IS CHEMICAL RECYCLING GREENWASHING?

The US is being seen as the testbed for the rollout of a range of technologies that proponents say are the solution to the worldwide plastic crisis. But can chemical recycling even be considered as recycling or is the oil and gas industry looking for a lifeline?

By **Conor McGlone**

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THE US HAS a serious plastic problem. Over the summer it emerged that the recycling rate of the ubiquitous material had sunk to less than 6 per cent. For context, the European Union together with Norway, Switzerland and the UK recycled on average 37 per cent of the plastic waste they generated in 2020.

The US generates more plastic waste than any other country in the world, according to the Organisation for Economic Co-operation and Development (OECD). In 2019, Americans generated 220.5kg of plastic waste per person, whereas Europeans generated an average of 121.6kg. Plastic production is expected to increase dramatically, with the amount of plastic waste produced globally on track to almost triple by 2060. Around half of this will end up in landfill and less than a fifth will be recycled, according to the OECD.

Given this trajectory, Dr Neil Tangri, science and policy director at the Global Alliance for Incinerator Alternatives (GAIA), says that, like others, he was encouraged when chemical recycling began to emerge on the scene around three years ago.

Chemical recycling is a broad term used to describe a range of technologies which the petrochemical sector claims can recycle plastic that is traditionally difficult to deal with mechanically. In the US, petrochemical companies are beginning to invest seriously in these technologies. The body that represents petrochemical companies in the US, the American Chemistry Council (ACC), says the country is "truly on the cusp of a massive scale up" of chemical recycling. Only in October, the US's largest oil and gas firm, ExxonMobil, announced it was launching 13 chemical recycling facilities that would recycle 454,000 tonnes of plastic waste by 2026.

Yet if this sounds too good to be true, many scientists and green groups in the US and Europe have told *E&T* they think it is. "When I heard there are new technologies able to recycle plastic in a different way, I thought 'great, finally'. And then we started digging into it. After three years of research, we have come back very disappointed," says Tangri.

Chemical recycling aims to turn plastic waste back into its molecular building blocks, in contrast to mechanical recycling, which does not alter the chemical structure of the plastic. By far the most prevalent type of chemical recycling, pyrolysis is a process in which plastics are broken down into a range of basic hydrocarbons by heating in the absence of oxygen. The primary product is pyrolysis oil, which can be refined into fuels or further processed to create chemicals or plastic.

Gasification uses high temperatures with low volumes of air or steam to degrade plastic. The primary product is a gas called 'synthesis gas', which can be processed into fuels or chemicals. Other forms of chemical recycling include solvent-based processes, which dissolve plastics and separate polymers from other components. Chemical depolymerisation uses thermal and chemical reactions to break the plastic polymer chain into individual monomers

Joshua Baca, vice president of plastics at the ACC, says chemical recycling is critical because plastics, "whether recycled or virgin, are essential to modern life, and now we are making changes to how we manufacture plastics, using alternative and recycled feedstock, to advance a circular economy with the lowest carbon footprint".

The petrochemical sector has promoted chemical recycling under many different guises including chemical conversion, molecular conversion and feedstock recycling. Today its preferred choice is advanced recycling.

Janek Vähk, climate, energy and air pollution programme coordinator at Zero Waste Europe (ZWE), says the name change came about because the word chemical "conveys toxicity".

Advanced recycling is also preferred because this implies all types of plastic can be completely recycled, he adds. "In the beginning [petrochemical companies] claimed it was 100 per cent that could be recycled. They said it's like taking a cake back to its original components of flour, sugar, butter and eggs.

"But we realised you cannot ever get it back to its original components – you lose a lot of material in the process. It was a marketing exercise," says Vähk.

Both mechanical recycling and depolymerisation struggle to process much of the plastic waste we generate, such as sweet wrappers, crisp packets, single-use cups and cotton swabs. These materials are made of multiple plastics like polyethylene and polypropylene, which are notoriously difficult to separate. They also have strong carbon-carbon bonds that resist depolymerisation. Pyrolysis is viewed as the only current viable way of recovering the raw materials from this waste stream.

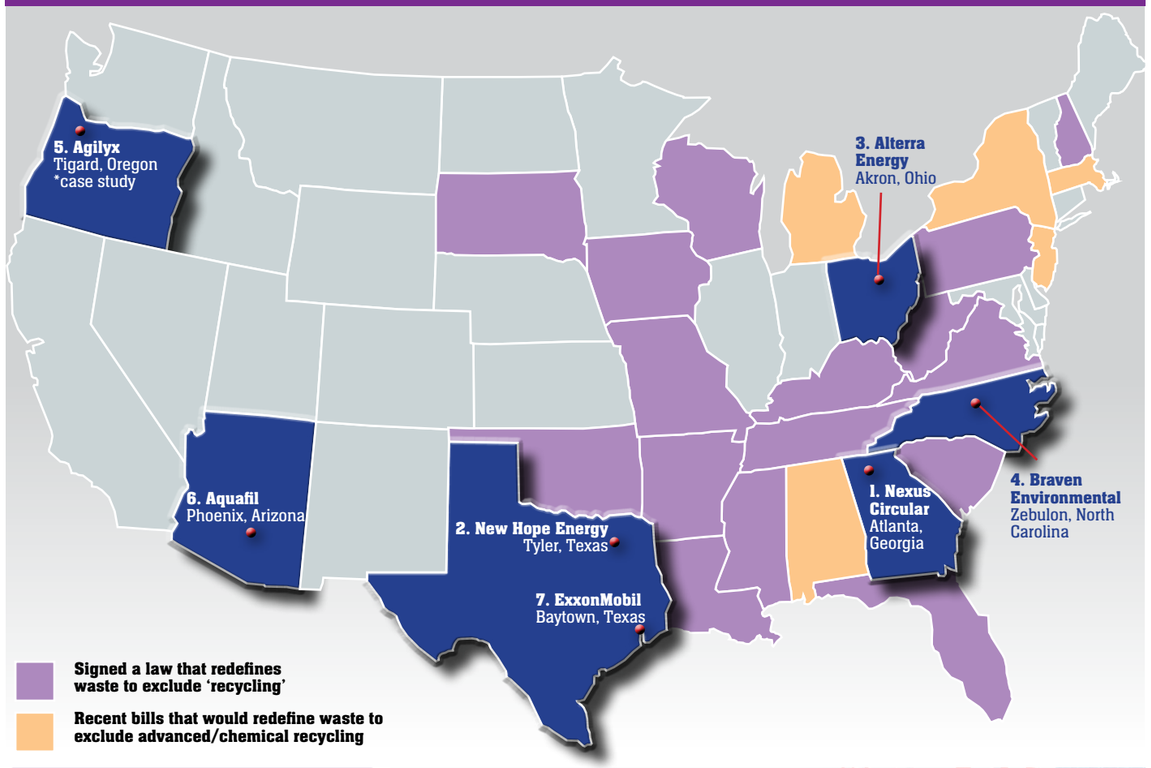
However, notes Vähk, more than 50 per cent of the original carbon in the plastics is lost during the pyrolysis process, while the resulting pyrolysis oil requires further energy-intensive purification before it can be used as a feedstock for polymer production at petrochemical plants known as steam crackers. This has major implications.

Hazardous waste

A plethora of recent reports in the US have raised concerns about the environmental impact of chemical recycling. Earlier this year, US NGO the Natural Resources Defense Council (NRDC) conducted in-depth research on eight chemical recycling facilities in the country. It concluded that the facilities are "generating hazardous waste and exacerbating environmental injustices under the false guise of recycling". It said most facilities are not producing or planning to produce new plastic but are performing "a kind of plastic incineration – turning plastic into dirty fuel using energy-intensive processes".

The NRDC says one facility it investigated claims to turn waste polystyrene into new polystyrene but in reality, it was sending >

USA
CHEMICAL RECYCLING IN THE UNITED STATES



Chemical recycling plants known to have operated in the USA

1. Nexus Circular, Atlanta, Georgia
Pyrolysis
Feedstock: Industrial & commercial plastic film
Volume processed: Claims to process 16,556t/yr

2. New Hope Energy, Tyler, Texas
Pyrolysis
Feedstock: Unknown
Volume processed: Uknown

3. Alterra Energy, Akron, Ohio
Pyrolysis
Feedstock: Mixed consumer plastics
Volume processed: Claims to process 19,867t/yr

4. Braven Environmental, Zebulon, North Carolina
Pyrolysis
Feedstock: Unknown
Volume processed: Claims to process 6,622t/yr

5. Agilyx, Tigard, Oregon
Pyrolysis
Feedstock: Sorted polystyrene
Volume processed: Claims to process 3,311t/yr

6. Aquafil, Phoenix, Arizona
Depolymerisation
Feedstock: Commercial and residential carpet
Volume processed: Claims to process 15,876t/yr

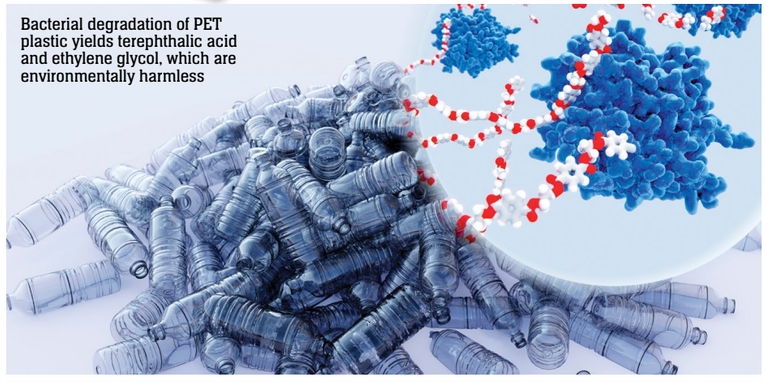
7. ExxonMobil, Baytown, Texas
Pyrolysis
Feedstock: Unknown
Volume processed: Claims to process 16,556t/yr

CHEMICAL RECYCLING PLANTS THAT HAVE BEEN ANNOUNCED BUT HAVE NOT YET STARTED OPERATION INCLUDE:

Brightmark pyrolysis plant, Ashley Indiana
Feedstock not determined

Purecyle solvent-based process, Ironton, Ohio Feedstock: Sorted polypropylene

Eastman methanolysis plant, Kingsport, Tennessee,
Feedstock: PET carpet



Bacterial degradation of PET plastic yields terephthalic acid and ethylene glycol, which are environmentally harmless

CASE STUDY
AGILYX

Agilyx, a polystyrene pyrolysis plant in Tigard, Oregon, is held up by the industry as a prime example of commercial-scale chemical recycling. In theory, Agilyx takes waste polystyrene, a common type of plastic, and uses pyrolysis to turn it back into styrene, which is then used to make new polystyrene. Yet, according to the NRDC, Agilyx is shipping hundreds of thousands of kilograms of styrene across the country for incineration. While some of this heat would have been recovered as energy, the process still emits more greenhouse gases than fossil-fuel-fired power plants, and releases harmful air pollution and toxic chemicals.

Data from the EPA showed that Agilyx generated nearly 228,000kg of hazardous waste in 2019, sending most to be burned. This waste consisted primarily of benzene, along with other toxic substances. The NRDC says that this facility and others are disproportionately located in communities where more than 25 per cent of residents identify as a racial minority, live below the federal poverty level, or both.

When contacted by *E&T*, Agilyx insisted that chemical recycling processors "are not producers of any significant amount of hazardous waste, especially compared to other manufacturing processes – including those for other green technologies like solar panels, batteries and wind turbines". While the firm refused to disclose how much waste it incinerated last year, a spokesperson said the amount of by-product waste has reduced in subsequent years.

In October, the US's largest oil and gas firm, ExxonMobil, announced it was launching 13 chemical recycling facilities that would recycle 454,000 tonnes of plastic waste by 2026

< much of the material across the country for incineration *(see box)*.

More research this year, carried out by consultancy Eunomia on behalf of ZWE, found that greenhouse gas emissions from chemical recycling are nine times greater than mechanical recycling.

The ACC disputes this, claiming advanced recycling technologies target plastics that cannot be mechanically recycled and, therefore, the more appropriate comparison would be to analyse the environmental footprint of energy recovery and landfilling.

However, says Vähk, this distinction "artificially makes chemical recycling look better than it really is". Chemical recycling is not the only alternative to mechanical recycling of hard-to-recycle plastics. A better alternative to pyrolysis is to use less plastic in the first place, he adds.

Real-world operational data is thin on the ground. A report from the not-for-profit group Chemsec this summer found the environmental impact of the different chemical recycling technologies such as waste and CO_2 emissions, as well as product and process chemicals, "is shrouded in mystery".

It was able to conclude, however, that "the technologies are costly, energy-intensive and often require the addition of a great deal of virgin plastic to work – the very material that needs to be phased out".

For the GAIA's Tangri, it is this paradox that shows you how "nefarious" chemical recycling is. "The pyrolysis oil produced is often contaminated... so you either go through a really energy-intensive process of trying to strip out the contamination ... or you say, well let's just mix it in with our virgin oil because this is really just a drop in the bucket.

"You can do that as long as your recycling is a tiny percentage of your virgin production, so if we are going to expand and scale up chemical recycling we're also going to have to expand and scale up virgin production."

Petrochemical companies claim that, eventually, the technology will improve so that diluting is not necessary. Petrochemical giant Neste says that "to turn chemical recycling into a viable and industrial-scale feed source for our downstream partners in the polymers and chemicals value chain, we have to bridge the quality gap between unprocessed liquefied waste plastic oil and our customers' raw material requirements".

Criticism of chemical recycling

However, Tangri does not buy this. "They're just trying to pull the wool over our eyes. This is not substituting for virgin production; this is about expanding it."

This is something the ACC denies. It argues that "advanced recycling displaces virgin production because it makes new plastics from used plastics that would have otherwise needed virgin resources to produce".

Another criticism of chemical recycling is that there is scarce evidence of it working at a commercial scale. Theresa Kjell, senior policy advisor at ChemSec, says: "For the majority of the chemical recycling technologies, we fail to see how it would be possible to scale up and make them financially viable. Even if scaling up was possible under the most optimistic scenarios, the future capacity would not come close to the volume of new plastics being produced and built-up legacy waste to be a solution."

The ACC disagrees. It claims that more than 50 certified products using plastic made from advanced recycling are on the global marketplace today, which is "evidence advanced recycling is already operating at commercial scale", according to vice president of plastics Baca.

However, *E&T* estimates there are just seven small chemical recycling facilities that may be operating in the US today, with a production rate of 118,613 tonnes per year. This is just 0.26 per cent of the 46 million tonnes of plastic waste generated in the US in 2021. The ACC broadly recognises these figures but says there are another two plants is operation and that production is likely to be marginally higher *(see map)*.

Campaigner and chemical engineer Jan Dell says she is sceptical that the few existing pyrolysis plants are operating. "If they are operating, I don't think they are processing mixed plastic waste from households as claimed by the ACC," she says. Dell says that in May 2022, she drove by the Brightmark pyrolysis plant in Ashley, Indiana, and saw first-hand that the plant was not operating. Nexus, she notes, has gone on record admitting that it uses clean, plastic film waste as the feedstock – not mixed plastic waste from households.

Faced with these allegations, the ACC says the industry is in the process of scaling up, "like any growing industry that disrupts the status quo".

"When Tesla first started, they were making several dozen cars a month. Imagine if they stopped and folded then – the electric vehicle revolution we are seeing now may not exist," a spokesperson added.

Critics also argue that there is no end market for chemically recycled plastic. Tangri points out: "If you are a plastic manufacturer, you would much rather be getting your ethane from a natural gas pipeline than from this dirty second-hand source and it is so cheap to do so, particularly here in the US where we have all of this fracked natural gas."

So why are petrochemical companies promoting and investing in the technologies?

Tangri has a theory: "It's just an excuse to be able to continue production because petrochemical companies want to be able to say we have a downstream solution to this. They say: 'It's not at scale, it has technical challenges, and the quality is low, but we have a technical solution and therefore we don't have to change anything about the manufacture of plastics.'"

Public concern

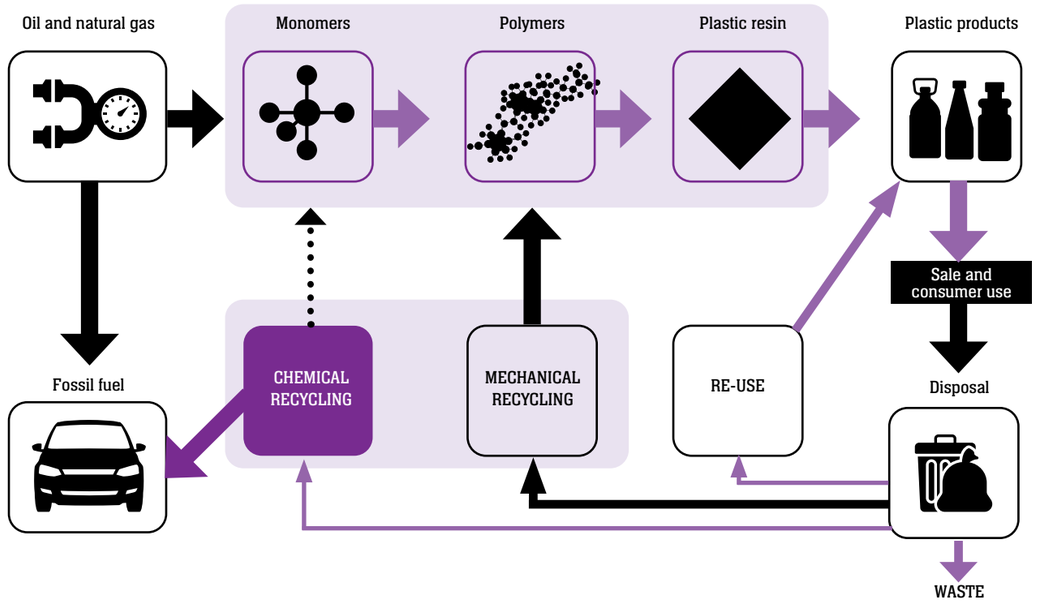
Tangri says oil and gas companies are rightly worried, with demand for oil and gas in the transportation sector expected to plummet this century due to the rollout of electric vehicles. "This is why billions of dollars are being invested in the US and around the world, to build new plastics factories – this is where the industry thinks its future is going to grow. At the same time, public concern about plastic is at an all-time high."

This is why the industry is keen to promote chemical recycling, according to Tangri. "No matter how slender a straw it is, they are grasping at whatever they can to say 'look, you don't need to touch production'."

Adrian Griffiths, the former director of Recycling Technologies, a start-up chemical recycling company in the UK that went into administration in September, sees it differently. Recycling Technologies was behind a machine which the company claimed could turn unrecyclable plastics >

PROCESSES

WHERE CHEMICAL RECYCLING CAN FIT IN



The US generates more plastic waste than any other country in the world, producing approximately 220.5kg of plastic waste per person in 2019 alone

< such as crisp packets and black plastics back into an oil – Plaxx – for use in the shipping industry.

Griffiths says his firm ran out of cash after a private equity house pulled out "at the eleventh hour".

"It's a classic valley of death when you are trying to raise significant amounts of money for a first of a kind," he says. "Perhaps they got jumpy about where the markets are at."

The firm received over £1.25m in funding from the UK government and at least €7m from chemical giant Neste. Other firms have gone bust.

Lacking in investment

In 2016, US firm Air Products announced it was exiting the waste-to-energy sector and offloading its two 50MW plasma gasification plants on Teesside, north-east England, at a loss of up to £1bn. The company said the decision was due to technical difficulties in making the technology work as expected.

Earlier this year, Brightmark Energy scrapped plans to build the world's largest plastic-to-fuel plant in the US state of Georgia. The $680m project fell apart after Brightmark missed a deadline to deliver "end product" to customers from a similar facility in Indiana.

But, as Griffiths says, "like all nascent industries, there are casualties". He thinks petrochemical companies should be investing much more in chemical recycling.

Over the last decade, he says, they have spent somewhere between $600bn and $900bn in adding new capacity to produce virgin plastic, whereas they have not yet invested $1bn into chemical recycling.

"In the last two or three years they've been coming to the party, but they still spend more on the Christmas parties than they do on chemical recycling," he adds. Despite this, Griffiths is hopeful for the future of the chemical recycling industry.

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> **Dr Neil Tangri** Global Alliance for Incinerator Alternatives

Neste says the closure of Recycling Technologies had no major impact on its general goal of advancing chemical recycling. The firm has just received a positive grant decision for up to €135m from the EU Innovation Fund for the company's project to build chemical recycling capacities at its Porvoo refinery in Finland.

Chemical recycling firms are receiving funding from the US government too.

In January in the US, the Department of Energy announced $13.4m in funding for next-generation plastics technologies, many of which included chemical recycling. Brightmark's Indiana facility was a recipient of $185m in state bonds.

Critics, including recycling expert Bernard Chase, say taxpayer money should only be invested in "proven technology" such as mechanical recycling.

"There is an abundance of companies attempting chemical recycling, but they all seem to exist at laboratory or a pilot plant scale and never ever go beyond this," says Chase. "They are always out there with a begging bowl looking for funding. Governments give them the money because they have bought in to the narrative that this is the solution, and they just need more funding, but it's not the solution and the market dynamics don't support it," he adds.

Raging battle

In the US a political battle is raging, with the coming months likely to be pivotal for the future of chemical recycling. The Environmental Protection Agency is currently debating whether to implement a Trump-era proposal to make pyrolysis and gasification facilities exempt from air emissions regulations under the Clean Air Act by categorising the process as manufacturing as opposed to incineration.

This prompted a coalition of more than 200 green groups to write to Congress in September warning that "eliminating these long-standing federal protections would sanction and promote uncontrolled burning of plastic waste – or any other waste – in pyrolysis and gasification incinerators across the country".

The ACC says chemical recycling should be classified as a manufacturing process and that, as such, it would be required to comply with the relevant environmental regulations pertaining to air emissions and water discharges. "These regulations are applicable to how an advanced recycling facility operates," Baca insists.

However, signatories to the letter asked why chemical manufacturers were fighting to remove federal health protections if they can operate pyrolysis and gasification facilities in compliance with Clean Air Act protections, as they claim.

While a national decision is in the works, the ACC has been lobbying individual states. Since 2017, 20 states have been persuaded to pass laws that advance chemical recycling, primarily by redefining solid waste processing as manufacturing, or plastic waste as a post-use polymer or recovered feedstock. A handful of proposed bills in other states, if passed, would do the same *(see map)*.

Tangri admits the state-to-state lobbying took his team by surprise, but green groups are now fighting back. "It was definitely a strategy that was rolled out under the radar, and we've been playing catch-up. Last year I testified to a number of state legislators – Maryland, Oregon, California – that were looking at these kinds of legal changes, and we were able to derail some of them," he says.

Some recent bills and laws explicitly define chemical recycling as 'recycling', which is controversial given that, in the US, there is no national legal definition of what constitutes recycling, unlike in the EU. "The European Union is pretty clear: if you're going to be calling something chemical recycling, you're going to have to be turning plastic back into plastic. In the US, most facilities that are coming up are really plastic to fuel facilities," says Tanrgi.

For Tangri, this is simply not recycling. "If you are going to call it recycling, you are going to have turn plastic back into plastic, and you have to have a pretty decent yield," he says. "If you're talking about a yield of one- or two-thirds of your feedstock becoming a waste product or carbon dioxide, that's not recycling; that's mostly converting plastic into carbon dioxide.

"When you're burning the output, that's not contributing to the circular economy, you're creating another dirty fossil fuel, and that's the last thing we need at this point."

Advanced recycling

The ACC says that only new plastic, chemicals and other non-fuel products produced through advanced recycling should count as recycling.

In Europe, the political fight centres around what can be claimed as recycled content. With plastic packaging taxes being introduced by many European countries, Zero Waste Europe's Vähk says it is important that businesses can avoid the tax only through using truly recycled material.

"There are a lot of greenhouse gas emissions involved and probably a lot of outputs you can't really use. And most importantly, you don't know where this recycled pyrolysis oil will end up. It is such a long value chain you cannot really allocate to any specific product because there is no physical or chemical traceability," he argues.

The industry answer is mass balance. The technique involves measuring what enters and what leaves a system. It has been used in the Fairtrade coffee and cocoa, forestry and paper, and renewable energy industry. The European Chemical Industry Council says mass balance "is one of the key tools to help enable a circular plastics economy as it is widely accepted as a chain of custody model".

Yet Vähk says the industry wants a "free allocation" of claims among co-products. This means claims for recycled materials can be concentrated into any of the co-products produced from the process into which waste materials were input. However, in the conversion process from plastic to oil, and then to finished products, energy or fuel products are also produced. In some processes, fuel products are consumed on-site to provide energy to the facility. In other cases, outputs may be consumed as fuels or converted to fuels by downstream customers.

"We are against this type of allocation because it would be greenwashing," says Vähk. "It would make claims that plastics have 30 per cent when they don't even have 1 per cent. It must be traceable."

Vähk thinks there is a place for chemical recycling as a last resort, but that "if you start doing pyrolysis as a mainstream thing instead of trying to improve design for recycling, you are probably going to produce too much CO_2 to meet the global Paris Agreement to limit global temperature increases to 1.5°C".

This is a major claim from green groups: a focus on chemical recycling can divert attention and investment from other methods, like designing easier-to-recycle single monomer packaging or capping the amount of plastic produced in the first place.

"Focusing the discussion on chemical recycling takes away attention from the much more difficult challenges, such as the elimination of hazardous substances and the reduction, rather than the increase, of plastic production," adds ChemSec's Kjell.

While the debate rages on, one thing is clear: the US needs a solution to its plastic waste crisis. National and state governments, as well as governments across the globe, must ensure investment is funnelled where it can be most effective. Advocates of chemical recycling say investment is needed to encourage technological innovation, but green groups counter that this should only happen if and when robust data is available. Whether the chemical recycling revolution takes off may well depend on this.