable plastic circularity.

The recycling industry is witnessing remarkable innovations in dealing with the systemic contamination problem. Whether industrial or consumer, recycling plastics with hundreds of different grades and thousands of potential contaminants makes breaking down first-use products into a transportable near virgin stock for second-life use is complicated and expensive. The success of companies such as Nexus and Agylix revolves around reliable and scalable access to feedstock that is currently unavailable. Automation processes are improving rapidly, but with scalable feedstock trailing behind government regulations for second-use inputs, it is conceivable that the cost of this feedstock will rise appreciably over time. Recycling and, therefore, the development of the circular economy will have to evolve locally, as the transportation of feedstock over more than 100 miles destroys the economics. This implies that plastic recycling is going to have to rely on scaling city by city, which will require the duplication of many hundreds of processing facilities near major centers not only in the United States but across the world. An underappreciated headwind for the circular economy is how much capital will be required to build out local circular plastic recycling. We are at the earliest of early stages of this capital deployment.

Policies requiring 30% recycled plastics in products such as garbage bags are completely unrealistic and out of touch with the availability of feedstock. While companies like Agylix and Nexus our innovating aggressively, the absence of reliable feedstocks and the localized nature of the recycling industry, means that scaling options are limited. Technology companies like Agylix, who are licensing their innovations, have a business model advantage, but it will be firms like Nexus Circular that have the capability of “localized scaling” if they have adequate access to funding and feedstock.

Most consumers couldn’t tell you whether or not you can recycle a pizza box. Is it any wonder that contamination rates a leading to less than 10% of first-use plastics being recycled? The opportunity set in plastic recycling is simply incredible, but the level of complexity needs to be appreciated by regulators and consumers alike.

Market value of plastic recycling worldwide form 2021 to 2031



Source: Statista

Discussion

Nexus Circular

Nexus Circular is an advanced plastic recycler, meaning that the company converts polypropylene, polyethylene, and polystyrene into a liquid that can produce new plastic.
Plastic consists of monomers that are built up to a long chain. The Nexus process reduces used plastic back to monomers for reuse, using temperature without oxygen, so the material is not burned but converted into a liquid that looks like vegetable oil. Nexus customers then use that liquid product as a feedstock.
Nexus was founded in 2008 and has been commercial since 2018. The company is in growth mode, including the conclusion at the end of 2022 of a $150mm funding round led by Cox Enterprises, which is now the majority owner. It recently announced new offtake partners, including Braskem, and further offtake agreements with Chevron Phillips Chemical.
In addition to the pyrolysis process for the plastics mentioned above, Nexus processes film, which is the most undervalued plastic, most of which goes into landfill.

Agilyx

Agilyx was founded 18 years ago, initially working on breaking down plastics but now working on technologies in the advanced chemical recycling space. Agilyx is focused on what is required to make the circular economy happen at scale.
Agilyx has developed the Cyclix Joint Venture Consortium to address sourcing and processing. The joint venture is with ExxonMobil, with Agilyx owning 75% and ExxonMobil 25%. This is entirely focused on making plastic waste available at the right price, quality, and scale to enable the industry.
The consortium around the joint venture includes the world's five largest producers of plastic: Exxon, Dow, LyondellBassell, SABIC, and INEOS, and around 25 other plastic producers.
Conversion technology is based on pyrolysis, converting mixed waste plastics, and depolymerizing specific plastics, known as molecular recycling.
Agilyx offers knowledge and technical innovation to enable other companies to improve their plastic processing. It has technology partnerships with Technique Plastique and with Mitsubishi on polystyrene and plexiglass. The company has a significant partnership with Exxon on feedstock and other companies as well.
At the end of 2022, Exxon announced a $100 million investment in feedstock-related units in Houston, creating the potential to drive up recycling rates dramatically.

The role of chemical and mechanical processes

Jodie Morgan:

Much of the recycling industry is focused on mechanical processing because it has been around much longer, and current recycling is almost entirely mechanical. While the hierarchy should always be to

reduce plastic and reuse it where possible, mechanical processing is preferable to advanced processing, incineration, or landfill.
Mechanical processing is well suited for rigid plastics such as PET and high-density polyethylene, about 22% of the plastic waste available. However, about 60% of available plastic is better suited to chemical recycling, including low-density polyethylenes such as grocery and garbage bags. In addition, film-based plastics, polystyrene, and polypropylene are well-suited to chemical processing.
The mechanical process does not change the product chemically, and the material output can only be used in certain applications. In contrast, the chemically recycled product acts like a virgin product and can be used in any application.
Advanced recycling as a feedstock requires consideration regarding the product's end use. For example, calcium carbonate is sometimes used as a filler in plastic, and it is unavoidably carried through to the finished product, which is undesirable. In this way, advanced recycling should be considered differently from mechanical recycling.

The diversity of chemical and mechanical processes

Tim Stedman:

Developing successful chemical processes depends on carefully considering the target market and desired process output. In addition, careful consideration throughout process development reduces the risk of feedstock or process output becoming more niche and expensive.
A cleaner and simpler feedstock is easier to process by recyclers, and therefore, this feedstock is more expensive. Thus, developing the conversion capability to take on distressed waste will become a competitive advantage. For example, polystyrene can be used in either chemical recycling with other products to take it back to synthetic crude and then rebuild the chemical chains, or it can be unzipped to its direct monomer styrene, which can be purified directly. In addition, a pure form of polystyrene with few impurities is expanded as protective packaging around products like a television. As a feedstock, this is desirable because of the absence of impurity, making it more expensive.
By contrast, the right technology, in terms of purification and conversion, would allow a recycling company to engage with feedstock material that other companies are not competing for, such as flame retardant foams from insulation boards in the construction industry. Unfortunately, however, the fluorinated compounds within those make them completely unusable for most types of recycling.
Agilyx has developed a technique and platform called TruStyrenyx through which they use polymerization to return more challenging polystyrenes to a basic form appropriate for any styrene use, which, interestingly, includes lego bricks. Different types of chemical recycling aim to take materials back to virgin products and take very distressed waste to produce food and pharmaceutical-grade applications. Mechanical recycling is the first port of call in plastic recycling, but molecules are gradually downcycled and then need chemical recycling to bring them back up to high-end uses.

Should recycling companies get a premium based on how distressed their feedstock material is?

Jodie Morgan:

There is no premium for the use or unlocking of different feedstocks. Still, consumer goods companies are asking, and governments are regulating, for higher post-use plastic content in final product formulation. There is a massive demand for these products, so they have a premium compared to a typical virgin material product.

The situation is different when a product is formulated using mechanically recycled products—for example, putting it through a blow mold to make containers. However, the contaminants, such as plasticizers, are not removed by mechanical processes, so they stay in the mix, which can be problematic for manufacturers.

To use mechanically recycled plastics, manufacturers sometimes have to derate the capacity of their plants by as much as 20-40%, which increases costs.

As chemically recycled content is the physical properties of virgin material, manufacturers can certify that their product contains recycled content without impacting productivity. Therefore, there is a premium on chemically recycled products.

The US policy environment for recycling

Jodie Morgan:

There are early signs of policy initiatives in progressive states such as California which are putting regulations in place where garbage bags must have 20% post-use plastic now.

The advanced recycling industry still has relatively low volumes, so this demand is met through mechanical recycling, which does not work well for film products. To make that work, the bags are thicker, so the same amount of virgin plastic is still used to accommodate the recycled content. This defeats the purpose.

Tim Stedman:

Despite Agylix being a Swiss company, Cyclyx is primarily focused on the US as it is much more innovation-friendly and recognizes that it has much further to go in building circularity for plastics.

The current waste industry is not going to solve the problem. ExxonMobil initially approached current industry players with their technology, seeking help to develop the feedstock flow. Still, the response disappointed them, and they partnered with Agilyx to launch Cyclyx.

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Regulation can and should help, but the risk is that it becomes something that constrains innovation. For example, pyrolysis gets conflated with incineration when it is entirely different.

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Cyclyx, ExxonMobil, and feedstock logistics

Tim Stedman:

An alternative term for waste is raw stock. This material is pouring out all over the place and does not meet anyone's specifications for conversion. It is possible to find a small stream or to get it cheap for a while, but when you need millions of tonnes, it is simply unavailable at the right quality, quantity, and price. Post-consumer waste streams are an unbelievably mixed bag of junk.
The raw stock should be processed within a reasonable distance of where it arises. Still, the output of the Cyclyx process is a compounded material designed explicitly for the anchor chemical recyclers of that particular unit. That material is dense enough to be moved a much further distance. Waste can be moved at different points, and as a correctly managed feedstock, there is an opportunity to push it further.
Existing recycling centers may touch as much as 10% or 15% of available plastic waste. To make drastic improvements, we need to consider how different plastics within waste streams can be used as recipe elements provided as feedstock to companies like ExxonMobil.
Cyclyx is building partnerships through the consortium to explore ways to access waste, including take-back programs at the industrial, commercial, and consumer levels. From this, we deliver recipes to meet the requirements of ExxonMobil and LyondellBassell.
Manufacturers will inevitably need more processing if manufacturers require 30% post-consumer content. So, Cyclyx launched a collaboration with TenCate Grass to use material with a certain tolerance for contamination, but it is a consistent product that can be used as a recipe component.
Various approaches towards sourcing are required, including the chemical characterization and analysis of how to use products in light of what the customer wants, and then establishing large-scale circularity centers to take more cost out through greater efficiency.
Houston's circularity center started at 40,000 tonnes and has now grown to 150,000 tonnes, improving efficiency at scale.
Large-scale sourcing relationships look critical to the success of Nexus and Agilyx, along with the development of chemistry and processes. How is Nexus scaling its feedstock access?

Jodie Morgan:

Industrial waste streams are much cleaner and more consistent than jumbled household recycling. Recycling machinery was initially set up to handle cardboard and paper because they have the most value. Most municipal recycling facilities start processing by blowing air onto incoming material to blow off cards and paper. If the film is present, it often gets blown off and contaminates the paper and cardboard stream.
Therefore, using innovative film handling techniques, Nexus has focused on film plastic to handle it directly. Nexus also take rigid plastics and foams, but 80% of their process is film.
When planning a new facility, Nexus conducts a study to assess the feedstock, ensuring a sufficient quantity of appropriate material within a 150-mile radius of the plant. The Nexus strategy is not to build mega-plants but to consider the area's demographics and plastic sourcing. For example, near urban

centers, there are generally adequate feedstock and clients to buy the products.

AMP Robotics and similar companies are bringing artificial intelligence to sort waste, but how important is the automation of the waste stream separation process to Nexus?

Jodie Morgan:

Pyrolysis reactors can take in paper and other contaminants, but the oil customers only want to purchase polypropylene, polyethylene, and polystyrene. Anything else is a contaminant and will reduce process yields.
Regarding robotic development, we need many people to be successful in this space for the industry to make a significant dent in plastic waste. Unfortunately, robotics cannot keep up with the rates that Nexus run its process. However, robotics technology is advancing quickly, and Nexus is just the beginning of deploying technologies at scale.
The four areas of focus for Agilyx are sourcing, processing, converting, and purifying. Cyclyx addresses sourcing and processing. What are the opportunities around conversion and purification?

Tim Stedman:

This end-to-end process aims to allow Cyclyx to engage with more distressed material to improve the economics by accessing stable waste streams at the correct scale and affordability.
Cyclyx does not build, own, or operate units, but its customers would pay for waste foam from construction sites to be processed by Cyclyx. Demolition companies currently pay for the disposal of that waste into landfills, so there is a diversion opportunity for companies with the correct conversion and purification processes.
On the west coast of the US, Agilyx has an exemplary unit currently processing polystyrene from the agricultural industry, including plant pots, low-end polystyrene, with lots of fillers and colorants, soil, and fertilizer mixed in. That material is taken directly into the Cyclyx unit without washing, forming a valuable product component. However, it would produce poor yields if the plant only processed that material.
The plant's objective is to not overreact to one incumbent source of relatively clean waste. The conversion enables more sourcing options.
The Cyclyx conversion unit does not use catalysts. They make chemical reactions faster and more effective, but they are problematic in the waste industry because they are sensitive to contaminants, and feedstocks are variable. A non-catalytic system enables a broader range of feedstock. Catalytic systems are appropriate for waste processing.
The product of mixed waste processing might typically go into a steam-cracker, costing a company $1-3 billion dollars to build. The owners would be very careful about what they put into that asset because even small contaminants can do enormous damage.

How will Nexus evolve?

Jodie Morgan:

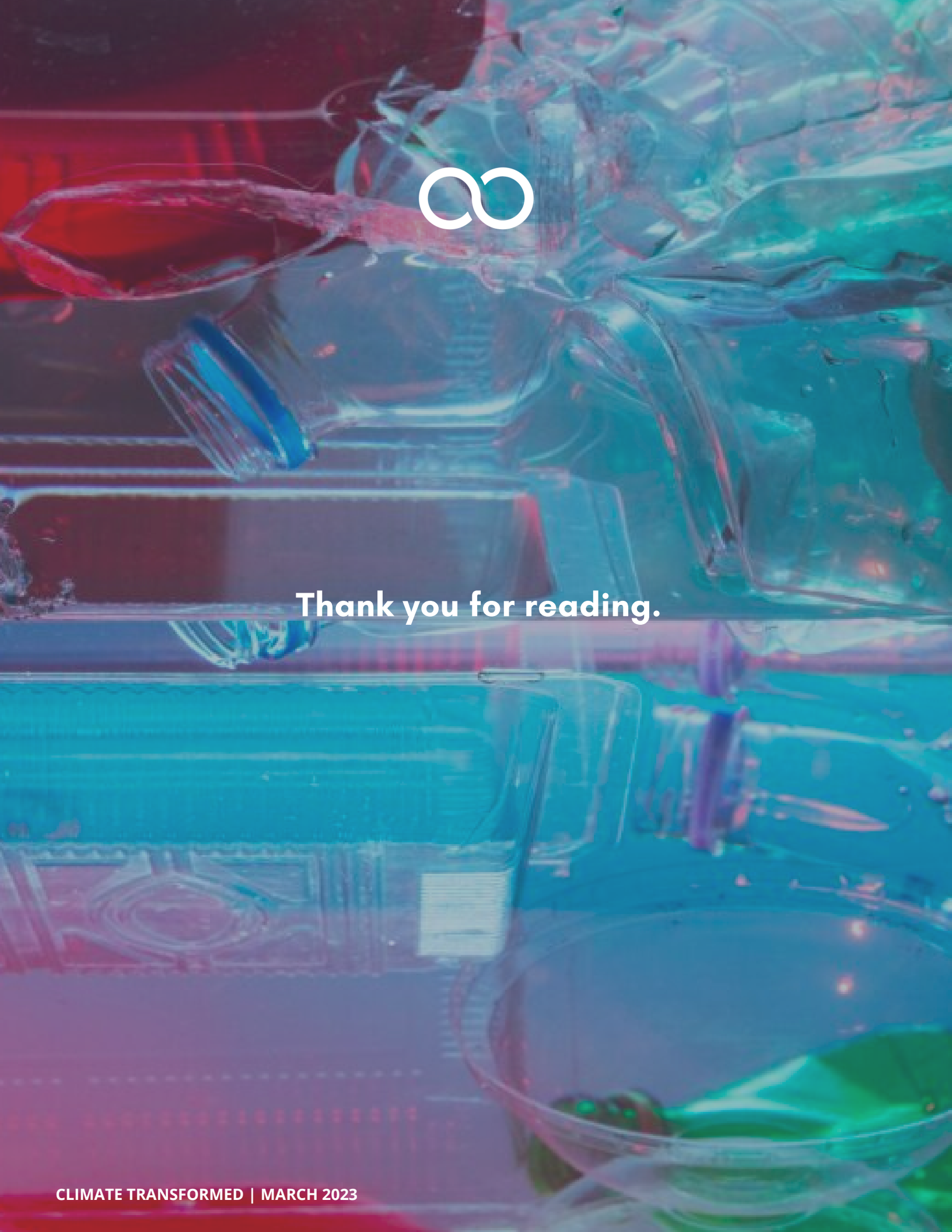
Nexus build, owns and operates facilities, though 10 years later, other options, such as licensing, may

evolve. However, the available technology must still be sufficiently mature to offer the best licensing model. Nexus is developing its steel efficiency and the onward path for process bi-products. High-yield, high throughput, and having a product that can be used directly in the client's asset are all cornerstones of Nexus development.
The IRA will help Nexus and the industry in general, though analysis of the opportunity is at an early stage.

What is next for Agilyx and Cyclyx?

Tim Stedman:

The build-out of facilities for Cyclyx, and increasing sourcing capability across the US, are crucial to providing clients with the products they need and impacting the waste stream. In addition, the data, leveraging, and recipe formulation will expand dramatically as plants become operational.
TruStyrenx was launched by Agilyx with Technip Energies, which produces 35% of fossil styrene technology globally, and 65% in the US. TruStyrenyx combines Agilyx conversion capability with Technips purification capability, moving beyond the traditional chemical industry to focus on styrene consumers, and there are 15-20 times more consumers than producers of styrene.
Polymethyl Methacrylate (PMMA), or plexiglass, is the focus of Agilyx's partnership with Mitsubishi, looking into how to bring that back to the pure product.
Agilyx aims to capture more value by skipping steps in the value chain, and developing processes to bring waste more directly to product manufacture.



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