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Coming around

How chemical companies must adapt to the circular economy

ShareAction»

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Executive Summary

Circular economy principles can help the chemical sector to reach net zero and address its plastic pollution

The chemical sector is responsible for over 5.8 percent of global greenhouse gas emissions and needs to reach net zero emissions by 2050[i] It is technically feasible and increasingly economically viable to produce emissions-neutral primary chemicals.[ii]

The sector must also address plastic pollution. Methanol and high value chemicals are ingredients for making plastics, and many chemical companies make plastic resins themselves. In the space of a single human lifetime, our reliance on single-use plastic products has created an unmanageable amount of plastic waste: more a tonne for every person alive today (8,300,000,000 tonnes).[iii]

The principles of the circular economy "reusing...and recycling existing materials and products as long as possible; and tackling the presence of hazardous chemicals along the whole value chain"[iv] can help chemical companies to address both of these issues.

Chemical producers can incorporate circular materials into their production processes

About half of the emissions from primary chemicals stem from using fossil fuels as feedstock. Feedstocks are a source of molecules, like hydrogen or carbon, needed to make any given chemical.

Fossil feedstocks contain carbon that is either released as a by-product of making a chemical or embodied in the chemical itself (and then released downstream), increasing emissions. Fossil feedstocks cannot align with 1.5-degree pathways and need to be replaced with emissions-neutral alternatives.

This means when carbon is needed as part of a chemical's molecular structure it must be sourced from carbon that is already in circulation. For example, carbon will need to be captured from the air. Products made with captured carbon and renewable energy would release no additional emissions.

An alternative source of circular carbon could be plastic waste, once reuse and mechanical recycling have been exhausted. Plastics are made with high value chemicals and methanol, so they contain a carbon molecule. Two chemical recycling technologies, pyrolysis and gasification, break plastic waste down with heat. This turns plastic into products that, once processed, can be used as feedstock to make new chemicals and plastics.[v] Pyrolysis and gasification will be explained in detail below.

The concept of chemical recycling is attractive but only certain technologies, under very strict conditions, have the potential to align with net zero. These conditions are not being met today

Neither pyrolysis nor gasification have been proven at a large scale so there is not enough evidence to give strong support to either approach. [vi]

That said, it would be desirable to have alternatives to incineration or landfill for plastic waste, which could keep materials and carbon in circulation, and provide an alternative feedstock for chemical producers.

Any technology that chemical companies want to explore must be able to align with net zero. Unaligned technologies do not have a long-term future and carry a material risk for investors. To align, a technology would have to be zero or near zero emissions and produce a feedstock that will be compatible with emissions-free production processes.

Pyrolysis and gasification are not meeting these conditions today[vii], and only one of these technologies has the potential to align with them.

Chemical companies that want to explore chemical recycling must therefore re-evaluate their investments.

Gasification has the potential to provide a source of circular carbon beyond 2050

Gasification heats plastic waste with very little oxygen present to turn it into ‘syngas’, a mixture of hydrogen and carbon monoxide. Once treated, the syngas could be an input into emissions-neutral methanol and high value chemicals production.[viii]

In its current form gasification creates high emissions due to high energy requirements, CO_2 released as a by-product in the process, and syngas being used for fuel instead of feedstock.[ix] However, the technology could be run in a different way to reduce emissions significantly,[x] according to the conditions below.

Chemical companies can only develop gasification if it meets the following conditions:

(The lifetime of a gasification facility is around 25 years, and the sector must reach net zero by 2050.)

1 Gasification plants they own or finance, which will become operational after 2025, must:

- electrify any external heat sources and have a plan to use 100 per cent renewable energy by 2050,
- use green hydrogen to upgrade 'raw' syngas (this can eliminate the CO_2 by-product at this stage[xi]), and
- not sell syngas for fuel.

2 Any syngas from plastic waste used in production processes is from plants that will be compliant with these conditions by 2050 at the latest.

3 Best available treatments are used to manage the risks to human health – including plant workers – and the environment created by toxic by-products of gasification. "Chemical recycling products are monitored to ensure toxic-free outputs in line with the EU legislation requirements for chemicals".[xii]

By contrast, there is a high risk that pyrolysis will lock in fossil assets, threaten net zero and put investors at risk

Pyrolysis involves heating plastic waste with no oxygen present to make 'pyrolysis oil' that, with further processing, can be a substitute for fossil feedstock. It needs to be fed into a steam cracker, which turns fossil feedstocks into high value chemicals.[xiii]

Pyrolysis oil needs to be diluted with virgin fossil feedstocks, so it is unlikely a steam cracker will ever run off pyrolysis oil alone.[xiv] This ties pyrolysis to virgin fossil fuel extraction, and to steam crackers, which need to be phased out.

Pyrolysis has no future beyond 2050 and could threaten net zero targets. There can be no new investments in pyrolysis.

Chemical recycling will only ever be a last resort. Chemical companies must prioritise enabling products to be reused and then mechanically recycled

Plastic use must be reduced as much as possible in the circular economy to address plastic pollution. The priority is therefore to design plastic out of use where possible, reuse plastic products for as long as possible, and then recycle them mechanically, which means turning plastic waste into a secondary raw plastic material without altering its chemical structure. This is the most efficient, lowest emissions way to recycle, and the only one proven at scale.

Reuse is the priority above any form of recycling as it avoids new resource extraction, new plastic production, additional processing of materials, and waste generation.[xv]

Only when these have been exhausted can chemical recycling be attempted, as a last resort to incineration or landfill.

To support circularity, chemical companies must address hazardous substances in their products which are a barrier to easy – and safe – reuse and recycling.[xvi] They must phase out or substitute harmful substances wherever possible and be transparent about the chemicals in their products, to help to monitor potential impacts of hazardous chemicals and raise awareness in their value chains.

Introduction

Introduction

What is the purpose of this investor briefing?

The purpose of this briefing is to help investors understand how applying the principles of the circular economy – “reusing…and recycling existing materials and products as long as possible; and tackling the presence of hazardous chemicals along the whole value chain”[xvii] – will help the chemical sector to reach net zero by 2050 and address plastic pollution. It will support investors to engage with companies on actions they are taking to incorporate circularity into their business models.

Why is circularity important for chemical producers and their investors?

The chemical sector is responsible for over 5.8 percent of global greenhouse gas emissions and needs to reduce these to net zero by 2050[xviii]

The chemical sector needs to mitigate emissions across the whole lifetime of chemicals, from their production to their disposal. The IEA is clear that the sector is not on track to achieve net zero; the sector’s emissions have risen 2.2 per cent since 2015.[xix]

The latest report of the Intergovernmental Panel on Climate Change found that “rapid and deep” reductions in CO_2 emissions across all sectors are required to limit global heating to 1.5 degrees, and the window of opportunity to achieve this is closing fast.[xx]

It is technically feasible and increasingly economically viable to produce emissions-neutral primary chemicals.[xxi]

Circularity can help chemical companies to transition to producing emissions-neutral chemicals

Chemical producers need to tackle their feedstock emissions, which make up about half of their emissions overall. Feedstocks are inputs in chemical production processes that provide the molecules, like hydrogen or carbon, needed to make any given chemical.

Fossil feedstocks contain carbon. Using them as feedstocks create emissions in two ways:

1. If the carbon is not required for the molecular structure of the desired chemical (for example, ammonia does not contain a carbon molecule), it is released as a by-product during the production process.

2. If the carbon *is* required for the molecular structure of the desired chemical, then it is embodied in that product and will be released later at Scope 3 (e.g, when a piece of plastic, derived from a primary chemical like methanol, is incinerated).

Fossil feedstocks need to be replaced with emissions-neutral alternatives that do not result in these emissions. For example, rather than sourcing hydrogen from natural gas, a fossil fuel, which releases CO_2 as a by-product, green hydrogen can be made with electrolysis using 100 per cent renewable energy. See our latest investor briefing on hydrogen for more detail.

Where carbon feedstock is required, as it is for methanol and high value chemicals, it must be sourced from carbon that is already in circulation, as this would result in no net change to the level of carbon in the atmosphere. Carbon will need to be captured from the air or, as an intermediate solution, from industrial emissions.

Another source of carbon could be end-of-life plastic waste that can no longer be reused or mechanically recycled. Plastics are made with methanol and high value chemicals, so they contain a carbon molecule.

Chemical recycling[1] processes change the chemical structure of plastic waste to convert it into a secondary material. Two chemical recycling technologies, pyrolysis and gasification, turn plastic waste into products that, with further processing, can be used as feedstocks to make new chemicals:

- **Pyrolysis** (from Greek *pyro* [fire] *lysis* [breaking]) involves heating plastic waste without oxygen to a high temperature to break it down into a crude-oil like product.

- **Gasification** is similar, but some oxygen is introduced to the process. This produces 'syngas', a mixture of gases including hydrogen and carbon monoxide.

1 'Chemical recycling' is an umbrella term that, in addition to describing processes that convert plastic waste into feedstocks, can also refer to processes that turn plastic back into its constituent polymers or monomers. These distinctions will be explained later, but feedstock recycling will be the focus of this briefing.

Chemical recycling is an attractive concept, but it is not proven at scale

Existing chemical recycling technologies are not operating at a large scale and real-world performance data is scarce or hard to access, which means there is not enough evidence to give strong support to any approach.[xxii] Though sometimes called 'advanced' recycling technologies, many ventures have failed to be technologically or financially viable.[xxiii]

Despite this it is desirable to develop ways to use end-of-life plastic waste that cannot be reused or mechanically recycled. The alternatives – landfill, leakage into the environment, or incineration – are all bad options. It estimated that 9 per cent of emissions from the plastic lifecycle are released at the end-of-life stage.[xxiv] Incineration creates more emissions than any of the chemical recycling processes being considered.[xxv]

There is still merit to exploring chemical recycling for these reasons.

However, a fundamental condition that any chemical recycling technology must meet is that it must be aligned with pathways to net zero by 2050.

Today, chemical recycling is not aligned with net zero

Currently both pyrolysis and gasification are high emissions technologies due to their energy requirements, carbon from the plastic waste being released in the process, and the products of both processes being used as fuels instead of feedstocks.[xxvi] Plastic-to-fuel is not recycling but simply means carbon spends a short time in another form before it is released.[xxvii]

In addition, some technologies produce feedstocks that will not be compatible with future emissions-neutral production processes, as detailed in our previous briefing.

In this form chemical recycling has no future. These are serious problems, and chemical recycling can only be developed if they can be resolved.

The long life of infrastructure, and the need to reduce emissions over the next three decades, means investments today must be net-zero aligned from now. Any that are not will lock in emissions, threatening the sector's climate commitments and posing a material risk to investors in the form of stranded assets.

Only certain chemical recycling technologies, under strict conditions, have the potential to align with net zero

As several chemical companies are already exploring chemical recycling, it is important to evaluate which technologies could be part of a net zero chemicals industry. The choice of technology and the way it is deployed are critical.

Technologies must show potential to become zero or near-zero emissions. They must also produce a feedstock that can plug into emissions-neutral chemical production processes. Chemical companies must also consider the toxic by-products chemical recycling can create, which can have serious implications for human health and the environment.[xxviii] These problems are explored in more detail below.

If chemical companies want to explore chemical recycling, the technologies they finance must meet these strict conditions:

- process emissions would have to be reduced to zero or near zero,
- the feedstock produced would need to be compatible with emissions-neutral production processes, as outlined in our last report;
- the products of chemical recycling could not be sold as fuels; and
- risks from toxic by-products would need to be monitored, disclosed, mitigated and carefully managed, in line with best available treatments and EU regulations.

These conditions are not being met today, so chemical companies must re-evaluate chemical recycling investments.

This briefing will evaluate whether pyrolysis or gasification could meet these conditions.

A reminder of emission-neutral production processes for methanol and high value chemicals

To produce methanol[xxix]:

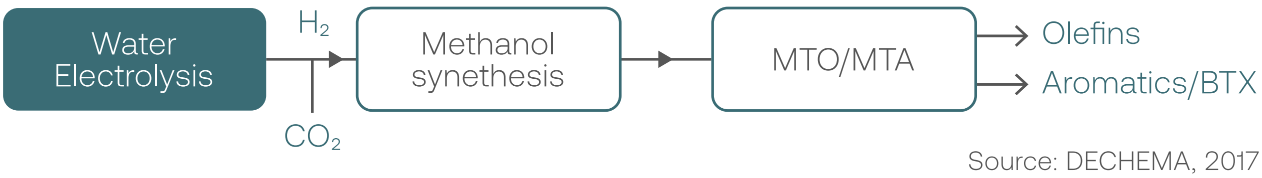
Methanol production requires hydrogen and carbon dioxide. Producers must replace fossil fuel feedstock with green hydrogen (made with electrolysis, powered by renewable energy) and captured carbon.

This is used to produce a syngas (hydrogen, carbon monoxide, and some carbon dioxide). The syngas is compressed and fed into a methanol converter. However, during the methanol synthesis in the converter, only about 5 percent of the feed gas is converted to methanol at each pass, resulting in a loop system to re-use “leftover” feed gas from the previous pass.

To produce olefins (ethylene, propylene) and aromatics (benzene, toluene, and xylene) – high value chemicals[xxx]:

With green methanol as the platform chemical, two further processes are required: methanol-to-olefin or methanol-to-aromatics.

Figure 1: Low-carbon methanol, olefins and aromatics production:



Source: DECHEMA, 2017

Our previous investor briefing explains these processes in more detail.

Ammonia does not require circular carbon

It is important to note that Ammonia does not require carbon for its chemical structure, so circular carbon is not relevant to ammonia production.

Chemical companies must prioritise enabling products to be reused and mechanically recycled, to reduce emissions and combat plastic pollution

In the circular economy, the priority is to minimise the need for new materials and products by designing out plastic where possible, reusing products for as long as possible, and then resorting to recycling with mechanical recycling.

Reuse avoids new resource extraction, new plastic production, additional processing of materials, and waste generation.[xxxi]

Mechanical recycling turns plastic waste into a secondary raw material without altering its chemical structure. It is the next best option for products that can no longer be reused as the lowest emissions ways to recycle, and the only way proven at scale.

Chemical recycling would only ever be appropriate once these options have been exhausted – in other words, as a last resort.

Reuse and recycling will reduce the need for fossil-based products before 2050, which can lower emissions.[xxxii] Modelling of a 1.5 degree-aligned pathway for the chemical sector by the International Renewable Energy Agency, and cited in the Intergovernmental Panel on Climate Change's latest report on climate change mitigation[xxxiii], estimated that circular economy interventions need to account for 16 per cent of emissions reductions if the sector is to decarbonise by 2050.[xxxiv]

At the same time, reuse and recycling will help to address the sector's contribution to plastic pollution.

Addressing plastic pollution

Plastic pollution must be a critical issue for chemical companies

The chemical sector is contributing to plastic pollution, as methanol and high value chemicals are the ingredients for plastic production, and many companies produce plastic resins themselves. Forty percent of methanol is used to produce formaldehyde, a basis for plastic[xxxv], and 85 percent of light olefins are used to make plastics.[xxxvi]

In the space of a single human lifetime, our reliance on single-use plastic products has created an unmanageable amount of plastic waste: more a tonne for every person on the planet today (8,300,000,000 tonnes). [xxxvii] It is estimated that around 40 per cent of plastic products have a useful lifetime of less than a month.[xxxviii] Global production of plastics grew from 2Mt to 380Mt between 1950-2015, yet it is estimated that only 9 per cent of all plastic ever produced has been recycled.[xxxix]

Much of this will take several centuries to decompose.[xl] Plastic pollution creates serious ecological impacts: threatening wildlife health with ingestion and entanglement, affecting bacteria that sequester carbon in the ocean, and degrading soil quality on land.[xli]

If plastic production rises, pollution would get worse. On current trajectories, it is estimated that by 2040 there would be 50kg of plastic in the ocean for every metre of global coastline.[xlii]

On its own, keeping materials in circulation will not address the plastic waste problem

Circularity does not just mean designing plastics to be reused and recycled. In the first instance, it means eliminating unnecessary plastic altogether.[xliii]

The need to reduce plastic use as much as possible is clear: even if 'immediate and concerted' global action was taken to adopt circularity measures, it is estimated that a high amount of leakage and waste would still be created in the coming decades.[xliv] Chemical and plastic producers have limited control over what happens to their products, even if they are made to be reused and recycled. And again, the technologies to recycle plastic waste that cannot be recycled by conventional means are not proven at large scale.[xlv]

Being able to make plastics from emissions-neutral chemicals, and supporting reuse and recycling, would not give plastic producers the green light to make ever-greater volumes of plastic. Ultimately, we must reduce plastic use as much as possible.

Chemical companies need to design out hazardous substances to make products easy to reuse and recycle

Many plastics contain harmful substances. This can become a barrier to safely reusing and recycling materials.[xlvi] This briefing will explore what chemical producers can do to address this problem.

Action is required across the whole plastics value chain

To address plastic pollution action is required at all levels, with chemical companies being just one part of the solution. **At all levels, the aim must be to reduce the need for plastic as much as possible.**

1. **Chemical companies and plastic resin producers** need to substitute toxic substances to make their products easy and safe to circulate.

2. **Plastic product manufacturers** need to **design out** plastic where possible, and where not possible, make products **easy to reuse and recycle by design**. This could include making products simpler and more durable. They need to take more responsibility for the plastic waste they create, such as through Extender Producer Responsibility schemes.[xlvii]

3. **Retailors** can **reduce** their plastic use as much as possible and engage with upstream companies to **design out** plastic packaging and products where possible, and where not possible, make products **easy to reuse and recycle by design**.

4. **Consumers** can **vote with their feet** by minimising their plastic footprint, prioritising reuse, and buying from brands and retailors that support these aims.

5. **A significant increase** in reuse schemes, like deposit return schemes, and rates of collection and mechanical recycling is required.

By making products that can be reused and recycled safely, chemical companies can contribute to the sector's efforts to reach net zero by 2050.

Why the chemical sector must act

Part I: Why the chemical sector must act

Companies that are slow to adapt to the circular economy will expose their investors to risks

The circular economy is a policy priority for Europe

A wave of regulations seeks to promote reuse and recycling and address toxic substances in the circular economy.

Several regulations have already been introduced to lower emissions, cut waste, and promote reuse and recycling since the EU Circular Economy Action Plan was published in 2018 (a revised version was published in 2020).[2]

Some regulations will affect chemical and plastics producers directly, such as proposed amendments to REACH to require the registration of polymers of concern.[xlviii] Others will have an indirect effect such as the EU Taxonomy's sustainability criteria for plastics, which promote mechanical recycling and, under some conditions, chemical recycling.[xlix]

As over 95 percent of manufactured products rely on chemicals[l], chemical producers could be exposed to regulations to promote circularity across a wide range of product types.

2 Another relevant strategy is the recently-published *EU strategy for sustainable and circular textiles*, which includes discussion of the need to increase recycled content and reduce material complexity via ecodesign requirements, and the need to address substances of concern with REACH regulation.

Figure 2: Recent and forthcoming circular economy regulation

Legislation	Description	Effective from
Single-Use Plastics Directive[li]	Market ban on select-single use plastic items	2021
	Consumption reduction targets for single-use plastic items that cannot be substituted	Action required now
	25% recycled plastic by 2025 in PET bottles and 30% by 2030 in all types of beverage bottles	Action required now
	Extended Producer Responsibility schemes that increase producers' responsibilities for waste management over the lifetime of a product	2024-2025
	Targets for separate collection of beverage bottles < 3 litres, 77% separate collection by 2025 and 90% by 2029	Action required now
EU Taxonomy Climate Delegated Act	Establishes criteria for sustainable plastics, which includes that they must be fully manufactured by mechanical recycling of plastic waste, or if this is not 'technically feasible or economically viable', by chemical recycling that meets certain emissions requirements	2022
Directive on packaging and packaging waste[lii]	By 31 December 2025, at least 65% by weight of all packaging waste must be recycled. Includes target for 50% by weight of plastic waste	Action required now
	Extended Producer Responsibility Schemes for all packaging	2025
Plastic Waste Tax[liii]	Member states to contribute to the EU budget according to their volume of non-recycled plastic waste, at a rate of 0.80EUR/Kg	2022
Virgin plastic taxes	UK[liv]: 200 GBP/tonne tax on packaging with < 30% recycled plastic	2022
	Italy[lv]: 450 EUR/tonne tax on select products containing virgin plastics	2023
	Spain[lvi]: 450 EUR/tonne tax on select products containing virgin plastics	2023
Draft UN resolution: Towards an international legally binding instrument to end plastic pollution[lvii]	Commits that resolution will include provisions; "to promote sustainable production and consumption of plastics, including, among others, product design, and environmentally sound waste management, including through resource efficiency and circular economy approaches"	Forthcoming
New Ecodesign for Sustainable Products Regulation, repealing the Ecodesign Directive.[lviii]	Proposes to appeal ecodesign directive 2009/125/EC	Forthcoming
	Proposes new ecodesign requirements to make products more energy efficient, reduce their carbon footprints, incorporate more recycled material, reduce substances of concern, and make products easier to reuse and recycle. Criteria for safe and sustainable by design chemicals are forthcoming	
	Also includes proposal for a Digital Product Passport carrying product environmental and sustainability information	
Ecodesign UK[lix]	Ecodesign and energy labelling requirements for certain goods, including many white goods and electronic displays	2021
Proposed review of Directive 94/62/EC on Packaging and Packaging Waste[lx]	Proposal to review Directive with aim of reducing packaging and packaging complexity, and enable greater packaging reuse	Forthcoming
Consultation on amendment of REACH [lxi]	A consultation to amend the Regulation on the Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) is considering several changes, including requirements to register polymers of concern (the building blocks of plastics)	Forthcoming

Source: Shareaction

Investors should understand that these are likely the **first steps** for the circularity agenda. Action taken so far will not be enough to bring plastic use down to sustainable levels.[lxii]

One possible future measure could be an international tax on virgin plastics to speed up recycled plastic cost parity. National levies already exist in several countries (see Figure 2), but an EU-wide approach would prevent such a levy being undermined by untaxed virgin imports.[lxiii]

This idea has already been scoped by a government-commissioned study in the Netherlands[lxiv], and will be relevant as the UN works on a legally binding international instrument to combat plastic pollution.[lxv]

These regulations aim to tackle emissions as well as pollution and waste. Plastics will therefore be a target of regulations on the basis of their emissions for as long as production is coupled with fossil fuel use. Chemical producers that do not respond will be increasingly exposed.

In the long-term, this regulatory agenda will make low-carbon, less toxic, and easy-to-reuse-and-recycle products more competitive in the circular economy.

Understanding recycling – where things go wrong

Part II: Understanding recycling – where things go wrong

An overview of reuse and different recycling methods

Improving recycling is essential to tackling emissions and pollution

Reuse and then recycling are ways of using materials more efficiently and reducing pollution. This is especially relevant for plastics.

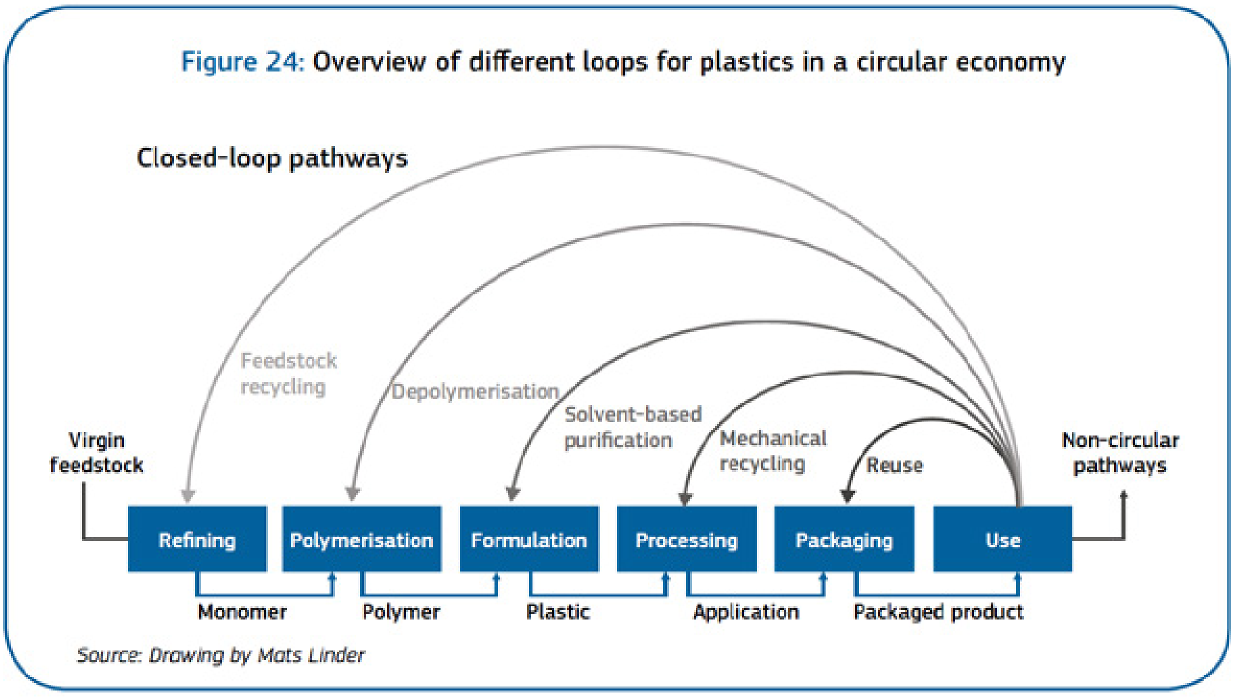
At one level, by keeping existing materials in circulation, emissions from creating new materials can be avoided. Modelling by *Accenture* suggests that a third of the 106 Mt of chemical products created by the chemical industry every year could be circulated with reuse and mechanical recycling.[lxvi]

At another level, end-of-life plastic waste could be recycled into a feedstock to make new chemicals, keeping carbon in circulation. Carbon is needed to make methanol and high value chemicals, which are used to make plastics and many other products.

However, chemical companies and plastic producers cannot rely on reuse and recycling to keep carbon from being released into the atmosphere if they keep making products with fossil feedstocks. This simply will not work. The only way chemical producers can resolve their Scope 3 emissions is by transitioning to emissions-neutral feedstocks, as outlined in our previous report.

There is a hierarchy of options for circulating materials, and some must be used more than others

Figure 3: Overview of different loops for plastic



Source: European Commission (2019), A Circular Economy for Plastics, p. 141

The priority is to make products that can be reused for as long as possible

Reuse is the simplest and most powerful way of circulating materials. When a product is reused, a new product is prevented, which avoids the additional resource extraction, energy use, emissions and waste this might entail.[lxvii] This also takes pressure off waste management systems that are struggling to collect, sort, and recycle large volumes of plastic waste.

Wherever possible products must be designed to be not only easy to recycle, but easy to reuse. Designing products to be more durable and to match standardised conventions can help them to be reused for longer. In addition, deposit return schemes for packaging encourage people to return used packaging to be refilled and sold again.[lxviii]

Making reusable products is more under the control of companies downstream of chemical producers themselves, but it is important to understand that reuse is the number one priority above any form of recycling.

Mechanical recycling is the most efficient and lowest emissions recycling method, and the only one proven at scale

Mechanical recycling is what most people think of when they hear 'recycling'. It is the most efficient and least resource intensive form of recycling, having the lowest environmental footprint. [lxix]

Plastic waste is separated by plastic type, ground up, and turned into recycled plastic pellets that can be used to make new plastic products.

When plastic is mechanically recycled the material quality degrades. Moreover, common types of plastic waste, such as complex packaging waste made of lots of different materials, are unsuitable for mechanical recycling.[lxx] This underscores the importance of designing products with reuse and recycling in mind.

Mechanical recycling will not be enough to create a closed loop for plastic, but it should still be prioritised and exhausted before anything else is attempted.

'Chemical' recycling technologies aim to treat plastic waste that cannot be reused or mechanically recycled

'Chemical recycling' is an umbrella term for controversial and immature technologies that alter the chemical structure of plastic waste.

As Figure 3 shows, some technologies, like chemical depolymerisation and solvent-based purification, produce polymers or monomers that are the building blocks of new plastics (this is also known as plastic-to-plastic recycling).[lxxi]

Others produce outputs that, once they've been processed to the right quality, can be used as feedstocks to make new chemicals, which are analogous to the fossil feedstocks that plastic was originally made from.[lxxii] This is known as 'feedstock recycling', 'waste-to-feedstock', or 'thermal depolymerisation'. These aim to provide a source of circular carbon.

Feedstock recycling is most relevant to chemical producers, so this will be the focus of this briefing.

Some feedstock recycling technologies hold promise, but none are operating at scale and all carry risks for investors

Chemical producers hope to use feedstock recycling to source circular carbon. It is desirable to find ways to keep carbon in circulation, and to develop alternatives to incineration or landfill for end-of-life plastics.

However, developing feedstock recycling technologies carries risks. Feedstock recycling technologies are not currently operating at a large scale. All release high emissions, and all face financial and technological barriers.[lxxiii]

Any feedstock recycling technologies that chemical companies want to develop need to be able to align with net zero and be compatible with emissions-neutral production processes. Fundamentally, if they cannot meet these conditions, then they have no long-term future.

Support for the wrong technologies could undermine the sector's net zero commitments.

Whenever investors hear the terms 'chemical recycling' or 'advanced recycling,' they need to look further to understand the underlying technologies.

Difficulties evaluating recycling methods

It can be difficult to compare different recycling options on a like-for-like basis. They create different outputs and perform differently under different conditions, such as with different types or qualities of waste input.

Investors should be aware that because chemical recycling is not being used at scale there is limited evidence available about the performance of chemical recycling in practice.[lxxiv]

Life cycle analyses that try to model the impacts of these technologies should be read carefully (see Annex 1: An investor's guide to reading life cycle analyses).

Mechanical recycling[lxxv]

After reuse, mechanical recycling needs to be prioritised

As the priority, we need to reduce plastic consumption as much as possible and reuse products for as long as possible. After that, the next option is mechanical recycling.

Plastic waste is turned into a secondary raw plastic material without altering its chemical structure. Waste is separated and washed to create a pure feed material. This is ground and converted into new plastic pellets, which can be used to make new plastic products.

This creates far lower emissions than the production of virgin resins (the amount of CO_2 avoided varies depending on the plastic type).[lxxvi]

Theoretically a pure stream of any plastic can be mechanically recycled. However, in practice it is difficult to separate and purify some plastics to allow them to undergo the process.[lxxvii] The presence of plastic additives like pigments and flame retardants, which are difficult or impossible to remove, can make mechanical recycling more difficult.[lxxviii]

Mechanical recycling causes the quality of the plastic to degrade, which means it has to be 'downcycled'. Eventually, the material will no longer be suitable for mechanical recycling.[lxxix]

As circularity of plastics is improved, producers will need to address the hazardous substances in plastic products. As more materials are circulated, harmful substances in those materials will stay in circulation too. Mechanical recycling cannot remove harmful substances (see 'Explainer: why toxicity becomes a bigger problem in the circular economy' below).

Both these issues underscore the importance of designing products with recycling in mind.

Advantages of mechanical recycling:

- mechanical recycling is an efficient low-emissions process,
- the technology is commercially mature, and
- a pure waste stream can produce a high-quality secondary material.

Disadvantages of mechanical recycling:

- the process causes the quality of the material to deteriorate,
- the process depends on having a homogenous waste stream to obtain a high-quality material, which can be difficult to obtain in practice, and
- the process cannot filter out undesirable substances from plastic waste, and because mechanical recycling does not change the molecular structure of plastic, it is difficult to combine different types of plastic.[lxxx]

Together, re-use and mechanical recycling are the most resource effective ways to recycle plastics and the only ways proven at scale as of today. They should be prioritised over other forms of recycling.

Explainer: why toxicity becomes a bigger problem in the circular economy

As reuse and recycling increase in the circular economy, a pre-existing problem becomes more serious: hazardous substances in plastics will accumulate.

Plastics contain many substances that are harmful to human health and the environment

Hazardous substances are present in plastics for lots of different reasons. For example[lxxxi]:

- Additives give plastics particular qualities, like flame retardants, or plasticisers for flexibility. Many are toxic to humans. Additives may not form a strong chemical bond with plastics, which means they can leak from plastics and enter the body.
- The building blocks of plastics are polymers, and these are made up of smaller units called monomers. Monomers can leak from polymers and enter the body. Many are toxic, such as Bisphenol A, which compromises the immune system.[lxxxii]
- Plastics may contain non-intentionally added substances, such as by-products of chemical reactions or contaminants from recycled materials.

Substances are added to plastics, subject to restrictions on the amounts they can be present in, despite being known to be toxic. One recent review identified 148 substances hazardous to humans being used in food and non-food plastic packaging.[lxxxiii]

Other substances are not regulated, despite uncertainty around their toxicity.[lxxxiv]

In a circular economy, harmful substances accumulate[lxxxv]

If plastics are reused and recycled, then any hazardous substances they contain may be circulated, too.

Some substances may not be harmful in small amounts, but they may accumulate at harmful levels in recycled materials, or react with other substances. For example, new additives could be added to recycled plastic that already contains additives from an original plastic product.

Even if a chemical is found to be dangerous and phased out of production, it may circulate for a long time.[lxxxvi]

Considering that perhaps 20 Mt of additives[lxxxvii] are put into circulation every year, the implications of this are big. Accumulation in materials or repeat exposure – for instance, for workers at recycling facilities[lxxxviii] – pose real risks to health.

Chemical companies need to design out or substitute hazardous substances wherever possible[lxxxix]

So far efforts have been to design out whole material types rather than specific substances.[xc] This approach won't solve the problems created by harmful substances being circulated in recycled materials. Harmful additives must be substituted for safe ones wherever possible.[xci]

In a circular economy, chemicals and chemical products that are safe by design will have a strong advantage over those that are not.

Chemical recycling

Currently end-of-life plastic waste that can't be mechanically recycled is either landfilled, leaks into the environment, or incinerated.

Chemical recycling could become one alternative for some of this waste. Unlike mechanical recycling, chemical recycling alters plastic's chemical structure. Two main technologies are used to turn plastic waste into feedstocks for making new chemicals. These are pyrolysis and gasification.

Pyrolysis

How does it work?

Pyrolysis (from Greek *pyro* [fire] *lysis* [breaking]) involves heating plastic waste without oxygen to a high temperature to break it down.

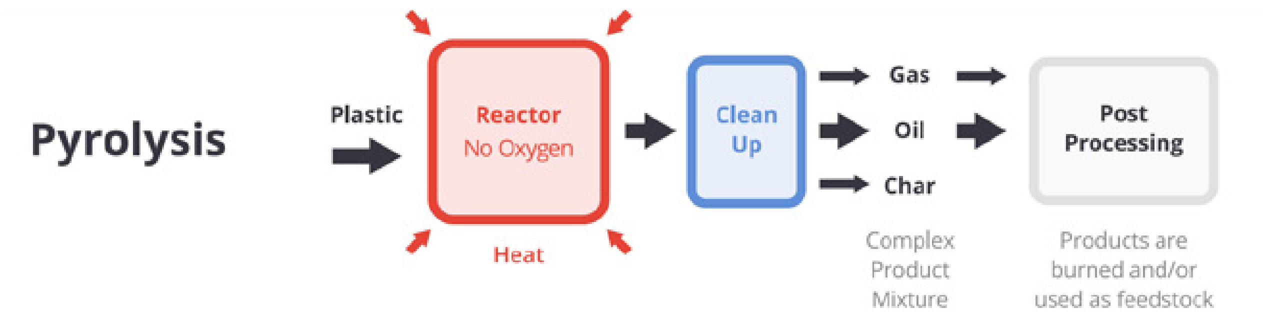
This produces pyrolysis oil, a crude-oil-like substance, which can be used as a substitute for fossil feedstock in steam cracking, the traditional process for making high value chemicals. By-products are mixed gases and char.[xcii]

Pyrolysis can accept a mixed plastic waste stream, but this can affect yields and create a more contaminated output that becomes too expensive to purify. PVC cannot be processed as this releases toxic substances.[xciii]

The efficiency of converting plastic waste into pyrolysis oil can vary and is influenced by the type of plastic waste.[xciv] With a mixed plastic waste stream efficiency can be lower, with less than 50 per cent of the plastic waste by weight being recovered as pyrolysis oil. [xcv] Lower efficiency means more plastic waste is needed.

While pyrolysis may remove some toxic elements from plastic waste, the impact of pyrolysis on substances of concern is not yet well understood.[xcvi] Further, pyrolysis can itself create toxic by-products with serious implications for human health and the environment, which must be carefully managed.[xcvii]

Figure 4: Simplified diagram of the pyrolysis process



Source: GAIA, 2020

If pyrolysis oil cannot be cost competitive with fossil feedstock then it may be sold as fuel, to generate heat, electricity, or be used to produce transport fuel.[xcviii] Several feedstock recycling businesses operate like this. Burning the products of chemical recycling is analogous to burning fossil fuels. It must be avoided at all costs.

In practice, pyrolysis oil needs to be diluted with virgin fossil fuel to produce a viable feedstock.[xcix] This is a fundamental problem with pyrolysis, as it is unlikely it can be decoupled from virgin fossil fuel extraction. This means it cannot be 1.5-degree aligned.

Where do emissions from pyrolysis come from?

Making plastic with pyrolysis oil creates higher emissions than mechanical recycling or virgin plastic production.[c]

Investors may read life cycle analyses that seem to show that chemical recycling is a relatively low emissions option. This is not true, and this impression may be given by the way that life cycle analyses sometimes count emissions (see Annex 1: An investor's guide to reading life cycle analyses).

There are several sources of emissions:

- **Energy intensity:** pyrolysis needs energy to collect and pre-treat plastic waste, power facilities, and treat the outputs to make them suitable as feedstocks.[ci] If the energy consumed is not from 100 per cent renewable sources, this will create emissions.

- **Heat generation:** to break down plastic waste high temperatures are required. Heat is produced from an external source and from recycling gas by-products.[cii] When these are combusted, greenhouse gases are released.

- **Emissions from by-products:** gas by-products are combusted for heat or may be released, creating further emissions. Char is used as a substitute for lignite in cement kilns.[ciii]

- **Further processes are required:** pyrolysis oil needs to undergo steam cracking to make high value chemicals. Further processes are required to turn these into plastic resins. If these use fossil fuels to generate electricity and heat, emissions will be released. For more details of these processes, see our previous investor briefing.

- **Blending with virgin naphtha:** pyrolysis oil can only be used if mixed with virgin naphtha to get a feedstock of the right quality. This means new fossil carbon will be embodied in the chemical product and released later.

In addition, high emissions will be released if pyrolysis oil is used for fuel instead of feedstock.

Could these emissions be mitigated?

Emissions from pyrolysis could be reduced if energy was 100 per cent renewable and heat was electrified[3], and emissions from steam cracking could be mitigated if an electrified steam cracker was used.

Other sources of emissions would not be resolved, though:

- **Gases are released during pyrolysis, which would need to be captured.** Gases are created during pyrolysis, including methane. These gases are combusted for heat. Greenhouse gases from this source would therefore need to be captured. Emissions would not be a problem if the plastic feedstock was emissions-neutral on a lifecycle basis, but no such plastic exists yet.

3 One LCA noted that renewable energy for processes would ‘significantly’ reduce emissions, and that they had modelled a 100 per cent renewable energy scenario, but full findings were not available. Another recent LCA found emissions would be far lower for ammonia and methanol production from the gasification of refuse-derived-fuel (pellets made from Municipal Solid Waste – not just plastics) in a future scenario with more power from renewable sources.

It has been suggested that low-carbon high value chemicals and methanol could be made with pyrolysis oil using an electrified steam cracker.[civ] Assuming energy was from 100 per cent renewable sources, energy requirements and heat generation for pyrolysis would release no emissions. Cracking releases methane as a by-product, which could then be synthesised into methanol.

There are two problems with this idea:

1. A steam cracker requires a consistent naphtha feedstock that meets cracker requirements (which will vary from plant to plant).[cv] It is difficult to secure a consistent quality feedstock from plastic waste, and upgrading it is expensive. This means virgin naphtha is needed to dilute pyrolysis oil. It is unlikely that a steam cracker could ever run off pyrolysis oil alone.[cvi]

2. Steam crackers would lock in fossil fuels and high levels of plastic use.

By 2050 high value chemicals need to be made with emission-neutral methanol-to-olefins and methanol-to-aromatics processes, not crackers. This is explained in detail in our previous briefing. Continuing to use steam crackers will delay this transition, especially as electric ones are not in use yet. The CEO of Dow recently suggested it will take "more than a decade to see electric steam cracking"[cvii], and this would be a long-life investment.

A typical steam cracker requires large volumes of feedstock to be economical, in the order of several hundred thousand tonnes a year. Even if pyrolysis oil of the right quality could be obtained to entirely replace virgin naphtha, and pyrolysis production could be scaled to meet cracker demand, this would lock in demand for a huge, continuous stream of plastic waste:

- In 2019 European steam crackers had a combined annual ethylene production capacity of **23,468,000 tons**[cviii] (which means they consumed more than this amount of feedstock).

- Assuming optimum pyrolysis efficiency,[4] more than **35 million tons**[5] of plastic waste would be needed to produce this much pyrolysis oil – more than the **29.1 million** tons of plastic waste created in Europe each year.[cix]

So, to meet cracker demand plastic production would have to increase with no additional reuse and recycling. Clearly this is not a desirable. We need to reduce our plastic use as much as possible.

4 Assumes yield of 70 per cent from mixed plastic waste, and further process losses of 3 per cent during purification, for 67 per cent total efficiency. Estimated yields and process losses from Eunomia (2020), *Chemical Recycling: state of play*, p. 30.

5 (23,468,000/67)*100

For these reasons there is no way forwards for pyrolysis. It would lock in fossil assets[cx] which, along with the pyrolysis projects themselves, would be at high risk of becoming stranded.

Advantages of pyrolysis[cxi]:

- it is possible to process mixed plastic waste streams, and
- it is an alternative to incineration or landfill.

Disadvantages of pyrolysis[cxii]:

- mixed waste can result in lower yields and a product that is expensive to purify,
- it is currently a high emissions process,
- raw products must undergo further processing before they are viable as feedstocks,
- toxic by-products can be created which must be carefully managed, and
- pyrolysis is reliant on virgin naphtha cracking to produce new primary chemicals, which makes it incompatible with net zero.

Gasification

How does it work?

Like pyrolysis, gasification also uses heat to break down plastic waste, but some oxygen is introduced to the process. The main product is ‘syngas’, a mixture of gases including hydrogen and carbon monoxide.[cxiii]

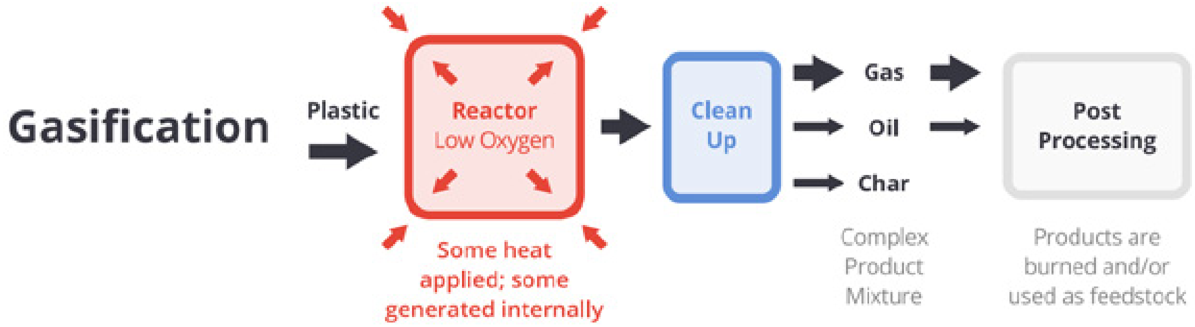
Like pyrolysis, gasification can accept a mixed plastic waste stream. However, it cannot process PVC, as this releases toxic substances.[cxiv] Plastic waste requires pre-treatment before it can undergo gasification.

Like pyrolysis, gasification can create toxic by-products with serious implications for human health and the environment.[cxv]

Syngas is a versatile resource, which can be combusted, used to make fuels like ethanol,[cxvi] or used as a feedstock to make new chemicals like methanol. Burning the products of chemical recycling is analogous to burning fossil fuels and must be avoided at all costs.

'Raw' syngas needs to be treated before it can be used as a feedstock, and there will be several steps between the gasification of plastic waste and the production of new chemicals.[cxvii]

Figure 5: Simplified gasification processes



Source: GAIA, 2020

Unlike pyrolysis oil, which requires blending with virgin fossil fuels, syngas could be used as a feedstock for the emission-neutral production of methanol.

The feedstocks for green methanol production are green hydrogen, made with 100 per cent renewable energy, and captured carbon. Instead, syngas from plastic waste can provide a source of both hydrogen and circular carbon. This process will be outlined in more detail in the next chapter.

Where do emissions from gasification come from?

As with pyrolysis, state-of-the-art gasification technologies are energy intensive and release emissions.

There are several current sources of emissions:

- **Energy intensity:** energy is required to collect and pre-treat plastic waste, power the plant facilities, and treat the outputs to make them suitable for use as feedstocks.[cxviii] If the energy consumed is not from 100 per cent renewable sources, this will create emissions.

- **Heat generation:** gasification requires a high temperature between 700-1500 degrees.[cxix] Heat is generated and sustained by chemical reactions in the gasifier, but an external source of heat is still required to start the process.[cxx]

- **Syngas upgrading:** 'raw' syngas contains some CO_2, which is removed and released. It also doesn't have the right balance of hydrogen and carbon monoxide for methanol synthesis. To fix this, steam is added to the syngas so that some of the carbon monoxide reacts with oxygen to form CO_2.[6] This adjusts the ratio, but it also produces CO_2. Nearly half of the feedstock carbon may be released in this stage.[cxxi]

- **Further processes are required:** syngas still needs to be turned into primary chemicals. In turn, further processes are required to chemicals into plastic resins. If these use fossil fuels to generate electricity and heat, emissions will be released. For more details of these processes, see the 'current production processes' outlined in our previous investor briefing.

Could these emissions be mitigated?

Emissions from gasification could be reduced if energy was 100 per cent renewable and heat was electrified.[7]

Emissions from syngas upgrading could be reduced significantly, if not entirely.[cxxii] Instead of adjusting the carbon monoxide:hydrogen ration by decreasing levels of carbon monoxide, which releases CO_2 as a by-product (see above), green hydrogen (made with renewable electricity) can be added to bring hydrogen levels up.

It has been calculated that with fully electrified process and the use of green hydrogen, emissions from turning gasified plastic waste into HVCs could be 0.3t CO_2/t olefins. This would represent a carbon recycling rate of 91 per cent.[cxxiii] Some residual 'diffuse' CO_2 might be emitted in processes to upgrade the 'raw' syngas.

Advantages of gasification:[cxxiv]

- it can process mixed plastic waste streams,
- it can be a lower emissions option than incineration[cxxv], and
- syngas can provide an alternative source of hydrogen and circular carbon to make emissions-neutral chemicals.

6 The technical term for this is the Water Gas Shift Reaction.

7 One LCA noted that renewable energy for processes would 'significantly' reduce emissions, and that they had modelled a 100 per cent renewable energy scenario, but full findings were not available. Another recent LCA found emissions would be far lower for ammonia and methanol production from the gasification of refuse-derived-fuel (pellets made from Municipal Solid Waste – not just plastics) in a future scenario with more power from renewable sources.

Disadvantages of gasification:[cxxvi]

- it is currently a high emissions process,
- raw products must undergo further processing before they are viable as feedstocks,
- PVC cannot undergo gasification as it creates toxic products, and
- toxic by-products can be created which must be carefully managed.

Gasification shows promise as a potential alternative option for treating end-of-life plastic waste. Evidence of gasification in real world conditions is insufficient to advocate for it strongly.[cxxvii]

That said, it would be technically possible to reduce gasification process emissions to near zero, and to integrate plastic waste-derived syngas with emissions-neutral chemical production. Chemical companies could pursue gasification in this form for a source of circular carbon.

Questions persist about the technical and financial viability of feedstock recycling

Despite the aspirations for feedstock recycling technologies, many ventures have failed, and existing projects are not large scale

Chemical recycling failures have been caused by technological problems and projects struggling to be profitable. Working with mixed plastic waste means the output is often contaminated and requires a lot of upgrading to produce a quality product, which is expensive and can result in low yields.

As one example, these problems contributed to the recent high-profile failure of plastic-to-fuel pyrolysis startup Renewology in Idaho.[cxxviii]

High costs can make it hard to compete with virgin fossil feedstocks.[cxxix]

These problems can make it is hard to make chemical recycling profitable. Companies may resort to selling fuel as well as, or instead of, feedstock[cxxx]

Plastic-to-fuel is not recycling as carbon is released into the atmosphere, not circulated. This should be avoided at all costs.

This has been the fate of a much-anticipated gasification plant in Rotterdam developed by the Canadian company Enerkem. Originally planned as a waste-to-chemicals methanol production facility by a consortium that included Air Liquide[cxxxi], it will now produce 'sustainable aviation fuel' instead, with only 25 per cent of the product being used for chemical production.[cxxxii]

In short, chemical recycling projects face challenges to becoming scalable, especially as they cannot be reliant on fuel production in a low-carbon future. Investors should ask chemical companies that want to develop chemical recycling how they intend to do this without creating unacceptably high emissions.

What chemical companies need to do now

Part III: What chemical companies need to do now

How could gasification fit into emission-neutral chemical production processes?

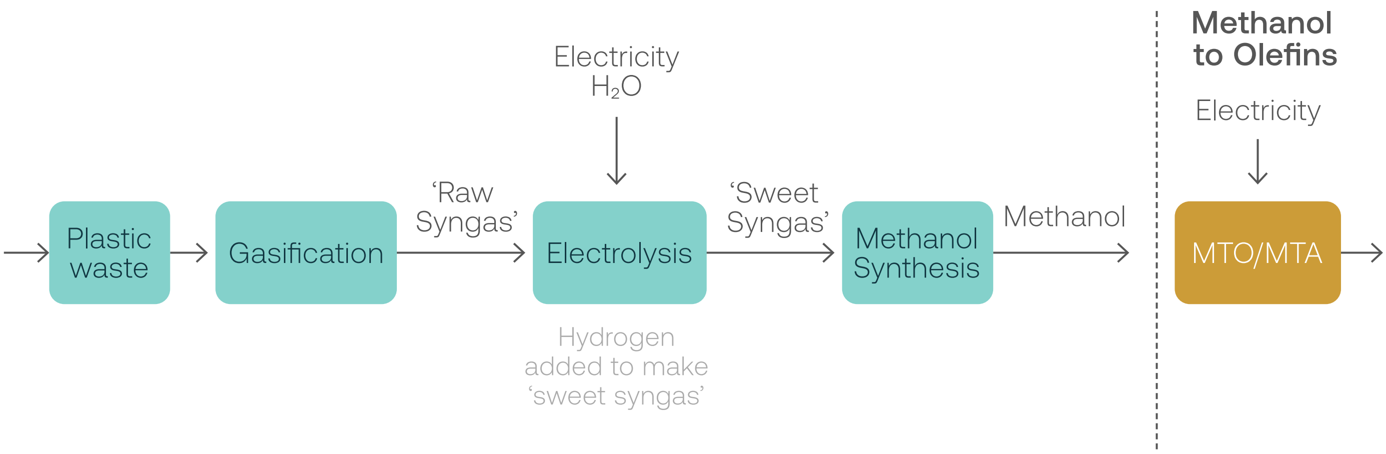
Gasification could in theory provide feedstock for emissions neutral chemicals – but only if strict conditions are met

Methanol is a key primary chemical and is also the platform chemical for producing high value chemicals via methanol-to-olefins and methanol-to-aromatics processes. Please see our previous briefing for more in-depth explanations.

To produce methanol, syngas (hydrogen, carbon monoxide, and some carbon dioxide) is required as an input. For green methanol, green hydrogen and captured carbon are used to produce syngas.

Instead, syngas from the gasification of plastic waste could be used. As this already contains a carbon molecule, the need to source captured carbon is avoided.

Figure 6: Making high value chemicals from gasified plastic waste



Source: Material Economics, 2019

With energy from 100 per cent renewable sources, electrified heat generation, and syngas upgrading via the addition of green hydrogen, emissions from gasification could be brought well below current levels from either conventional high value chemical production or current gasification. Carbon embodied in the feedstock (if derived from plastic made with fossil fuels, all plastic in existence today) can still be released at Scope 3.

Key decision points for chemical producers

Chemical companies have a small window to ensure chemical recycling investments align with net zero

If gasification facilities are developed that rely on fossil fuels for energy and heat, and which release CO_2 when syngas is upgraded, this will lock in high emissions.

In addition, companies must make every effort to manage the serious risks to human health – including plant workers – and the environment created by toxic by-products of gasification. Best available treatments can mitigate risks from emissions to air and water, and risks posed by solid waste.[cxxxiii] Companies need to support the most stringent regulations on emissions control and be transparent about plant emissions and risk management processes.

Whether or not these conditions are met will depend on the investment decisions chemical producers make now about how to grow gasification.

Because of the long lifetime of infrastructure investments for chemical recycling, chemical companies must make critical decisions now to ensure that new investments will be aligned.

Figure 7: List of European chemical company targets that are currently exploring pyrolysis or gasification

		Development of/investment in	
Company	Country	Pyrolysis	Gasification
BASF SE	Germany	Link	
Covestro AG	Germany	Link	
Croda International plc	UK		
EMS Chemie Holdings AG	Switzerland		
Evonik Industries AG	Germany		
Koninklijke DSM N.V.	Netherlands	Link	
L’Air Liquide S.A.	France		Link
Lanxess AG	Germany		
Lyondell Basell	Netherlands	Link	
Givaudan SA	Switzerland		
Solvay SA	Belgium		
Yara International ASA	Norway		
Symrise AG	Germany		

Source: ShareAction

Pyrolysis

The sector needs to reach net zero emissions by 2050. The lifecycle of a pyrolysis plant is approximately 20-25 years.[cxxxiv] This means any pyrolysis facilities that become operational later than 2030 would likely lock in emissions past 2050 or become stranded.

Investments before 2030 would still lock in fossil assets until nearing the mid-century, in the decades where the chemical sector must reduce emissions sharply.

Future pyrolysis investments by chemical companies would carry a material risk for investors and undermine pathways to net zero. There can be no new investments in pyrolysis.

Gasification

The lifetime of gasification facilities is around 25 years.[8] Commissioning and building a new plant may take several years on top of this.

This means chemical companies must ensure that:

1 Gasification plants they own or finance which will become operational after 2025 –

- use electrified external heat sources and have a plan to source 100 per cent renewable energy by 2050,
- use green hydrogen to upgrade 'raw' syngas, and
- do not sell syngas for fuel.

2 Any syngas used in production processes is from plants that will be compliant with these conditions by 2050 at the latest.

3 Best available treatments are used to manage the risks to human health – including plant workers – and the environment created by toxic by-products of gasification. "Chemical recycling products are monitored to ensure toxic-free outputs in line with the EU legislation requirements for chemicals."[cxxxv]

8 For example, this gasification facility by Levenseat Renewable Energy ltd., and this one by Suncor (both waste-to-energy).

Syngas that meets these conditions can be used for emission-neutral methanol and high value chemical production.

What can chemical producers do to support circularity downstream of production?

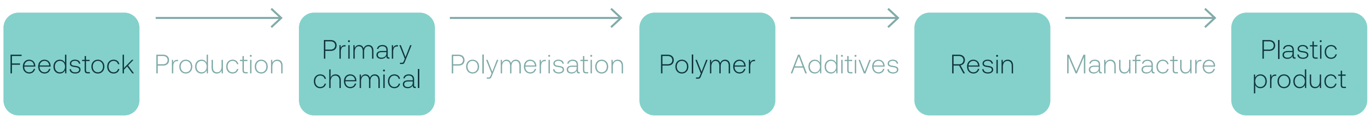
Chemical companies can enable increased reuse and recycling of chemical products

As well as making primary chemicals like methanol and high value chemicals, many chemical companies go one step further and make plastics and plastic additives.

How primary chemicals become plastics

To make plastics, primary chemicals undergo a process called polymerisation. Lots of small chemical units called monomers are joined together to form long chains, or polymers. Polymers are combined with additives to produce plastic resins, which can be turned into pellets and used to make plastic products.[cxxxvi] For example, the monomer ethylene becomes the polymer polyethylene, a very common plastic.

Figure 8: how primary chemicals become plastics:



Source: ShareAction

Several of the chemical companies under discussion here are resin producers.

Figure 9: List of European chemical company targets producing plastics

Company		Methanol	Light Olefins	BTX	Plastic Resins
BASF SE	Germany	X	X	X	X
Covestro AG	Germany		X	X	X
Croda International plc	UK				X
EMS Chemie Holdings AG	Switzerland		X	X	X
Evonik Industries AG	Germany		X	X	X
Koninklijke DSM N.V.	Netherlands				
L'Air Liquide S.A.	France	X	X	X	
Lanxess AG	Germany		X	X	X
Lyondell Basell	Netherlands	X	X	X	X
Givaudan SA	Switzerland			X	
Solvay SA	Belgium	X	X	X	X
Yara International ASA	Norway				
Symrise AG	Germany	X	X	X	

Source: ShareAction

To enable reuse and recycling, companies need to design harmful substances out of products wherever possible

Regulation plays a big role, but chemical companies can be proactive with phasing out or substituting harmful chemicals.

There are many substances of concern in plastics. One recent study identified 1,500 which should be prioritised for substitution with safer alternatives where possible.[cxxxvii]

Tools exist to enable this.[cxxxviii] Examples include the Chemsec SIN List (Substitute it Now), a directory of over 1000 chemicals, going beyond those covered by the REACH regulation, which should be phased out or substituted.

These allow chemical companies and their customers to identify problematic chemicals in their own processes that should be candidates for substitution.

Products that are easy and safe to reuse and recycle will enable the circular economy, and be more competitive in it.

Chemical companies should be more transparent about the chemicals they are putting into the circular economy

Poor transparency around harmful substances in plastics (as opposed to general inventories of additives that might be present in a plastic product) make it difficult to address the problems they cause.

Information gaps are due to information being withheld on grounds of commercial sensitivity, or because an additive falls outside reporting requirements for regulation, or simply because of poor reporting.[cxxxix]

This makes it hard to understand hazards and manage them further down the value chain.[cxl]

Transparent disclosure by chemical companies will enable better management of risks in the plastic value chain[cxli], and should raise awareness of the use of hazardous substances that hinder the circular economy.

Clean Production Action have drawn up Principles for Chemical Ingredient Disclosure. These are an excellent guide for chemical companies to follow.

Principles for Chemical Ingredient Exposure include[cxlii]**:**

- **"Disclose all intentionally added chemical ingredients,** including name(s)… function, presence on specified lists of chemicals of concern, and other chemical hazard characteristics of the ingredient. Chemicals of concern…are not confidential business information;

- **"Proactively engage supply chains and interested stakeholders** to increase full chemical ingredient information disclosure. Manufacturers and retailers need reliable documentation to trace chemical information along supply chains;

- **"Advocate for filling data gaps to characterize the hazards of chemicals;**

- **"Make accurate chemical ingredient information easily accessible to consumers, government agencies, manufacturers, brands, retailers, and others in the supply chain; and**

- **"Support public policies and industry standards that advance the above Principles."**

Chemical companies that are serious about supporting the circular economy must disclose if they are making products that will make circularity harder. This will help to find safer alternatives.

Investor recommendations

Part IV: Investor recommendations

(If the company intends to invest in gasification) does the company have a plan to ensure that gasification is close to zero emissions?

Tracking outcomes:

- Gasification plants owned or financed by the company that will become operational after 2025:

    a. use electrified external heat sources and have a plan to source 100 per cent renewable energy by 2050,

    b. use green hydrogen to upgrade 'raw' syngas (this could eliminate CO_2 emissions at this stage[cxliii]), and

    c. do not sell syngas for fuel.

- Any syngas from plastic waste used in production processes is from plants that will be compliant with these conditions by 2050 at the latest.

(If the company intends to invest in gasification) does the company have a plan to manage the risks of toxic by-products from gasification?

Tracking outcomes:

- best available treatments are used to manage the risks to human health – including plant workers – and the environment created by toxic by-products of gasification;

- "chemical recycling products are monitored to ensure toxic-free outputs in line with the EU legislation requirements for chemicals"[cxliv]; and

- there is full transparency on plant emissions and risk management processes.

(If the company is invested in pyrolysis) will the company commit to no new investments in pyrolysis?

Tracking outcomes:

- the company commits to no new investments in pyrolysis, and
- the company commits to exit any existing pyrolysis investments by 2050 at the very latest.

Does the company have a strategy to phase out or substitute chemicals of concern in its products?

Tracking outcomes:

- the company has identified chemicals of concern in its products and is transparent in disclosing these, as well as the threshold it uses to define substances of concern; and
- the company has a plan to phase out or substitute chemicals of concern which is publicly available.

Will the company adopt the first of the Principles for Chemical Ingredient Exposure, to disclose all intentionally added chemical ingredients?

Tracking outcome: the company makes publicly available a list of all intentionally added chemical ingredients, such as plastic additives, to its value chain partners and the public.

Annex 1

Annex 1: An investor's guide to reading life cycle analyses

Life Cycle Analyses can be useful tools for understanding chemical recycling, but they can also make it difficult to understand emissions

Life Cycle Analyses try to assess emissions and other impacts across the whole or part of a process, based either on real or imagined scenarios, or real or extrapolated data.

Results are extremely sensitive to the conditions of each study. They can be misread or misrepresented.

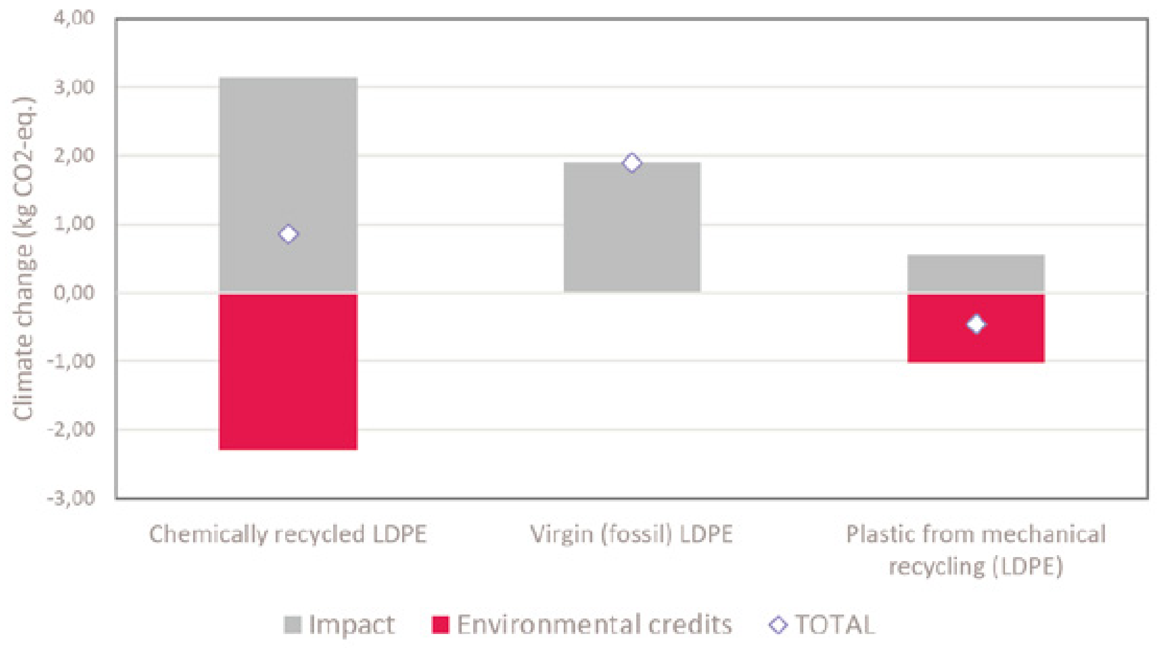
Investors should beware studies that count 'avoided emissions'[cxlv]

Some analyses may assume that if plastic waste had not been chemically recycled it would have been incinerated instead, and therefore net off the 'avoided' emissions against the actual emissions from chemical recycling.

On this basis, analyses may seem to show chemical recycling as a low emissions option, or even that net emissions from chemical recycling are lower than mechanical recycling. In Figure 10 below the red bars represent net emissions against actual process emissions, shown in grey.

This makes chemical recycling look like the best option. It obscures the fact that direct emissions from chemical recycling are several times higher than for mechanical recycling.

Figure 10: 'Avoided' emissions (red) vs process emissions (grey) in a pyrolysis life cycle analysis



Source: Quantis, 2020

It is also wrong to judge emissions on the basis of a hypothetical scenario. If the imagined waste had not been incinerated, then the chemical recycling pathway would represent a strong net gain in emissions.

Equally, if the products of chemical recycling are later burned as fuel instead of being used for feedstock, this would release high emissions downstream. [cxlvi]

Studies may also have different parameters. For example, 'cradle-to-gate' measures emissions up to a product being created, but 'cradle-to-grave' measures emissions to the end of a product's life. The two are incomparable, and not measuring end-of-life emissions is a big omission.

Life Cycle Analyses need to be read carefully – executive summaries do not tell the full story, and findings are sometimes reported selectively.[cxlvii]

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