Fifty years: chemical recycling's fading promise

Industry landscape overview

November 2024

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Executive summary

Chemical recycling[1] is being presented as a potential fix for the plastic waste crisis, but cracks are starting to show. As the Global Plastics Treaty negotiations intensify and the EU pushes for a 'competitive' circular economy, questions are mounting on whether chemical recycling is truly the tantalising solution it claims to be to solve the climate and plastic waste crises. With the EU's commitment to prioritise the scale-up of secondary materials to reduce reliance on virgin plastics, chemical recycling faces significant criticism over its scalability, environmental impact, and economic viability.

Broadly, chemical recycling is defined as "the process of converting plastic waste by changing its chemical structure and turning it back into substances that can be used as raw materials for the manufacturing of plastics or other products. The industry claims chemical recycling can be used for difficult-to-recycle plastic waste, which would otherwise result in incineration or landfill".[2]

The industry argues this 'game-changer' technology 'can contribute to a circular economy for plastics', reducing the need for fossil fuels and solving the problem of plastic waste.[3]

However, there is an increasing concern from outside the industry that chemical recycling may not deliver all that it promises, as shown by the lawsuit filed in the US by the Californian General Attorney against ExxonMobil and by the back out from Shell's withdrawal from its commitment to use 1 million tonnes of plastic waste a year in its global chemicals plants by 2025 .[4][5]

For this industrial landscape overview, two prominent experts dedicated to reducing the petrochemical industry's reliance on fossil fuels were interviewed. The first was Jean-Paul Lange, a former senior principal science expert at Shell, whose mission over the last 25 years was to defossilise the petrochemical industry. The second was Stephen Salve Doliente, a Doctor of Philosophy in Chemical Engineering at Imperial College London, whose work is also focused on transitioning the chemical industry away from the use of fossil fuels.

Both experts agree that pyrolysis - by far the most common form of chemical recycling[6] - is currently only a form of "partial recycling". They also agree that the technology has proved expensive and complex and that any successful commercialisation will require huge financial and regulatory support and time. Currently,

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[1] In this document, and for easier understanding, ZWE uses the term "chemical recycling" as proposed by the chemical industry, i.e including technologies like pyrolysis and gasification. However, ZWE does not classify these technologies as "chemical recycling", but as "chemical recovery". See our previous position paper for further information.
[2] Plastics Europe. 2023. *"Chemical Recycling • Plastics Europe."*
[3] Plastics Europe. 2023. *"Chemical Recycling • Plastics Europe."*
[4] Noor, Dharna. 2024. *"California Sues ExxonMobil over Alleged Role in Plastic Pollution Crisis."* The Guardian. September 23, 2024.
[5] Noor, Dharna. 2024. *"Shell Quietly Backs Away from Pledge to Increase 'Advanced Recycling' of Plastics."* The Guardian. July 17, 2024.
[6] British Plastics Federation. 2024. *"Chemical Recycling / Non-Mechanical Capacity."* British Plastics Federation. 2024.

petrochemical refineries can only accept a tiny fraction of the oil produced by chemical recycling because it is heavily contaminated.[7]

Lange believes that chemical recycling can lead to a scenario in 50 years' time where up to 50% of the global plastic stream will be made of recycled plastics. **For pyrolysis, he predicts in 50 years, one-third of the carbon entering the steam cracker will be fossil and two-thirds recycled**.

To make this a reality, the industry says it requires a legal recognition of mass balance for chemical recycling to become commercially successful, which raises concerns over transparency along the value chain.[8 9]

Doliente, who worked on a joint project modelling a s**uccessful defossilisation of the global petrochemical supply chain, found that the number one intervention was a reduction in the consumption of plastics and fertilisers.**

On the other hand, Lange claims there is no "problem ramping up production, as long as we deal with the waste responsibly".

Reducing plastic pollution requires systemic solutions that target the producers and authorities responsible, not just individual consumers. This is where industry diverges from the views of the European Union and the UK governments, both of which have signed the Bridge to Busan, a declaration stating that virgin polymer production must "match ambitions for a circular economy for plastics while aligning with the Paris Agreement goal of limiting warming to 1.5°C". In other words, it must be reduced.[10]

Upon an information request to the European Commission concerning a meeting between the major European chemical companies and the EU Commission in April, European Commission Vice-President Maroš Šefčovič expressed his hope that the producers would "share goals on limiting the production of primary plastic polymers". However, notes from the meeting reveal the petrochemicals "would not share the same understanding on the limiting of primary plastic polymers and addressing hazardous chemicals".[11]

Currently, chemical recycling strategies appear closely linked to maintaining high levels of virgin plastic production. Indeed, the process requires a vast quantity of virgin oil to produce 'recycled' plastic that contains a drop of pyrolysis oil; in other words, this recycling approach will not substantially reduce overall plastic production.

This strategy opposes the EU's "waste hierarchy", enshrined in the Waste Framework Directive, which prioritises waste prevention over both recycling and recovery.

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[7] Beyond Platics, IPEN, *Chemical Recycling: A Dangerous Deception - Why Chemical Recycling Won't Solve The Plastic Pollution Problem*, 2023

[8] *"How the EU Can Enable a Circular Economy in Plastics Packaging."* 2022. POLITICO. December 1, 2022.

[9] *"Infinite Plastic Recycling: The Technology Is Ready, but What about Legislation?"* 2023. POLITICO. June 28, 2023.

[10] Bridge to Busan. 2024. *"Bridge to Busan."*

[11] *"Cabinet of Executive Vice-Presid."* n.d. Accessed November 15, 2024.

Waiting decades for a technology to mature, which in the meantime relies on the continued increase in virgin production, cannot be considered a viable and sustainable option. Fossil fuels must stay in the ground.

Recommendations

- The Global Plastic Treaty as well as EU legislation more generally shall explicitly incorporate the established EU waste hierarchy framework, - i.e. emphasising first waste prevention and reuse, followed by recycling, - to reduce disposal and incineration in accordance with their environmental impact and resource efficiency.
- Decision-makers must implement comprehensive measures such as production cap to systematically reduce virgin polymer production to align with the Paris Agreement to achieve climate neutrality by 2050.
- By exercising their governance rights and fiduciary responsibilities, shareholders shall compel corporate entities to implement systematic reductions in production volumes.
- The recycling process should deliver safe, non-toxic, and decontaminated products, by-products, and waste without dilution practices with virgin feedstock.
- When defining recycled content for plastic, the methodology should ensure transparent and reliable claims based on weight (using segregation and controlled-blending models).
- Public funding should not be given for the construction of pyrolysis and gasification plants, as the environmental value of these techniques still needs to be proven, and the risks exceed the benefits.

An elegant solution to an intractable problem?

On the surface, chemical recycling - or "advanced recycling", as the industry markets it - is an elegant solution.[12]

The production of plastic in the EU is a large contributor to climate change. The extraction and conversion of crude oil into virgin polymer plastics currently release around 13.4 million tonnes of CO_2 every year into the atmosphere. This amounts to 20% of the EU chemicals industry's emissions.[13]

On a global level, a recent study found that, in 2019, production of virgin plastic spewed about 2.24 billion metric tonnes of carbon dioxide equivalent into the atmosphere, or 5.3% of total greenhouse gas (GHG) emissions.[14]

Global consumption of plastic is also accelerating. Over half of the plastic production ever manufactured has occurred since 2000; and if the current trend continues, we are set to double our current global annual production by 2050.[15]

Pressure is on the petrochemical supply chain to defossilise. As the greatest contributors to climate change, oil and gas companies find themselves in an ongoing struggle to repair their reputations by leaving fossil fuels in the ground while maintaining profits. Meanwhile, plastic manufacturers are increasingly looking for ways to reduce their tax burdens given the upcoming plastic packaging taxes announced across Europe in recent years.

In parallel, plastic waste is a growing burden on society and nature worldwide. Only 9% of the plastics ever produced worldwide have been recycled, and 12% have been incinerated. The remainder is either still in use or has been disposed of in landfills or released into the environment, including the oceans.[16]

Without meaningful action, flows of plastic waste into aquatic ecosystems are expected to nearly triple from around 11 million tonnes in 2016 to around 29 million tonnes in 2040.[17]

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[12] In this document, and for easier understanding, ZWE uses the term "chemical recycling" as proposed by the chemical industry, i.e including technologies like pyrolysis and gasification. However, ZWE does not classify these technologies as "chemical recycling", but as "chemical recovery". See our previous position paper for further information.

[13] European Environmental Agency, *"Plastics."* 2023.

[14] Berkeley National Laboratory, *Climate Impact of Primary Plastic Production*, 2024

[15] Geyer R. and all, *Production, use, and fate of all plastics ever made*, 2017

[16] UNEP, *Drowning in Plastics – Marine Litter and Plastic Waste Vital Graphics*, 2021

[17] UNEP, *Drowning in Plastics – Marine Litter and Plastic Waste Vital Graphics*, 2021

Petrochemicals claim that chemical recycling is a solution that will solve both problems. They argue the technology can convert plastic waste back into its original polymers without requiring the extraction of fossil fuels.

According to the petrochemical industry, this solution should help them defossilise by providing an alternative feedstock to fossil fuels to produce new plastic. At the same time, the downstream problem of plastic pollution leaching into the environment will also be solved, as difficult-to-recycle plastic will no longer be dumped; it will become a valuable feedstock.

However, the industry accepts it is not quite that simple.

Pyrolysis, the most dominant process, involves the heating of plastic waste in the absence of oxygen. This produces pyrolysis oil that the chemical industry argues can be transformed back into 'virgin-like' plastic".

To create new plastics, plastic-derived pyrolysis oil has to be fed into a steam cracker to produce polymer precursors. However, it is too contaminated to be fed directly into this established industrial system designed for virgin petroleum naphtha. Purifying it of its contaminants requires multiple stages of energy-intensive treatment.

According to Jean-Paul Lange, former Senior Principal Science Expert at Shell, pyrolysis "is expensive because the waste is dirty and you have a lot of contaminants and impurities you need to remove."

Stephen Salve Doliente, a doctor of philosophy in Chemical Engineering at Imperial College in London, thinks petrochemicals would need to spend billions to upgrade plastic waste pyrolysis oil due to the strict feedstock specifications of existing steam crackers to take this oil.

According to the industry trade body Chemical Recycling Europe (CRE), currently, "the only feasible option to offtake pyrolysis oil for polymer production, is to dilute the pyrolysis oil with a petroleum-based mixture".[18] The dilution factor varies depending on the contaminants encountered, and one assumption is that it might be feasible to blend 5 to 20% pyrolysis oil with 80 to 95% petroleum naphtha to counter contaminants.[19]

In the same statement, CRE said: "This is well known and accepted by all stakeholders since the goal of the industry is to scale these quantities to gradually replace naphtha using the existing petrochemical infrastructure. Installing separate infrastructure to process pyrolysis oil for polymer production would incur a high economic and environmental cost."

[18] Chemical Recycling Europe, *"Chemical Recycling Europe (CRE) Rejects Claims Made in Zero Waste Europe Report on Pyrolysis."*, 2023

[19] Zero Waste Europe, *Leaky loop "recycling": A technical correction on the quality of pyrolysis oil made from plastic waste*, 2023

"This also ensures purification is not needed at current levels. However, as the goal is to increase the volumes of pyrolysis oil, purification and upgrading will be needed to ensure alignment between pyrolysis oil specifications and those of steam crackers and refineries."[20]

Pyrolysis is also extremely inefficient in terms of carbon emissions. A study found that chemical recycling emits nine times more greenhouse gas emissions than mechanical recycling.[21] Doliente notes that it is "because part of the carbon goes into CO_2 production as well as into other gases and you would need to have a very good catalyst to minimise the losses from CO_2 production".

Lange agrees. "If you look at the whole value chain [for pyrolysis], you are losing carbon all over the place in terms of byproduct that you eventually burn to provide energy for the process. At the end of the chain, you only have 50% of the carbon coming into the product. This makes the process more expensive as well but it is still better than nothing, it is better than putting everything into incineration and recycling nothing."

Given the technology's inefficiencies, how does the petrochemical industry intend to make it economically and environmentally viable? This is where the mass balance accounting system comes in.

[20] Chemical Recycling Europe, *"Chemical Recycling Europe (CRE) Rejects Claims Made in Zero Waste Europe Report on Pyrolysis."*, 2023

[21] Oekoinstitute, *Climate impact of pyrolysis of waste plastic packaging in comparison with reuse and mechanical recycling*, 2022

Mass balance accounting

Correspondence between the trade body Plastic Europe and the European Commission goes back as far as 2021, calling for the Commission to adopt a mass balance accounting method to make the "business case" for chemical recycling.[22]

The industry repeatedly and publicly wrote to the European Commission calling for the institution "to urgently adopt a mass balance chain of custody to calculate chemically recycled content in plastics.[23] [24]

In mass balance, a certified volume of renewable or recycled material is input across a production run but may not be evenly distributed across each individual product.

For example, a plant may use 30% recycled material overall, but one piece of produced packaging could contain 100% recycled material, and the next 100% virgin material, or any mix between those two extremes. Via this method, plastic manufacturers can state that they use a certain percentage of recycled or renewable material in their products, without having to prove that percentage in each individual product produced. See Figure 1 for a visual example of this process.

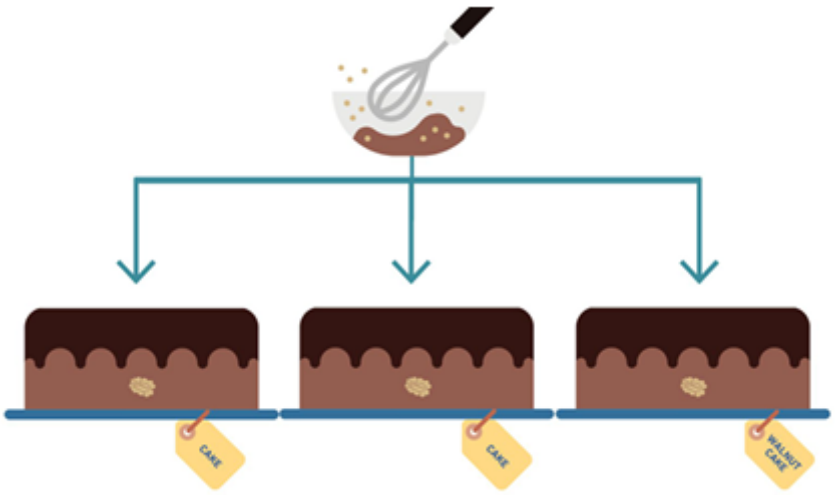

Figure 1: The cake comparison. [Source: ECOS, RPa, ZWE, *Determining recycled content with the 'mass balance approach' – 10 recommendations for development of methods and standards*, 2021]

[22] *"Cabinet of Timmermans"* n.d. Accessed November 15, 2024.
[23] Plastic Europe, *"Cross Sectoral Statement on the Policy Framework Needed to Deliver Recycled Content in Key Plastics Applications."* 2023
[24] Cefic, *"Supply Chain Letter on the Need for Mass Balance Fuel-Use Exempt for Chemical Recycling."* n.d. Accessed November 15, 2024.

Christian Krüger, head of global sustainability and advocacy for chemical recycling at BASF, said in a podcast in February 2024: "If you mix something sustainable which is new with conventional feedstock in your production network and you are using only a very little sustainable feedstock with a lot of conventional– it is highly diluted – nobody can measure anything in the output side and then mass balance comes into play. Then you can attribute these sustainable benefits to one product or to feedstock another product, which then really gives market value for somebody who will buy that."[25]

This is crucial for the industry: persuading customers to spend a premium on products that could possibly only contain a minuscule amount of recycled material will fund the industry's efforts to improve the process. "If no one is paying a premium for that, then the chemical company could not earn anything in addition, which would go against its own earnings," said Krüger.

Pointing to his research paper, Lange claims: "What we are saying is, let's not let go of the [optimal big picture], where you make the whole industry fossil-free and circular. Eventually, the whole industry needs to be circular."[26] One problem is the time this would take. According to Lange, it will take fifty years to "successfully ramp up chemical recycling" but even then, he speculates, steam crackers will only accept two-thirds of recycled feedstock, with the remaining third derived from fossil fuels.

"When we get to a highly circular economy, there will be no doubt for any consumer that the product they buy has recycled carbon [but] in order to get fifty years ahead, we need to make the steps today," he added.

Even if consumers are content to accept mass balance recycling claims that may or may not be a true representation of the product they have purchased at a premium, fifty years is too long to wait. To remain within the Paris Agreement commitment to limit global warming to 1.5°C degrees, the plastic sector has to define a tangible roadmap to meet net zero by 2050. However, based on the current trajectory, this sector alone is on a trend to be as high as 3.5°C.[27]

Plastic Europe's roadmap to net zero sets out a similar scenario. It projects that substituting fossil-based plastics will be gradual, and will reach 65% by 2050 "in an ambitious scenario". It states that, even in 2050, 35% of plastics will still be derived from fossil fuels.[28]

The EU is currently considering which type of mass balance methodology to adopt but the petrochemical industry is pressuring it to mirror the UK government's decision allowing for fuel-use exempt model adopted in October 2024.[29]

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[25] Plastic. Climate. Future. 2024. *"Plastic. Climate. Future. Podcast Feat. Circularise with Christian Krüger from BASF."* YouTube. February 15, 2024.
[26] J-P Lange, *Plastic recycling stripped naked – from circular product to circular industry with recycling cascade*, 2024
[27] Eunomia, *Is Net Zero Enough for the Material Production Sector?*, 2022
[28] Plastic Europe. 2024. *"The Plastics Transition • Plastics Europe."*
[29] UK Government, *Plastic Packaging Tax - chemical recycling and adoption of a mass balance approach*, 2024

Beforehand, the UK government carried out a consultation on the most appropriate mass balance method to use in the context of the UK's plastic packaging tax, which is levied on plastic packaging components which contain less than 30% recycled plastic.[30]

Responding to the consultation, trade bodies representing chemical companies and plastic manufacturers explained that businesses want to use more recycled plastic but are currently unable to source material that meets their needs. They suggested that acceptance of a mass balance approach for the tax using a fuel-exempt allocation was necessary to make chemical recycling economically viable. They argued that the significant investment required to set up a chemical recycling plant "requires a high attributable yield".

Supporters of the fuel-exempt approach saw it as "striking the right balance between ensuring that chemical recycling is contributing to the circular economy and ensuring the technology is investable and able to grow".[31]

Transparency concerns

However, the fuel-exempt method allows the feedstock from recycled material that goes into non-polymer products such as waxes, tarmacs, and pharmaceuticals to be attributed to plastic packaging use. A number of respondents to the consultation expressed concerns that this model could lead to the "appearance of greenwashing".

Even among respondents who recognised that the proportional or polymer-only methods were more closely aligned to the objectives of the tax, some nonetheless argued for the fuel-exempt approach, even though this enables a claim of higher levels of recycled content in polymer output than would realistically be achieved.

The UK government also "noted the concerns raised about the potential environmental impacts of chemical recycling and the potential for the adoption of a mass balance approach to disincentivise efforts to move waste up the hierarchy".

The EU is currently deciding which model to accept. A surge in paid advertorials and articles from the chemical industry calling for fuel- exempt mass balance accounting system has flooded the industry press in recent years, putting pressure on the European Commission.[32] [33]

However, if mass balance accounting must be used to achieve circularity and environmental targets, the 'proportional model' should be the one implemented.[34] It allows consumers to know the proportion of recycled plastic used in the manufacture of a given number of packaging components, the recycled content within each

[30] UK Government, *Plastic Packaging Tax - chemical recycling and adoption of a mass balance approach*, 2024
[31] UK Government, *Plastic Packaging Tax - chemical recycling and adoption of a mass balance approach*, 2024
[32] *"How the EU Can Enable a Circular Economy in Plastics Packaging."* 2022. POLITICO. December 1, 2022.
[33] *"LyondellBasell Drives Circularity Forward in Automotive Applications."* Sustainable Plastics. October 15, 2024.
[34] Zero Waste Europe, *Mass balance – time to play fair*, 2023

component is taken to be equal to the proportion of the inputs to the manufacturing process that were recycled.

This is the fairest approach where the outputs of chemical recycling cannot be attributed to any specific inputs, and the one most likely to preserve a level playing field between chemical and mechanical recycling and to offer the largest potential environmental benefits.[35] A number of respondents also argued that this was "the easiest method for those without technical knowledge to understand and provided greater transparency, reducing ambiguity about recycled content in plastic outputs and the associated risk of greenwashing".[36]

In defending its decision to adopt the fuel-exempt mass balance model, the UK government said it understood the case made for the proportional and polymer-only methods of mass balance allocation as "a way of more closely reflecting the recycled content present in plastic packaging".

However, the government said that the fuel-exempt method strikes the "right balance between providing a strong incentive to invest in the UK chemical recycling sector and maintaining the integrity of the tax and consumer confidence in recycling".

Perhaps the most controversial decision of the UK government is to allow the use of the lower heating value (LHV) unit of measurement to calculate the inputs and outputs from a cracking process. The chemical industry favours the use of the LHV as the common denominator between different chemicals in order to measure them.

However, the use of LHV can be extremely misleading, as it is a crude measurement that reveals little about the unique chemical composition and characteristics of the chemical being measured.[37]

Similarly, a chemical for which there is no sustainable alternative via bio or circular or bio-circular source could be replaced and claimed sustainable by using equivalent LHV from another sustainable chemical. Thus, making something possible, which is not chemically feasible.

The UK government's decision allows for a combination of mass and LHV, which means it will be possible to use two different metrics for one material depending on where it is measured in the supply chain. For example, when a molecule is in a refinery, a firm can decide to use LHV as a common denominator, but the same molecule can be measured through mass when it is in the form of plastics. This is unacceptable as it risks interested parties using the metric that best fits their narratives and could lead to greenwashing.

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[35] CE Delft, *Impacts of allocation rules on chemical recycling – consequences on the environment and maximum circularity of plastics*, 2023

[36] UK Government, *Plastic Packaging Tax – chemical recycling and adoption of a mass balance approach*, 2024

[37] Using this logic, for example, if a doctor tells the patient they need to eat an apple every day, but there is a lack of apples, the patient can eat an orange which has the equivalent number of calories – the common denominator. Under this methodology, the patient can now tell their doctor they have eaten an apple when in fact they have eaten an orange.

Major retailers and brands have expressed concern about the use of LHV. In 2023, Perstorp, Lego, IKEA and Velux said in a joint paper that any mass balance accounting methodology used "should be transparent and have credibility and acceptance from all parties in the value chain, including brand owners and end consumers". It states that "the recycled/renewable raw material can only replace its own part/share of the product", which would rule out the use of LHV as a measurement.[38]

Who to trust?

BASF's Christian Krüger also acknowledges that consumer trust is vital.

"If I go into the supermarket and I buy a fairtrade value chocolate, I feel good as I know there is something good somewhere upstream done. That's guaranteed by certification schemes. And that's trust. Certification gives you trust. It's tracked along the whole supply chain, and every supply chain actor is checked that he is doing the right thing, that there is no double counting allowed."

Krüger claims standards like the FairTrade certification scheme can give consumers confidence but mass balance certification in other sectors, including the FairTrade label have been criticized for a lack of transparency.[39] [40] [41]

The chemical recycling industry already uses standards for mass balance to inform consumers about the recycled content of the plastic they purchase and is pushing for the European Commission to recognise them under law.

However, there are concerns that the industry itself was behind the design of the standards, representing a worrying conflict of interest.

Redcert2 certification for mass balance was jointly developed by BASF – the largest chemical company in the world - and certification body TÜV SÜD.[42]

The other main standard for mass balance, already being adopted by the industry, was developed by the International Sustainability and Carbon Certification (ISCC) certification body. The ISCC PLUS certificate legitimises the free allocation model of mass balance. Moreover, six of its seven board members come from

[38] Perstorp, Lego, IKEA, Velux, *Proposal for an EU definition of mass balance*, 2023
[39] In 2005, a Dutch investigative journalist set up his own brand of chocolate after realizing that there is no guarantee that a chocolate bar with a fairtrade logo has not been produced with forced child labour - Source
[40] The Better Cotton Initiative (BCI) said in 2020 that its mass balance system could eventually be replaced with full traceability due to concerns over its failure to uncover forced labour issues in China - Source
[41] The Dutch Authority for Consumers and Markets criticised H&M and Decathlon for their misleading claims on sustainable cotton at the product level while using a mass balance system – "You will need to distinguish between general information about your company's efforts with regard to sustainability, and specific information about the benefits of an individual product." - Source
[42] REDcert^2, *Scheme principles for the certification of sustainable material flows for the chemical industry*, 2019

the chemical or fuel industries, including Eastman, Dow, and BP, leading to criticism that the standard is "really a system of self-certification."[43]

Scientific papers

BASF set out the case for the use of mass balance in chemical recycling in a paper in 2015, including its intention to employ LHV as a measuring unit, which is highly problematic as shown previously.[44]

In 2019, BASF followed this by contributing to a white paper with the Ellen MacArthur Foundation, "to encourage the chemical industry to apply the mass balance approach also to recycled feedstock".[45]

Two months later, a peer-reviewed paper was published on Science Direct "for integrating the biomass balance approach into life cycle assessment with an application in the chemicals sector". Alongside scientists from the University of Manchester, two BASF employees, Christian Krüger and Andreas Kircherer, are cited as authors.[46]

In 2021, Krüger is cited in another Science Direct paper, which claims that the pyrolysis of mixed plastic waste (MPW) emits 50% less CO_2 eq. than energy recovery and that chemically recycled plastic generates 2.3 t CO_2 eq./t less than virgin plastic, and global warming potentials of pyrolysis and mechanical recycling are comparable. The calculations are derived from BASF's own production data and draw on the 2019 Science Direct paper which in turn sets out BASF's mass balance methodology.[47]

Decision-makers are relying on these documents too. The Joint Research Centre for the European Commission's policy paper in 2023 on "a better definition and calculation of recycling" also cites the same BASF paper to make the point "that chemical recycling of mixed plastic waste via pyrolysis had about 50% lower climate change impact and life cycle energy use relative to energy recovery from plastic waste".[48]

This claim, based on the industry's own, limited data, comes to very different conclusions to another research paper, which found that greenhouse gas emissions from plastic waste pyrolysis are likely to be between 10 and 100 times higher than those emitted from the production of virgin plastic.[49]

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[43] Creswell, Julie, and Hiroko Tabuchi. 2024. *"Why Plastic Water Bottles May Not Contain as Much Recycled Plastic as Advertised."* The New York Times. August 26, 2024.

[44] Kormann, Claudius, and Andreas Kicherer. *"A Mass Balance Approach to Link Sustainable Renewable Resources in Chemical Synthesis with Market Demand"*, 2015

[45] EMAF, *Enabling A Circular Economy For Chemicals With The Mass Balance Approach – A white paper from Co.Porject mass balance*, 2019

[46] Jeswani, Harish K., Christian Krüger, Andreas Kicherer, Florian Antony, and Adisa Azapagic., *"A Methodology for Integrating the Biomass Balance Approach into Life Cycle Assessment with an Application in the Chemicals Sector."*, 2019

[47] Harish Jeswani,Christian Krüger,Manfred Russ,Maike Horlacher,Florian Antony,Simon Hann,Adisa Azapagic, *"Life cycle environmental impacts of chemical recycling via pyrolysis of mixed plastic waste in comparison with mechanical recycling and energy recovery"*, 2021

[48] Joint Research Center, *Towards abetter definition and calculation of recycling*, 2023

[49] Taylor Uekert, and all, *Technical, Economic, and Environmental Comparison of Closed-Loop Recycling Technologies for Common Plastics*, 2023

Greenwashing claims

Despite such powerful industry influence, regulators in some parts of the world appear to be ramping up vigilance against claims made by the industry.

This year in the US, following a two-year investigation, California's attorney general, Rob Bonta, filed a first-of-its-kind lawsuit against ExxonMobil for allegedly deceiving the public about the plastic pollution crisis.[50]

"For decades, ExxonMobil has been deceiving the public to convince us that plastic recycling could solve the plastic waste and pollution crisis when they clearly knew this wasn't possible," Bonta stated. [51]

As part of the investigation, he issued a subpoena to the oil giant ExxonMobil and plastic trade groups. The content of the internal documents reveals a startling picture. ExxonMobil has been "advocating for public acceptance of "advanced recycling" "to avoid the 'negative' impacts/consequences of the looming implementation/adoption of the circular economy way of thinking," it says. Executives at the oil and gas giant also admit in their internal correspondence that the "driving motivation" behind its advanced recycling push is that "the public perception benefits received will be invaluable … even if it proves to not be financially sustainable." Bonta added: "All the while, ExxonMobil has known that mechanical recycling, and now 'advanced recycling,' will never be able to process more than a tiny fraction of the plastic waste it produces."

He also alleges that ExxonMobil has made numerous misleading statements to the public that its ISCC PLUS certification ensures "circularity" and other substantial environmental benefits of the products that result from "advanced recycling." In reality, Bonta said, "the ISCC PLUS certification utilised by ExxonMobil allows for little to no physical traceability between its "advanced recycled" polymers to the products that consumers are purchasing. In fact, products marketed as having ISCC PLUS "certified circular polymers" likely contain little to no physical recycled content or environmental benefits at all. This is because the ISCC PLUS certification that ExxonMobil uses allows "mass balance" with "free allocation" or "free attribution."

As shown above, having the industry knowingly lobbying for technology even if there are serious doubts about its viability, in order to improve "public perception" is a form of greenwashing.

[50] SUPERIOR COURT OF THE STATE OF CALIFORNIA, *ATTORNEY GENERAL OF CALIFORNIA v. EXXON MOBIL CORPORATION*, 2024
[51] SUPERIOR COURT OF THE STATE OF CALIFORNIA, *ATTORNEY GENERAL OF CALIFORNIA v. EXXON MOBIL CORPORATION*, 2024

Why are some larger petrochemical players pulling out now?

Within the industry, there is a growing realization that chemical recycling does not offer an economically viable route to defossilising the sector. Doliente, who worked with a team from the University of Bath, the University of Cambridge, and the University of California Santa Barbara in his postdoc, ran over 4 billion possible simulations on a model of the global petrochemical supply chains, to see how it can successfully defossilise, they found that the number one intervention required for the defossilisation of the chemicals industry was a reduction in the consumption of plastics and fertilisers.

In July, it emerged that oil and gas giant Shell had quietly backed away from a pledge to rapidly increase its use of "advanced recycling". The firm had invested in pyrolysis since 2019 and set an ambition to use 1m tonnes of plastic waste a year in our global chemicals plants by 2025." But in its sustainability report, Shell stated that the "scale of this ambition was unfeasible".[52]

Former Shell employee, Lange says it is not just Shell lowering its chemical recycling ambitions. "You see Shell retracting, Exxon being sued, other big players are also facing very big challenges coming to commercialization, and small recyclers going bankrupt" big players are also facing very big challenges coming to commercialisation," he said.

In the same manner, INEOS quietly pulled out of a project it launched with Plastic Energy in 2022 to produce 100,000 tonnes per annum of recycled raw materials through pyrolysis. When contacted, INEOS refused to give a reason for its reversal but said "driving new advanced recycling capabilities will be vital for meeting the Packaging and Packaging Waste Regulation (PPWR) recycled content requirements in the future".

According to Lange, big players are reducing their ambitions for chemical recycling because society is "not ready". "The consumer – you and I – are not ready to pay and the voter - you and I again - are not ready to vote for aggressive environmental politics, just because it is too expensive."

"The big corporations are there to make money for society. The shareholders are part of society, the pension funds are part of society, the employees are part of society. A well-functioning company needs to make money

[52] Shell, *Sustainability Report 2023*, 2024

that needs to be distributed back to society, and the final choice needs to come from society, from consumers and voters."

Lange warns that if Shell spends aggressively on green policies when the consumer appetite is not there, the share price will fall, leading to another oil and gas giant such as BP or Exxon "swallowing Shell and destroying all the green ambition".

It is clear investor groups can have a decisive impact when calling for a reduction in the production of virgin polymers:

> *As responsible investors and their representatives, we are concerned that petrochemical companies are not proactively addressing their plastic-related risks with actions aimed at reducing their dependence on fossil fuel feedstocks and eliminating hazardous chemicals and additives from their products, and as a result, face higher costs and miss out on business opportunities, ultimately diminishing investment returns and long-term value creation. We therefore urge companies to act and align their business practices with a clearly defined transition plan to a safe and circular plastics economy, as outlined below.*[53]

Shareholder action is already having an effect. This summer US company PureCycle settled a $12M lawsuit from its shareholders who claimed the firm had made misleading statements about the potential of its chemical recycling technology. The shareholders argued this "artificially inflated the price of PureCycle securities, and that the securities' prices dropped in response to certain subsequent disclosures."[54]

Cheap feedstock, expensive technology

Lange says another reason some chemical firms are retreating is the current lack of demand for contaminated plastic.

"In over thirty years in the industry, I saw that cheap feedstocks require expensive processes. The waste might be cheap when it is on your doorstep, but it needs to be collected, sorted, washed and treated, then reprocessed or, worse, cracked back to elementary building blocks and rebuilt back to full polymer. This all brings costs. Moreover, sorted waste comes at a modest volume. Processing at such a small scale is much more expensive than at the 10-100x larger scale at which virgin plastics are presently produced."

The process is expensive because it is "complex and small scale", according to Lange. The feedstock becomes expensive because everyone wants it. Suddenly the brand owners are saying they are willing to pay a bit more

[53] Planet Tracker, *"Petchem Investor Full Statement - Planet Tracker."*, 2024.
[54] *"PureCycle Settles Lawsuit Claiming Misleading Statements for $12M."* Sustainable Plastics. May 17, 2024.

for it because they can make a nice advertisement for it but it is just for that label. Eventually, you see the industry completely squeezed – you can't make a business case like that."

Lange thinks with mass balance accounting, petrochemicals will be able to finance the scaling up of chemical recycling because they will be able to allocate the initially small fraction of recycled carbon to the few applications that can afford higher cost charge consumers more and avoid plastic packaging taxes. Once scaled-up the technology will be cheaper and will be affordable for many more products able to pay for itself. "You need to make use of stepping stones that you can afford," he says.

The chemical industry, which generated upwards of €760bn in sales in 2022 in the European Union, should be in a position to potentially finance research and development on technologies that are as of yet unproven at scale. This argument becomes even more compelling when considering that the technology in question has been under development for decades with little commercial success demonstrated.[55]

[55] *"The Fraud of Plastic Recycling | Center for Climate Integrity."* Climate Integrity, 2024

Public funding

However, the taxpayer is shouldering a significant burden. In 2023, the European Commission announced its European Investment Fund (EIF) was contributing €50m to Infinity Recycling's Circular Plastics Fund I SCSp, a European impact fund that invests in companies developing new processes for the advanced recycling of plastics.[56] With a target size of €150m, the fund is aimed at bolstering "the industrial and commercial scale-up of companies enabling advanced recycling of plastics".

This is just one route to EU public funding for chemical recyclers. Last year, chemical giant LyondellBasell announced it had secured €40m under the EU Innovation Fund for its planned chemical recycling plant at its Wesseling site in Germany. It was one of 41 winning projects to receive a total of €3.6bn for innovative technologies with "low carbon emissions".[57]

Versalis, the chemical branch of Italy-based oil and gas giant Eni, also received EU innovation funding to build a demonstrator pyrolysis plant in the northern Italian region of Lombardy. It did not disclose the amount of funding received.[58]

In the UK, the government announced in 2023 that it was setting aside £60m as part of its Smart Sustainable Plastic Packaging (SSPP) Challenge, which it labels the "largest and most ambitious UK government investment to date in sustainable plastics research and innovation". Some grants will be made available for "next-generation chemical recycling technologies that have the potential to provide a recycling route for these harder-to-recycle waste streams", the government states.[59]

[56] Press Corner - European Commission, *"InvestEU: EIF invests €50 million to support circular plastics"*, 2023
[57] *"LyondellBasell Advanced Recycling Project Selected for EU Innovation Fund Grant."*, LyondellBasell, 2023
[58] *"Versalis Starts Construction of Chemical Recycling Plan in Italy."*, Sustainable Plastics, 2023
[59] UK Government, *"Smart Sustainable Plastic Packaging."*, 2023

Partnerships

Lange says many small companies "do well in the lab but have no experience in developing and scaling up processes". Many go bankrupt at demo or commercial stage. "I've seen that time and time again in the biofuel area. One of the best recipes for the startups is for them to partner with a big company that helps them to commercialise the process," he said.

One such company is Plastic Energy.

The firm, headquartered in London, describes itself as "a global leader in advanced recycling, specializing in recycling end-of-life plastics that would otherwise be destined for landfill, incineration or end up in the environment". The company claims its patented technology – a form of pyrolysis - transforms plastic waste into raw materials that can be used to create virgin-quality polymers.

Plastic Energy announced in 2021 that it would collaborate with ExxonMobil on an advanced recycling project in France that would convert post-consumer plastic waste into raw materials for the manufacturing of virgin-quality polymers. It was to be one of the "largest advanced recycling plants in Europe, with an initial capacity of 25,000 tonnes of plastic waste per year and plans to scale up to 33,000 tonnes in the near future.

However, when contacted, Plastic Energy stated it had transferred its stake in the project to another company, Green-Dot. Green-Dot said it was currently still in the process of "creating the conditions for the further development of the project, having only recently taken it over" and was therefore unable to provide a new status. The firm said it was in ongoing discussions with ExxonMobil, but the oil and gas giant did not respond when contacted.

Similarly, Plastic Energy agreed on a deal with oil and gas giant INEOS in 2022 for its largest plant to produce 100,000 tonnes of raw materials from plastic waste in 2022. It was to be "the largest use of Plastic Energy technology on the market, with the new raw materials it creates producing "a circular approach to producing essential plastic items that meet the requirements of demanding food contact and medical applications".[60]

This project was removed from their website and nothing else was announced publicly.

Its sustainability report says that Plastic Energy made 'steady, solid progress' throughout 2023 across its project portfolio. It still has two European joint ventures underway. The first project was announced in 2020 and is a joint partnership with Total Energies to build a 15,000 tonnes/year conversion facility in France. The second project was announced in 2018 and is a partnership with Sabic to build a pyrolysis plant in the Netherlands.

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[60] *"INEOS Signs Agreement with Plastic Energy for Its Largest Plant to Produce 100,000 Tonnes of Raw Materials from Plastic Waste."* INEOS, 2022

However, neither plant has yet completed construction and Plastic Energy's most recent financial accounts show that the firm made losses amounting to £89m over the 2022 financial year.[61]

The firm states: "Plastic Energy has and continues to invest heavily in the business to support its future growth ambitions. As a result, the Group is currently loss-making and therefore reliant on securing funding to ensure it is able to continue as a going concern."[62]

The accounts reveal that Plastic Energy has successfully undertaken multiple rounds of fundraising over recent years. In 2021 the firm completed "a significant capital raise of €146m", allowing it to repay all material borrowings and "support the acceleration of investment in its development and growth" and last year the company completed a second round of funding, "bringing in an additional €105m of capital from both existing shareholders and a number of new investors".[63]

Some of the larger oil and gas companies are pulling out of partnerships but companies like Plastic Energy continue to persuade shareholders to invest in their patented technology. Both taxpayers and shareholders may want to question why so many projects announced by the industry come to nothing.

[61] Plastic Energy, *Consolidated Financial Statement For The Year Ended 31 December 2022*, 2023
[62] Plastic Energy, *Consolidated Financial Statement For The Year Ended 31 December 2022*, 2023
[63] Plastic Energy, *Consolidated Financial Statement For The Year Ended 31 December 2022*, 2023

Conclusion

Even if there were no concerns about the environmental impact of chemical recycling, its impact would be a drop in the ocean. Christian Krüger from BASF notes that there are about 10-15 million tonnes of chemical recycling feedstock in Europe, whereas European crackers have a capacity of almost 100 million tonnes.

At best, the promotion and subsidising of chemical recycling will act as a distraction from efforts to reduce production. At worst, it could be used as a form of greenwashing to mislead consumers about the environmental impact of their purchasing decisions.

Meanwhile, petrochemicals will continue to increase the production of virgin polymers as planned, contributing to the climate change crisis, while ever-increasing volumes of plastic waste will continue to leach into the world's oceans and rivers. Toxic chemicals and carbon will continue to be released into the atmosphere.

It is concerning that the chemical industry is harnessing its vast lobbying power to influence policy that will enable it to present chemical recycling as a successful green technology.

Meanwhile, the chemical industry is using its marketing power to draw attention away from its plans to ramp up production by offering a false solution to a very real problem. In an era when fossil fuel companies are under increased pressure to decarbonise, chemical recycling offers the right optics for the industry. However, chemical recycling will not reduce the extraction of fossil fuels in any meaningful way, nor will it solve the problem of plastic pollution.

Recommendations

- The Global Plastic Treaty as well as EU legislation more generally shall explicitly incorporate the established EU waste hierarchy framework, - i.e. emphasising first waste prevention and reuse, followed by recycling, - to reduce disposal and incineration in accordance with their environmental impact and resource efficiency.
- Decision-makers must implement comprehensive measures such as production cap to systematically reduce virgin polymer production to align with the Paris Agreement to achieve climate neutrality by 2050.
- By exercising their governance rights and fiduciary responsibilities, shareholders shall compel corporate entities to implement systematic reductions in production volumes.
- The recycling process should deliver safe, non-toxic, and decontaminated products, by-products, and waste without dilution practices with virgin feedstock.

- When defining recycled content for plastic, the methodology should ensure transparent and reliable claims based on weight (using segregation and controlled-blending models).
- Public funding should not be given for the construction of pyrolysis and gasification plants, as the environmental value of these techniques still needs to be proven, and the risks exceed the benefits.

Zero Waste Europe (ZWE) is the European network of communities, local leaders, experts, and change agents working towards a better use of resources and the elimination of waste in our society. We advocate for sustainable systems; for the redesign of our relationship with resources; and for a global shift towards environmental justice, accelerating a just transition towards zero waste for the benefit of people and the planet.
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Date: November 2024

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