The Plastics Transition

Our industry's roadmap for plastics in Europe to be **circular** and have **net-zero emissions** by 2050

PLASTICS EUROPE

Plastics Europe

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Foreword

"The roadmap is our North Star designed to guide us for the years to come. It is an invitation to our value chain and to policymakers to reflect on our ambitions, respective roles, and the enabling conditions required to make this transition a reality. It is an opportunity to challenge our thinking and identify areas where we can join forces and progress faster."

Virginia Janssens,

Managing Director
Plastics Europe

"We need a thriving and competitive European plastics industry that allows us to increase investment and innovation in circularity and decarbonisation. We are at an inflection point. The decisions we collectively make today will determine our ability to continue to serve the many downstream industries with the sustainability solutions they need."

Marco ten Bruggencate,

President Plastics Europe

"The Plastics Transition roadmap is a reflection of a fundamental cultural change happening within our industry, driven by the people working within it. It captures their dynamic approach to problem solving, and their commitment to addressing the issue of waste and reducing our carbon emissions thereby transforming the European plastics system."

Rob Ingram,

Vice-President Plastics Europe
and Chairman of Roadmap
Task Force

Society's relationship with plastics is complicated.

We share and take very seriously societal concerns about the contribution of our industry to climate change, the challenge of plastics waste, and the need to ensure the safety of plastics.

However, it is also important to recognise that plastics have a vital role to play in enabling the sustainability transitions and supporting the competitiveness of many sectors in Europe. The reality is that plastics will remain irreplaceable for many applications and sectors that underpin our changing world.

The Plastics Transition roadmap is our North Star, designed to inform and guide us for the decades ahead. It reinforces the commitment of European plastics manufacturers to addressing these concerns by making plastics circular, driving lifecycle emissions to net zero, and fostering the sustainable use of plastics. For the first time, our members are united around a common vision and ambitions which reflects the cultural change that has taken place in our industry and organisation. It is a major step forward for our industry, one which has the power to shape our future.

It establishes an ambitious but realistic pathway to net zero and circularity, including milestones for 2030, key actions and indicators. In terms of circularity, it projects that the substitution of fossil-based plastics will be gradual and could reach 25% in 2030 and 65% by 2050. It also sets-out a potential pathway to reduce greenhouse (GHG) emissions from the overall plastics system by 28% by 2030, and towards net-zero by 2050.

It details immediate (2023 – 2025), short-term (2025 – 2027) and medium-term (2027 – 2030) industry actions and provides a longer-term perspective on the necessary changes. Our progress against the roadmap's indicators for circularity and GHG emissions will be assessed and transparently reported every two years.

The roadmap is a dynamic process which will be progressively updated based on new insights and changes to our industry environment, the enabling policy framework, and value chain input, as well as industry progress.

Whilst Plastics Europe members are already undertaking substantial investments and driving major advances towards circularity and net zero emissions, we are under no illusions about the scale, complexity, and cost of this transition, and the barriers and bottlenecks that need to be overcome. This is a generational-scale task.

To overcome these challenges, we need a harmonised and enforceable EU policy framework that fully supports the industry's transition. One that helps to create enough high-quality, sustainably sourced feedstock; supports a massive upscaling of collection, sorting and recycling (both chemical and mechanical); and provides access to a diverse mix of abundant and affordable renewable energy.

We also need EU policymakers to recognise that without measures to safeguard the competitiveness of our industry, Europe will become increasingly dependent on imports from abroad, and our ability to invest in the transition in Europe will be undermined.

Doing so would allow Europe to continue to benefit from the critical role of plastics in delivering on the EU Green Deal in all sectors, secure the future of the 1.5 million people across 52,000 European companies that work in the plastics industry, and ensure the EU continues to lead the global path to plastics sustainability.

As an industry, we know that we need to listen and work much more closely with our value chain to find solutions, and engage on shared initiatives that accelerate change.

We believe the roadmap will make a very important contribution to informing and promoting dialogue and collaboration with all stakeholders with a shared interest in practical solutions to transform the European plastics system.

The European plastics system has reached a decisive moment in its history. Decisions taken in the next couple of years will determine whether and how quickly we can fulfil the ambitions set-out in the European Green Deal and roadmap. The window of opportunity is rapidly closing.

However, with collective ambition and urgency we can create a sustainable plastics system that continues to meet consumer and societal demands, whilst supporting the transitions of many downstream industries, and remains a strategic asset for the European economy.

We need your support. So, join us to help get this done – together.

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Executive Summary

About the Plastics Transition roadmap

Plastics Europe and our members recognise the **severity of the climate crisis** and **challenge of Plastics Transition** and that faster systemic change is essential to successfully meet the EU's net-zero and circularity objectives.

The plastics transition roadmap builds upon 'ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe'. Commissioned by Plastics Europe in 2021, the ReShaping Plastics report provides an independent perspective on transitioning to the EU's net-zero carbon emissions and circularity goals by 2050.

Plastics Europe proposed a package of measures to help implement the report's recommendations, including the development of a roadmap, to help the plastics value chain to accelerate its transition towards the EU's 2050 goals.

In this roadmap, developed with the support of Deloitte, **we lay out a potential pathway for a circular and net-zero plastics industry in Europe**[1]. It replaces Plastics Europe's previous 'Voluntary Commitment, Plastics 2030' and puts forward a more comprehensive set of ambitions covering all aspects of the plastics life cycle.

The roadmap provides a framework, milestones for 2030 and indicators to monitor progress, identify bottlenecks and find solutions to keep moving forward. Based on aggregated results from a survey of Plastics Europe's members, the industry's progress against these indicators for circularity and greenhouse gas (GHG) emissions, will be assessed and transparently reported to monitor progress, alongside any identified bottlenecks or accelerators, every two years.

The system-wide aspirations and forward-looking indicators show the extent to which **Plastics Europe members aspire to contribute to the ambitions of the EU Green Deal**. Within this framework each member of Plastics Europe will decide how the strategic pillars will be implemented within their company. This provides them with the flexibility to determine plans and company targets independently, in line with their particular circumstances and the market-based landscape within which they are operating.

Our data-driven roadmap is a living document that will be progressively updated based on new insights and changes to our industry environment. **It aims to guide, incentivise and accelerate industry action and performance**, and provide an evidence base **to inform value chain dialogue and policy-making.**

> “If we look back at the end of this decade and realise that this was the time where the plastics industry in Europe was unable to evolve, then we will have not delivered for our industry, for our value chains or for the planet. So now is the time to act. Now is the time to make the decisions.”
>
> **Marco ten Bruggencate**

1 Subject, of course, to the appropriate legal advice that Plastics Europe and/or its members will seek for the implementation of the different steps and elements in this roadmap.

A critically important industry for Europe

The European plastics value chain, comprising manufacturers, converters, waste management companies, and machinery manufacturers, employed over 1.5 million people in the EU in 2021. These workers were spread across 52,000 companies, and generated turnover of more than €400 billion.

Plastics are a strategically important material for the European economy, with applications in almost every sector, including automotive, construction, packaging, consumer goods, healthcare and renewable energy.

RENEWABLE ENERGY

Plastics are critical for the development of clean, efficient and durable alternative and renewable energy solutions, including wind turbines and solar panels, as well as electric and hydrogen powered vehicles. These solutions reduce greenhouse gas emissions and increase resource efficiency.

BUILDING & CONSTRUCTION

Plastics are increasingly used in building insulation due to their excellent insulating properties, which can help reduce energy demand for heating and cooling. Because they are corrosion-resistant, they are used to create pipes and fittings for plumbing and drainage systems. Plastics are used to make energy-efficient windows and doors as well as weather-resistant roofing and facades.

HEALTH

Modern healthcare would be impossible without the many plastic-based medical products we take for granted. Plastics are everywhere, from personnel protective equipment, sterile syringes, intravenous blood bags and heart valves, to "artificial skin" for emergency burns treatment and orthopaedic devices. Innovations in plastics are making new advances in healthcare possible and 3D-printing has opened up the possibility of using plastics to print kidneys, skin, bones, cartilage, tissues and blood vessels.

AUTOMOTIVE

Plastics help to reduce vehicle weights and improve fuel efficiency. They are used in airbag housings, seatbelts, door panels and many other components owing to their flexible, durable and lightweight characteristics. Plastics are ideal for exterior components in vehicles (bumpers, hoods, ...) thanks to their high resistance to impact and corrosion. The materials are also used for battery housing for electric vehicles and help improve energy efficiency, which is key to scaling up e-mobility.

AGRICULTURE & FOOD

Plastics are used to produce agricultural films, protecting the crops from pests and diseases, minimising water evaporation and improving crop yields. Plastic packaging also reduces food waste by extending shelf life and avoiding damage to fresh produce during transport and storage.

ELECTRICAL & ELECTRONICS

Plastics provide a protective barrier against moisture and dust that can damage electronic components. Their lightweight properties make them crucial for creating portable electronics. Durable plastics are also key to expand the power transmission infrastructure needed to support the growth of renewables.

Figure 1: Plastics are a strategically important material for the European economy

It is important to recognise that because of the unique material characteristics of plastics **there are no functionally suitable alternatives for many applications**. Substituting plastics with other materials in existing applications will often increase the GHG emissions. Therefore, the "ReShaping Plastics" report confirmed that overall, the substitution of plastics with other materials provides very limited scope for reaching net-zero emissions.

Plastics applications will therefore continue to play a key role in meeting a wide range of functional needs, while **enabling circularity, delivering emissions savings for a number of sectors and supporting the development of Europe's renewable energy sector**.

This includes, for example, enabling safe and emissions-free transportation; providing materials, such as insulation, pipes, flooring and windows, that reduce emissions from buildings; supporting Europe's digital transformation; the provision of more innovative healthcare and medical device solutions; and the manufacture of solar panels and wind turbines.

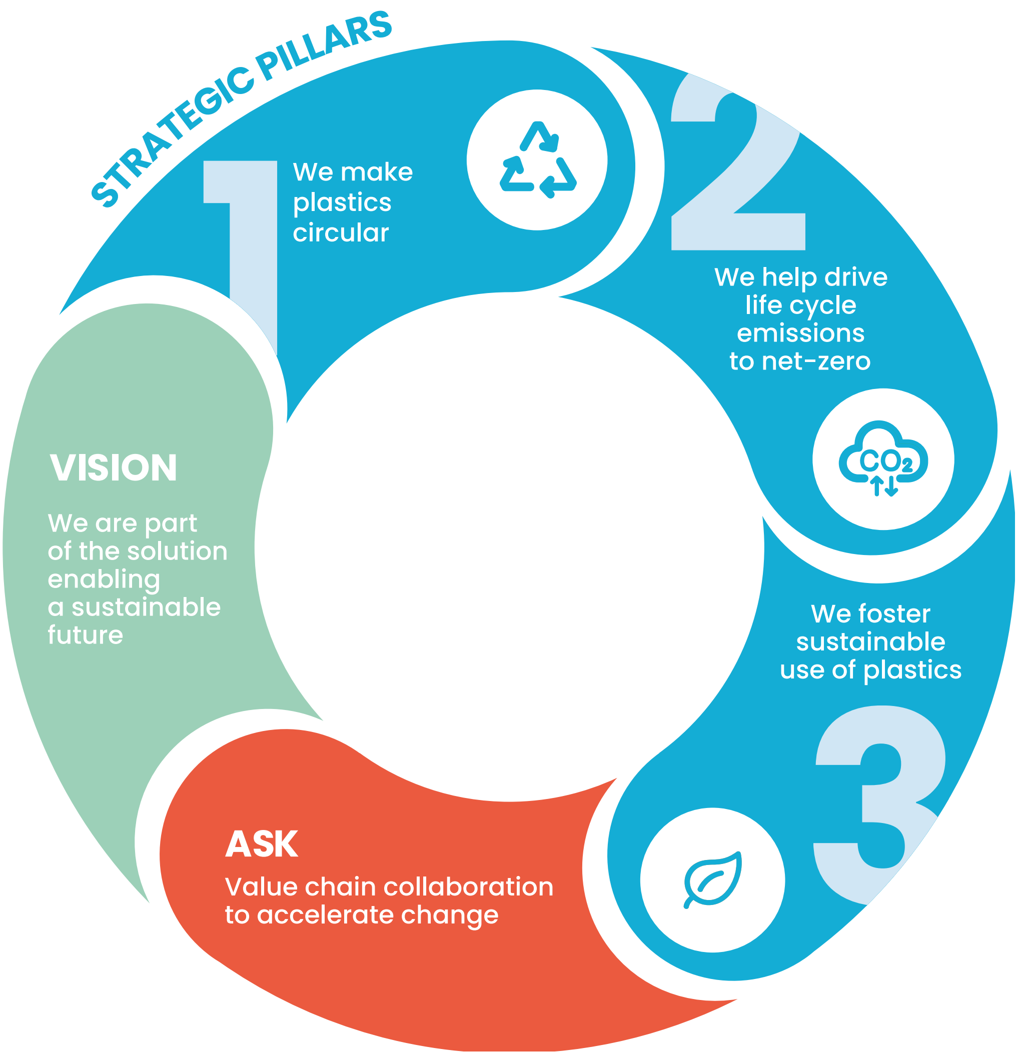
The European industry, which produced 57.2 million tonnes (Mt) of plastics in Europe (EU27+3) in 2021, **is under significant pressure due to global competition**. In the 1980s, European plastics production held one third of the global share, but this has steadily decreased. While differences in regional population and economic growth can in part explain these trends, a growing competitiveness gap between Europe and the rest of the world (including energy costs, access to raw materials, and the regulatory landscape) is a major factor.

The erosion in global competitiveness means Europe is gradually changing from an export to an import market, with significant implications for its strategic autonomy and the plastics system transition. Unless addressed, this will: increase our dependency on imports of plastics or plastic products which do not necessarily meet EU sustainability standards; and threaten the viability of many downstream industries in Europe. It will also limit the ability of the European industry to invest in the transition.

Our vision and strategic transition pillars

Plastics Europe and its members have a vision for a sustainable plastics system that continues to meet consumer and societal demands, whilst supporting the transitions of many downstream industries, and remains a strategic asset for the European economy.

Figure 2: Plastics Europe has a vision for a sustainable plastics system



As an industry we are part of the solution which enables a sustainable future. Our vision is to transition the European plastics system to a net-zero and circular model through innovation and investment. This roadmap is therefore built on three ambitious strategic pillars that we view as critical to achieving our vision:

1 Making plastics circular

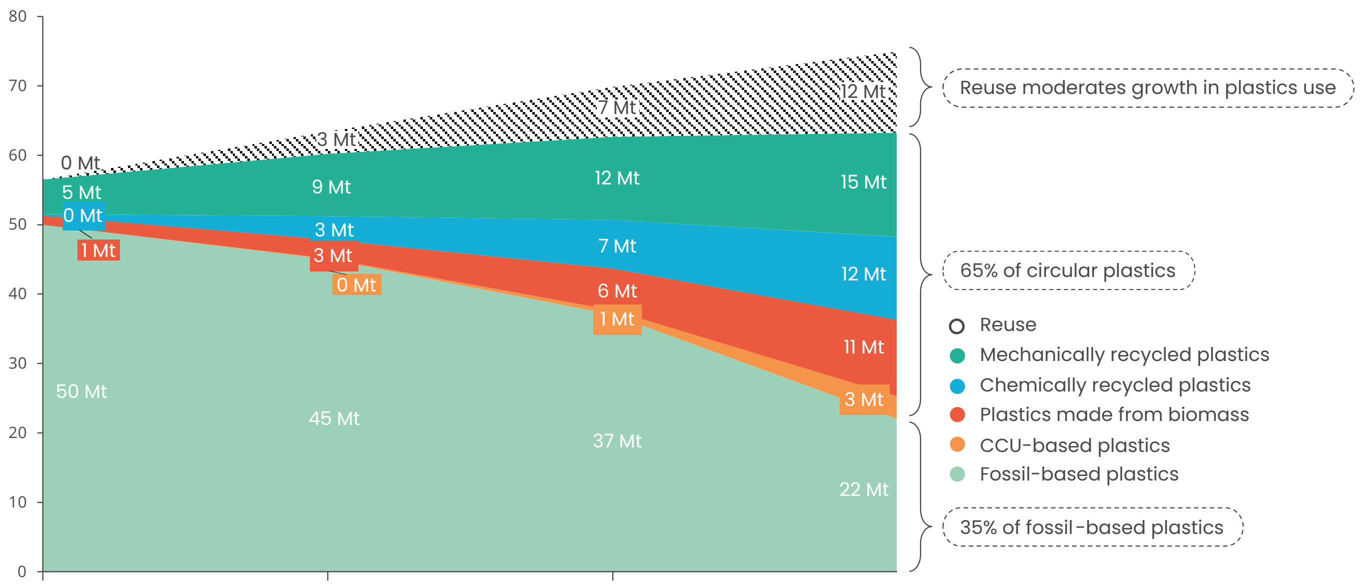
As confirmed by the "ReShaping Plastics" report, **circularity is one of the fastest, most affordable, effective and reliable methods for reducing GHG emissions from the plastics system**, and a key driver of system emissions reduction in the short to medium term.

All up- and down-stream levers need to be engaged, including reuse that reduces single use applications, design for recycling, mechanical and chemical recycling, plastics from biomass and CO2 captured in a carbon capture and utilisation (CCU) process. We need to significantly increase the collection, sorting and use of high-quality circular feedstock to reduce the dependence on fossil feedstocks and considerably lower the GHG emissions of the plastics system.

With the support of policymakers and increased collaboration with value chain partners, the strong growth in circular plastics will be able to meet an important part of the demand for plastics. Taking into account the expected constraints in availability of sorted plastic waste, sustainably sourced biomass, captured carbon and low-carbon hydrogen, the substitution of fossil-based plastics will be gradual and is projected to reach 65% by 2050 in an ambitious scenario.

Long technology maturity cycles and capex lock-in for large infrastructure investments mean that decisions taken in the 2020s will determine the industry's chances of reaching net zero GHG emissions by 2050. Thus, the next few years are a critical window for action.

Figure 3: With the support of policymakers and increased collaboration with value chain partners, circular plastics will be able to grow and gradually replace fossil-based plastics



2021	2030	2040	2050	
57 Mt	60 Mt	62 Mt	65 Mt	Converter's use (in Mt)
12%	25%	40%	65%	% of circular plastics compared to total converter's use

2 Helping to drive the plastics life cycle to net-zero

Plastics Europe members support the 2050 net-zero objectives of the EU Green Deal. **This roadmap demonstrates a potential pathway to reduce GHG emissions from the overall plastics system by 28% by 2030 (and the enabling conditions needed for such a transition), setting us on the pathway towards net-zero by 2050.**

To meet these objectives impactful measures are needed. Measures to promote reuse and circular business models would improve materials utilisation, lowering the demand for new plastic products, thus cutting production-related CO2 emissions by 35.7 Mt by 2050.

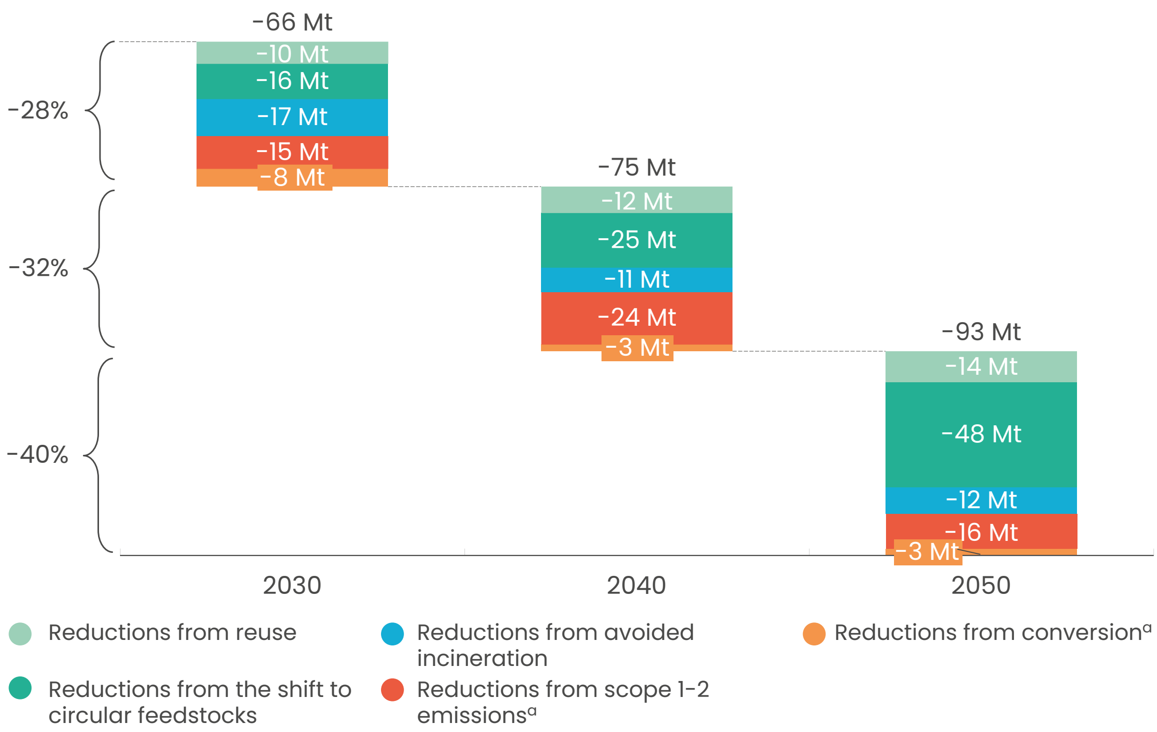
Moreover, shifting towards more circular feedstock will minimise upstream GHG emissions, displacing fossil-based plastics while increasing biogenic carbon from biomass as well as CCU and decreasing downstream emissions when plastic waste is diverted from incineration.

Overall, the sector is projected to reduce total annual GHG emissions by 129 Mt (55%) by 2050, compared to the baseline volume, through circular plastics (excluding reuse) and reductions due to avoided waste incineration.

The roadmap projects that by 2050, after reuse and the circular shift, plastics production needs to reduce the remaining 55 Mt of GHG emissions. The four levers necessary to abate these remaining emissions and achieve net-zero are: energy efficiency measures, use of renewable and low-carbon fuels, electrifying production processes, and utilising carbon capture & storage (CCS). Some of the technologies required to reduce emissions within the industry are currently in the research and development stage, but are expected to scale up in the next decades.

Driving the plastics life cycle to net-zero not only requires investments to reduce GHG emissions during manufacturing, but also further upstream in the feedstock production and downstream in the conversion and end-of-life stages.

Figure 4: This roadmap demonstrates a potential pathway towards net-zero by 2050



[a]Reductions through net-zero plastics production levers; maximising energy efficiency, electrifying production with low-carbon electricity, using low-carbon fuels and investing in carbon capture & storage

[1]Calculations based on ReShaping Plastics (2022), European Environment Agency (2021), OECD (2019), Material Economics (2019), Agora (2019)

3 Fostering the sustainable use of plastics

Sustainable use of plastics means producing and using plastics applications in a way that is safe for human health and the environment.

The members of Plastics Europe are working continuously to ensure the safety of plastics and mitigate their potential impact on human health. This includes developing new actions, tools and methodologies to manage operational risk, providing further transparency towards stakeholders, enhance collaboration with the value chain. We also recognise that any plastic waste in the environment is unacceptable and concerning. Therefore, we will continue to build intelligence and collaborate closely with scientists to better understand the impact of microplastics on the environment and health, and with policymakers and regulators to introduce measures to help mitigate their release.

Priorities for the industry include mapping and assuring the safe use of chemical additives applied to different polymers for different applications, preventing pellet loss in plastics production, and harnessing tools to share data across the value chain.

Figure 5: Key levers for the transition

WE MAKE PLASTICS CIRCULAR BY

- Fostering circular design and business models
- Enhancing mechanical recycling
- Unlocking chemical recycling
- Expanding production from sustainable biomass
- Making plastics from captured carbon

WE HELP DRIVE LIFE CYCLE EMISSIONS TO NET-ZERO BY

- Leveraging the circular transition
- Maximising energy efficiency
- Using low-carbon fuels (hydrogen, biofuels)
- Electrifying production with low-carbon electricity
- Investing in carbon capture & storage

WE FOSTER SUSTAINABLE USE OF PLASTICS BY

- Managing risks in operations
- Providing further transparency to stakeholders
- Collaborating with value chain partners to prevent leakage

Our industry in transition

Plastics Europe members are undertaking huge investments and a far-reaching reorganisation of their production and technology base. This has accelerated in recent years, although long investment cycles mean that it will take a number of years for the full benefits to become apparent.

We are already working with our partners in the plastics value chain to deliver new systems thinking, mindset and behavioural changes, higher performing products, ecodesign innovation and new infrastructure. **Our members are also driving major advances in the sustainability of their operations, including investing in innovation in both mechanical and chemical advanced recycling technologies, renewable and low carbon energy and producing more plastics from biomass and CO2.**

Undertaking this transition is a generational-scale task, and Plastics Europe is under no illusions about the scale, complexity and cost of this transition. This involves multiple supply chains, thousands and thousands of products and companies, each with their own business strategies and models.

The European plastics systems transition will require significant short and longer-term investments from different private and public actors, as well as new infrastructure and business models, and further technological innovations. cumulative additional investments and operational costs for circular and net-zero production by 2050, for example, are projected by Deloitte to be €235 billion.

It will also require a supportive regulatory framework and policy incentives to ensure that such a transition for Europe remains viable in response to an ever-growing competitiveness gap compared to other key plastics-producing regions.

To further accelerate the transition, the European plastics industry has identified key actions.

Figure 6: Potential actions for industry members to consider, with an illustrative timeline, that need the collaboration of policymakers and value chain partners

IMMEDIATE
2023 - 2025

- Provide stakeholders with aggregated data and insights on the status and solutions to achieve the industry vision
- Partner with waste management organisations to secure circular feedstock and manage investment risks
- Invest in new technologies and collaborate to speed up technology development
- Prevent plastic leakage in the supply chain through compliancy with Operation Clean Sweep® (OCS), and encourage broader value chain adoption
- Determine minimum requirements for risk management systems for plastics additives
- Experiment with digital product passports and speed up the development of digital tools to share information in the value chain
- Utilise power purchase agreements to increase green electricity uptake

SHORT TERM
2026 - 2027

- Bring plastics to the market that are functional and affordable but also easy to recycle or repurpose at the end of their life cycle
- Shift away from linear practices to circular ones, through new circular business models and technologies such as recycling, plastics from biomass and captured carbon
- Invest in joint infrastructure for hydrogen, renewable energy and carbon capture and storage (CCS)
- Lead by example and cooperate with stakeholders and value chain partners to overcome hurdles and knowledge gaps to address plastic leakage
- Scale up power purchase agreements to accelerate green electricity uptake

MEDIUM TERM
2028 - 2030

- Further the cooperation with suppliers of sustainably sourced biomass to scale up plastics from biomass
- Have chemical recycling operational at scale by investing in capacity and partnering with technology providers
- Maximise energy efficiency and use carbon capture and storage (CCS) to reduce GHG emissions
- Implement third-party verified risk management systems for plastics additives

Accelerating systemic change

The speed and extent to which the European plastics system transitions to circularity and net-zero are heavily influenced by three critical factors: the urgent need for more intense and more combined efforts of all parts of the European plastics system and of policymakers and regulators; the ability of the European plastics system to remain globally competitive along this transition; and the creation of a policy and regulatory framework that enables, rather than frustrates, the industry's transition.

In doing so, there are several critical challenges that need to be addressed:

- Incentivise the availability of and demand for circular feedstocks and help industry in developing recyclable products
- Phase out landfilling and incineration of recyclable plastic waste and favour reuse and recycling
- Legally recognise the mass balance approach for both recycled and bio-attributed plastics feedstocks as a key enabler of the plastics transition
- Create a level playing field and regain European competitiveness
- Provide accessible funding opportunities that make circular plastics production in Europe competitive and speeds up the circular transition, and develop a true EU equivalent to the US Inflation Reduction Act
- Make low carbon energy and hydrogen accessible and affordable
- Ensure a harmonised and consistent regulatory framework across the EU Single Market
- Ensure a material-agnostic, science- and data-based approach to policies framing this transition

Figure 7: Asks to policymakers and value chain partners with indicative timeline

IMMEDIATE 2023 - 2025	SHORT TERM 2026 - 2027	MEDIUM TERM 2028 - 2030
• Develop an EU equivalent to the US Inflation Reduction Act to make circular plastics production in Europe competitive • Have a material-agnostic view when addressing single-use applications • Codify the fuels-exempt mass balance approach for chemical recycling • Harmonise requirements for recycled content measurement and certification • Impose minimum circular content targets and enforce implementation also for imported plastics • Improve waste collection and sorting and incentivise investments in recycling infrastructure by Extended Producer Responsibility (EPR) and other instruments • Phase out landfilling and incineration of recyclable plastic waste by harnessing instruments such as EU ETS and disposal taxes • Simplify and speed up permitting processes for circular and net-zero infrastructure • Make OCS-like requirements and certification legally binding for all plastics pellets handling actors in the EU	• Promote and enforce design for recycling to improve quality of collected waste • Make shipping of recyclable waste easier within Europe and treat recyclable plastic waste as a secondary raw material destined for recycling, which should be covered by product legislation • Harmonise definitions and improve statistics for plastic waste management • Provide economic incentives to use sustainable biomass as feedstock for plastics and endorse the mass balance approach for bio-attributed plastics • Endorse trustworthy certification systems and standards for the sustainable sourcing of biomass feedstocks • Increase citizens' awareness and leverage public procurement for circularity to create a market pull for circular products • Step up the research for CCU • Include the industry in the impact assessment of the Carbon Border Adjustment Mechanism (CBAM) • Increase renewable energy capacity drastically	• Enhance the quality and quantity of collected biowaste suitable as feedstock for plastics • Provide funding for low-carbon hydrogen production and transportation infrastructure • Create incentives and a legal framework to valorise CO_2 emission savings via CCU • Secure long-term contracts for production of basic chemicals from captured CO_2 • Make risk management systems for plastics systems obligatory for the whole plastics sector • Enable the free flow of electricity between EU countries and ensure competitive renewable electricity prices for industry • Reduce CO_2 emissions in plastics conversion

Objectives of this roadmap

1

Although plastics are instrumental for the economic, social and environmental ambitions of Europe, they can only be future-proof if the societal concerns related to the life cycle of plastics are properly addressed.

Plastics value chains are still too linear, with many valuable resources wasted all along the life cycle of plastic products. Equally, the potential to reduce greenhouse gases can be further tapped into.

Safety has always been an industry priority, also supported by extensive chemicals legislation that safeguards against health and environmental hazards. Nonetheless, societal expectations and scientific knowledge are changing, resulting in concerns around the use of certain additives in plastics production and the occurrence of leakage to the environment.

Our industry wants to address these societal concerns. **We agree that industry, in collaboration with value chain partners and supported by policymakers, has an important role in producing more circular plastics, reducing GHG emissions and fostering sustainable use of plastics.** We aspire to be a partner for European policymakers and value chain actors to move towards a better environment and a thriving society.

In this roadmap, we lay out a potential pathway for a more circular and net-zero plastics industry in Europe. The strategic pillars are ambitious, yet realistic if the enabling conditions are met. This roadmap aims to contribute to policy and stakeholder debates by providing industry data and a forward-looking perspective.

The task ahead is difficult. Achieving this vision will require collaboration by policymakers and a wide range of other stakeholders across the plastics value chain, including product manufacturers, supply chain partners, waste management companies, research & academic institutes, and civil society. Moreover, the vision can only succeed if the European industry can compete globally. The current geopolitical outlook with high prices for energy in Europe and demanding EU environmental requirements are challenging for plastics and other manufacturing industries in Europe. Therefore, this roadmap calls for measures to safeguard the viability of the European industry, so it can maintain its leading role in the green transition.

This roadmap builds upon ‘ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe’[1]. Commissioned by Plastics Europe in 2021, the report provides an independent perspective on transitioning to the EU’s net-zero carbon emissions and circularity goals by 2050. This roadmap also replaces Plastics Europe’s previous ‘Voluntary Commitment, Plastics 2030’ and puts forward a more comprehensive set of ambitions covering all aspects of the plastics life cycle.

The roadmap is structured as follows. Chapter 2 addresses the market, role and challenges of plastics. Chapter 3 puts forward the vision of Plastics Europe. Chapters 4 to 6 focus on the actions from plastics producers, asks to policymakers as well as value chain partners, and indicators to monitor progress vision. Chapter 7 summarises the main points and puts forward a high-level milestone plan.

1 https://plasticseurope.org/changingplasticsforgood/reshaping-plastics/

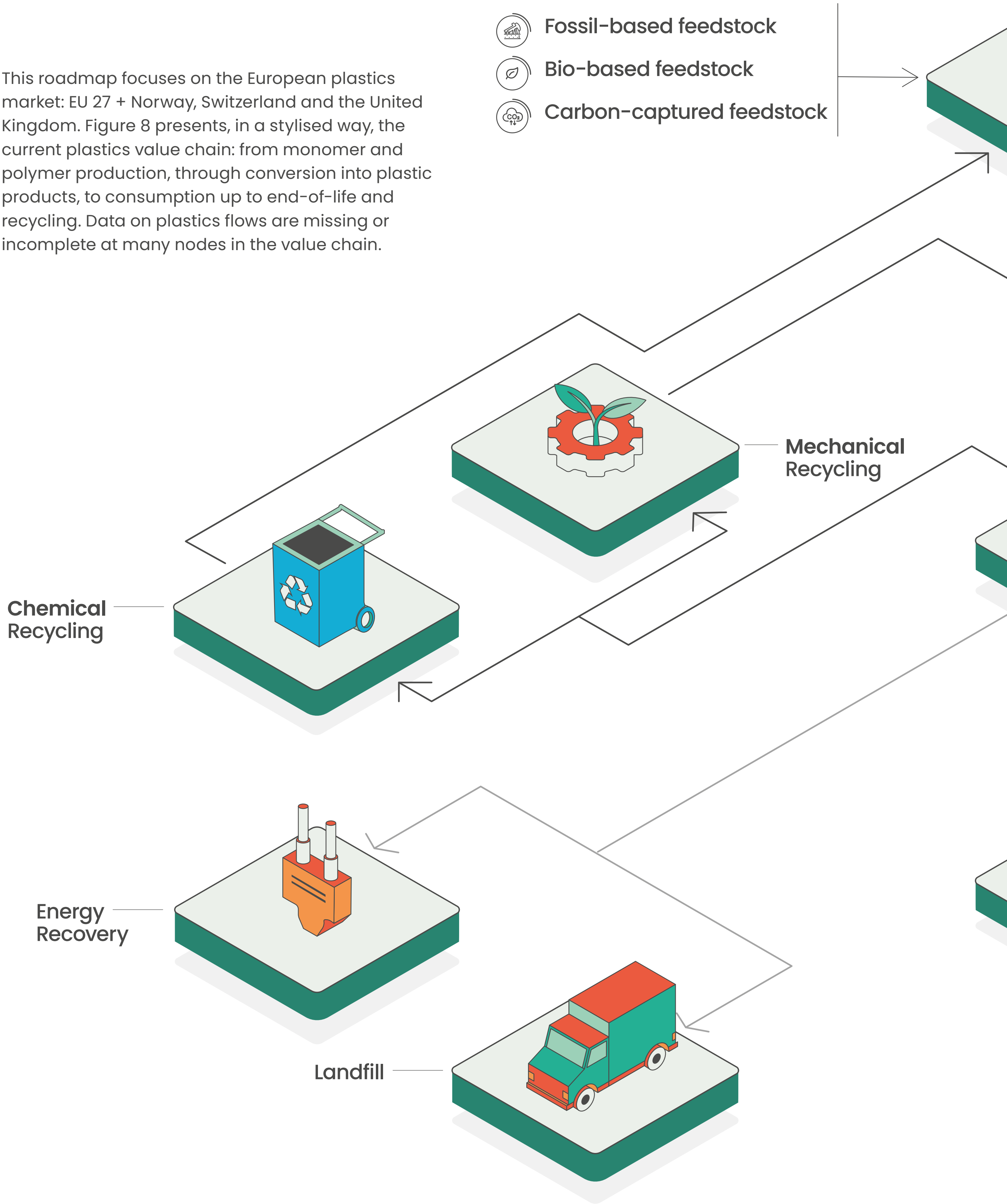
The European Plastics Industry today

This chapter looks at the current production and applications of plastics in Europe, the benefits this brings to society, and sustainability challenges.

2

2.1 Production and lifecycle in Europe

This roadmap focuses on the European plastics market: EU 27 + Norway, Switzerland and the United Kingdom. Figure 8 presents, in a stylised way, the current plastics value chain: from monomer and polymer production, through conversion into plastic products, to consumption up to end-of-life and recycling. Data on plastics flows are missing or incomplete at many nodes in the value chain.



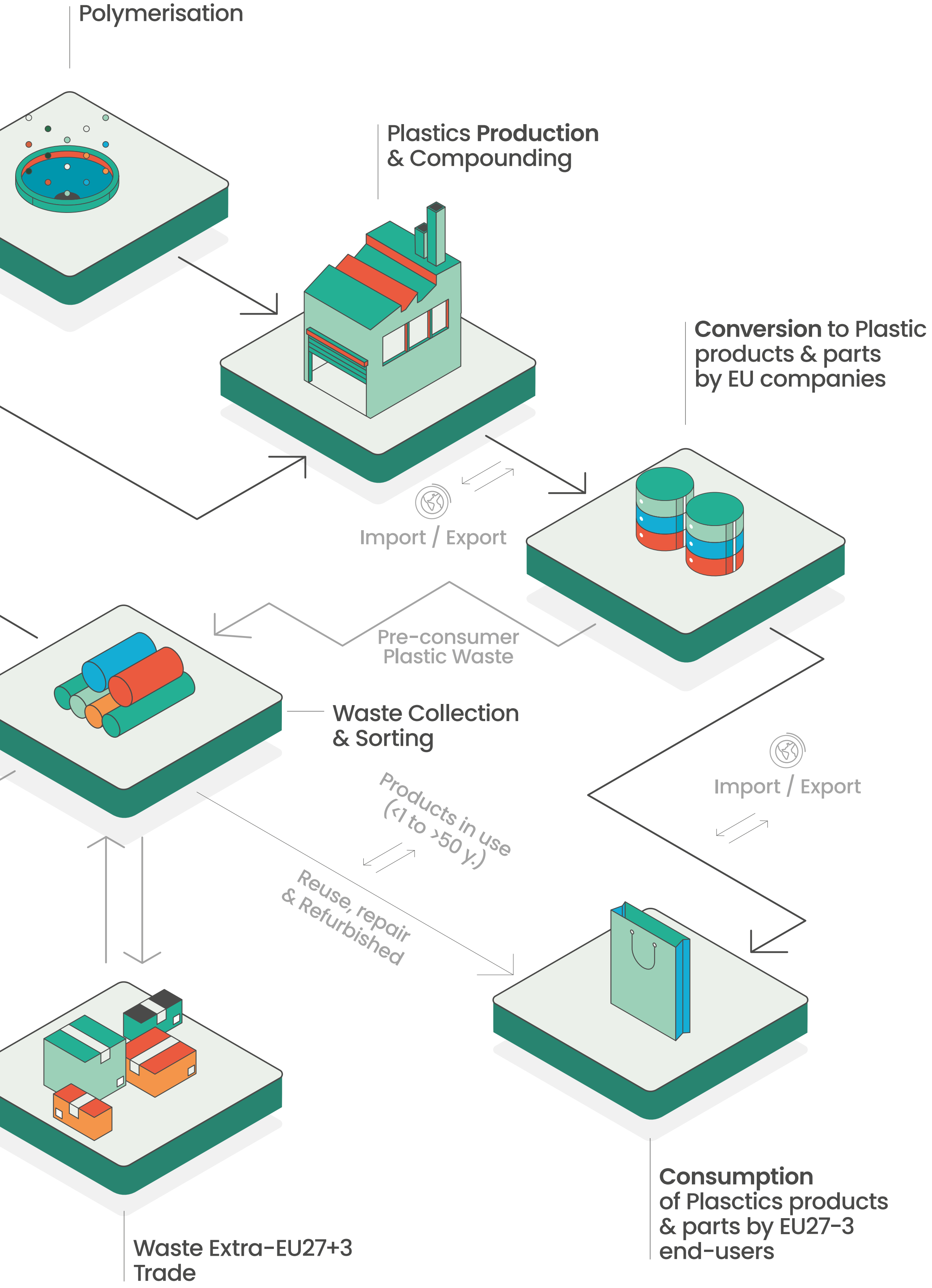
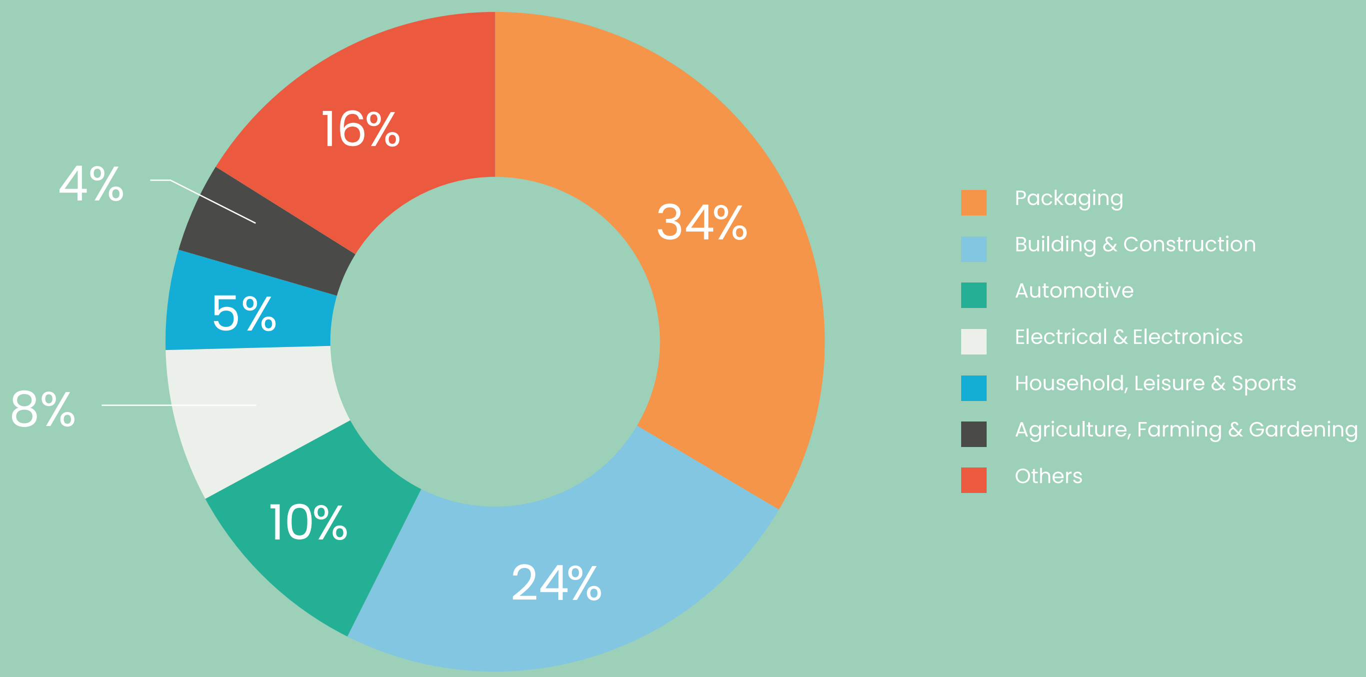


Figure 8: The market size of the European plastics industry can be measured at different stages of the value chain

The market size (weight) of the European plastics market differs at each stage due to imports and exports, additives and losses in various processes. The most relevant data points for the roadmap are:

PRODUCTION	CONVERTER USE	CONSUMPTION
57.2 million tonnes (Mt) of plastics were produced in Europe (EU27+3) in 2021 (Plastics Europe 2022). This comprises fossil-based plastics, recycled plastics and plastics from biomass. It includes thermoplastics, thermosets and polyurethane (PUR) used for plastic parts and products. Polymers not used to convert plastic parts and products (i.e. for textiles, adhesives, sealants, coatings, etc.) are excluded.	56.9 Mt of plastics were converted in Europe into products and parts in 2021. This comprises fossil-based plastics and recycled content (together 55.6 Mt, Plastics Europe 2022) and plastics made from biomass (1.3 Mt, Deloitte estimate based on production data from Plastics Europe 2022 and expert interviews – preliminary assumptions based on European polymer production capacities).	56.6 Mt plastic products and parts were sold to end-users in Europe in 2021. This estimate is based on 2020 consumption (53.6 Mt, Plastics Europe 2022) and a growth factor towards 2021 (equivalent to the growth of converter use in the same period, Deloitte analysis).

Figure 9: Plastics consumption in the EU27+3
in %, 2020 actuals (Plastics Europe, 2022)



This roadmap uses the available data on production in Europe to benchmark aggregated data coming directly from more than 25 members of Plastics Europe. The roadmap builds on the converter use to model a circular and net-zero pathway for plastics by 2050. The available data on consumption are used for a perspective on applications and an estimate of the waste amount generated in Europe described further in this roadmap.

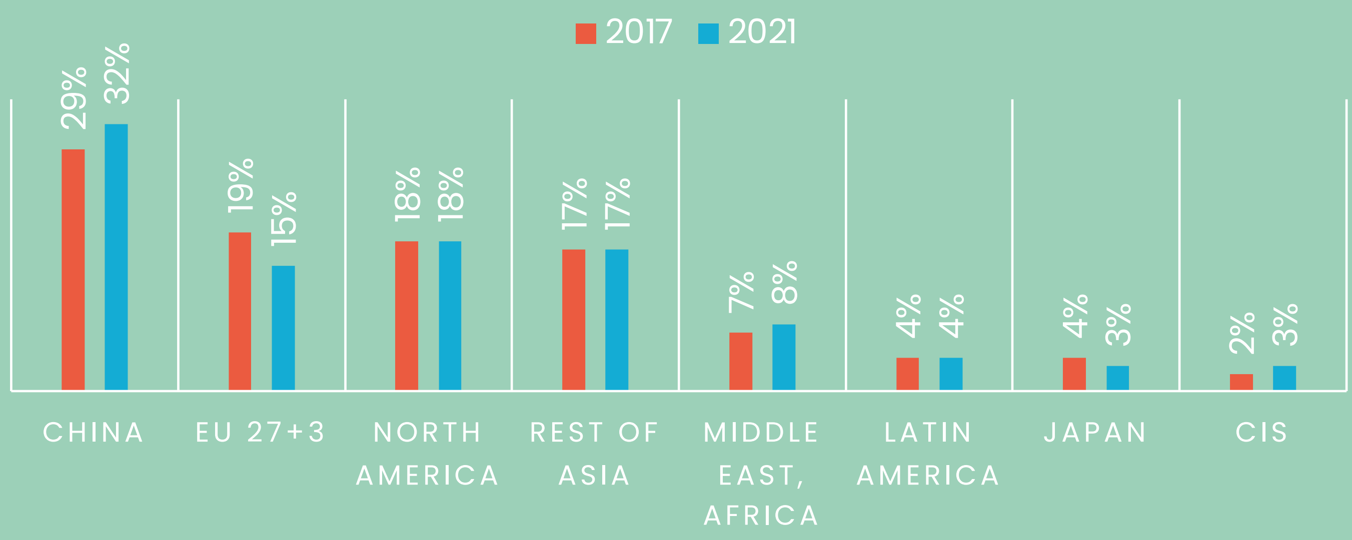
Plastics are used in a wide range of applications and sectors: consumer and industrial packaging, food protection, construction, automotive, electrical and electronics, household goods, leisure and sports, and agriculture (Plastics Europe, 2022). Among these, packaging is the largest end-use market (Figure 9).

Production is under pressure in Europe due to global competition. In the 1980s, European plastics production held one third of the global share. European production has since increased steadily, but slower than other regions (OECD, 2022a). Between 2017 and 2021 Europe's share of the global plastics production dropped from 19% to 15% (Figure 10) (Plastics Europe, 2022). China on the other hand rose from 29% to 32%, and the Middle East from 7% to 8%. Differences in regional growth of population and economy are driving these trends, but the European industry is also losing competitiveness.

The European plastics market is gradually changing from an export market to an import market. The EU27 trade balance showed that that export surplus in plastics production declined from €10.4 billion in 2015 to €9.0 billion in 2021 (Plastics the Facts 2022). The remaining export surplus is mainly due to packaging, while electronics, automotive, houseware and leisure & sports packaging are more imported than exported in the EU 27+3 (Plastics Europe Circular economy publication 2022).

The current geopolitical context of rising European wages, feedstock prices and energy costs (far beyond those elsewhere) is accelerating imports. To keep industrial activities from migrating out of Europe to other regions with fewer environmental regulations and/or more favourable investment conditions, policy measures are needed.

Figure 10: Evolution of plastics production around the world
in %, 2017-2021 (Plastics Europe, 2022)[1]



1 2017 data include only thermoplastics and PUR. CIS: Commonwealth of Independent States (Azerbaijan, Armenia, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Uzbekistan and Ukraine).

2.2 The role and societal benefits

The European plastics value chain, comprising manufacturers, converters, waste management companies, and machinery manufacturers, employed over 1.5 million people in the EU in 2021. These workers are spread across 52,000 companies, which generated turnover of more than €400 billion (Plastics Europe, 2022). The plastics industry is vital for Europe, generating significant added value for the economy and key sectors.

Plastics are a group of materials with various characteristics suitable for a wide range of applications. They are chosen for their economic and environmental benefits in sectors critical for Europe's industrial strategy (European Commission 2020). Figure 11 illustrates how instrumental plastics are in a non-exhaustive set of industrial sectors. Other future-proof applications can be found in packaging, medical applications, digital services and renewable energy production. **Accelerating innovation and investment in sustainable plastics production and use is therefore essential to reach societal targets such as making Europe net-zero by 2050.**

Figure 11: Plastics are instrumental for the green transition: examples of plastic applications in sectors that are critical for Europe's industrial strategy

Building & Construction

Plastics are increasingly used in building insulation due to their excellent insulating properties, which can help reduce energy demand for heating and cooling. Because they are corrosion-resistant, they are used to create pipes and fittings for plumbing and drainage systems. Plastics are used to make energy-efficient windows and doors as well as weather-resistant roofing and facades.

Electrical & Electronics

Plastics provide a protective barrier against moisture and dust that can damage electronic components. Their lightweight properties make them crucial for creating portable electronics. Durable plastics are also key to expand the power transmission infrastructure needed to support the growth of renewables.

Renewable Energy

Plastics are critical for the development of clean, efficient and durable alternative and renewable energy solutions, including wind turbines and solar panels, as well as electric and hydrogen powered vehicles. These solutions reduce greenhouse gas emissions and increase resource efficiency

Automotive

Plastics help to reduce vehicle weights and improve fuel efficiency. They are used in airbag housings, seatbelts, door panels and many other components owing to their flexible, durable and lightweight characteristics. Plastics are ideal for exterior components in vehicles (bumpers, hoods, ...) thanks to their high resistance to impact and corrosion. The materials are also used for battery housing for electric vehicles and help improve energy efficiency, which is key to scale up e-mobility.

Health

Modern healthcare would be impossible without the many plastic-based medical products we take for granted. Plastics are everywhere, from personnel protective equipment, sterile syringes, intravenous blood bags, heart valves, “artificial skin” for emergency burns treatment and orthopaedic devices. Innovations in plastics are making new advances in healthcare possible and 3D-printing has opened up the possibility of using plastics to print kidneys, skin, bones, cartilage, tissues, and blood vessels.

Agriculture & Food

Plastics are used to produce agricultural films, protecting the crops from pests and diseases, minimising water evaporation and improving crop yields. Besides, plastic packaging reduces food waste by extending shelf life and avoiding damage of fresh produce during transport and storage.

2.3 Challenges to be addressed

The roadmap groups the concerns related to the production, use and end-of-life of plastics into three challenges (Figure 12).

Figure 12: Three main challenges with the current use of plastics

LINEAR LIFE CYCLE

- Unsustainable use of **single-use** products
- In 2021, only **10%** of plastic products in Europe were made from **recycled content and 2% from biomass**

GHG EMISSIONS

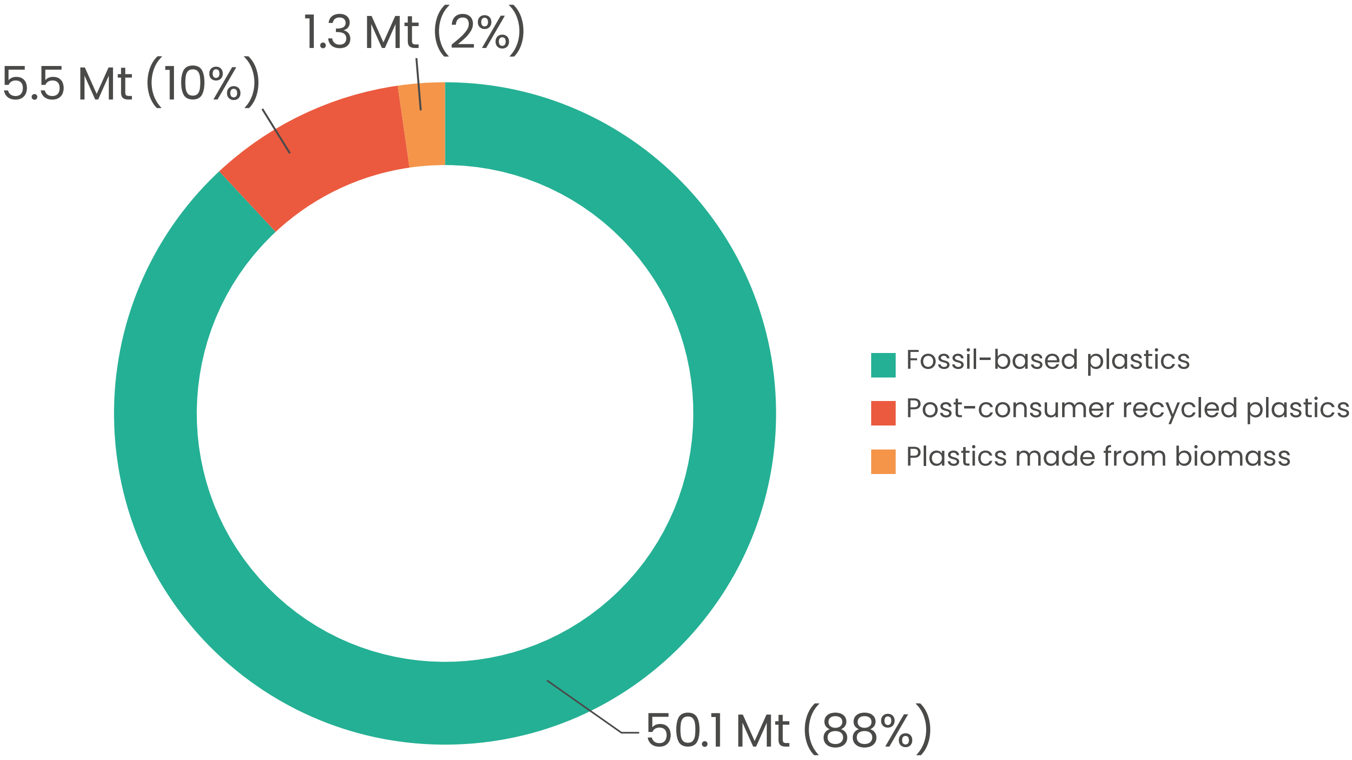
- The European plastics value chain emitted **175 Mt** of **GHG** in 2021, **equivalent to 4.9%** of all European emissions

HEALTH CONCERNS AND LEAKAGE INTO THE ENVIRONMENT

- Potential exposure in daily life to **(micro) plastics** and chemicals they contain
- In Europe, **0.9 Mt** of plastics **leaked** into the environment in 2021

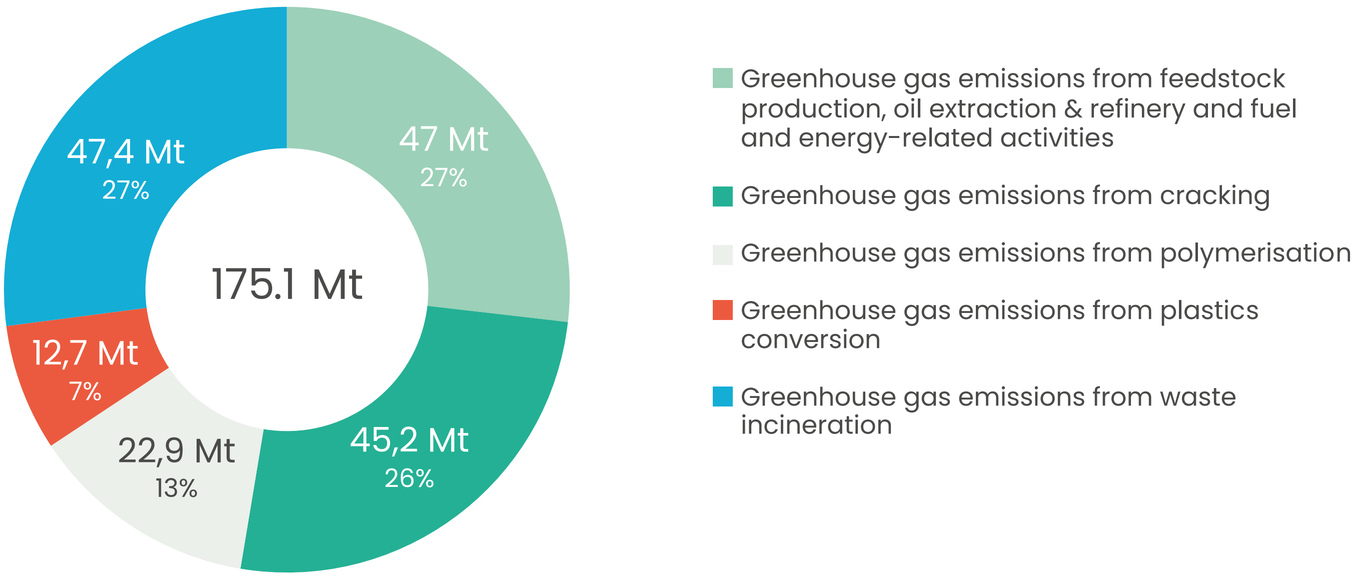
The first challenge relates to the current linear life cycle of plastics. Unsustainable use of single-use products is being increasingly scrutinised, namely through new regulations such as the Single-Use Plastics Directive (SUPD). Typically, the environmental problem is less related to the choice of plastics as a material, but rather to applications such as disposable items that have a short life cycle and are used in significant amounts. Moreover, overall separate collection and recycling rates are low and plastic products in Europe are still predominantly made from fossil-based feedstocks (88% of converters' use in 2021). Only 9.7% of plastic applications are made from recycled plastics and 2.3% from biomass (Figure 13). **Technologies for recycling are evolving rapidly, but structural improvements in the current low circularity of plastics will only take place if the appropriate economic and legal framework is put in place in Europe.**

Figure 13: Converter use breakdown by feedstock
in Mt, 2021 (Plastics Europe, 2022) (Deloitte analysis, 2023)



The second challenge relates to the carbon footprint of plastics. OECD (2022b) attributes 1.8 billion tonnes (Gt) or 3.7% of global emissions to the plastics life cycle, and estimates that, in a baseline scenario, global emissions will double to 3.5 Gt by 2050. In Europe, the plastics industry generated 175.1 Mt or 4.9% of the total 3.6 Gt of EU emissions in 2021 (Eurostat, 2022). This includes CO_2e emissions from the activities of scope 1 (monomer and polymer production – for recycled plastics this includes emissions from recycling), Scope 2 (energy to power production plants), Scope 3 upstream (supply of feedstock), and Scope 3 downstream (conversion of plastics into products and parts, and waste incineration) (Figure 14). Reducing the carbon footprint of the different life cycle stages of plastics will be important to reaching the EU Green Deal net-zero objective by 2050.

Figure 14: GHG emissions of the life cycle of plastics in Europe[1]
in Mt, 2021 (Plastics Europe, 2022) (Deloitte analysis, 2023)



The third challenge refers to potential health concerns and environmental leakage due to mismanagement along the value chain. Recent studies highlight that microplastics (particles < 5 mm) can be found in a multitude of living organisms, and that human exposure can take place via a wide range of pathways including ingestion of food, inhalation and dermal contacts (Domenech & Marcos, 2021). The OECD (2022a) estimated that in 2021 microplastics leakage from a wide range of sources – including tyre and brake wear, paint erosion and pellet loss in the supply chain – amounted to 2.8 Mt globally and to 0.3 Mt[2] in Europe. An even more visible challenge is plastic waste in the environment. The OECD estimated that 20.0 Mt leaked into the environment and around 6.1 Mt ended up in rivers and oceans, with the main leakage sources located in Asia and Africa. Leakage of macroplastics in Europe amounted to 0.6 Mt[3], 3% of the global macroplastics leakage according to the OECD (2022a). Owing to the incomplete understanding of the issues and the difficulty in assessing some of the potential risks, addressing leakage is not straightforward. Actions will have to combine leakage prevention, improved waste infrastructure and collection, research, improved information flows and improved control mechanisms.

1 GHG emissions from the plastics life cycle are based on the volumes of plastics converters use.

2 The OECD estimated that in Europe, the four main pathways leaking microplastics into the environment are wastewater sludge (0.12 Mt), tyre abrasion (0.08 Mt), microplastics dust (0.03 Mt) and pellet loss in production of plastics (0.02 Mt).

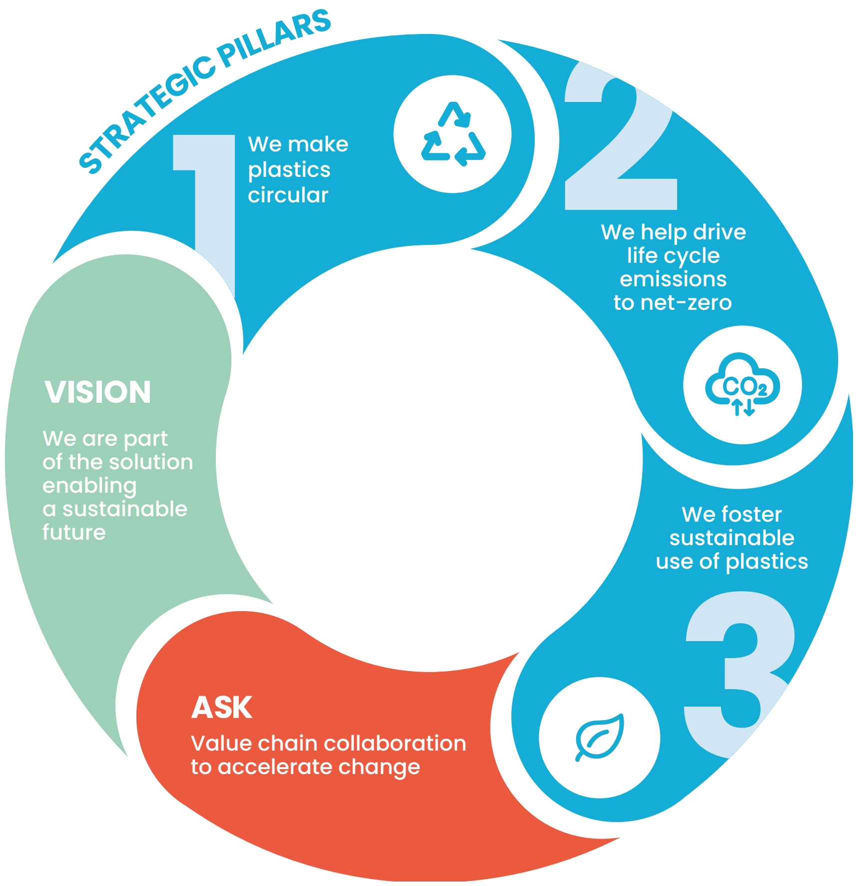
3 The OECD estimated that in Europe, macroplastics leakage comes from mismanaged waste and littering (0.5 Mt) and marine activities (0.1 Mt).

Our Vision

3

Plastics play a decisive role for achieving the objectives of the EU Green Deal and many of the Sustainable Development Goals (SDGs). **We have a vision for the industry which includes a truly sustainable plastics system that continues to meet consumer and societal demands**, whilst supporting the transitions of many downstream industries, and remains a strategic asset for the European economy.

Figure 15: Plastics Europe and its members have an ambitious vision for 2050



To achieve the vision, the members of Plastics Europe have developed a strategic vision to proactively take action and address societal expectations (Figure 15). It contains three ambitious pillars (further discussed in the next sections):

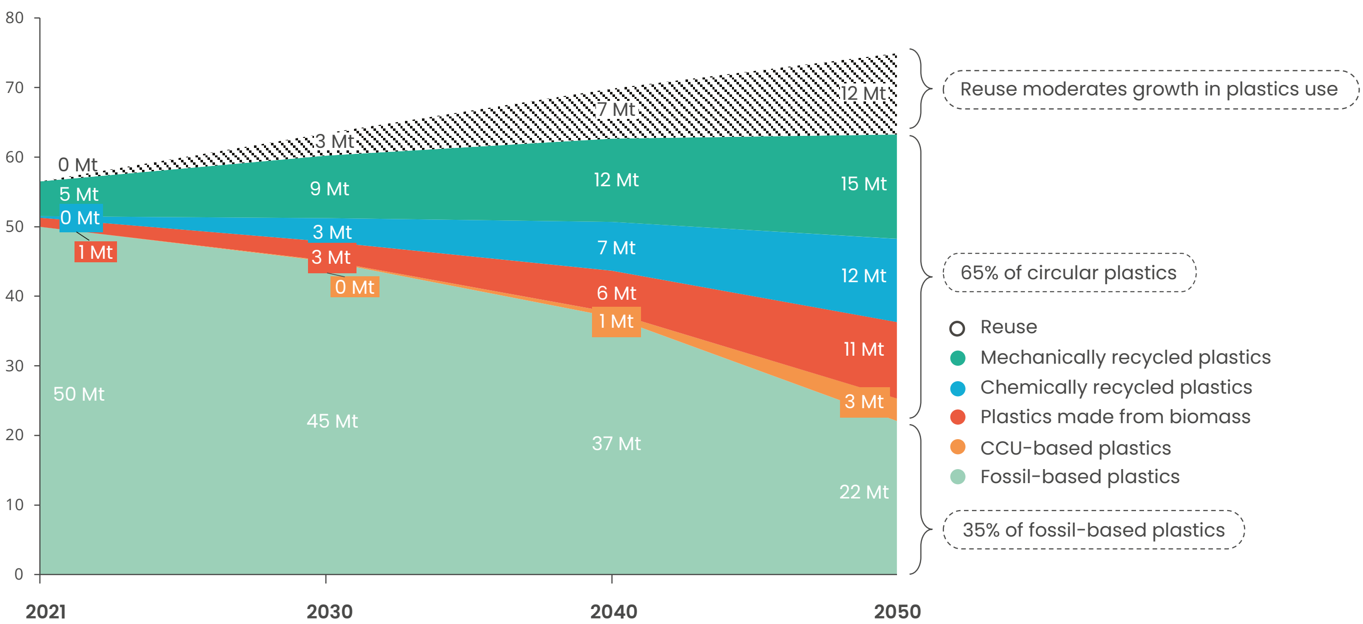
1. **Circular plastics** are made from mechanically recycled plastic waste, chemically recycled plastic waste, sustainably sourced biomass or CO2 captured in a carbon capture and utilisation (CCU) process. With support from policymakers and value chain partners, we can increase circularity drastically and achieve 65% circular plastics consumed in Europe by 2050.
2. **Driving the plastics life cycle to net-zero** requires not only investments to reduce GHG emissions during manufacturing, but also upstream in the feedstock production and downstream in the conversion and end-of-life stages. We need to intensify the collaboration with policymakers and value chain partners to reduce the GHG emissions of the plastics life cycle to net-zero by 2050.
3. **Sustainable use of plastics** means putting products on the market that are safe for human health and the environment. We will continue to apply safe and compliant production processes while gearing up the transparency towards stakeholders and collaborating with value chain partners to reduce leakage to the environment across the life cycle of plastics.

3.1 Circular plastics

Projecting the future growth of circular plastics is not straightforward: market dynamics are intricate and policy impacts are difficult to foresee, especially to 2050. The annex presents the assumptions and functioning of the analytical model used to make projections about the future. It relies on a variety of sources, including literature studies such as the OECD (2022a) (2022b) and SystemIQ (2022), and individual interviews and aggregate results of market surveys with several Plastics Europe members. While the estimates are based on the data currently available, the roadmap will update its projections, incrementally integrating new insights as they become available.

Figure 16 projects a baseline scenario with a 1% compound annual growth rate of plastics converter use, rising from 56.9 Mt in 2021 to 76.2 Mt in 2050[1]. However, the vision strives to achieve a more circular trajectory where ecodesign, reuse systems and circular business models moderate this growth to a compound annual growth rate (CAGR) of 0.43% between 2021 and 2050. The reductions are projected to mainly occur in single use applications, including single use packaging. By 2050 converter use could be lowered by 11.7 Mt, reaching 64.5 Mt (SystemIQ, 2022) (Deloitte analysis, 2023).

Figure 16: Circular plastics use by European converters and their feedstock[2]
EU 27+3, in Mt, 2021-2050 (Deloitte analysis, 2023)



1 35% growth towards 2050 is based on growth rates of end-applications according to (SystemIQ, 2022), see annex for assumptions taken.

2 Circular plastics based on estimated converter use.

In the scenario described in the mission, circular plastics will increasingly substitute fossil-based plastics used by converters.

- 42.2 Mt (around 65%) of the projected 64.5 Mt of plastics converted would be circular by 2050.
- Mechanically recycled plastics would grow steadily to 15.3 Mt (24%) by 2050.
- Chemically recycled plastics would scale up by 2030 and then accelerate to 12.4 Mt (19%) by 2050.
- Plastics from biomass would double every decade to reach 11.4 Mt (18%) by 2050.
- Plastics based on captured carbon & utilisation (CCU) would only really take off after 2040, evolving to 3.2 Mt (5%) by 2050.

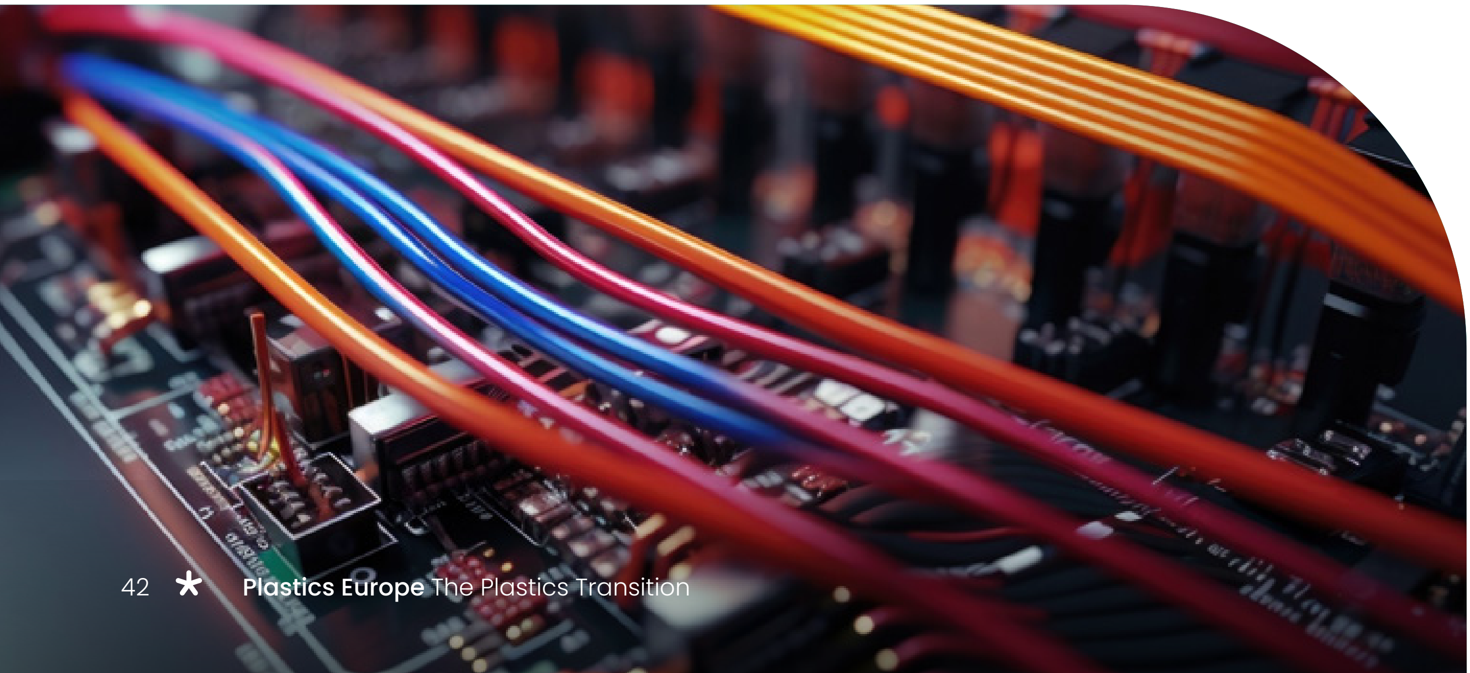
This overall eight-fold increase in the weight of circular plastics highlights how the market will have to structurally shift over the next three decades.

It seems unlikely that 100% circularity is feasible, even in an ambitious scenario. The projected remaining 35% of primary fossil-based plastics would be needed to meet the societal needs in 2050 for several reasons:

- The analytical model projects that the amount of waste generated represents only 75% of the plastics consumed, given that plastics are used for many long-life applications, especially in construction. This means that in a growing market there is less waste than plastics used (OECD, 2022a) (Material Economics, 2019) (SystemIQ, 2022).
- Although improvements in technology will be immense by 2050, the projection assumes that there will still be substantial residual losses during the processing of this material (25%) (European Commission, Technical University of Denmark, 2021).
- The total losses limit the quantity of recycled material available for new circular plastics. The amount of available recycled plastics is expected to only cover around 43% of the 64.5 Mt of converter use.
- Thanks to a positive outlook on technological improvements in plastics from biomass and CCU, their combined market share is projected to increase from about 2% in 2021 to 23% of the 64.5 Mt converter use in 2050.

Despite the aspired strong growth in circular plastics, the expected constraints in availability of sorted plastic waste, sustainable sourced biomass, captured carbon and low-carbon hydrogen, make full substitution of fossil-based plastics overly optimistic for 2050.

Plastics producers are at the forefront of addressing circularity challenges, but achieving true circularity will require the combined efforts of all stakeholders in the ecosystem, including feedstock manufacturers, converters, plastic product manufacturers, end-users, waste management companies and regulators. Therefore, it is crucial that all parties support these circularity ambitions. Chapter 4 will elaborate further on the levers that producers are implementing and on the enabling conditions needed to realise circularity ambitions.

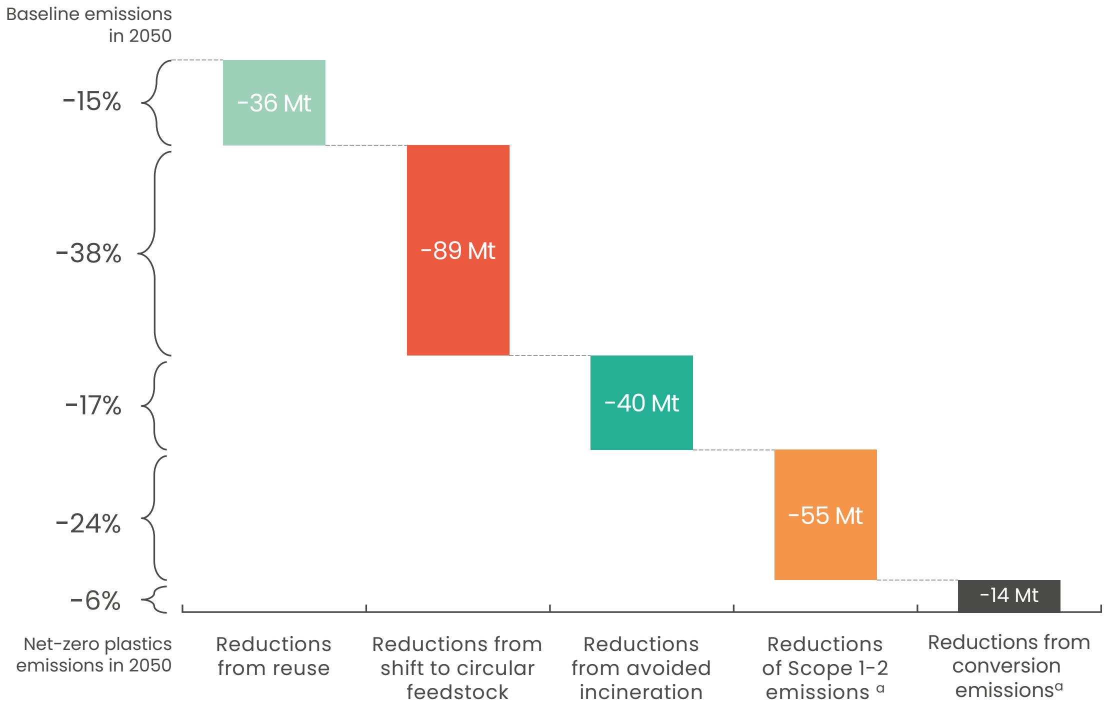


3.2 Net-zero GHG from the life cycle of plastics

Without additional action, overall greenhouse gas emissions during the plastics life cycle are expected to follow the baseline growth of plastics and reach 233 Mt by 2050 (Figure 17).

Figure 17: Reductions needed to reach net-zero in 2050[1]

In Mt CO_2e, 2050 (Deloitte analysis, 2023)



ᵃReductions through net-zero levers; maximising energy efficiency, electrifying production with low-carbon electricity, using low-carbon fuels and investing in carbon capture & storage

To meet the circular and net-zero objectives of the EU Green Deal, impactful measures are needed. Measures imposed to promote reuse and circular business models would improve materials utilisation, lowering the demand for new plastic products, mainly in single use applications, thus cutting production-related CO2 emissions by 36 Mt. Moreover, shifting towards a more circular feedstock will provide a strong tailwind for the plastics system to minimise Scope 3 upstream emissions (fewer fossil-based plastics, and biogenic carbon captured in biomass-based and CCU-based plastics) and Scope 3 downstream emissions (less incineration of plastic waste). Overall, circular plastics (excluding reuse) are projected to reduce total projected annual carbon emissions by 129 Mt (55%) compared to the baseline volume, through circular and Scope 3 reductions due to avoided waste incineration.

The scope 1 and 2 CO2e emissions that remain after reuse and the circular shift may be reduced through: energy efficiency measures, transitioning from fossil to renewable and low-carbon fuels, electrifying production processes, and utilising CCS. The analytical model projects that, together, these four levers could reduce emissions by 55 Mt. Some of the technologies required to reduce emissions within the industry are currently in the research and development stage, but are expected to scale-up in the next decades. Fewer emissions from converters can reduce downstream emissions by an estimated 14 Mt CO2e.

Chapter 5 will elaborate further on the levers being implemented by the producers, and the enabling conditions required for the net-zero pillar of the vision.

1 GHG emission reductions are calculated based on the estimated volumes of converter use.

3.3 Sustainable use of plastics

Plastics are needed in applications critical for Europe's future, but can only fulfil their role effectively if societal concerns are properly addressed. There are concerns from the public regarding potential health and environmental risks from daily exposure to plastics and the chemicals they may contain. Fostering sustainable use is instrumental for achieving wide acknowledgement of plastics as a future-proof material.

Figure 18: Levers and actions to foster sustainable use of plastics

Lever	Actions to foster the sustainable use of plastics
Managing risks in operations	**Assure the safety of plastics additives.** Determine minimum requirements and disclosure rules for third-party verified, additive-risk management schemes by 2025.
	Prevent pellet loss in production. Ensure all Plastics Europe members comply with Operation Clean Sweep® (OCS) requirements, including third-party verification, by 2025, and motivate supply chain partners to do the same.
Providing further transparency towards stakeholders	**Harness tools to disclose and share information across the value chain.** Proactively envision the role and support the development of the Digital Product Passport (DPP) and other tools or labels to share circular, net-zero and sustainable use data in the value chain.
	Communicate proactively and contribute to the public debate with scientific insights. Plastics Europe will continue to be a constructive partner for dialogue and a reliable data-provider by leveraging reports such as 'Plastics - the Facts' and periodic monitoring of roadmap indicators.
Collaborating in the value chain to accelerate change	**Help overcome knowledge gaps and reduce leakage across the value chain.** Work with research institutes to improve the knowledge base on microplastics e.g. BRIGID project, and support value chain partnerships to accelerate change e.g. European Tire and Road Wear Particles (TRWP) Platform, Circular Plastics Alliance (CPA), Alliance To End Plastic Waste (AEPW).

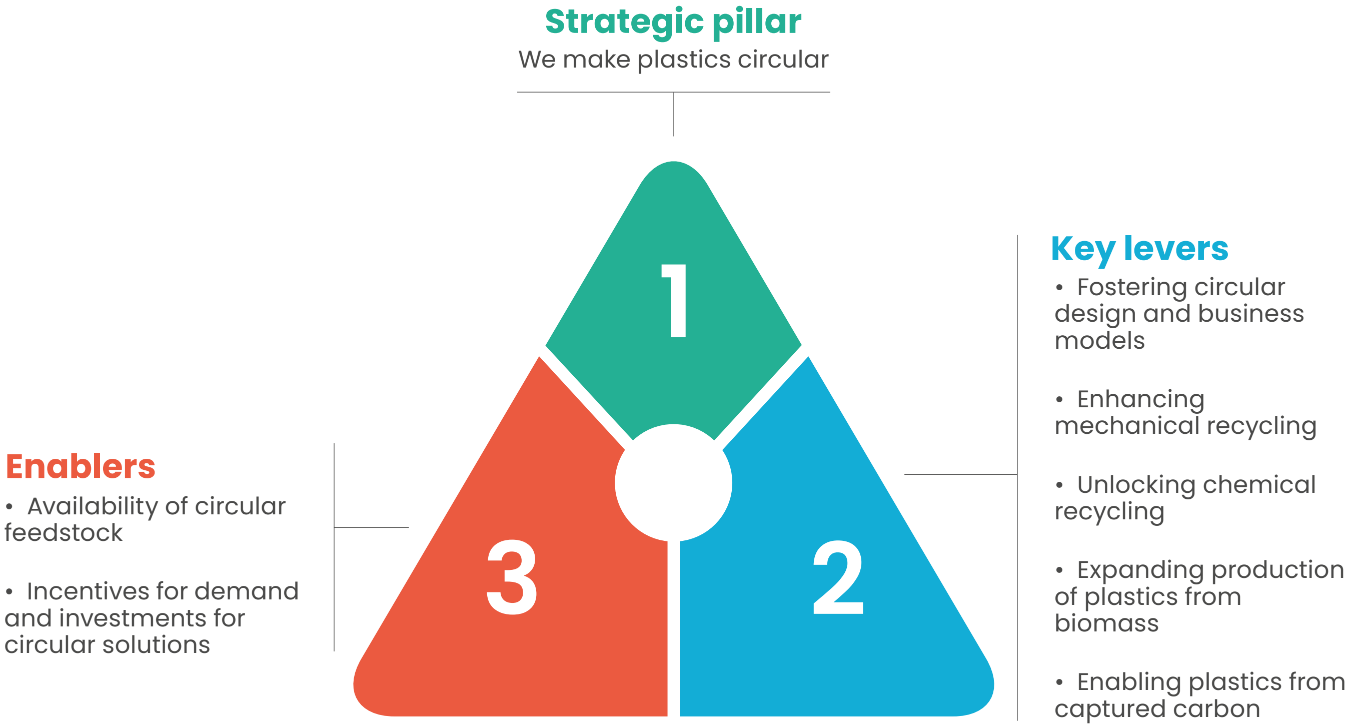
To foster sustainable use of plastics, producers are working on three levers (Figure 18). Chapter 6 provides more information about these and the actions needed.

Pillar 1: Making Plastics Circular

4

This chapter discusses the levers being used by the industry and the enabling conditions (including the supportive regulatory framework) to pursue the strategic pillar on circularity (Figure 19).

Figure 19: The levers and enablers to achieve the circular pillar



4.1 Key levers for action by the industry

Plastics producers are developing new circular approaches relating to reuse of products, product design and business models. Other levers include producing plastics from recycled material, from biomass, and from captured carbon combined with low-carbon hydrogen.

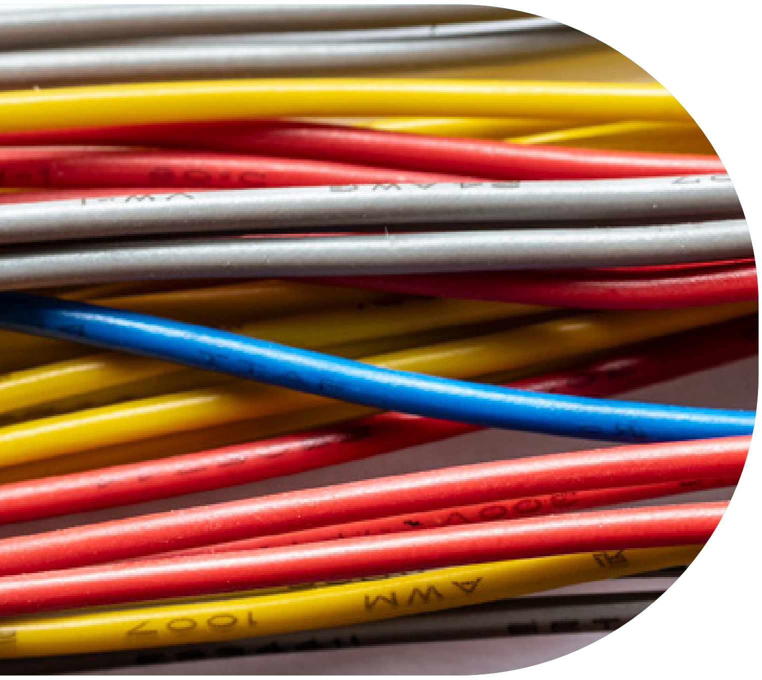
4.1.1 Fostering circular design and business models

Since the quantity of materials drives many of the environmental effects, policymakers from Europe and beyond are looking for ways to restrain the global growth of materials' consumption (PBL 2021, EEA 2021, Circle Economy 2023). This could significantly reduce plastics production for single-use applications, including packaging. It also holds opportunities for companies in the plastics industry because reuse systems and other circular business models generate new revenue streams, and often require the light weight and durability benefits of plastics.

The impact of reuse systems will differ per sector. The added value and largest business opportunities are expected where environmental benefits are the largest, for example as alternatives for single-use products and packaging. Sharing economy opportunities in the automotive sector are also considered significant, while the gains in construction would be limited (Reshaping Plastics, 2021). The projections assume the following reductions of plastics converter use in 2050 due to the uptake of reuse (see also the Annex):

- 9 Mt of plastic packaging (household and industrial packaging)
- 0.9 Mt in automotive applications
- 0.8 Mt in household goods
- 0.2 Mt in building and construction
- 0.7 Mt in electrical and electronics
- 0.1 Mt in agriculture

Plastics producers are fostering this trend by bringing innovative plastics to the market that facilitate reuse and recycling. They are also setting up new partnerships and business models to tap further into the potential of the circular economy and facilitate Design for Recycling/Circularity. The following business example[1] illustrates the activities of the industry.



UPSYDE

A joint venture of Braskem and Terra Circular, is committed to making a tangible impact by upcycling mixed and hard-to-recycle plastic waste. Upsyde focuses on developing and manufacturing various reusable products - including pallets, road plates and heavy duty mats – moving the needle towards a circular economy where reusable products are made with plastic waste. This initiative supports Braskem's 2030 targets, which includes diverting 1.5 Mt of plastic waste from incineration, landfills, and the environment. With an existing installed capacity of over 20 Kt per year, Upsyde plans to further expand its operations, leveraging its patented smart upcycling technology to contribute to a sustainable future.

4.1.2 Enhancing mechanical recycling

Mechanical recycling of plastic waste (sorting, grinding, washing, cleaning and reprocessing; or dissolution of the polymer and reprocessing) has a high technological maturity in several polymers and applications. It represents the majority of the recycling capacity in Europe, with 5.3 Mt of post-consumer recycled plastics converted in 2021 (Deloitte analysis, 2023). Mechanical recycling will remain the preferred recycling solution for many waste streams, as the technology is cost- and energy-efficient.

Figure 16 puts forward an ambitious projection of 8.6 Mt of mechanically recycled plastics converted by 2030. This steady growth (5.5% CAGR) reflects the technology's maturity and therefore the potential to further scale it up in the short term. Between 2030 and 2050, mechanical recycling could keep growing in the same linear way in industries where it is already common practice, reaching 15.3 Mt (CAGR of 3%).

1 https://www.upsyderecycling.com/
https://www.braskem.com/news-detail/braskem-announces-new-commitments-to-sustainable-development
https://www.braskem.com/wenew/news-detail/braskem-and-terra-circular-launch-upsyde-a-company-focused-on-converting-difficult-to-recycle-plastic-waste-using-a-patented-technology

The projected growth of mechanical recycling will need:

- stricter regulations ensuring the availability of high-quality waste,
- as improved collection and sorting will highly impact recycling;
- advancements in technology such as AI-improved sorting;
- and incentives to increase demand for recycled plastic products in Europe (see 4.2).

Members of Plastics Europe are innovating and developing solutions to enhance mechanical recycling, as illustrated by the following business examples[2].

BOREALIS

Borealis continues to invest in the expansion of its advanced mechanical recycling capabilities by building a commercial-scale plant in Schwechat, Austria. The plant will operate based on Borealis' Borcycle™ M technology, capable of transforming polyolefin-based post-consumer waste into high-performance polymers suitable for demanding applications. The technology was tested in a demonstration plant Borealis operates together with Tomra and Zimmerman, showing successful value chain cooperation for circularity. Mechanical recycling plays a major role in Borealis' strategic approach to achieving circularity. From 2025 onwards, the plant will contribute 60 Kt of advanced mechanical recycled polyolefin solutions per year, contributing to Borealis' circularity targets of supplying a capacity of 600 Kt of circular productions and solutions by 2025 and 1.8 Mt by 2030.

SOLVAY

Solvay recently teamed up with French start-up Ostium to enable the mechanical recycling of single-use surgical instruments manufactured in its specialty polymers portfolio. This collaboration is pioneering the recycling and upcycling of valuable polymers from used healthcare devices. Solvay has proven it is possible to recycle and upcycle the polymer material and is now developing a way to ensure consistently high recycling standards, which involves controlling every step in the life cycle of its materials. The recycled product could be used in high-end markets such as automotive, and sports and leisure equipment, thus integrating end-of-life surgical instruments into an open loop circular ecosystem.

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2 https://www.borealisgroup.com/news/borealis-advances-plastics-circularity-with-the-first-of-its-kind-borcycle-m-commercial-scale-advanced-mechanical-recycling-plant
https://www.solvay.com/en/press-release/solvay-partners-french-start-ostium-single-use-surgical-instruments-material
https://investor.trinseo.com/home/news/news-details/2022/Trinseo-Completes-Acquisition-of-Heathland-B.V/default.aspx
https://www.ineos.com/businesses/ineos-styrolution/news/ineos-styrolution-and-coexpan-claim-food-contact-standards-across-all-dairy-formats-using-100-mechanically-recycled-polystyrene/
https://www.prnewswire.com/news-releases/styrenics-circular-solutions-seeks-further-efsa-opinion-confirming-the-safety-of-mechanically-recycled-polystyrene-as-food-contact-material-301476681.html

HEATHLAND

The acquisition of recycler Heathland B.V. in January 2022 by Trinseo served as an important milestone in its strategic positioning within the market and enhances its footprint as a sustainable solutions provider. As a plastic waste collector and recycler based in Utrecht, the Netherlands, Heathland is focused on converting PCR and PIR polymethyl methacrylate (PMMA), polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polystyrene (PS) and other thermoplastic waste. The company collects, pre-treats and processes plastic waste materials using mechanical and chemical recycling processes, and captures the materials' maximum value by transforming them into high quality recycled raw materials for a wide range of high-end applications.

INEOS STYROLUTION

INEOS Styrolution aims at meeting food contact standards for mechanically recycled polystyrene. Together with technology partners, the company develops a super-clean process that produces polystyrene tested to food contact standards. Coexpan, a plastics converter that is part of the project, shows that it reaches food contact standards across all dairy formats using 100% mechanically recycled polystyrene from INEOS Styrolution. Additionally, Styrenics Circular Solutions (SCS), a value chain initiative bringing plastics producers, converters and brand owners together, has filed two applications for EU authorisation of mechanically recycled polystyrene as food contact material to be assessed by the European Food Safety Authority (EFSA).

4.1.3 Unlocking chemical recycling

Despite the advantages of mechanically recycled plastics, their suitability for many high-end uses is limited, and after many cycles the plastics' quality is degraded. In case of plastic packaging, molecules from packaged goods can contaminate the polymer matrix via migration or diffusion, causing issues with odours, colours or other quality aspects. Such contaminants can originate from food or detergents, but also from a wide range of other products. Because mechanical recycling is not able to clean the polymers at the chemical level, polymers often end up being downcycled. Moreover, thermoplastic polymers are mixed with additives that protect against thermal degradation during fabrication, improve characteristics such as anti-static or UV-resistance, or add essential packaging functionalities. At the waste stage, the exact mixture of additives captured in the polymer matrix is not known. Also, polymers may degrade during the use-stage due to heat, UV-light and other factors, even when additives are used. For example, the molecular weight of polyethylene (PE) tends to increase, while its molecular weight distribution broadens and may in extreme cases even make crosslinks that form gels. Conversely, the molecular weight of polypropylene (PP) tends to decrease during use, and the molecular weight distribution becomes more narrow. In the long term, these effects reduce the quality of the plastics. Mechanical recycling technologies alone cannot resolve these issues.

Chemical recycling thus complements mechanical recycling. It produces premium-quality plastics and provides an effective solution for difficult-to-recycle plastic waste, and for applications such as food-contact packaging or medical use (Material Economics, 2019) (Plastics Europe 2022). A recent JRC study further highlights that chemical recycling can reduce GHG emissions for plastic waste that is not being mechanically recycled (GARCIA-GUTIERREZ, et al., 2023).

Chemical recycling technologies (pyrolysis, depolymerisation, gasification, etc.) are under development and still in the early stages of commercialisation. In 2021 only a limited quantity of chemically-recycled plastics was converted.

But **several members of Plastics Europe have publicly announced strong investment plans (€8 billion by 2030) in pilot plants and scale-ups** (see business examples[1]).

The ambition set forward in Figure 16 is to reach 3.4 Mt of chemically recycled plastics by 2030. Moreover, once the enabling regulatory, technical and economic conditions are met, the technology can be rapidly deployed and scaled. With high expected growth rates, the analytical model projects that chemical recycling capacity could double each decade starting in 2030, reaching 12.4 Mt in 2050 (through a CAGR of 7%).

DOW

In July 2022 Dow and Mura Technology announced their joint commitment to scale the chemical recycling of plastics. The two corporations plan to build multiple 120 Kt facilities in Europe and other regions - collectively adding as much as 600 Kt of aggregate chemical recycling capacity by 2030.
Dow's role in the partnership is to become a key off-taker of circular feedstock that Mura produces. This circular feedstock, derived from plastic waste currently destined for landfill or incineration, reduces reliance on fossil-based feedstocks and will enable Dow to produce a recycled plastic feedstock for the development of new, virgin-grade plastics which are in high demand from global brands.
By using chemical recycling as a complementary technology to mechanical recycling, Dow is making significant progress towards its sustainability, climate and plastic waste reduction targets.

LYONDELLBASELL

LyondellBasell announced in 2022 a new Circular and Low Carbon Solutions business to deliver on its ambition to produce and market at least 2 Mt of recycled and renewable-based polymers annually by 2030. This would represent approximately 20% of its global PE and PP sales in 2022. The company developed the first commercial scale, single-train advanced recycling plant using LyondellBasell's proprietary technology based in Germany. Additionally, it produced and marketed 175 Kt of recycled and renewable-based polymers since 2019 and is growing its mechanical recycling and sorting footprint globally with partners to increase and secure access to feedstock.

1 https://corporate.dow.com/en-us/news/press-releases/dow-and-mura-technology-announce-largest-commitment-of-its-kind-.html
https://www.lyondellbasell.com/499604/globalassets/investors/bond-information/lyb-green-financing-spo.pdf
https://www.lyondellbasell.com/en/news-events/products--technology-news/lyondellbasell-makes-decision-to-progress-advanced-recycling-plant-in-wesseling-germany/
https://www.lyondellbasell.com/en/news-events/corporate--financial-news/lyondellbasell-details-accelerated-momentum-in-2022-sustainability-report/
https://www.repsol.com/en/sustainability/circular-economy/our-projects/chemical-recycling-of-polyurethane-foam/index.cshtml
https://www.shell.com/business-customers/chemicals/media-releases/2021-media-releases/shell-invests-in-plastic-waste-to-chemicals-technology-company-bluealp.html
https://versalis.eni.com/en-IT/news/press-release/2020/versalis-nasce-hoop-il-riciclo-chimico-verso-una-plastica-infinitamente-reciclabile.html
https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/chemcycling.html
https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy.html

REPSOL

Repsol is building the first polyurethane foam chemical recycling plant in Spain to help its customers meet their sustainability objectives and respond to the growing need to recycle and extend the useful life of its products. The new plant, expected to be 100% operational by September 2023, will involve a €12 million investment. The plant will be capable of processing around 2 Kt of polyurethane foam waste per year, equivalent to 200,000 mattresses. This will become the polyurethane foam's raw material for new mattresses and furniture, closing these essential products' recycling circle. The new plant is to be integrated into Repsol's Puertollano complex to ensure this circular product's quality by maximising synergies with the facility's standard processes.

SHELL

In Europe, Shell and BlueAlp signed a strategic partnership to develop, scale and deploy BlueAlp's plastic waste to chemical feedstock technology. The technology, often referred to as chemical recycling, transforms plastic waste which is tough to recycle into a recycled feedstock (i.e. pyrolysis oil) that can be used to make sustainable chemicals. Shell and BueAlp are to build two pyrolysis units with the combined capacity to process approximately 30Kt of tough-to-recycle plastic waste. The two units are expected to be operational in 2025 and Shell will use one 100% of the pyrolysis oil at its chemical plants in the Netherlands. As part of the agreement Shell has taken a 21% equity stake in BlueAlp, an investment that will help reach the company's ambitions.

VERSALIS

Hoop® is Versalis' project to develop a new technology for the chemical recycling of plastic waste.
The initiative was launched in 2020 through a joint development agreement with the Italian engineering company Servizi di Ricerche e Sviluppo (S.R.S), owner of a proprietary pyrolysis technology.
This technology is being further developed to transform mechanically non-recyclable waste into raw material to produce polymers with the same technical characteristics as fossil-based ones. Versalis has planned to build an initial 6 Kt per year demonstration plant, with the objective of a subsequent progressive scale-up starting with plants in Italy.

BASF

ChemCycling® is BASF's chemical recycling business to manufacture high-performance products from chemically recycled plastic waste on an industrial scale. BASF cooperates with technology partners that use pyrolysis to transform plastic waste into pyrolysis oil. This oil is fed into BASF's production network (Verbund) at the beginning of the value chain, preserving fossil resources. The recycled material share in Verbund-manufactured products is attributed through a third-party audited mass balance approach. BASF's portfolio includes over 200 Ccycled® products for applications e.g. in automotive, functional textiles or packaging.
By 2030 BASF aims to double its circular economy solutions sales to €17 billion, achieved through developing products from renewable or recycled materials, employing the mass balance approach, increasing resource efficiency, extending material lifespan and improving mechanical recycling through plastic additives.

4.1.4 Increasing plastics production from biomass

Plastics made from biomass can significantly reduce GHG. In applications with long life cycle they can even serve as a form of carbon storage.

Biomass used as feedstock for plastics production can come from first-generation plants (sugarcane, cereal crops, wood grown specifically for that purpose), or from second-generation organic waste and residues (used cooking oil, bagasse, tall oil or other). The plastics can be made from biomass in segregated and dedicated production processes (bio-based plastics). Or it can be made in existing interlinked production systems processing biomass together with fossil-based feedstock (labelled mass balance 'bio-attributed' plastics). By sourcing the biomass sustainably, negative environmental impacts (deforestation, biodiversity loss, water scarcity, indirect land-use change) can be avoided (European Commission, 2022) (Plastics Europe, 2022).

Although biomass can be used for many applications, there will not be enough to cover all future needs. The European Commission (2022) predicts a gap of 40- 70% by 2050 between the supply and demand for biomass for food, materials and energy in Europe. Hurdles preventing biomass plastics competition include fuel incentive policies (issued by the recent revision of the Energy Taxation Directive) which push biomass more towards biofuel production (European Commission, 2021). But there are also policies that may change the balance in favour of materials applications. For example, in the EU's forest strategy for 2030, the European Commission (2022) proposed integrating the 'cascading principle of biomass use' into European and national support schemes. This would prioritise using biomass for materials (including plastics) above energy generation.

Currently, plastics production from biomass only represents 2% of plastics converter use, with 1.3 Mt produced in 2021 (Plastics Europe, 2022). This limited adoption is due to current high costs and other barriers, including no standardised sustainability assessment tools[1], regulations, labels or certification criteria (European Commission, 2022). With appropriate economic incentives and regulatory frameworks, plastics from biomass used by converters could approximately double every decade: to 2.7 Mt by 2030 (CAGR of 8,5%) and 11.4 Mt by 2050 (7,5% CAGR). Acknowledging the challenge of foreseeing long-term technological trends, the plastics made from biomass are modelled as evenly split into bio-based and bio-attributed plastics, with first- and second-generation biomass each used for 50% of biomass sourced[2]. Several members of Plastics Europe are investing in Europe and beyond to scale up sustainably-sourced plastics from biomass in line with the vision as illustrated by the business examples[3].

1 Assessments as well as methods to assess the sustainability of biomass treatments are diverse. Consequently, the results of LCA and carbon footprint approaches (ISO 14067, EN15804, etc.) diverge. Standardising the accounting and allocation along the value chain of the biogenic carbon and CO2 disposal footprint would objectivise the analysis.

2 The evolution towards 2050 of the shares used of bio-based and bio-attributed plastics, as well as first and generation biomass, will heavily depend on policies taken.

3 https://www.braskem.com/europe/news-detail/braskem-invests-in-capacity-expansion-and-partnerships-for-the-production-of-biobased-plastics
https://www.braskem.com.br/news-detail/braskem-affirms-commitment-to-circular-economy-and-to-achieve-carbon-neutrality-by-2050
https://www.novamont.com/public/Bilancio%20di%20sostenibilit%C3%A0/Novamont_Sustainability%20Report%202021%20(NFS).pdf
https://lamede.totalenergies.fr/nos-activites-futures/la-bio-raffinerie
https://totalenergies.com/expertise-energies/projets/bioenergies/grandpuits-biofuels-bioplastics

BRASKEM

Braskem, a pioneer in the production of bio-based plastics, has tapped into the growing demand for renewable polymers from biomass. As part of its international product portfolio, Braskem has focused on the production of green polyethylene and EVA using ethanol from sustainably sourced sugarcane as a feedstock, producing over 200 Kt per year of plastics from biomass. To create sustainable solutions from sugarcane, Braskem is utilising the existing ethanol industry and repurposing degraded pasture land for sugarcane production, precluding both deforestation and the depletion of available arable land. Furthermore, Braskem has recently announced a target to annually produce 1 Mt of polymers from biomass by 2030, and is committed to further scaling up technologies for sustainably sourced plastics from biomass.

NOVAMONT

With a current production capacity of about 200 Kt per year, Novamont produced bioplastic with a bio-based content of around 40% and more. These materials are obtained by pioneering technologies using feedstock such as starches, cellulose and vegetable oils. Novamont currently rolled out these technologies in Italy in at least 3 production facilities.

TOTALENERGIES

As part of its ambition to produce 30% circular polymers by 2030, TotalEnergies is developing products obtained from non-fossil feedstock such as bio-feedstocks. Bio-based renewable naphtha will be produced from animal fats from Europe and used cooking oil, supplemented with other vegetable oils like rapeseed (but excluding palm oil). Up to 50 Kt of renewable naphtha can be produced in the bio-refinery of La Mède, France, for production of bio-certified PE/PP/PS. From 2024 onwards, 50 additional Kt will be available from the Grandpuits bio-refinery in France.

4.1.5 Enabling plastics made from captured carbon

The upscaling of carbon capture & storage (CCS)[1] will lead to large amounts of available captured carbon. Scientists are stepping up efforts to find new uses for this stream. A promising pathway towards carbon capture & utilisation (CCU)[2] is combining captured CO2 from industry with low-carbon hydrogen (green, blue or pink hydrogen) to produce methanol. Green hydrogen is made exclusively from renewable energy, blue hydrogen is made from natural gas with use of CCS, while pink hydrogen is generated through electrolysis powered by nuclear energy. In contrast, grey hydrogen is made from natural gas without any use of CCS. Currently, 96% of the hydrogen used in the EU is grey hydrogen, and one of the main challenges of low-carbon hydrogen is its current elevated cost. However, as hydrogen production scales up in Europe and import routes are explored, the price of low-carbon hydrogen is expected to become more cost-competitive. Methanol formed with captured carbon and low-carbon hydrogen can be converted into polymers through the methanol-to-olefins (MTO) process. Materials produced this way result in 90% fewer CO_2 emissions than those produced through the conventional fossil-based route (European Commission, 2018).

These **innovative CCU technologies show promise, but they are still in the early stages of development.** The infrastructure to capture, transport and produce the feedstock for the plastics still needs to be built, and current price levels must come down. As research in the area continues and investments bring production up to commercial scale, it is expected that carbon capture and hydrogen-based plastics will only account for 0.1 Mt in 2030, but then grow seven-fold to 0.7 Mt by 2040, and further scale up five-fold to 3.2 Mt by 2050. This is an overall modest but significant contribution to the strategic pillar of 65% circular plastics in 2050. In line with this projection, **members of Plastics Europe are experimenting with these techniques to build expertise and identify business opportunities for growth** as highlighted in the following business examples[3].

1 Carbon capture and storage (CCS) entails capturing CO2 at the source, compressing it for transportation, and then injecting it into an underground rock formation (Global CCS Institute, 2023).

2 Carbon capture and utilisation (CCU) encompasses the capturing of CO2 to produce new products (Global CCS Institute, 2023).

3 https://www.rohm.com/news-detail?news-title=rohm-revises-its-greenhouse-gas-emission-reduction-targets-for-2030&defaultGroupId=false
https://dowcircles.nl/en/sustainability/steel2chemicals

RÖHM

Röhm has set ambitious goals to reduce and eliminate carbon emissions throughout its whole value chain. By 2030 Röhm aims to reduce its global Scope 1 and 2 carbon footprint by more than 50% compared to 2018. To achieve this target, Röhm will focus on 4 strategic pillars – one of them is to replace fossil raw materials with renewable or recycled raw materials. One flagship initiative for Röhm is to assemble a demonstration unit including capturing of CO2 and using it together with blue hydrogen for manufacturing of its feedstock methanol, effectively making carbon capture & utilisation technology a reality in plastics manufacturing.

DOW

In its Steel2Chemicals project, Dow is investigating the use of alternative raw materials for its chemicals production processes. The project started with a screening for synergies between different large companies' production units in the same region. One synergy that was identified and now actively pursued is synthesis gas, which combines carbon monoxide (CO) and hydrogen (H). Dow produces hydrogen in its site in Terneuzen, Belgium, and the nearby blast furnaces of ArcelorMittal produces significant amounts of carbon monoxide that is currently being burned. The two companies are preparing a collaboration and as such setting an example of industrial symbiosis in the service of the circular economy.

4.2 Enabling conditions and asks of policymakers and value chain partners

Members of Plastics Europe are fostering the transition towards circular plastics by harnessing the power of innovation, industrial expertise and investment power. But the vision can only be achieved by efforts and support from all stakeholders in the ecosystem.

Two critical enabling conditions for success are the availability of circular feedstock and the demand for circular solutions (Figure 20).

Figure 20: Enablers to achieve 65% circular plastics by 2050

INCREASE AVAILABILITY OF CIRCULAR FEEDSTOCK

- Availability of sorted plastic waste
- Availability of sustainably sourced biomass
- Availability of captured carbon and hydrogen at affordable prices

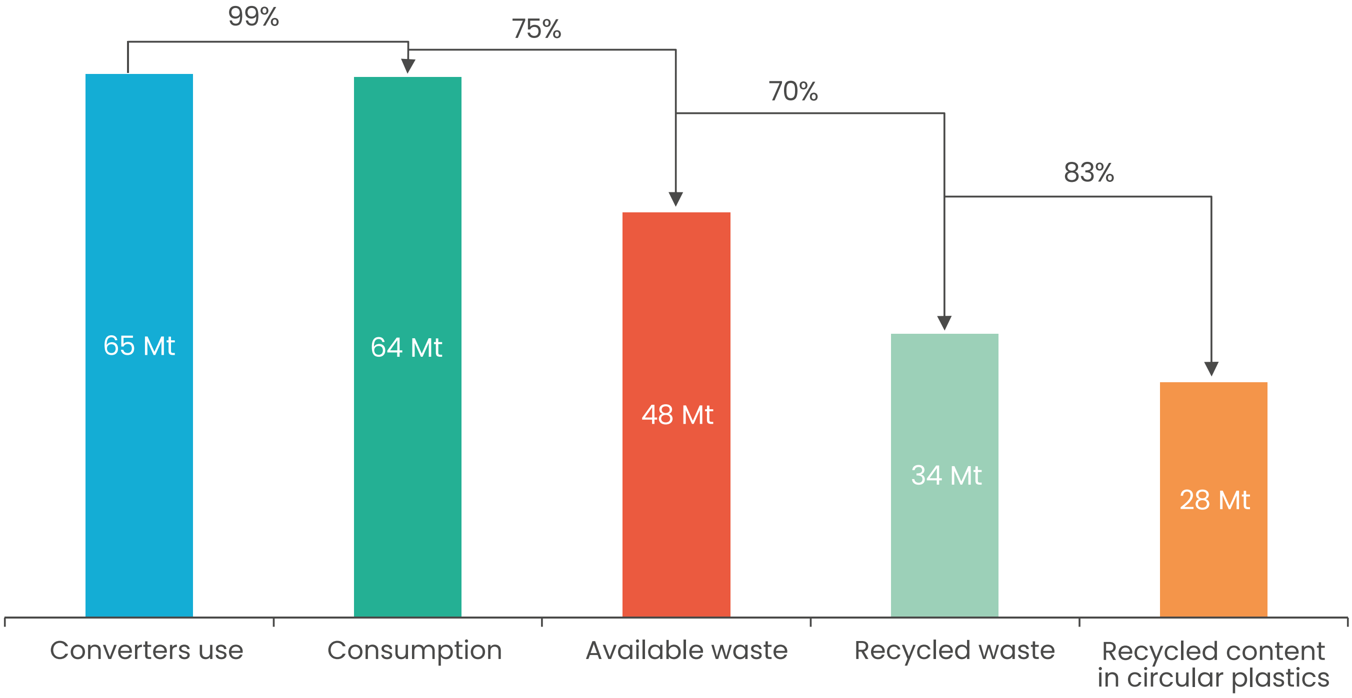
INCENTIVISE DEMAND AND INVESTMENT IN CIRCULAR SOLUTIONS

- Promote circular design and create a positive business case for circular plastics via Extended Producer responsibility (EPR), recycled content obligations and other policy instruments
- Support investments in circular production infrastructure financially and by permitting processes that have a reasonable timeframe and predictable conditions

4.2.1 Availability of sorted plastic waste

Figure 21 shows the projection for 2050 in which recycling waste can provide up to 28 Mt of recycled content, or around 40% of projected plastics use by converters.

Figure 21: Projected flow of recycled plastic waste
In Mt, 2050 estimates (Deloitte analysis, 2023)



Several elements drive the flow of recycled plastic waste and constrain the availability of circular plastics. The uncertainty around these elements is high, especially for the future:

Projected plastics converter use in 2050

Figure 16 presents the projections for 2050. Projected converter use is 64.5 Mt.

The assumed relation between converter use and consumption in 2050

The data displayed in Plastics Europe (2021) highlight that current converter use is slightly larger than consumption of plastics (factor 1.01). The model assumes that this factor stays constant over time even though changes in global trade patterns may affect it (see annex for an overview of the assumptions). This leads to 64 Mt of projected plastics consumption in 2050.

Estimated waste arising rate

The data presented in Plastics Europe (2022) imply that in 2021 the 'waste arising rate' (the identified waste flows divided by the amount of plastics consumed) represents around 55%. Due to the combination of growth and long life cycles for some applications (some construction applications are in use for more than 30 years), it is logical that the amount of plastic waste is lower than the demand for new plastics. However, in a market that grows annually by 1%, the average life cycle of a plastic product in the economy should be around 60 years to have a waste arising rate of 55%. Such a long average life cycle is highly unlikely, taking into account that packaging is the largest application of plastics (section 2.1) and has a short average life cycle below one year[1]. The identified streams of plastic waste are probably an underestimation of the real amounts. The 'missing plastics' can be partially explained by a combination of elements:

- Not all waste streams containing plastics have been identified.
- Europe exports packaging solutions and imports durable plastics (Plastics the Facts, 2021). This further increases the average life cycle of plastics in Europe and reduces the ratio between current waste generation and converter use.
- Used durable goods (such as cars and to a lesser extent electronics) are exported from Europe towards lower-income countries. For example, the United Nations Environment Programme reported that Europe exports yearly close to two million used vehicles. This logically reduces the amount of plastic waste generated and available for recycling in Europe (UNEP, 2020).

To deal with the 'missing plastics' issue, this roadmap assumes a waste arising rate of 75% an average of the ranges put forward by ReShaping Plastics (2022), Material Economics (2021), SystemIQ (2022) and OECD (2022a). Under the condition that the missing plastics can be identified and kept in Europe, the available waste in 2050 would relate to 48.1 Mt.

Recycling rate

The next element that drives recycled feedstock availability is the recycled fraction, i.e. the waste that is collected for recycling and that goes effectively to recycling processes. OECD (2022) and "Reshaping Plastics" (2022) both estimate that in an ambitious scenario, European recycling rates could rise to 70% in 2050, more than doubling the current average rate in the EU. Accordingly, the model underlying the projections assumes that the recycling rates (collected-for-recycling minus sorting losses) is 70% by 2050. This logic leads to 34 Mt of recycled plastic waste by 2050.

Process losses in recycling

A final driver for the amount of circular plastics that can be produced via recycling, concerns losses in the processing steps. Currently, around 1.8 tonnes of plastic waste are, on average, needed to produce 1 tonne of mechanically recycled plastic. However, thanks to technology improvements and development of more efficient solutions, that ratio is estimated to fall to 1.4 in 2050 (European Commission, Technical University of Denmark, 2021). Since chemical recycling technologies are still in the early stages of commercialisation and the competing technologies are diverse, projecting the efficiency rates requires averages and strong assumptions. The European Commission (2021) puts forward an average input of 1.3 tonnes of plastic waste to produce 1 tonne of chemically recycled plastic. Due to efficiency gains, this is estimated to improve by 2050 to 1.2 tonnes of needed input taking into account the fuels-exempt mass balance approach. As a final step, recycled content as feedstock for circular plastics is 28 Mt by 2050.

Not only the quantity but also the quality of the waste sent to recycling matters. One of the actions needed to remediate the current lack of high-quality

1 Geyer (2020) estimates a 10-year average life cycle of plastics applications.

waste is to foster 'design for recycling' (Material Economics, 2019) and limit where possible complex designs with hard to separate mixed materials (Plastics Recyclers Europe, PRE). Other required improvements include innovation in additives that upgrade the quality of recycled content.

Achieving such ambitious goals will require the combined efforts of many stakeholders. **Many members of Plastics Europe are taking initiatives and setting up partnerships to increase the supply of recyclable feedstock, but support is essential. More specifically, a sound regulatory framework will be needed to achieve the envisioned economy-wide change** (Table 1).

Table 1: Asks to policymakers for the availability of collected and sorted plastic waste

IMMEDIATE 2023 - 2025	**Incentivise investments in recycling infrastructure** Policymakers are asked to leverage and expand Extended Producer Responsibility (EPR) schemes and other policy instruments to increase and warrant the long-term financing of collection, sorting and recycling infrastructure with the aim to increase the quantity and quality of plastic waste collected for recycling.
	Phase out landfilling and incineration of recyclable plastic waste Policymakers are asked to phase in minimum landfill and incineration taxes on all waste streams containing plastics that steadily increase and go beyond €100 per tonne in 2030 to be effective in deviating recyclable waste from landfilling or incineration to recycling.
SHORT TERM 2026 - 2027	**Make shipping of sorted waste and recycled feedstock easier** Policymakers are requested to ensure fully harmonised implementation of the Waste Shipment Regulation (WSR) at national level – with digital tools, streamlined administrative procedures and predictable outcomes within a reasonable timeframe. This would foster intra-EU trade and increase the value of recyclable plastic waste as a secondary raw material destined for recycling, which should be covered by product legislation.
	Harmonise definitions and improve statistics for plastic waste management Policymakers are asked to make statistics on plastic waste management within and between EU countries more robust and comparable. This will improve understanding of the market and bottlenecks blocking more circularity, and will serve as a basis for smart regulation.
	Help the industry develop recyclable products Policymakers are asked to put forward clear definitions and practical methodologies (e.g. at CEN or ISO level), and to impose binding requirements to design products for the EU market (including imports) in such a way that they can be easily recycled and valorised as high-quality feedstock for the industry.

4.2.2 Availability of sustainably sourced biomass

Increasing the production of plastics from biomass is an important path to make plastics more circular, but it may also have important environmental impacts. As the type of feedstock and its cultivation conditions have diverging impacts on land use and productivity, projecting the biomass feedstock for plastics production 2050 will require averages and assumptions which strongly depend on biomass related policy measures (see annex for assumptions taken). The model is based on reference data for biomass needed for plastics production (EEA 2021), land use for biomass production (Deloitte analysis), and efficiency gains over time (Escobar and Britz 2021). It estimates a 50% split between first- and second-generation biomass, with a tonne of plastics generated from first-generation biomass requiring, on average, 1.3 tonnes of biomass or 0.15 ha of land (see appendix for assumptions). In line with the current situation, the model projects that 50% will be produced locally by 2050. Second-generation biomass is assumed to have no direct land use impact.

To pursue the mission, 5.7 Mt of plastics will have to be sourced by 2050 from first-generation biomass. This implies that by 2050, 8,749 km^2 or 0.28% of EU arable land would be needed, taking into account 50% of first-generation biomass will be sourced locally (Deloitte analysis, 2023). Creating a sustainable and resilient delivery system for biomass that can meet these expectations will require collaboration between stakeholders along the value chain. **Several members of Plastics Europe are partnering with biomass producers and co-investing in technological development, but also have several asks to policymakers** (Table 2).

Table 2: Asks to policymakers to support the use of sustainable biomass as feedstock

Term	Asks
SHORT TERM 2026 - 2027	**Make use of sustainably sourced biomass for production of plastics financially attractive** Policymakers are asked to set up incentive schemes that enhance the use of biomass for materials.
	Endorse the mass balance approach for bio-attributed plastics Policymakers are asked to legally endorse the mass balance approach allowing the attribution of biomass quantities in a multi-output process to plastics where demand for bio-attributed plastics is the highest.
	Endorse trustworthy certification systems and standards for the sustainable sourcing of biomass feedstocks Policymakers are called upon to create a legally binding framework with clear sustainability criteria and incentives for labels, and externally assured third-party certification systems to create a thriving European market for sustainably sourced biomass streams.
	Harmonise definitions, requirements and reporting for organic waste and by-products in the EU Policymakers are requested to develop a policy framework with clear definitions, requirements and reporting for biomass streams that can be used as feedstock for materials.
MEDIUM TERM 2028 - 2030	**Enhance the quality and quantity of collected biowaste suitable as feedstock for plastics** Policymakers are asked to incentivise biowaste sorting by households and enterprises for biomass streams that can serve as feedstock for plastics.

4.2.3 Availability of captured carbon and low-carbon hydrogen

In order to reach the aspired amount of 3.1 Mt of plastics produced using methanol from CO2, sufficient quantities of both captured carbon and low-carbon hydrogen need to be available. As 2.8 Mt of methanol are needed to produce approximately 1 Mt of polymers (Deloitte analysis, 2023), the need for methanol in 2050 can be estimated at 8.7 Mt. Current production volumes exist but are still far from this scale. For example, Carbon Recycling International, produces 0.1 Mt of methanol per year with geo-thermally produced green hydrogen as feedstock (Iceland) (SystemIQ, 2022). Upscaling these technologies will require time, research, investments and partnerships along the value chain. Members of Plastics Europe are collaborating with hydrogen and CCU actors and are negotiating long-term contracts to secure a stable and reliable supply of methanol from captured carbon, but they need support from policymakers to realise the ambition (Table 3).

Table 3: Asks to policymakers for the availability of captured carbon and hydrogen

Term	Ask
SHORT TERM 2026 - 2027	**Support research and development for CCU** Policymakers are asked to promote research and investment to scale up CCU for the production of plastics.
MEDIUM TERM 2028 - 2030	**Formalise the CO2 emission savings from CCU in regulation** Policymakers are asked to create a transparent legal framework harmonised across the EU market to calculate and validate the CO2 savings from CCU.
	Build industrial low-carbon hydrogen production and transportation capacity in Europe Policymakers are requested to plan and incentivise as a priority stream the required capacity for a green economy with low-carbon hydrogen feedstock for circular plastics.
	Standardise the regulatory framework for the transportation of CO2 within the EU Policymakers are asked to ensure that regulations for CO2 transport are workable and consistent across all EU countries to facilitate transport and optimise usage.

4.2.4 Demand for circular solutions

As the European plastics industry moves forward to make plastics more circular, **regulators also have a role in pulling demand for circular plastics and creating a positive business case for investments and new business models** (Table 4).

Regulatory measures and economic instruments – such as mandatory targets for reuse or recycled content, or more generally circular plastics content – effectively increase the demand for circular business offerings and plastics based on recycled, biomass or CCU sources. Moreover, such 'market-pull' rules can avoid downcycling of the recycled material (i.e. using recycled content in plastic applications with lower technical requirements). Other measures should include the revision of historic regulatory barriers that hold back recycled content in the medical sector or food industry.

Specifically for chemical recycling, a new legal and economic framework is needed that acknowledges the process as a high-value circular solution that can recycle plastic waste otherwise incinerated or sent to landfill, and that delivers recycled material with fossil-based plastic properties. **For chemical recycling technologies to be implemented successfully, the legal approval of the 'mass balance' approach, with appropriate attribution rules, is essential to scale up** (Ellen MacArthur Foundation, 2019). The accounting methodology of mass balance with credit is employed in the production of final plastics within established large-scale processes that utilise multiple inputs and outputs, with the primary purpose of attributing recycled content in the final products. Furthermore, it effectively measures the replaced fossil-based feedstock and facilitates the allocation of recycled feedstock to the economically compelling output product (in cases where a process generates multiple outputs), accurately reflecting market demand and the value assigned to recycled content.

In response to the lack of an existing framework, the European Commission recently established a set of rules to calculate the recycling rate of municipal waste in case of multi-output processes through mass balance (CARO, et al., 2023).

The acceptance of mass balance will play a key role in reaching the Single Use Plastics (SUP) Directive targets[1] and should be considered in the development of future rules to measure recycled content and set minimum recycled plastics content targets.

Table 4: Asks to policymakers to increase the demand for circular solutions

IMMEDIATE 2023 - 2025	**Define mandatory minimum circular plastic content targets** Policymakers are requested to develop minimum circular plastic content targets for key plastics applications in the European market to create a market pull for circular plastics.
	Legally recognise the mass balance approach for chemical recycling[2] Policymakers are asked to approve and formalise in regulations the mass balance with credit approach (with fuel-use exempt attribution rule). It allows the attribution of recycled quantities (in a process with multiple inputs and outputs) to those where there is a market demand for recycled content, deducting output used as fuels.
	Have evidence-based and material-agnostic view on prevention Policymakers are asked to focus on preventing excessive use of materials at the level of applications rather than the choice of material. It is crucial to base decisions on scientific life cycle assessment principles, comprehensively evaluating all revenant factors, to avoid unjustified material substitutions.
SHORT TERM 2026 - 2027	**Leverage public procurement** Policymakers are requested to leverage the large public procurement footprint to make circularity a priority for products and services offered in the market.
MEDIUM TERM 2028 - 2030	**Increase citizens' awareness** Policymakers are asked to communicate widely about the need for more circularity, and further incorporate circularity in all educational curricula.

1 25% of recycled content in PET beverage bottles from 2025, and 30% in all plastic beverage bottles from 2030.

2 As this policy is currently under debate (May 2023), the ask is subject to change in the next months.

4.2.5 Infrastructure to produce circular plastics

To produce circular plastic products, the recycling and production infrastructure needs to be in place. Table 5 builds on the data presented in Figure 16, with cost estimations and assumptions on learning effects (see annex for assumptions) to calculate the cumulative system cost across the plastics life cycle: from feedstock cost through circular and fossil-based plastics production, to conversion, waste transport and treatment. The projected costs are highly uncertain, take rough averages across polymers, and should be interpreted with care. Moreover, the projected costs may underestimate recent cost increases induced by the current macro-economic context.

Table 5 has three scenarios for 2050:

- The baseline scenario with 35% conservative growth of converter use
- An intermediate reuse scenario that only takes reuse measures into account to restrain growth to 13%
- The circular plastics scenario that includes reuse, i.e. 13% growth, and increases the fraction of circular plastics to 65%

Reuse is a powerful measure, and in the intermediate scenario above is projected to reduce CAPEX by 13% (from €751 billion to €670 billion) compared to the baseline scenario and OPEX by 11% (€2,541 billion to €2,289 billion). Reuse is driven by regulation and new business models, for which costs are spread throughout society and probably relatively low compared to investments in production infrastructure. As no costs have been integrated in the model for reuse, the gains are overestimated, but probably still represent a relevant order of magnitude for the analysis.

Table 5: System cost estimations for circular investments (cumulative investment excl. net-zero infrastructure)[1] (Deloitte analysis based on Reshaping Plastics, 2022)

Projections for 2050[2] Cumulative investment	**Baseline Scenario**	**Intermediate reuse scenario**	**Circular plastics including reuse**
CAPEX	**€751 billion**	**€670 billion**	**€726 billion**
Fossil-based production	€674 billion	€593 billion	€355 billion
Mechanical recycling	€55 billion	€55 billion	€123 billion
Chemical recycling	€3 billion	€3 billion	€122 billion
Plastics made from biomass	€19 billion	€19 billion	€94 billion
Plastics from captured carbon and hydrogen	-	-	€32 billion
OPEX	**€2,541 billion**	**€2,289 billion**	**€2,306 billion**
Fossil production	€2,305 billion	€2,053 billion	€1,309 billion
Mechanical recycling	€143 billion	€143 billion	€290 billion
Chemical recycling	€9 billion	€9 billion	€279 billion
Plastics made from biomass	€84 billion	€84 billion	€340 billion
Plastics from captured carbon and hydrogen	-	-	€88 billion

1 All stated financial data are expressed in real values. To represent the exceptional price increases in materials, staffing and other costs in 2021-2022, a one-off inflation factor has been applied on all financial values, see appendix for financial assumptions.

2 The CAPEX related to fossil-based assets supporting the flow of bio-attributed and chemical recycled feedstock is taken into account in the respective circular technologies.

Even when taking into account the benefits of reuse, **the investments in the circular plastics scenario will be important and high-risk**. The cumulated capex needed to build circular production infrastructure over the next three decades is estimated at €726 billion. This is €25 billion of CAPEX lower than the societal investments projected in the baseline scenario, highlighting that **investments will need to be shifted from established business cases to new ones** and repurposed, **but in the long term are not necessarily higher for society**. The OPEX costs in the Circular scenario confirm this observation. Cumulated OPEX by 2050 is €220 billion (9%) lower in the circular scenario than in the baseline. Importantly, the costs presented for the circular scenario do not yet include the costs to make the life cycle of plastics net-zero (see 5.2.3).

Figure 22: OPEX evolution of production technologies (monomer production, polymerisation, conversion)
In € per tonne produced, 2021-2050 estimates (Deloitte analysis)

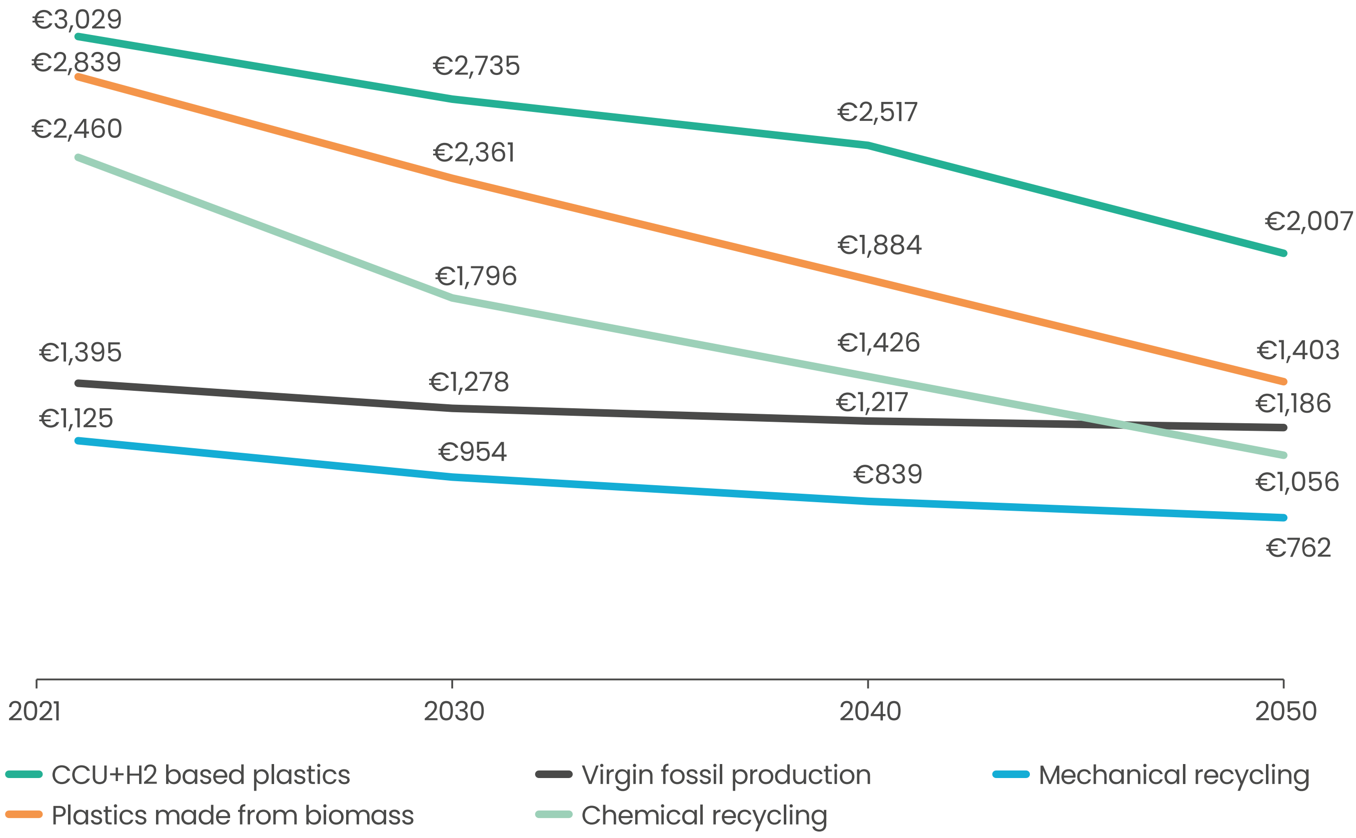


Figure 22 depicts indicative operational costs per tonne of circular and fossil-based plastics. These projected costs are highly uncertain, take rough averages across polymers, and should be interpreted with care. A cost reduction is applied to the operational costs through time, to reflect process optimisation due to increased experience[1].

Notably, the OPEX of mechanical recycling is already 19% lower than fossil-based production, with a steady expected decline of 35% by 2050. This cost is, however, only representative for streams that are well sorted and suitable for mechanical recycling. The operational costs of chemical recycling and plastics made from biomass are expected to become cost competitive with fossil-based production by 2050. CCU combined with low-carbon hydrogen will remain the most expensive technology

1 The model applies the 'experience curve' that assumes a consistent relationship between the cumulative production quantity of a product/technology and the cost of production, i.e. the more experience is gained in manufacturing a product, the lower its cost of production.

in 2050, but its cost is expected to further decline beyond 2050. Overall, benefits of scale and learning effects lead to cost efficiency improvements in circular production technologies, making them cost competitive with fossil-based production by 2050. This however requires significant short-term investments in a globally competitive market, flagging the need for policy support in transforming the European industry and infrastructure in line with the circular pillar of the vision (Table 6).

To facilitate the construction of state-of-the-art installations, permit processes should be streamlined to increase efficiency and reduce administrative burden. For example, one of the key causes of delay in renewable energy production is the long permit process. It can take up to 10 years to build a wind energy project. This has led to a situation in which four-times more wind capacity is blocked in permitting delays than is under construction in Europe (Dosanjh et al. 2023). This is clearly deflating the momentum around renewable energy production and slowing down the European transition to net-zero in 2050. For circular plastics investments as well, permit processes should be streamlined and digitised so companies can build new infrastructure within a reasonable timeframe and predictable conditions.

Table 6: Asks to policymakers related to the infrastructure for circular plastics

IMMEDIATE **2023 - 2025**	**Provide funding that makes circular plastics production in Europe competitive and speeds up the circular transition** Policymakers are requested to closely monitor the competitive handicap of the European industry compared to other regional blocks, provide funding and other incentives to compensate for this disadvantage, and speed up circular investments in recycling and plastics from biomass and captured carbon.
	Speed up permit processes for circular infrastructure Policymakers are asked to improve the efficiency of permit processes. This can be done by, among other things, digitalisation and/or automation, and having a clear communication framework, more resources, and specific time frames for permits.

4.3 Circularity indicators

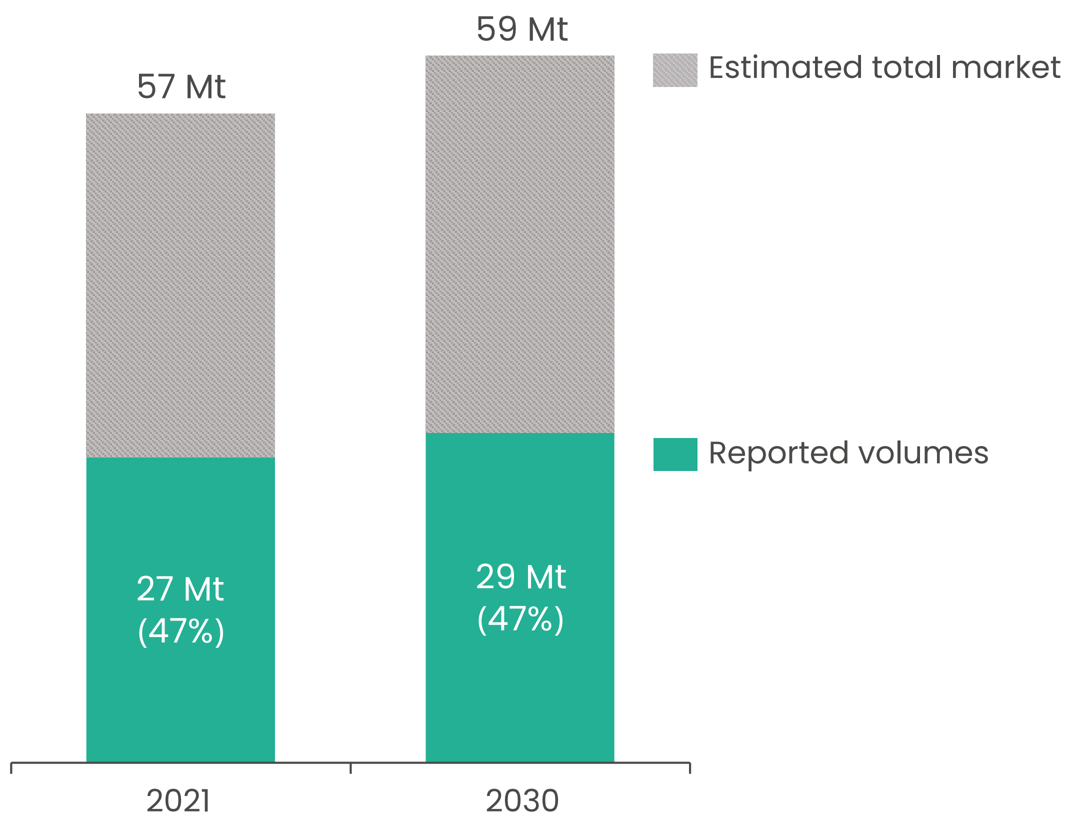
A roadmap requires checkpoints to monitor progress, identify bottlenecks and find solutions to keep pursuing the vision.

During development of the roadmap, **a survey gathered key data from more than 25 members of Plastics Europe, representing almost half of the estimated market in the EU** 27+3, about their current states and expectations related to the production of plastics. As members differ in many aspects, the aggregated results of the survey should be interpreted with care.

Production is closely related to converter use, but can diverge due to imports and exports before conversion. European plastics production in 2021 of 57.2 Mt (Plastics Europe 2022) is almost the same as the converter use of 56.9 Mt represented in sections 2.1 and 3.1. For the sake of traceability, the model assumes that this close relation remains unchanged in the coming years, although trade patterns and global competition may have an important impact.

Figure 23 shows that the survey participants among Plastics Europe members represent close to half of the plastics production market in Europe. It reflects a high participation rate, but caution is needed when extrapolating these results to the whole plastics industry, because the participants likely represent the most ambitious companies in the market. Importantly, recycled content from mechanical recycling is only mixed with fossil-based plastics at the compounding or conversion stage, an activity that few resins producers participate in directly, meaning that those circular plastics will not be captured in this survey.

Figure 23: Production reported in the Plastics Europe survey compared to estimated European production in 2021 (Plastics Europe 2022) and 2030 (Deloitte analysis)

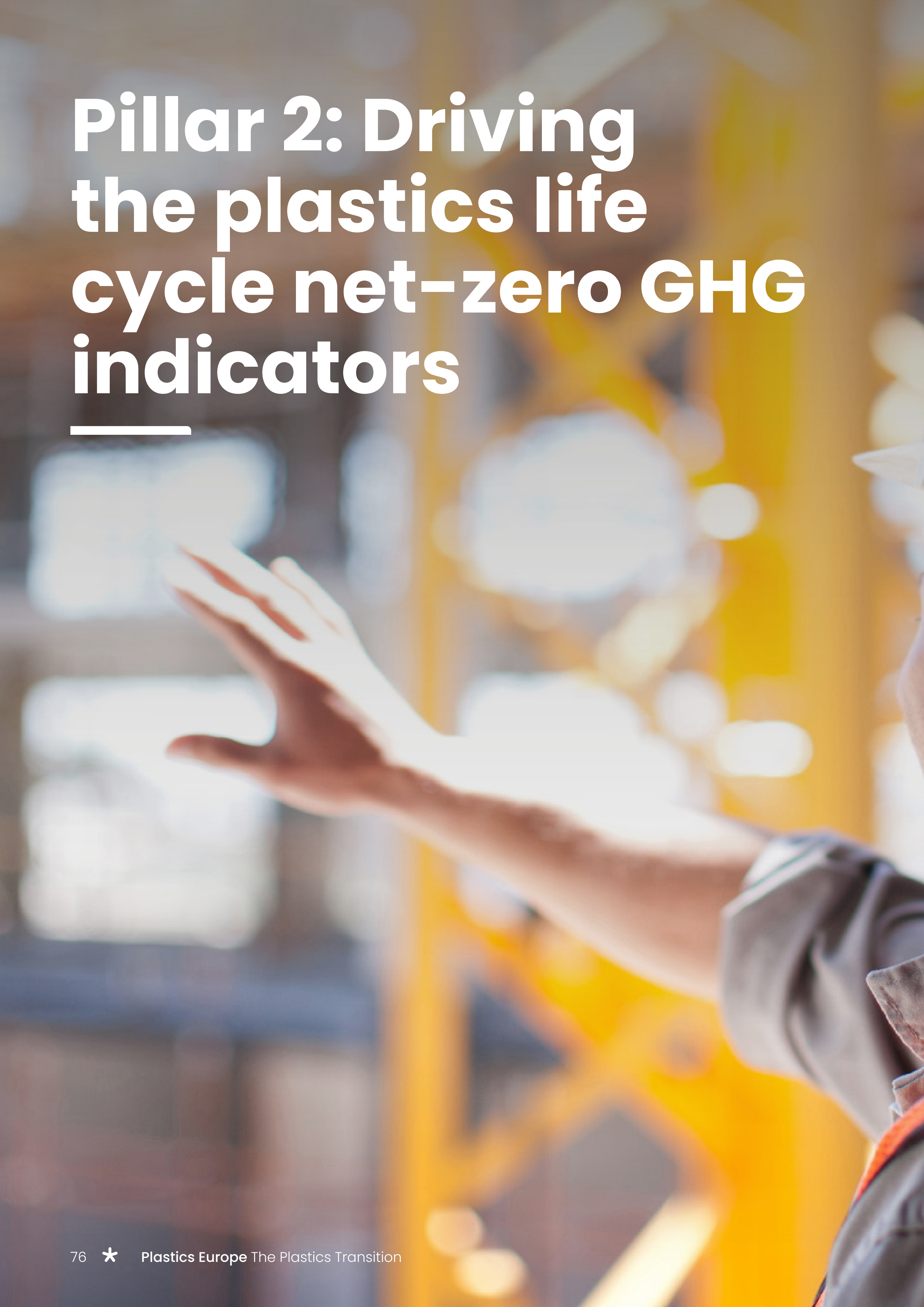


The survey data was gathered into a dashboard putting forward indicators to monitor progress in the circular pillar of the vision. Table 7 contains the 2021 baseline that can be used for future benchmarking, as well as the ambitions reported by several members for 2030. **The ambitious increase in circular metrics between 2021 and 2030 highlights the willingness of plastics producers to act.**

Table 7: Indicator dashboard with aggregated baseline 2021 and 2030 aspirations reported by numerous Plastics Europe members that represent almost half of estimated converter use

	2021		2030	
	Kt	%	Kt	%
Fossil based plastics	26,820 Kt	98.5%	22,211 Kt	77.0%
Mechanical recycling	298 Kt	1.1%	2,871 Kt	9.9%
Chemical recycling	5 Kt	0.0%	2,057 Kt	7.1%
Plastics made from biomass	112 Kt	0.4%	1,661 Kt	5.8%
Plastics from CCU + H2	0 Kt	0.0%	62 Kt	0.2%
All plastics	27,236 Kt	100.0%	28,862 Kt	100.0%

Since actions are decided at individual company level, the forward-looking metrics at sector level of Table 7 cannot constitute hard commitments or binding targets. Nonetheless, they represent the strong motivation of Plastics Europe members to actively contribute to a more circular life cycle. To achieve these strategic aspirations, policymakers and value chain partners will also have to take up their part of the actions (section 4.2).



Pillar 2: Driving the plastics life cycle net-zero GHG indicators

5

This chapter discusses the levers available to plastics producers and the enabling conditions needed to successfully pursue the net-zero greenhouse gas (GHG) emissions pillar (Figure 24).

Figure 24: Levers for action by the industry and enabling conditions

5.1 Key levers for action by the industry

Plastics producers control only part of the GHG emissions across the plastics life cycle that includes emissions from feedstock production and processing, direct emissions from plastics production and downstream emissions from plastics converters, Orignial Equiment Manufacturers (OEMs) and end-of-life processes like incineration. Plastics producers aim to reduce their own emissions to net-zero emission by 2050 and work with the value chain to realise a net-zero future. For the emissions under their control, **plastics producers can leverage the circular transition, energy efficiency measures, low-carbon fuels, electrification of production processes and carbon capture & storage (CCS) to pursue the vision of a net-zero plastics life cycle**.

5.1.1 Leveraging the circular transition

Reuse, circular feedstock and phasing out incineration of plastic waste are projected to reduce GHG emissions by 123 Mt, or 54% of the baseline amount (see Figure 17). Circularity and decarbonisation therefore go hand in hand.

The levers being used by Plastics Europe members and the asks to policymakers and value chain partners to make plastics more circular can be found in Chapter 4.

5.1.2 Furthering energy efficiency

Members of Plastics Europe are striving to further reduce energy consumption, lower costs, and decrease GHG emissions through energy-efficient technologies, practices, or designs such as heat recovery, advanced energy control systems and smart metering[1]. The following business case[2] illustrates the measures that plastics producers are deploying.

ARKEMA

Arkema strengthened its Climate Plan in July 2022 and set a target to reduce its Scope 1 and 2 GHG emissions by 46% by 2030 (target 2.0 MtCO2e) compared with 2019, including emissions from Scope 3 (target 85 MtCO2e). Arkema has been working to reduce its carbon footprint for many years. In concrete terms, the climate plan is implemented with each of its business lines and industrial facilities. The Arkema Energy Global Programme adopted in 2013 is one of the key levers. The energy efficiency of the industrial operations has already improved by 15% compared with 2012, the aim is to increase this gain to 25% by 2030.

5.1.3 Using low-carbon fuels (hydrogen, biofuels)

Several members of Plastics Europe are preparing to use low-carbon hydrogen and biofuels for process heating in crackers or powering electricity generating turbines. However, due to high current costs, the renewable fuels only represent a small part of companies' fuel mix today. Moreover, hydrogen used by members could be produced using renewable energy sources, such as electrolysing water (green hydrogen). But almost all of the supply is grey hydrogen produced from fossil fuels, resulting in CO_2 emissions (European Commission, 2020). Production capacity of low-carbon hydrogen is expected to be scaled-up to 40 GW by 2030 (against 6 GW by 2025) and maturity is expected to be reached by 2050 (European Commission). Biofuels are another renewable solution that could become important for Europe. While demand in the EU is expected to reach at least 18 exajoules in terms of primary energy equivalent, the production capacity of biomass is expected to be scaled-up to only 13 exajoules by 2050 following current scenarios (Material Economics, 2021), so sustained investments will be required to meet the new needs. The business cases[3] illustrate the investments that some members of Plastics Europe are making to use low-carbon fuels.

1 Energy efficiency measures are estimated to reduce energy needs for plastics by 5% by 2050 (OECD, 2022b)

2 https://www.arkema.com/global/en/media/newslist/news/global/csr/2022/20220607-commitment-climate/

3 https://www.ineos.com/news/ineos-group/ineos-secures-3.5-billion-financing-for-project-one---the-greenest-cracker-in-europe/
https://www.inovyn.com/news/ineos-announces-over-2-billion-investment-in-green-hydrogen-production
https://www.covestro.com/press/fortescue-future-industries-and-covestro-announce-plans-to-enter-a-long-term-green-hydrogen-supply-agreement/

INEOS

INEOS is constructing a € 4 billion state-of-the-art ethane cracker in the Port of Antwerp, Belgium, called Project ONE. This cracker is designed using the best available technology, including the use of hydrogen as a fuel, resulting in emissions at start-up which are one third of the emissions of the average European cracker and one fifth of the emissions of the most emitting cracker in Europe today. By using ethylene produced from Project ONE, INEOS will be able to reduce the overall carbon footprint of its existing downstream products by 2 Mt per year.

INOVYN

Inovyn has announced that it is to invest more than €2 billion into electrolysis projects to make zero-carbon, green hydrogen across Europe. Its first projects are in Norway, Germany and Belgium with investments also planned in the UK and France. The first unit to be built will be a 20MW electrolyser to produce clean hydrogen through the electrolysis of water, powered by zero-carbon electricity in Norway. In Germany, Inovyn plans to build a larger scale 100MW electrolyser to produce green hydrogen at its Cologne site. The development will further support the decarbonisation of Inovyn's operations at the site. Hydrogen from the units will be transformed in green ammonia, later on to be used in chemicals and polymers manufacturing units.

COVESTRO

As one of the pathways towards decarbonization and ultimately net-zero in 2050, Covestro is investing in the green hydrogen market. The German polymer supplier announced in 2022 a long-term green hydrogen supply agreement with Fortescue Future Industries to ship, as of 2024, up to 100k tonnes of green hydrogen (and its derivatives) to Covestro's sites in Europe and other parts of the world. This arrangement is expected to help Covestro reduce its GHG emissions by up to 900 Kt of CO2 equivalent a year by switching from grey to green hydrogen.

5.1.4 Electrifying production with low-carbon electricity

One major application for electrification concerns steam cracking, an industrial process that uses heat and steam to break down large hydrocarbons into smaller molecules, which can then be used as feedstock to produce chemicals and polymers such as plastics. Because a steam cracker typically operates at temperatures between 600-1100°C, it is a major contributor to CO_2 emissions. In an electrified steam cracker (e-cracker) using low-carbon electricity, heat is generated from electricity instead of fossil fuels, reducing the overall carbon footprint of the operations.

With a lifespan of up to 60 years, crackers require a large upfront investment, which may lock in conventional production capacity past 2050 if investments are not made rapidly. However, e-cracking technology is still in development, lacks scale, would require a structural infrastructure overhaul, and struggles with availability of low-carbon energy. Nonetheless, if research and investments in this area are encouraged, this method is expected to scale up in the next decades. As highlighted by the business examples[1], some **members of Plastics Europe have publicly announced that they are experimenting with these technologies and preparing for implementation**.

INOVYN

Inovyn has announced the development and installation of new world leading technology to electrify the production of vinyl chloride at the Rafnes site, Norway, making it possible to replace fossil energy with renewable electricity. This project will reduce CO2 emissions from the operations at Rafnes by up to 21 Kt per year and leading to an elimination of the CO2 emissions for the vinyl chloride monomer (VCM) cracking operations.

BASF

BASF, SABIC and Linde, an engineering company with expertise in cracker furnace technologies, have pioneered the construction of the first demonstration plant for a large-scale electrically heated steam cracker furnace. The process uses renewable electricity to power up the cracker and therefore has the potential to reduce CO2 emissions by 90% compared to conventional stream cracking. Two technologies will be tested in parallel at the demonstration plant with the aim of showing that using electricity as a heat source is a reliable solution to produce olefins.

VICTREX

Victrex has established a net-zero aspiration for its own operations that includes the use of renewable electricity and alternative fuels & technologies. The company has set different programmes into place and its plans to use only 100% renewable energy by 2024 is on track, with 100% of electricity for its UK sites already from renewable sources, and 97% globally. This is partly in the form of renewable certificates, in combination with its solar electricity generation, which the company firmly intends to expand.

1 https://www.ineos.com/businesses/inovyn/news/inovyn-takes-the-next-step-in-developing-and-implementing-green-technology-at-its-petrochemical-site-in-rafnes/
https://www.basf.com/global/en/media/news-releases/2022/09/p-22-326.html
https://www.victrex.com/en/news/2021/10/victrex-science-based-target-initiative

5.1.5 Realising carbon capture & storage

Carbon capture & storage (CCS) is seen as one of the most cost-effective tools for reducing hard-to-abate emissions (International Energy Agency, 2019). In 2021, the global annual CCS capacity was around 40 Mt, while in Europe, the capacity amounts to 2 Mt of CO2e/year (International Association of Oil & Gas Producers, 2019). Importantly, CCS can produce negative CO2 emissions when emissions are captured from industrial processes with biomass feedstock that has extracted CO2 from the atmosphere.

However, scaling up CCS requires significant investments, further technological development, and overcoming challenges associated with transporting carbon to long-distance offshore storage. To intensify ongoing research, the European Commission plans to launch a call for CCS proposals under the innovation fund, which has a total budget of €3 billion (International Energy Agency, 2019). The model projects that CCS in the plastics industry would account for approximately 4% of avoided CO2 emissions (3 Mt of CO2e/year) by 2030 and 12% (7.5 Mt of CO_2e/year) by 2050 (International Energy Agency, 2020). The business case[2] illustrates that **several members of Plastics Europe are already investing actively in this lever**.

INEOS

Arkema strengthened its Climate Plan in July 2022 and set a target to reduce its Scope 1 and 2 GHG emissions by 46% by 2030 (target 2.0 MtCO2e) compared with 2019, including emissions from Scope 3 (target 85 MtCO2e). Arkema has been working to reduce its carbon footprint for many years. In concrete terms, the climate plan is implemented with each of its business lines and industrial facilities. The Arkema Energy Global Programme adopted in 2013 is one of the key levers. The energy efficiency of the industrial operations has already improved by 15% compared with 2012, the aim is to increase this gain to 25% by 2030.

2 https://www.ineos.com/news/ineos-group/ineos-led-consortium-announces-breakthrough-in-carbon-capture-and-storage/

5.2 Enabling conditions and asks to policymakers

The net-zero vision of Plastics Europe, can only materialise if economic and legal conditions enable and incentivise it. This **requires the availability of energy sources such as low-carbon hydrogen and renewable energy, adapted infrastructure and net-zero downstream processes** (Figure 25).

Figure 25: Enablers to achieve net-zero GHG emissions by 2050

MAKE LOW-CARBON ENERGY AND HYDROGEN ACCESSIBLE

- Availability of production and logistical infrastructure for renewable hydrogen and other low-carbon fuels
- Availability of low-carbon electricity

ENABLE NET-ZERO PLASTICS PRODUCTION IN EUROPE

- Investment of money and manpower to build net-zero infrastructure and execute research
- Framework conditions and incentives to maintain the competitiveness of European industries

REDUCE DOWNSTREAM GHG EMISSIONS

- Ensure a net-zero transition of plastics conversion
- Phase out incineration of plastic and mixed waste streams

5.2.1 Availability of low-carbon hydrogen and other renewable fuels

The development of an EU clean hydrogen economy will be key to decarbonise the whole manufacturing industry in Europe. To boost hydrogen demand, the Commission developed the EU hydrogen strategy, setting an aspiration of 10 Mt of renewable hydrogen production capacity by 2030. In the same perspective, the REPowerEU Plan includes a hydrogen accelerator to build 17.5 GW of electrolysers by 2025 to fuel the EU industry with homegrown hydrogen production. In addition, the creation of an EU hydrogen market is needed to match regional differences in hydrogen supply and demand, and connect Europe to neighbouring regions with an abundant and cost-competitive hydrogen supply potential. Hydrogen pipelines will be the most cost-efficient option for long-distance high-volume transport (€0.11-0.21/kg), outcompeting ship transport by a factor of 3 to 5 (depending on country of origin and whether conversion is needed) (Guidehouse, 2021) (European Investment Bank, 2022). The EU annual demand for hydrogen is expected to increase significantly: 35 Mt in 2030, 86 Mt in 2040, and over 100 Mt by 2050 (Deloitte, 2021), stressing high expected growth for the hydrogen economy.

Hydrogen currently accounts for less than 2% of Europe's present energy consumption and is primarily used to produce chemical products, such as ammonia, methanol and fertilisers. To reach the net-zero emissions ambition, enough low-carbon hydrogen will have to be provided at a competitive price (+/- €2 per kg) on the European market (European Commission, 2020). The revised Renewable Energy Directive includes a binding target to reach 42% of renewable hydrogen within the total industrial consumption by 2030. To contribute to the efforts of the whole manufacturing industry in Europe, **plastics producers are participating in value chain partnerships**, such as the Clean Hydrogen Alliance, **to scale up hydrogen production and ensure reliable access to low-carbon hydrogen. However, support from policymakers will be needed to structurally increase the uptake of low-carbon hydrogen in the plastics industry** (Table 8).

Biofuels such as biodiesel and bioethanol can increase Europe's independence and reduce direct GHG emissions. But if not sourced sustainably, they could produce biodiversity losses and additional GHG emissions due to indirect land use change (ILUC). The revised Renewable Energy Directive II already provides a policy framework for renewables in Europe. It introduces mechanisms to address ILUC, as well as sustainability criteria for biofuels and bio-based materials (GHG emission savings, sustainable land-use, food security, rights of local communities, traceability). The current system limits the amount of high ILUC-risk biofuels, bioliquids and biomass fuels that European countries can count in their renewable energy targets to 2019 levels, but progressively decreases this constraint from the end of 2023 and lets it eventually disappear in 2030. The main uptake of biofuels is, however, expected in the transport sector. In its revised Renewable Energy Directive, the EU sets a target of 29% renewable energy in the transport sector with at least 5.5% of advanced biofuels and renewable fuels of non-biological origin, which means that the availability of biofuels and other biomaterials for the plastics sector may be limited. Therefore, some members of Plastics Europe are setting up long-term contracts with biomaterials producers to take away some of the investment risks. But policymakers are asked to take additional measures to enable further investments and ensure that enough renewable energy is available (Table 8).

Table 8: Asks to policymakers to increase the availability of low-carbon hydrogen

IMMEDIATE 2023 - 2025	**Increase renewable electricity production** Policymakers are asked to put in place the required legal framework and economic incentives to increase production of renewable electricity, such that low-carbon hydrogen can be produced at scale for all hard-to-decarbonise sectors where other alternatives might not be feasible or have excessive costs.
SHORT TERM 2026 - 2027	**Develop a crop strategy with clear sustainability requirements** Policymakers are asked to develop a crop strategy for European arable land highlighting the priority for applications and sectors, to reduce investment risks, and to impose unambiguous sustainability demands for biomass going to fuel or materials production.
MEDIUM TERM 2028 - 2030	**Create a single European market for industrial hydrogen** Policymakers are asked to establish an open and competitive hydrogen market with seamless cross-border trade and an efficient distribution of hydrogen among sectors, including the plastics industry. Investments and policies are to be coordinated between Member States to scale up projects and remove policy hurdles.
	Invest in hydrogen transportation infrastructure Policymakers are requested to improve pipeline, rail and waterway transport of hydrogen through public-private partnerships and to develop a multi-modal single European transport area, in collaboration with industry.
	Set up a fund to deploy low-carbon hydrogen Policymakers are asked to financially support the deployment of low-carbon hydrogen technologies up to demonstration plants and first-of-their-kind plants via a dedicated fund.
	Incorporate hydrogen in National Energy and Climate Plans Member States are asked to develop hydrogen plans that align with EU plans.

5.2.2 Availability of low-carbon electricity

Net-zero GHG emissions require electrification of plastics production processes, combined with the use of low-carbon electricity. The EU has set a binding target of 42.5% renewable energy in the overall EU energy mix by 2030, as well as an indicative 1.6% annual increase in renewable energy use by industry. This will require a significant increase in renewable energy generation capacity, including a three-fold increase in solar power and a 2.5-fold increase in wind power, for which the EU plans a €210 billion investment in the energy system by 2027 (European Commission, 2022).

Renewable energy projects are too often delayed with long permit procedures. This would have significant repercussions for the net-zero pillar of the Plastics Europe roadmap. The European commission proposes that Member States put in place dedicated 'go-to' areas for renewables, with shortened and simplified permit processes in areas with low environmental risks.

Other requirements for making affordable low-carbon electricity available to industry include a European electricity transmission system to connect renewable generation capacity with plastics producers across Europe. **Planning to increasingly electrify production, plastics producers are signing partnerships to secure low-carbon electricity, or are building their own renewable production capacity. However, industry members will need a clear regulatory and economic framework to have enough low-carbon electricity available** (Table 9).

Table 9: Asks to policymakers to increase the availability of renewable electricity

IMMEDIATE 2023 - 2025	**Increase renewable energy capacity drastically** EU policymakers are asked to implement and upscale renewable energy strategies such as the EU solar strategy, bringing online over 320 GW of solar photovoltaic by 2025 and almost 600 GW by 2030. Similar efforts will also be needed for other renewable energy technologies.
SHORT TERM 2026 - 2027	**Enable the free flow of electricity between EU countries** Policymakers are requested to facilitate transport and competition between sources of energy to decrease energy prices and increase energy security.
	Ensure competitive renewable electricity prices for industry Policymakers are asked to ensure competitive energy prices by promoting massive investments in low-carbon electricity production, implementing incentive schemes, and simplifying the deployment of renewable electricity projects, including by streamlining permit processes.

5.2.3 Infrastructure to produce net-zero plastics in Europe

Significant investments are necessary to reorient and develop net-zero infrastructure for plastics production and logistics (Table 10). The cumulated additional CAPEX investment for net-zero infrastructure by 2050 would add up to €18 billion, while OPEX could rise to €477 billion.[1] These costs are related to plastics production, but additional societal costs will also have to cover the development costs for Europe-wide hydrogen infrastructure. For example, the development of a 53,000 km hydrogen pipeline network by 2040 will require an estimated total investment of €80 billion to €143 billion, but will unlock hydrogen use for many applications and sectors (European Hydrogen Backbone, 2022).

Table 10: CAPEX AND OPEX estimations (Deloitte analysis based on SystemIQ (2022))

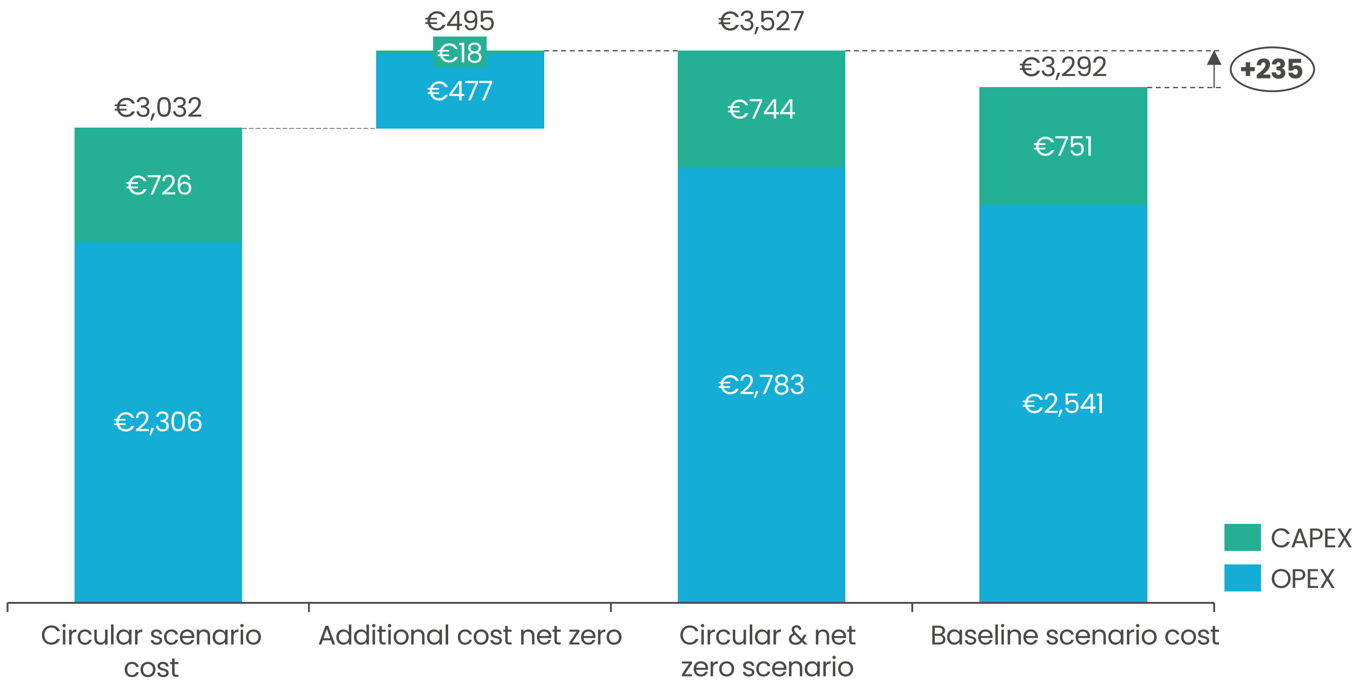
Technology	Cumulative additional investment by 2050
CAPEX	**€18 billion**
CCS	€6 billion
Renewable fuels	€4 billion
Electrification of production	€8 billion
OPEX	**€477 billion**
CCS	€307 billion
Renewable fuels	€114 billion
Electrification of production	€56 billion

In addition to the costs for the net-zero pillar, important investments for mechanical recycling, chemical recycling, biomass and CCU technologies will also be required (see section 4.2.5). When costs for net-zero infrastructure are combined with the costs for circular plastics, the additional system costs add up to €235 billion to the baseline scenario (Figure 26). The key driver of this additional system cost is the higher total operational cost from alternative production technologies. Notably, the additional CAPEX in clean technologies for monomers production is €18 billion. Of course, **major investments to reduce carbon emissions generated during cracking will be needed** (Table 10). But due to the shift to plastics made from mechanical recycling, bio-based plastics, and captured CO2 and hydrogen (together 37% of converter use in 2050), investments in cracker capacity will be freed up, and are expected to go towards technologies reducing carbon emissions in monomer production (see annex for assumptions). The projected, **additional** average system **cost-per-tonne of plastics** is €290 (around 17% of the system cost or 25% of the cost per tonne of plastics produced), **highlighting the need to support European plastics producers to remain competitive in a global market while pursuing the net-zero vision.**

1 Includes the additional investment and operational costs of alternative monomer production technologies compared to the CAPEX and OPEX per tonne of a steam cracker.

Figure 26: Additional CAPEX and OPEX of a circular and net-zero plastics scenario compared to baseline

In billion € (Deloitte analysis based on Reshaping Plastics, 2022)



The next five years are a critical window for action to achieve the 2050 time horizon. Due to long technology maturity cycles, and a CAPEX lock-in for infrastructure related to recycling plants, crackers and energy infrastructure, decisions taken this decade will define whether the circular and net-zero ambitions can be achieved. Infrastructure development will rely on a wide array of financial instruments, with public funding crucial to leverage other financial sources (venture capital, private equity, etc.). The European Commission is looking into specific funding instruments for CCS infrastructure (Clean Air Task Force, 2022), but more incentives are needed to trigger the infrastructure overhaul of the whole industry.

The additional cost of a circular and net-zero plastics life cycle

> According to the preliminary projections, the additional system cost of €235 billion equals a €87 cost-per-tonne of abated CO2e, and represents an additional €290 system cost-per-tonne of plastics consumed

towards 2050. When looking at the additional production cost compared to current plastics prices, a price difference of €499 is noted (a 25% cost increase) As an illustrative example of the order of magnitude of the impact on products, Table 11 presents the average additional cost for some relevant end applications (see annex for assumptions).

Table 11: Additional cost per end-application (Deloitte analysis)

Application	Additional cost	Average cost increase per product
Car	€87.5	0.35%
Laptop	€0.2	0.03%
Solar panel (2 Kw)	€3.2	0.09%
CubeSatellite	€0.87	0.03%
Packaging wrap for medical equipment	€0.05	8.60%

A paramount issue for developing net-zero production infrastructure in Europe is the declining competitiveness of the European plastics industry (Figure 10). The war in Ukraine has recently worsened the situation, as prices for energy and feedstocks increased more in Europe than elsewhere.
Without further support mechanisms, imposing decarbonisation efforts could ruin the European plastics industry. To address this, recent initiatives such as the Carbon Border Adjustment Mechanism (CBAM)[1] have been developed to equalise the price of carbon paid for imported goods with the one for European products. CBAM aims to protect the European industry's competitiveness against regions without regulated carbon markets in place, as only products with a lower carbon footprint than those produced in Europe will be exported to Europe without buying CBAM certificates (European Parliament, 2022). However, CBAM leads to a possible transfer of the risk of carbon leakage to downstream products, that would not be covered by the same scheme. In addition, CBAM does not currently protect European products exported outside Europe and facing competition from countries without the same climate ambition (Plastics Europe, 2022). It is therefore not clear whether extending the current CBAM scope to include plastics would create the necessary level playing field for the European plastics industry. An impact assessment of the inclusion of plastics in CBAM is due to be carried out by the European Commission by 2026.

1 Mechanism that requires European importers to register and buy CBAM certificates, whose price will be based on direct emissions and on European CO_2 pricing.

In response to the US Inflation Reduction Act (IRA)[2], and to enhance the competitiveness of Europe's net-zero industry and support the fast transition to climate neutrality, the European Commission presented the Green Deal Industrial Plan in early 2023. It is based on four pillars: a predictable and simplified regulatory environment, speeding up access to finance, enhancing skills, and open trade for resilient supply chains. To simplify the regulatory framework, the Commission proposed a Net-Zero Industry Act to establish measures for strengthening Europe's net-zero, technology-products manufacturing ecosystem (European Commission, 2023). But further support mechanisms will be needed. Table 12 puts forward the asks to policymakers to ensure that net-zero plastics can be produced in Europe.

Table 12: Asks to policymakers to build the infrastructure to produce net-zero plastics

IMMEDIATE **2023 - 2025**	**Develop an EU equivalent to the US Inflation Reduction Act** Policymakers are asked to implement measures (including providing state aid, subsidies and tax credits for recycling, sustainably sourced biomass to materials technologies, renewable energy, green hydrogen, and biofuels), and setting-up one-stop shops, to attract new net-zero investments in high-risk and innovative net-zero technologies.
	Simplify and fasten permit procedures for projects Policymakers are requested to streamline permit procedures for projects to build installations with low-carbon industrial technologies.
SHORT TERM **2026 - 2027**	**Include the industry in the impact assessment of the CBAM** Policymakers are requested to evaluate the downstream impact of implementing, or not, a CBAM on polymers, and involving Plastics Europe in the discussion.
MEDIUM TERM **2028 - 2030**	**Adopt a social climate fund** Policymakers are asked to financially support the transformation of technologies and infrastructure in the plastics industry to innovative, low-carbon and sustainable solutions.
	Increase pre-commercial procurement (PCP) to support uptake Policymakers are asked to support the uptake of innovative decarbonisation technologies for plastics production with low market maturity by issuing tenders for these solutions.

2 The Inflation Reduction Act (IRA) of 2022 approved by the U.S. Senate is a law addressing domestic inflation brought about both by the global energy crisis and climate change. Approximately $370 billion will be allocated to initiatives that promote energy security and facilitate the transition to clean energy. Additionally, the IRA will provide funding for projects that involve CCU.

5.2.4 Reduce downstream GHG emissions

The life cycle of plastics can only become net-zero if all value chain stakeholders, including conversion and waste management actors, take up their part of the actions. Plastics conversion contributed 12.7 Mt of CO2e (7%) to the GHG emissions of the plastics life cycle in Europe (Plastics Europe, 2022). In the net-zero roadmap, emissions from conversion are to drop to 0.6 Mt by 2050. Waste management, and more specifically waste incineration, also has a major impact on total GHG emissions of plastics. In 2020 42% of plastic waste was still incinerated (Plastics Europe, 2022), with one tonne of plastics burned producing 2.2 tonnes of net CO2 emissions (SystemIQ, 2022). In 2021, an additional 43.5 Mt of CO2 were emitted due to plastic waste incineration. Improvements in waste management practices therefore not only contribute to higher volumes of high-quality recycled feedstock, but also decrease GHG emissions. Table 13 puts forward asks to policymakers and other stakeholders to reduce the GHG emissions related to plastics outside of the reach of plastics producers.

Table 13: Asks to policymakers and other stakeholders to decrease the emissions in downstream activities

IMMEDIATE 2023 - 2025	**Include waste incineration in EU ETS** Policymakers are asked to envisage a future without incineration of recyclable plastic waste by incentivising better sorting, collection, and recycling processes.
MEDIUM TERM 2028 - 2030	**Reduce CO2 emissions in plastics conversion** Plastics converters are invited to reduce CO2 emissions in the conversion of plastics to plastic products through the use of renewable and low-carbon energy sources, and to become part of the net-zero journey of the whole plastics industry.
LONG TERM 2031 - 2050	**Make carbon capture obligatory for remaining waste incinerators** Policymakers are requested to make carbon capture via Carbon Capture and Storage (CCS) or Carbon Capture and Utilisation (CCU) obligatory for the exploitation after 2040 of waste incinerators, such that the GHG emissions are minimized for the specific waste streams where incineration is the only viable option.

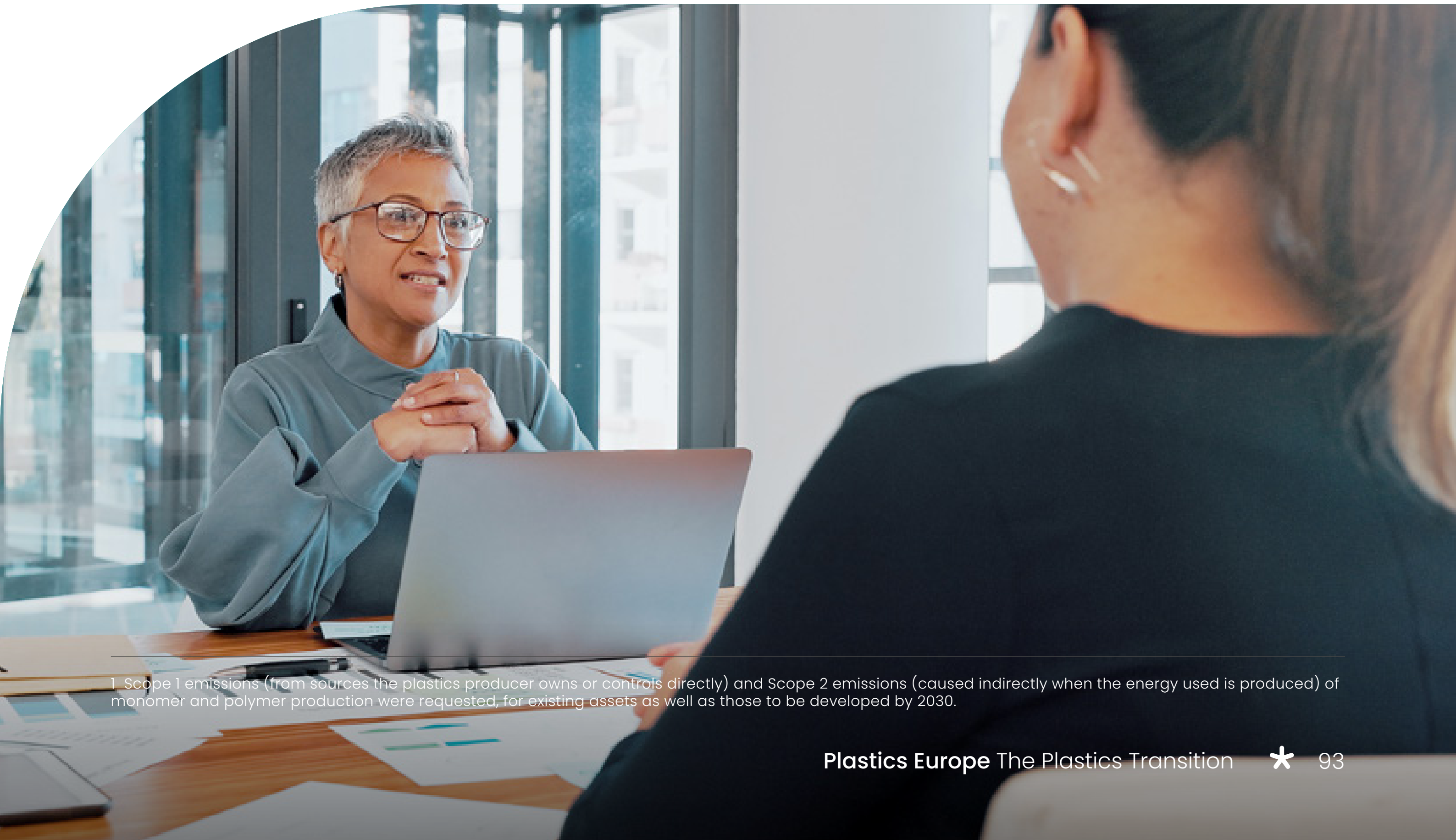
5.3 Net-Zero GHG Indicators

In view of the net-zero ambitions, a survey was sent to the members of Plastics Europe and the data collected from more than 25 members, representing close to half of the estimated EU27+3 market, was gathered into an indicator dashboard. Taking into account members' diversity, the aggregation of the reported numbers should be interpreted with caution.

Table 14 contains **the baseline of 2021 that can be used for future benchmarking**, and the ambitions reported by numerous members for 2030[1]. **The decrease in the CO2 intensity of plastics production and the increase in CCS capacity highlights the ambition of Plastics Europe members**.

Table 14: Indicator dashboard with baseline 2021 and 2030 aspirations reported by numerous members of Plastics Europe that represent almost half of the estimated converter use

	FY21	FY30
Scope 1-2 tonnes of CO2e/tonnes of plastics produced	1.29	0.90
% reduction in CO2 intensity (tonnes CO2/ tonnes plastics)	0%	-30.23%
CCS capacity (1000 tonnes, Kt CO2e)	0	2,600



1 Scope 1 emissions (from sources the plastics producer owns or controls directly) and Scope 2 emissions (caused indirectly when the energy used is produced) of monomer and polymer production were requested, for existing assets as well as those to be developed by 2030.

Since actions are decided at individual company level, the forward-looking metrics at sector level cannot constitute hard commitments or binding targets. Nonetheless, they highlight the strong motivation of Plastics Europe members to actively contribute to a net-zero life cycle of plastics. Importantly, making progress is only possible if policymakers and value chain partners take up their part of the actions (section 5.2).

Scope 3 emissions are an important part of the emissions of the plastics life cycle and this roadmap includes estimations for Scope 3 at converter use level. However, only a few producers have this information at company level readily available, and the measurement methodologies and scope differ between producers. The Scope 3 data at company level are therefore not aggregated or included in this publication. The members of Plastics Europe will investigate how to align on the scope and methodology in order to enable future aggregated reporting of Scope 3 emissions.

To achieve the aspirations and indicators, **plastics producers are investing to reduce CO_2 emissions in their own operations and are leveraging their commercial strength to incentivise suppliers to follow suit. They are also launching CCS projects and participating in the development of a low-carbon EU economy by:**

- **Joining value chain initiatives to foster production of hydrogen and biofuels**
- **Powering-up their production plants with renewable energies**
- **Collaborating with research institutions on key enabling technologies**

Multiple members of Plastics Europe are further investing in low-carbon renewable energy sources. On one hand, companies are setting individual targets for the use of renewable energy sources to help reach the industry milestones. On the other hand, they are collaborating and co-investing in renewable energy infrastructure to accelerate the transition and spread the risks. Finally, the technologies to reach a net-zero plastics are not mature yet. Consequently, several Plastics Europe members are collaborating with value chain partners and research institutes (via projects such as the 'Circular Valley' of Europe), bringing together multiple organisations to find technological solutions for circular and net-zero challenges.

Pillar 3: Fostering Sustainable Use of Plastics

6

Sustainable use of plastics means producing and using plastic applications in a way that is safe for human health and the environment. **Members of Plastics Europe are continuously developing new actions, tools and methodologies to comply with legal obligations and foster sustainable use of plastics. They have three levers at their disposal** (Figure 27):

- **Managing risks in own operations:** Setting up standardised management schemes for additives, with transparent methodologies and external verification demonstrates safety in production. Additionally, producers are taking action to prevent pellet loss in plastics production.
- **Transparency towards stakeholders:** By sharing non-confidential information about circular and safety data on the production, composition and purpose of plastics, a constructive dialogue is supported.
- **Collaborating with value chain partners:** Working together with suppliers, product manufacturers, policymakers, academics and other stakeholders, leads to upscaling of good practices, an improved understanding of plastic leakage, and minimised losses across the plastics value chain.

Figure 27: Levers, enablers and actions

Plastics Europe aims to share and upscale good practices within its membership. However, to achieve the objectives the whole plastic industry – including transporters, importers, suppliers and converters – will need to be engaged as well.

6.1 Assure the safe management of plastics additives

There is already extensive legislation in place to identify and manage potentially hazardous substances. For example, the EU regulation Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) introduced in June 2007 requires the registration of all substances manufactured, imported or put on the European market. Owing to the overall low concern, polymers are exempt from registration and evaluation in REACH. However, to produce plastics, a wide range of substances is used, including fillers and additives that also fall under regulations such as REACH. Some of the additives are of higher concern than the polymer molecule itself and their use requires action under Reach. The members of Plastics Europe are fully compliant with REACH and other laws that regulate the management of hazardous substances, and will continue to meet evolving regulations.

Despite the existing legal framework, stakeholders want more assurance and transparency on the use of hazardous substances and more specifically plastics additives. Indeed, policy documents such as the EU Chemical Strategy for Sustainability introduced in 2020 put the management of potentially hazardous substances high on the agenda. Also, in the UNEP-driven Intergovernmental Negotiating Committee to develop an internationally legal binding instrument on plastic pollution (UNEP, 2023), banning or phasing out chemicals and polymers of concern, including some plastics additives, are among the options for discussion. Assuring the safety of additives used in production and potentially present in products is therefore important.

Already in 2016, ECHA and 21 industry actors launched a two-year European project aimed at mapping plastics additives used in higher volumes (more than 100 tonnes per year registered in REACH) (ECHA, 2016). The outcome was a list of 400 additives, combined with additional work analysing the release of these additives into the environment. The information helps steer updates of regulations such as REACH (ECHA, n.d.). But the database needs further work to become fully functional.

To address the concerns of stakeholders, members of Plastics Europe foster risk management systems that analyse the additives used and assess their risk profile. Owing to the diversity in the plastics sector in terms of size and product portfolio, a one-fit all system would not be efficient or effective. Moreover, most **members of Plastics Europe already have a bespoke risk-management systems in place.** To warrant the quality of the systems while leaving flexibility to optimise efficiency, members of Plastics Europe have set forward the following actions:

- By 2025, a working group will examine minimum requirements, common methods and disclosure rules for additive-risk management systems in the plastics industry. The risk-management system should include a transparent and published methodology, as well as third party assurance.
- Once the risk management framework is endorsed, each member will adapt its existing risk management system to fulfil the recommendations of the working group.

Owing to the current public attention for the use of additives in plastics production, new legal developments and industrial initiatives can be expected. For example, the International Council of Chemical Associations (ICCA) has recently launched an initiative to develop a database for plastics additives. Plastics Europe will set up a working group to help develop confidentiality safeguards and other framework conditions relevant for the European industry. Plastics Europe is convinced that harmonisation of methodologies across global regions and countries would be desirable in order to avoid divergent international standards.

The working group can build further on existing risk management schemes, for example:

- SABIC's Safer Chemistry programme
- Product/polymer-specific methodologies (VinylPlus product label)
- Publicly available methodologies (Portfolio Sustainability Assessment from the World Business Council for Sustainable Development)
- Frameworks integrating risk assessment and safety-based considerations in line with the EU Chemical Strategy for Sustainability's Safe and Sustainable-by-Design[1] criteria

The business cases[2] below provide more information on these methodologies.

SABIC

SABIC's "Safer Chemistry Programme" has been created in 2020 to reduce and manage the use of chemicals of concern in production processes. The programme entails pro-active internal assessments of the portfolio, in which more than 1,800 substances were analysed, from which about 350 were identified as meeting SABIC's "chemicals of concern" definition. These substances were afterwards ranked using an internal prioritisation tool. The current outcome is that 50 chemicals of concern were identified based on priority scores and were subsequently further assessed on opportunities to substitute, eliminate or reduce these chemicals of concern in the SABIC portfolio.

VINYPLUS

VinylPlus, a value chain initiative of the European PVC industry, developed an Additive Sustainability Footprint (ASF) tool. Using a ten-step approach the tool allows users to assess PVC additives across the entire product life cycles. This includes production and use phases, and highlights the roles of the additives in the performance of PVC applications. Connecting the dots in the value chain was key, which VinylPlus members showcased by collaborating with the additives producers directly.

1 'Safe and sustainable-by-design' principles promote new and alternative products and technologies by integrating safe and sustainable criteria throughout the design, production, use, and disposal stages. This provides consumers with more confidence in the safety, environmental and societal benefits of products they purchase.

2 https://www.sabic.com/en/sustainability/product-stewardship/initiatives-and-engagement/safer-chemistry
https://productlabel.vinylplus.eu/wp-content/uploads/2018/06/Additive-Sustainability-Footprint_ASF_Presentation.pdf

6.2 Prevent pellet loss in plastics production

Loss of plastic pellets in the supply chain is a key challenge for the plastics industry. To eliminate losses in the supply chain, Plastics Europe created the Zero Pellet Loss (ZPL) initiative in 2013, integrated into Operation Clean Sweep® (OCS)[3] two years later. The programme puts forward best practices for all pellets handling operations along the supply chain (production, conversion, logistics). Furthermore, Plastics Europe developed the OCS Europe Certification Scheme in collaboration with European Plastics Converters (EuPC).
The certification formally recognises that facilities have effectively implemented adequate management system to prevent the loss of plastic pellets, flakes and powders. Adhesion to the OCS programme became mandatory for all Plastics Europe members in 2020. Members will also have their facilities OCS-certified through third-party verification by 2025.

Building on the work performed by Plastics Europe and EuPC, the ask to policymakers is to make OCS-like requirements and certification legally binding for all plastics pellet handling actors in the EU, including recyclers, converters, shipping companies, logistics providers and other relevant actors.

Develop industry-led standards and tools to prevent leakage

Plastics Europe, together with European Plastics Converters (EuPC), has developed the **Operation Clean Sweep® (OCS) Europe Certification Scheme.** Operational from February 2023, the certification reinforces the initial OCS programme by including harmonised controls and reporting procedures. To achieve certification, a company must first adopt and implement the recommended practices, which include carrying out a risk assessment, organising employees training and conducting regular audits to ensure compliance. The company must then undergo an external audit by an approved third-party auditor to verify that they have met OCS requirements. The programme has already had a positive impact.
For instance, in 2017 the Port of Antwerp was the first to sign up to OCS in Europe and reduced reported pellet losses by approximately 70% between 2017 and 2021.

3 Operation Clean Sweep® (OCS) was originally created in the early 1990s by the Plastics Industry Association in the US.

6.3 Harness tools to share data across the value chain

A Digital Product Passport (DPP) is one way to share information on plastic production, composition and purpose. A product-specific data set can be electronically accessed to register and share product information across the value chain.
The European Commission launched the DPP initiative in the proposed Ecodesign for Sustainable Products Regulation (ESPR) (European Commission, 2022). This first communication announced the launch of pilots in several sectors (batteries, textile, electronics). In its current set-up, the DPP for products containing plastics provides information on a product's origin, composition, repair and disassembly possibilities, including how the various components can be recycled or reused. Adding carbon footprint and safety information would make it an even more comprehensive data source. Consumers could take more informed purchasing decisions with regards to the sustainability of the products. This would, in turn, incentivise manufacturers to make their products more sustainable. **Plastics Europe and several members will intensify their participation in pilots** (see the business cases below for illustration of industrial initiatives[1]) **to lead the development and speed up the economy-wide roll-out of the DPP.**

A sustainable product label is a certification or verification mark that identifies a product as having met certain criteria related to sustainable production or safety. By meeting the criteria for sustainable product labels, plastics producers can demonstrate that their products comply with regulations and best practices related to chemical safety. The VinylPlus Product Label, for example, provides producers using PVC for their products the opportunity to communicate about their sustainability efforts (see section 6.1 for more details). Although these labels can be powerful for specific applications or polymers, the added value of an additional label at the plastics level would probably be low. The creation of labels is therefore left up to individual product groups and not part of the actions put forward by this industry roadmap.

Digital Product Passport Innovation

Covestro has launched its innovative Digital Product Passport (DPP) solution, the scannable Niaga tag. By scanning the Niaga tag, users can access a DPP to see exactly what a product is made of and how to return it after each use-cycle. This helps all parties in the value chain, including recyclers and producers, to keep valuable raw materials in the loop to be used over and over again. Because of its contribution to accelerating the transition to a circular economy, Niaga has been awarded the European Institute of Innovation and Technology (EIT) prize in the Digital Product Passport category.

Experiment with the Digital Product Passport to speed up its roll-out

The **Catena-X project** for the automotive industry is a frontrunning initiative to test the functioning and speed up the development of a Digital Product Passport (DPP) with **BASF** as a member since 2021. The project aims to achieve an uninterrupted exchange of standardised data sets among the automotive value chain players. Sustainability data is one part of the equation, with product carbon footprint data being collected and exchanged.

1 https://www.niaga.world/en/check-your-tag/
https://catena-x.net/en
https://www.basf.com/global/en/media/news-releases/2023/01/p-23-119.html

6.4 Communicate proactively

Transparent communication contributes to gaining trust of society, including policymakers and end-consumers. Moreover, **there is a need to feed the public debate with scientific insights, so that decisions by policymakers, brand manufacturers and end-consumers are fact-driven. Plastics Europe will continue to strengthen its role as a provider of publicly available and reliable data through its reports and publications**. The short description below of two flagship reports[2] of Plastics Europe highlight the type of high-quality information that the sector is sharing with its stakeholders.

New tools such as digital platforms can enable disclosure and information sharing with a wider public. For example, Spherity, a company that specialises in creating digital identities for products, has launched a podcast season featuring interviews with key actors who influenced the development of the Ecodesign for Sustainable Products Regulation (ESPR) and contributed to the emergence of the DPP. Plastics Europe is building on similar social media communication campaigns to feature circular, net-zero or safety efforts and foster a constructive dialogue between producers, policymakers and consumers.

Feeding the public debate with facts and figures

Plastics Europe publishes a range of studies to inform the public debate. For example, **Plastics - the Facts** is a yearly public report that analyses the latest data related to plastics production, demand, conversion and waste management in Europe. Similarly, **The Circular Economy for Plastics**, a report that comes out every two years, contributes to a better understanding of the circular economy of plastics and addresses the production of recycled plastics and their use in different application sectors. These reports provide an insight into the industry's status and contribution to European society.

2 https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022-2/
https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-overview-2/

6.5 Collaborate to reduce plastic leakage across the value chain

Minimising **microplastic leakage** is possible, but eliminating it altogether is unrealistic, because, as with other materials, wear and tear during use will continue to occur. **Members of Plastics Europe are involved in scientific research related to microplastics. This involvement takes various forms, including funding our own industry project, Brigid, dedicated to microplastics and human health. Additionally, we serve as industry stakeholders in other EU and national projects active in the microplastics environment**, such as MOMENTUM, LimnoPlast, and the CUSP Cluster.

Since most plastic leakage occurs in the use and end-of-life stages of plastic products, the direct impact of plastics producers on overall leakage is low. Nonetheless, plastics producers can partner and collaborate with both public and private stakeholders to address current and legacy leakage issues. The Circular Plastics Alliance (CPA) and the Tyre and Road Wear Particles (TRWP) platform illustrate that members of the plastics industry are collaborating with stakeholders to scale up efforts and accelerate change.

Assess risks of microplastics

To fill the knowledge gap on the impact of microplastics, in April 2022 **Plastics Europe** launched the **BRIGID** project. The five-year, €5 million research project collaborates with external partners such as the Wageningen University and Research (WUR) and the Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO). The aim is to analyse the potential risks of microplastics exposure on human health through ingestion and inhalation, the two main pathways into the human body.

The project consists of six work packages (WP):

- WP1: Classification of all microplastics
- WP2: Exposure assessment
- WP3: Hazard assessment
- WP4: Risk-assessment based on WP2 and WP3 data
- WP5: Communication of outcome
- WP6: Project coordination

Collaborate to deliver circular and sustainable aspirations

The **Circular Plastics Alliance** (CPA) is an initiative under the European Strategy for Plastics. This voluntary pledge was launched by the European Commission in December 2018 to deliver on the circular economy for plastics and substantially increase the use of recycled plastics into new products. Covering the full plastics value chain, including over 300 industry, academia and public organisations, the Alliance aims to boost the EU market for recycled plastics to 10 Mt by 2025.

Share insights and co-develop actions to mitigate leakage

Tyre and Road War Particles (TRWP) are tiny fragments produced during normal driving conditions from the friction between the tyre and the road. Because of their size and composition, these particles are commonly associated with **microplastics.** To better understand and address TRWP, in 2018 the **European Tyre & Rubber Manufacturers Association (ETRMA)** launched a multi-stakeholder initiative, the European TRWP Platform. This cross-sectorial initiative brings together industry sectors, public authorities and research institutes to share scientific knowledge and co-create mitigation actions to tackle the generation and release of tyre and road wear particles into the environment. (CSR Europe, n.d.)

Milestones, Levers and Asks

7

Figure 28 summarises the levers members of Plastics Europe are using to realise the circular, net-zero and sustainable use pillars of the mission. Within the framework provided by this roadmap, each member of Plastics Europe will decide how the strategic pillars will be implemented within their company. **All actions are related to the three pillars**:

1. **Spearhead circularity circular**
Members of Plastics Europe are shifting from linear practices to circular ones, through new business approaches and technologies such as recycling, plastics from sustainably sourced biomass, and captured carbon. Replacing fossil-based feedstocks with waste currently sent to landfills and incineration, plastics producers will increase resource efficiency and make valuable products with the same functional performance as fossil-based products, meeting a growing downstream demand for circular products.

2. **Drive GHG emissions to net-zero**
Plastics Europe members are investing in new technologies and developing innovative solutions to cut GHG emissions and increase the use of circular feedstocks

3. **Foster sustainable use of plastics**
Plastics Europe members aim to address health concerns by demonstrating the safety of produced plastics, gearing up transparency to stakeholders and reducing leakage to the environment by collaborating with value chain partners.

Figure 28: Key levers to achieve the mission

WE MAKE PLASTICS CIRCULAR

- Fostering circular design and business models
- Enhancing mechanical recycling
- Unlocking chemical recycling
- Expanding production from sustainable biomass
- Making plastics from captured carbon

WE HELP DRIVE LIFE CYCLE EMISSIONS TO NET-ZERO BY

- Leveraging the circular transition
- Maximising energy efficiency
- Using low-carbon fuels (hydrogen, biofuels)
- Electrifying production with low-carbon electricity
- Investing in carbon capture & storage

WE FOSTER SUSTAINABLE USE OF PLASTICS BY

- Managing risks in operations
- Providing further transparency to stakeholders
- Collaborating with value chain partners to prevent leakage

Dialogue with policymakers is necessary, as is cooperation with up- and downstream value chain players, to enable the industry to take actions such as presented in Figure 29. Therefore, Figure 30 summarises the asks to policymakers and the invitations to stakeholders to partner with members of Plastics Europe.

In sections 4.3 and 5.3 the roadmap puts forward indicators that form the baseline in 2021 and highlight the direction for 2030. To actualise them periodically and turn the roadmap into a living document with moving targets, this survey will be integrated into the other periodic reports of Plastics Europe. Members will contribute every two years to an update of the survey to transparently report on progress, successes and bottlenecks.Figure 29: Potential actions for industry members to consider, with an illustrative timeline, that need the collaboration

Figure 29: Potential actions for industry members to consider, with an illustrative timeline, that need the collaboration of policymakers and value chain partners

IMMEDIATE
2023 - 2025

- Provide stakeholders with aggregated data and insights on the status and solutions to achieve the industry vision
- Partner with waste management organisations to secure circular feedstock and manage investment risks
- Invest in new technologies and collaborate to speed up technology development
- Prevent plastic leakage in the supply chain through compliancy with Operation Clean Sweep® (OCS), and encourage broader value chain adoption
- Determine minimum requirements for risk management systems for plastics additives
- Experiment with digital product passports and speed up the development of digital tools to share information in the value chain
- Utilise power purchase agreements to increase green electricity uptake

SHORT TERM
2026 - 2027

- Bring plastics to the market that are functional and affordable but also easy to recycle or repurpose at the end of their life cycle
- Shift away from linear practices to circular ones, through new circular business models and technologies such as recycling, plastics from biomass and captured carbon
- Invest in joint infrastructure for hydrogen, renewable energy and carbon capture and storage (CCS)
- Lead by example and cooperate with stakeholders and value chain partners to overcome hurdles and knowledge gaps to address plastic leakage
- Scale up power purchase agreements to accelerate green electricity uptake

MEDIUM TERM
2028 - 2030

- Further the cooperation with suppliers of sustainably sourced biomass to scale up plastics from biomass
- Have chemical recycling operational at scale by investing in capacity and partnering with technology providers
- Maximise energy efficiency and use carbon capture and storage (CCS) to reduce GHG emissions
- Implement third-party verified risk management systems for plastics additives

Figure 30: Asks to policymakers and value chain partners with indicative timeline

IMMEDIATE
2023 - 2025

- Develop an EU equivalent to the US Inflation Reduction Act to make circular plastics production in Europe competitive
- Have a material-agnostic view when addressing single-use applications
- Codify the fuels-exempt mass balance approach for chemical recycling
- Harmonise requirements for recycled content measurement and certification
- Impose minimum circular content targets and enforce implementation also for imported plastics
- Improve waste collection and sorting and incentivise investments in recycling infrastructure by Extended Producer Responsibility (EPR) and other instruments
- Phase out landfilling and incineration of recyclable plastic waste by harnessing instruments such as EU ETS and disposal taxes
- Simplify and speed up permitting processes for circular and net-zero infrastructure
- Make OCS-like requirements and certification legally binding for all plastics pellets handling actors in the EU

SHORT TERM
2026 - 2027

- Promote and enforce design for recycling to improve quality of collected waste
- Make shipping of recyclable waste easier within Europe and treat recyclable plastic waste as a secondary raw material destined for recycling, which should be covered by product legislation
- Harmonise definitions and improve statistics for plastic waste management
- Provide economic incentives to use sustainable biomass as feedstock for plastics and endorse the mass balance approach for bio-attributed plastics
- Endorse trustworthy certification systems and standards for the sustainable sourcing of biomass feedstocks
- Increase citizens' awareness and leverage public procurement for circularity to create a market pull for circular products
- Step up the research for CCU
- Include the industry in the impact assessment of the Carbon Border Adjustment Mechanism (CBAM)
- Increase renewable energy capacity drastically

MEDIUM TERM
2028 - 2030

- Enhance the quality and quantity of collected biowaste suitable as feedstock for plastics
- Provide funding for low-carbon hydrogen production and transportation infrastructure
- Create incentives and a legal framework to valorise CO_2 emission savings via CCU
- Secure long-term contracts for production of basic chemicals from captured CO_2
- Make risk management systems for plastics systems obligatory for the whole plastics sector
- Enable the free flow of electricity between EU countries and ensure competitive renewable electricity prices for industry
- Reduce CO_2 emissions in plastics conversion

Glossary

of policymakers and value chain partners.

TERM	DEFINITION
Bio-attributed plastics	Plastics with attributed bio-based content. The determination of bio-based content can be done via feedstock attribution. Note: These products should contribute to the legislative requirements of bio-based content.
Bio-based feedstock	Raw materials of biological origin, grown and naturally replenished at human time scale, excluding materials embedded in geological formations and/or fossilised. It can either be produced from grown crops ('first-generation': maize, rapeseed, etc.) or organic residuals and waste ('second-generation': agricultural waste, frying oils, manure).
Bio-based plastics	Plastics fully or partially produced from bio-based feedstock. Bio-based plastics can be made entirely or partially from biomass, and can be both biodegradable and non-biodegradable (European Commission, 2022).
Carbon capture and usage	Process of capturing CO_2 from potential system emissions streams before it enters the atmosphere, or from the atmosphere itself (direct air capture). Captured CO_2 can then be used as a feedstock to produce plastics.
Carbon captured feedstock	Raw material derived from technically captured CO_2 from air or industrial processes used as a feedstock.
Chemical recycling	Converts e. g. polymeric waste by changing its chemical structure to produce products (e.g. waxes) or substances (e.g. oil and gas) used as raw materials for manufacturing plastics or other products. Products exclude those used as fuels or means to generate energy. There are different chemical recycling technologies, such as pyrolysis, solvolysis, gasification, hydro-cracking and depolymerisation. Note: Alternatively, the terms 'feedstock recycling' (synonym per ISO 15270: 2008) or 'advanced recycling' (preferred in the American region) are used.
Chemically recycled feedstock	Feedstock derived from waste through chemical recycling.
Chemically recycled plastics	Plastics fully or partly produced from chemically recycled feedstock. The determination of recycled content can be done via feedstock attribution. Note: Those products should contribute to the legislative requirements of recycled content.

Circular feedstock	Circular feedstocks are recycled feedstock, bio-based feedstock, carbon captured feedstock. Note: The definition is based on the feedstock used and does not refer to the end-of-Life of the plastics
Circular plastics	Group of plastics fully or partially produced from circular feedstock, including recycled plastics, bio-based plastics, bio-attributed plastics and plastics derived from carbon capture. Note 1: Antonym of fossil-based plastics Note 2: The definition is based on the feedstock used and does not refer to the end-of-life of the plastics.
Closed-loop recycling	A recycling process in which the output (e.g. recyclate) is included in a product or application of the same plastic sector it originated from (e.g. packaging, automotive).
Decarbonisation	Reduction of carbon. In the context of a circular economy of plastics, it means the reduction of greenhouse gas emissions throughout the life cycle of a plastic material. Decarbonisation can include measures of reduction in production (e.g. via process optimisation or green energy use), sourcing (e.g. via changes in feedstock used), or CO_2 storage. The decarbonisation can be measured and demonstrated scientifically by using methodologies such as life-cycle-analysis. Note: The term refers to the CO_2 emissions throughout a material's life cycle. A plastic material consists fully or partly of carbon.
Depolymerisa-tion	Conversion of a polymer to its monomer(s) or to a polymer of lower relative molecular mass. The process can be mediated by e.g. heating, chemical solvents or enzymatic/catalytic reactions. Note: The process belongs to chemical recycling processes.
Dissolution	A purification process through which the polymer present (e. g. in a mixed plastics waste or in a multi-layer formulation/composite) is selectively dissolved in a solvent, allowing it to be separated from the waste and recovered in a pure form without changing its chemical nature. Note: The process belongs to physical recycling processes.
Elastomer	Macromolecular material which returns rapidly to its initial dimensions and shape after substantial deformation by a weak stress and its release. Note: The definition applies under room-temperature test conditions.
Extended Producer Responsibility (EPR)	Set of measures taken to ensure that producers of products bear operational responsibility or finance an organisation for the management of the waste stage of a product's life cycle.

Feedstock	Raw material or material that is the principal input for an industrial production process
Feedstock attribution	Allocating the characteristics of a feedstock (e.g. bio-based or recycled) – which is added at the beginning of the production process – to the end product. Mass balance is one well-known chain-of-custody approach that can be used to trace the flow of materials through the value chain, resulting in associated claims for the allocation.
Fossil-based plastics	Polymer resin produced directly and fully from fossil feedstock. Note: Externally, these plastics are sometimes called virgin plastics or virgin fossil plastics.
Fossil feedstock	Raw material that is derived from fossil resources (crude oil, natural gas, coal).
Fossil-equivalent quality	An adjective describing the quality of a material that has not undergone processes resulting in changes of chain length or non-traceable addition of additives. For example, the term differentiates plastics directly derived from polymerisation from mechanically/physically recycled plastics, based on technical criteria such as chain length, colours, or food grade approval. Note: The term 'virgin-quality' or 'virgin-like' is used equivalently.
Gasification	A process where mixed after-use materials, such as polymeric waste, are heated in the presence of limited oxygen to produce primarily syngas that can be converted into polymers again. Note: The process belongs to chemical recycling processes
Mechanical recycling	A processing method by which plastics are recovered from plastic waste without intentionally changing the basic polymeric structure of the material. Plastic waste undergoes processes in specialised sorting facilities to separate different plastic streams. After cleaning and grinding the sorted plastic waste, the material is recovered by melting, or dissolution of the polymer out of the plastic, and reshaping (e.g. regranulating) to produce pellets, flakes or powders used in the manufacture of plastic parts and products.
Mechanically recycled plastics	Plastics fully or partial produced by a mechanical recycling process.
Open-loop recycling	A recycling process in which the output (e.g. recyclate) is converted into a different type of product (e.g. park benches, fibres) from the one for which the polymer was first used.
Organic recycling	Recycling (via composting or anaerobic digestion) of biodegradable/compostable organic waste (including plastics) under controlled conditions using microorganisms. In the presence of oxygen, stabilised organic residues, carbon dioxide and water are produced. In the absence of oxygen, stabilised organic residues, methane, carbon dioxide and water are produced. Note 1: The term 'biological recycling' is used synonymously. Note 2: Landfill shall not be considered a form of organic recycling.

Physical recycling	Physical recycling refers to a number of different processes for recycling plastics that include mechanical recycling, but also other physical treatments such as selective dissolution, extraction, precipitation and crystallisation to purify the plastic without (intentionally) modifying its polymer chains chemically. Note: Some stakeholders use the term physical recycling for dissolution processes only.
Physically recycled plastics	Plastics fully or partly produced by physical recycling process.
Plastic	Material which contains as an essential ingredient an organic polymer and which at some stage in its processing into finished products can be shaped e.g. by flow, extrusion, or moulding. Note 1: Elastomeric materials not shaped by flow, extrusion, or moulding, are not considered as plastics. Note 2: Additives or other substances may have been added, and which can function as a main structural component of final products.
Plastics directly produced from polymerisation (PPP)	Resin produced directly by a plastic production facility using polymerisation. Note: This includes the use of fossil, bio-based, carbon capture, and chemically recycled feedstock.
Plastics waste	Any plastic material or object which the holder discards, or intends or is required to discard.
Polymers	A substance consisting of molecules characterised by the sequence of one or more types of monomer units. Such molecules must be distributed over a range of molecular weights, wherein differences in the molecular weight are primarily attributable to differences in the number of monomer units. A polymer comprises the following: (a) a simple weight majority of molecules containing at least three monomer units which are covalently bound to at least one other monomer unit or other reactant (b) less than a simple weight majority of molecules of the same molecular weight Note by Plastics Europe member experts: Although the given definition is the official taken from (EC) No 1907/2006, polymers can, but not must have a molecular weight distribution.
Post- consumer recycled plastics (PCR)	Recycled plastics made from waste generated by households or commercial, industrial and institutional facilities in their role as product end-users, which can no longer be used for its intended purpose. This includes returns of material from the distribution chain or the installation of plastic products (e.g. remnants of insulation, flooring, or wall-covering boards).
Post-consumer plastic waste	Waste generated by households or commercial, industrial and institutional facilities in their role as product end-users, which can no longer be used for its intended purpose. This includes returns of material from the distribution chain or the installation of plastic products (e.g. remnants of insulation, flooring or wall-covering boards).

Pre-consumer plastic waste	Waste arising from plastics manufacturing (production and converting) processes (e.g. faulty production and sprues, edge sections of sheets, production leftovers). Note: This term excludes reutilised material, such as rework, regrind or scrap generated in a given process and capable of being reclaimed within that same process.
Pre-consumer recycled plastics	Recycled plastics made from waste diverted during the plastics manufacturing (production and converting) processes. Note 1: It excludes reutilised material, such as rework, regrind or scrap generated in a given process and capable of being reclaimed within that same process. Note 2: The term 'post-industrial recycled plastics (PIR)' is sometimes used synonymously.
Pyrolysis	A thermal process of heating up polymeric waste (e.g., plastic) in the absence of oxygen. It converts polymers into a range of simpler hydrocarbon compounds mainly in the form of liquid pyrolysis oil. Note: Pyrolysis is also used for cracking other substances/materials such as naphtha. The above definition refers to the pyrolysis of polymeric waste. Note: The process belongs to chemical recycling processes.
Recycled plastics	Plastics fully or partially produced from waste via a recycling process. Recycled plastics can be used as feedstock in the manufacture of plastic parts and products. Recycled plastics may be produced either from post-consumer waste or pre-consumer waste.
Repair	Operation by which a faulty or broken product or component is returned to a usable state to fulfil its intended use.
Reuse	Reuse of plastic products or parts without undergoing a recycling process or significant modification.
Solvolysis	A process by which plastic waste is divided into its monomer components by means of different chemical solvents, thus accordingly called glycolysis, methanolysis, hydrolysis, aminolysis. Note: The process belongs to chemical recycling processes.
Sorting	Physical processing techniques and processes to separate materials in waste fractions or streams. Sorting can be performed automatically with sorting technologies or manually.

References

Agency, E. C. (2022). Substances of Very High Concern. Retrieved from ECHA.Europa: https://www.echa.europa.eu/substances-of-very-high-concern-identification

Agency, E. E. (2022). EU Emissions Trading System (EU ETS). European Commission.

American Chemistry Council. (2015). Plastics Help Deliver Renewable Energy. Retrieved from Plastics Make it Possible: https://www.plasticsmakeitpossible.com/whats-new-cool/technology-science/plastics-help-deliver-renewable-energy/

Anderson, A., Grose, J., Pahl, S., Thompson, R., & Wyles, K. (2016). Microplastics in personal care products: Exploring perceptions of environmentalists, beauticians and students. (. Marine Pollution Bulletin, 113(1-2), 454-460. doi:https://doi.org/10.1016/j.marpolbul.2016.10.048

BBC Earth. (n.d.). Turning carbon emissions into plastic. Retrieved from BBC Earth: https://www.bbcearth.com/news/turning-carbon-emissions-into-plastic

Bio-based Industries Consortium. (n.d.). Novamont. Retrieved from Biconsortium: https://biconsortium.eu/membership/full-members/novamont

Borealis. (2022, October 19). Borealis advances plastics circularity with the first-of-its-kind Borcycle™ M commercial-scale advanced mechanical recycling plant. Retrieved from borealis: https://www.borealisgroup.com/news/borealis-advances-plastics-circularity-with-the-first-of-its-kind-borcycle-m-commercial-scale-advanced-mechanical-recycling-plant

Braskem. (2022, October 25). Braskem invests in capacity expansion and partnerships for the production of biobased plastics. Retrieved from Braskem: https://www.braskem.com.br/europe/news-detail/braskem-invests-in-capacity-expansion-and-partnerships-for-the-production-of-biobased-plastics
CARO, D., ALBIZZATI, P., CRISTOBAL GARCIA, J., SAPUTRA LASE, I., GARCIA-GUTIERREZ, P., JUCHTMANS, R., . . . TONINI, D. (2023). Towards a better definition and calculation of recycling. Publications Office of the European Union. doi:10.2760/636900

CE Delft. (2019). Exploratory study on chemical recycling. Update 2019.

Cefic. (2022). Circular Economy In Action With Eastman's Advanced Recycling Technologies. Retrieved from Cefic: https://cefic.org/a-solution-provider-for-sustainability/chemical-recycling-making-plastics-circular/chemical-recycling-via-depolymerisation-to-monomer/circular-economy-in-action-with-eastmans-advanced-recycling-technologies

Center for International Environmental Law. (2019). Plastic & Climate: The Hidden Costs of a Plastic Planet.

CHEM Trust. (2020). Chemical recycling: Is it worth the energy?². Retrieved from https://chemtrust.org/chemical-recycling/

Circle Economy. (2022). The Circularity Gap.

Clean Air Task Force. (2022). A European Strategy for Carbon Capture and Storage.

CSR Europe. (n.d.). European TRWP Platform Included as Good Example in the Tyre Industry's Sustainability Retrieved from https://www.csreurope.org/newsbundle-articles/european-trwp-platform-included-as-good-example-in-the-tyre-industrys-sustainability- plan

Deloitte. (2021). The potential of hydrogen for the chemical industry. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/xe/Documents/energy-resources/me_pov-hydrogen-chemical-industry.pdf

Deloitte analysis. (2023).

Deloitte analysis. (2023).
Deloitte analysis. (2023). Deloitte analysis based on SystemIQ (2022) and Plastics the Facts (2022).

Domenech, J., & Marcos, R. (2021, June). Pathways of human exposure to microplastics, and estimation of the total burden. Current opinion in food science, pp. 144-151.

Dosanjh, M. K., Zeller, R. B., Moneo De Las Morenas, E., Nigam Sinha, V., & Fruegaard, W. (2023, January 5). Speeding up renewable energy – bottlenecks and how you resolve them. Retrieved from World Economic Forum: https://www.weforum.org/agenda/2023/01/speeding-up-sustainable-energy-bottlenecks-and-how-you-resolve-them-davos2023/

Eastman. (n.d.). Polyester renewal technology. Retrieved from Eastman: https://www.eastman.com/Company/Circular-Economy/Solutions/Pages/Polyester-Renewal.aspx#:~:text=Eastman%27s%20polyester%20renewal%20technology%20unzips,with%20virgin%20or%20nonrecycled%20content

ECHA. (2007). Understanding REACH. Retrieved from European Chemicals Agency: https://echa.europa.eu/regulations/reach/understanding-reach

ECHA. (2016). Plastic additives initiative. Retrieved from ECHA.Europa.Eu: https://echa.europa.eu/plastic-additives-initiative

ECHA. (2018). Chemicals in our life - chemicals of concern-svhc.

ECHA. (2022). Candidate list of Substances of Very Hugh Concern for Authorization.

ECHA. (n.d.). Mapping exercise – Plastic additives initiative. Retrieved from European Chemicals Agency: https://echa.europa.eu/mapping-exercise-plastic-additives-initiative

EEB. (2021). Statement on the registration of polymers under REACH.

Ellen MacArthur Foudation. (n.d.). Our vision for a circular economy for plastics. Retrieved from Ellen MacArthur Foudation: https://ellenmacarthurfoundation.org/plastics-vision

Ellen MacArthur Foundation. (2019). Enabling a circular economy for chemicals with the mass balance approach .

European Bioplastics. (2020). Mechanical Recycling.

European Commission. (2017). A European strategy for plastics in a circular economy.

European Commission. (2018, November 19). Waste CO2 to be turned into ingredients for fuel, plastics and even food. Retrieved from European Commission: https://ec.europa.eu/research-and-innovation/en/horizon-magazine/waste-co2-be-turned-ingredients-fuel-plastics-and-even-food

European Commission. (2020). A hydrogen strategy for a climate-neutral Europe.

European Commission. (2021, July 14). Revision of the Energy Taxation Directive (ETD): Questions and Answers. Retrieved from European Commission: https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3662

European Commission. (2022). Biobased plastic : sustainable sourcing and content : final report. Publications Office of the European Union. Retrieved from https://data.europa.eu/doi/10.2779/668096

European Commission. (2022). COM(2022) 681 : EU policy framework on biobased, biodegradable and compostable plastics. Retrieved from https://environment.ec.europa.eu/system/files/2022-12/COM_2022_682_1_EN_ACT_part1_v4.pdf

European Commission. (2022). Establishing a framework for setting ecodesign requirements for sustainable products and repealin Directive 2009/125/EC. Brussels.

European Commission. (2022). EU Bioeconomy Strategy Progress Report.

European Commission. (2022, May 18). REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition. Retrieved from European Commission: https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131

European Commission. (2023, February). The Green Deal Industrial Plan: putting Europe’s net-zero industry in the lead. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/ip_23_510

European Commission. (n.d.). EU Hydrogen Strategy.

European Commission, T. U. (2021). Recycling of post-consumer plastic packaging waste in the EU: Recovery Rates, Material Flows and Barriers. Elsevier.

European Commission, Technical University of Denmark. (2021). Recycling of post-consumer plastic packaging waste in the EU.

European Environmental Agency (EEA). (2021). Growth without economic growth.

European Hydrogen Backbone. (2022). Estimated Investment & Cost. Retrieved from EHB: https://www.ehb.eu/page/estimated-investment-cost

European Investment Bank. (2022). Unlocking the hydrogen economy - Stimulating Investments Across the Hydrogen Value Chain.

European Parliament. (2022, December 13). Deal reached on new carbon leakage instrument to raise global climate ambition. Retrieved from European Parliament: https://www.europarl.europa.eu/news/pt/press-room/20221212IPR64509/deal-reached-on-new-carbon-leakage-instrument-to-raise-global-climate-ambition
Eurostat. (2022, December 21). EU economy emissions in 2021: -22% since 2008. Retrieved from ec.eurostat.eu: https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20221221-1

GARCIA-GUTIERREZ, P., AMADEI, A., KLENERT, D., NESSI, S., TONINI, D., TOSCHES, D., . . . SAVEYN, H. (2023). Environmental and economic assessment of plastic waste recycling. Publications Office of the European Union. doi:10.2760/0472

Geyer, R. (2020). Plastic: Too much of a good thing? Santa Barbara.

Geyer, R., Jambeck, J., & Lavendar Law, K. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7). doi: 10.1126/sciadv.1700782

Guidehouse. (2021). Analysing future demand, supply, and transport of hydrogen.

International Association of Oil&Gas Producers. (2019). The Potential for CCS .

International Energy Agency. (2019). Transforming Industry through CCUS.

International Energy Agency. (2020). Energy Technology Perspective.
Kaur Dosanjh, M., Bohle Zeller, R., De Las Morenas Moneo, E., Nigam Sinha, V., & Fruergaard, W. (2023). Speeding up renewable energy – bottlenecks and how you resolve them. World Economic Forum.

Kleimann, D., Poitiers, N., Sapir, A., Tagliapietra, S., Véron, N., Veugelers, R., & Zettelmeyer, J. (2023). How Europe should answer the US Inflation Reduction Act. bruegel.

Massachusetts Institute of Technology. (2011). Mass Impact and Deployment Characterisation.

Material Economics. (2019). Industrial transformation 2050.

Material Economics. (2021). EU biomass use in a net-zero economy: A course correction for EU biomass.

Notarstefano, V. (2022, January). Raman Microspectroscopy Detection and Characterisation of Microplastics in Human Breastmilk. Polymers.

OECD. (2019). Business Models for the Circular Economy.

OECD. (2019). Plastic leakage and greenhouse gas emissions are increasing. Retrieved from Plastics: https://www.oecd.org/environment/plastics/increased-plastic-leakage-and-greenhouse-gas-emissions.htm

OECD. (2022a). Global Plastics Outlook: Economic drivers, environmental impacts and policy options. Paris: OECD Publishing.

OECD. (2022b). Global plastics outlook: policy scenarios to 2060.

OECD. (2023, 01 06). Ocean pollution. Retrieved from https://www.oecd.org/ocean/topics/ocean-pollution/

PBL. (2021). Integrale circulaire economie rapportage. Retrieved from PBL (2021) Integrale circulaire economie rapportage, https://www.pbl.nl/sites/default/files/downloads/pbl-2021-integrale-circulaire-economie-rapportage-2021-4124.pdf

Planet Tracker. (2022). Breaking the Mould – Business as Usual is a High-Risk Strategy for the EU Plastic Industry.
Plastic Soup Foundation. (n.d.).
Plastics Europe. (n.d.). Sustainable use.

Plastics Europe. (2022). Plastic the facts 2022. Plastics Europe.

Plastics Europe. (2022). Plastics - the Facts 2022.

Plastics Europe. (2022). Plastics Europe position on complementarity of chemical and mechanical recycling.

Plastics Europe. (2022). Position paper-Carbon Border Adjustment Mechanism (CBAM).

Plastics Europe. (2022). Renewable resources (bioplastics). Retrieved from Plastics Europe: https://plasticseurope.org/sustainability/climate/sustainable-feedstocks/renewable-resources-bioplastics/

Plastics Europe. (n.d.). Additives.

Plastics Europe. (n.d.). Chemical Recycling.

Plastics Europe. (n.d.). The Impact of the Energy Crisis on the European Plastics Manufacturers. Retrieved from Plastics Europe: https://plasticseurope.org/media/the-impact-of-the-energy-crisis-on-the-european-plastics-manufacturers/

Plastics Industry Association. (2021). Plastics are changing transportation for the better.

Plastics recyclers Europe. (n.d.). Design for recycling. Retrieved from Plastics recyclers Europe: https://www.plasticsrecyclers.eu/what-we-do/design-for-recycling/

Port of Antwerp-Bruges. (2020). Antwerp@C investigates potential for halving CO2 emissions in Port of Antwerp by 2030. Retrieved from Port of Antwerp-Bruges: https://newsroom.portofantwerpbruges.com/antwerpc-investigates-potential-for-halving-co2-emissions-in-port-of-antwerp-by-2030

Ragusa, A., Notarstefano, V., Svelato, A., Belloni, A., Gioacchini, G., Blondeel, C., Giorgini, E. (2022). Raman Microspectroscopy Detection and Characterisation of Microplastics in Human Breastmilk. Polymers, 14(13).

Shell. (2022, June 16). SHELL AND DOW START UP E-CRACKING FURNACE EXPERIMENTAL UNIT. Retrieved from Shell: https://www.shell.com/business-customers/chemicals/media-releases/2022-media-releases/shell-and-dow-start-up-e-cracking-furnace-experimental-unit.html

Soares, J., Miguel, I., Venâncio, C., Lopes, I., & Oliviera, M. (2021). Public views on plastic pollution: Knowledge, perceived impacts, and pro-environmental behaviors. Journal of Hazardous Materials, 412. doi:https://doi.org/10.1016/j.jhazmat.2021.125227

Statista. (2019). Share of consumers concerned by packaging materials in Europe. Retrieved from https://www.statista.com/statistics/1073096/consumers-concerned-by-packaging-materials-europe/

SystemIQ. (2020). Breaking the Plastic Wave.

SystemIQ. (2022). Reshaping plastics.

The Harvard Gazette. (2020). DNA damage linked to plastic additive.

Thompson, R. C. (2004, May 7). Lost at sea: Where is all the plastic ? Retrieved from Brevia.

UNEP. (2020). Used vehicles and the environment, a global overview of use light duty vehicles: flow, scale and regulation.

UNEP. (2023). Potential options for elements towards an international legally binding instrument, based on a comprehensive approach that addresses the full life cycle of plastics as called for by United Nations Environment Assembly resolution 5/14, 13 April.

Vogt, B., Stokes, K., & Kumar, S. (2021). Why is Recycling of Postconsumer Plastics so Challenging? Applied polymer materials, 3(9), 4325-4346.

World Economic Forum. (2018). This is how long everyday plastic items last in the ocean.

Annex

Assumptions analytical model

TOPIC	ASSUMPTION	UNIT	SOURCE
General			
2021 general converter use of plastics products and parts by end-users	55.6	Mt	Plastics - the Facts (2022)
2021 converter use plastics made from biomass	1.3	Mt	Deloitte analysis (2023)
2021 fossil-based converter demand	50.4	Mt	Plastics - the Facts (2022)
PP fossil-based converter demand	10.0	Mt	Plastics - the Facts (2022)
PE fossil-based converter demand	14.8	Mt	Plastics - the Facts (2022)
PVC fossil-based converter demand	5.2	Mt	Plastics - the Facts (2022)
PUR fossil-based converter demand	4.1	Mt	Plastics - the Facts (2022)
PET fossil-based converter demand	4.0	Mt	Plastics - the Facts (2022)
PS fossil-based converter demand	3.1	Mt	Plastics - the Facts (2022)
ABS/SAN fossil-based converter demand	0.8	Mt	Plastics - the Facts (2022)
PA fossil-based converter demand	0.9	Mt	Plastics - the Facts (2022)
PC fossil-based converter demand	0.8	Mt	Plastics - the Facts (2022)
PMMA fossil-based converter demand	0.2	Mt	Plastics - the Facts (2022)
Other thermosets (excl. PUR) fossil-based converter demand	3.8	Mt	Plastics - the Facts (2022)

Other thermoplastics fossil-based converter demand	2.7	Mt	Plastics - the Facts (2022)
Packaging share of converter use	34.4	%	Circular Economy for Plastics (2022)
Household goods share of converter use	3.8	%	Circular Economy for Plastics (2022)
Construction share of converter use	23.6	%	Circular Economy for Plastics (2022)
Automotive share of converter use	8.0	%	Circular Economy for Plastics (2022)
Industrial packaging share of converter use	5.0	%	Reshaping Plastics (2022) and Plastics - the Facts (2022)
Electronics share of converter use	5.6	%	Circular Economy for Plastics (2022)
Agriculture share of converter use	4.2	%	Circular Economy for Plastics (2022)
Others share of converter use	15.3	%	Circular Economy for Plastics (2022)
Growth towards 2050 packaging	34.0	%	Reshaping Plastics (2022)
Growth towards 2050 household goods	31.0	%	Reshaping Plastics (2022)
Growth towards 2050 construction	44.0	%	Reshaping Plastics (2022)
Growth towards 2050 automotive	20.0	%	Reshaping Plastics (2022)
Growth towards 2050 other end-markets	30.0	%	Deloitte analysis (2022)
Waste volumes			
Packaging without bottles	5.8	Mt	Reshaping Plastics (2022) Deloitte analysis
Packaging household	16.7	Mt	Reshaping Plastics (2022)
Industrial packaging	3.3	Mt	Reshaping Plastics (2022) Plastics - the Facts (2022)
Electronics	2.3	Mt	Reshaping Plastics (2022) Plastics - the Facts (2022)
Automotive	3.3	Mt	Reshaping Plastics (2022)
Agriculture	1.1	Mt	Reshaping Plastics (2022) Plastics - the Facts (2022)
Construction	10.3	Mt	Reshaping Plastics (2022)

Reuse volumes after consumption			
Reuse	11.7	Mt	Reshaping Plastics (2022) Deloitte analysis
Packaging household	7.2	Mt	Reshaping Plastics (2022)
Packaging industrial	1.8	Mt	Reshaping Plastics (2022) Deloitte analysis
Household goods	0.8	Mt	Reshaping Plastics (2022)
Construction	0.2	Mt	Reshaping Plastics (2022)
Automotive	0.9	Mt	Reshaping Plastics (2022)
Electronics	0.7	Mt	Reshaping Plastics (2022) Deloitte analysis
Agriculture	0.1	Mt	Reshaping Plastics (2022) Deloitte analysis
Other	-	Mt	Reshaping Plastics (2022) Deloitte analysis
Circular plastics			
Recycled converter's use	5.5	Mt	Plastics - the Facts (2022)
Plastics production	1.3	Mt	Plastics - the Facts (2022)
Circular feedstock production			
Share of mechanical recycling in industrial packaging	100.0	%	Deloitte analysis (2023),
Share of mechanical recycling in electronics	80.0	%	Deloitte analysis (2023),
Share of mechanical recycling in agriculture	80.0	%	Deloitte analysis (2023),
Share of mechanical recycling in others	40.0	%	Deloitte analysis (2023),
2021 chemical recycling rate	70.0	%	Eunomia (2020). SABIC (2022). Institute for Applied Technology (2022)
2050 expected chemical recycling loss	20.0	%	SABIC (2022)
Biomass to plastics production rate	70.0	%	European Bioplastics (2019) and Nova Institute (2019) via EEA (2021)
2050 efficiency gain biomass for plastics production (expected)	30.0	%	Escobar N.. Britz W. (2021)

Average mechanical recycling sorting rate	70.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate PET	81.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate PP	57.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate PS	47.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate HDPE	76.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate PVC	73.0	%	European Commission. DTU (2021)
Average mechanical recycling sorting rate 75th percentile	80.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate 75th percentile PET	91.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate 75th percentile PP	79.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate 75th percentile PS	65.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate 75th percentile HDPE	91.0	%	European Commission. DTU (2021)
Mechanical recycling sorting rate 75th percentile PVC	73.0	%	European Commission. DTU (2021)
Average mechanical recycling rate	80.0	%	European Commission. DTU (2021)
Mechanical recycling rate PET	80.0	%	European Commission. DTU (2021)
Mechanical recycling rate PP	71.0	%	European Commission. DTU (2021)
Mechanical recycling rate PS	66.0	%	European Commission. DTU (2021)
Mechanical recycling rate HDPE	88.0	%	European Commission. DTU (2021)
Mechanical recycling rate PVC	80.0	%	European Commission. DTU (2021)

Average mechanical recycling rate 75th percentile	80.0	%	European Commission. DTU (2021)
Mechanical recycling rate 75th percentile PET	91.0	%	European Commission. DTU (2021)
Mechanical recycling rate 75th percentile PP	85.0	%	European Commission. DTU (2021)
Mechanical recycling rate 75th percentile PS	71.0	%	European Commission. DTU (2021)
Mechanical recycling rate 75th percentile HDPE	93.0	%	European Commission. DTU (2021)
Mechanical recycling rate 75th percentile PVC	80.0	%	European Commission. DTU (2021)
Share of bio-based plastics from 1st generation sourced biomass	25.0	%	Deloitte analysis (2023)
Share of bio-based plastics from 2nd generation sourced biomass	25.0	%	Deloitte analysis (2023)
Share of bio-attributed plastics from 1st generation sourced biomass	25.0	%	Deloitte analysis (2023)
Share of bio-attributed plastics from 2nd generation sourced biomass	25.0	%	Deloitte analysis (2023)
Waste			
Waste/plastics put on market	79.0	%	OECD (2022). Reshaping Plastics (2022)
Waste/plastics put on market	80.0	%	Material Economics (2021)
Waste collected for recycling	10.3	Mt	Plastics - the Facts (2022)
2050 share of waste collected for recycling (expected)	70.0	%	OECD (2022)
2021 landfill	38.0	%	Reshaping Plastics (2022)
2050 landfill (expected)	62.0	%	Reshaping Plastics (2022)

Biomass land use			
2021 Land use for plastics from biomass EU production	0.22	ha/t	Institute for Bioplastics and Biocomposites (2022)
Share of EU produced biomass for plastics	50.0	%	Deloitte analysis, expert interview (2023)
Efficiency gains by 2050 of biomass (expected)	30.0	%	Escobar N., Britz W. (2021)
Arable land EU	1,600,000.0	km^2	World Bank (2020)
Methanol to olefins production			
Carbon to produce 1 tonne of methanol	1.5	t	European Commission JRC (2015)
Hydrogen to produce 1 tonne of methanol	0.2	t	European Commission JRC (2015)
Electricity to produce 1 tonne of methanol	0.2	MWh	European Commission JRC (2015)
Methanol to produce 1 tonne of plastics	2.5	t	Deloitte analysis
2030 European carbon captured and stored across all industries (expected)	70.0	Mt CO_2e	IEA (2022)
2050 European carbon captured and stored across all industries (expected)	570.0	Mt CO_2e	K. Simson (2022)
Net-zero plastics life cycle			
ETS emissions			
2005 ETS emissions	2,370.0	Mt CO_2e	EEA (2022)
2020 ETS emissions	1,382.0	Mt CO_2e	EEA (2022)
2030 ETS GHG emission reduction target	62.0	%	European Parliament (2022)
2050 EU GHG reduction target	100.0	%	European Commission (2020)
Carbon footprint			
Feedstock production as share of Scope 1-2 and 3 upstream emissions	15.0	%	Material Economics (2021) and Reshaping Plastics (2022)

Fuel- and energy-related activities not included in Scope 1-2 as share of Scope 1-2 and 3 upstream emissions	15.0	%	Material Economics (2021) and Reshaping Plastics (2022)
Refining as share of Scope 1-2 and 3 upstream emissions	10.0	%	Material Economics (2021) and Reshaping Plastics (2022)
Cracking and other foreground processes as share of Scope 1-2 and 3 upstream emissions	39.0	%	Material Economics (2021) and Reshaping Plastics (2022)
Polymerisation and blending as share of Scope 1-2 and 3 upstream emissions	20.0	%	Material Economics (2021) and Reshaping Plastics (2022)
2021 carbon footprint PP	1.7	tCO_2e/t polymer produced	Plastics Europe (2014)
2021 carbon footprint PE	1.9	tCO_2e/t polymer produced	Plastics Europe (2014)
2021 carbon footprint PVC	2.0	tCO_2e/t polymer produced	Plastics Europe (2017)
2021 carbon footprint PUR	3.2	tCO_2e/t polymer produced	Plastics Europe (2017)
2021 carbon footprint PET	2.2	tCO_2e/t polymer produced	Plastics Europe (2017)
2021 carbon footprint PS	2.3	tCO_2e/t polymer produced	Plastics Europe (2022)
2021 carbon footprint ABS/SAN	3.0	tCO_2e/t polymer produced	Plastics Europe (2015)
2021 carbon footprint PA	4.5	tCO_2e/t polymer produced	Plastics Europe (2014)
2021 carbon footprint PC	3.4	tCO_2e/t polymer produced	Plastics Europe (2019)
2021 carbon footprint of PMMA	4.0	tCO_2e/t polymer produced	Plastics Europe (2015)
2021 carbon footprint other thermoplastics	4.0	tCO_2e/t polymer produced	Plastics Europe (2014)
2021 mechanical recycling	0.2	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 chemical recycling	1.4	tCO_2e/t polymer produced	Reshaping Plastics (2022)

2021 bio-attributed plastics	-1.1	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 bio-based plastics	-1.6	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 CCU+H2 based plastics	-1.2	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2050 mechanical recycling (expected)	0.1	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2050 chemical recycling expected	1.4	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2050 bio-attributed plastics (expected)	-1.5	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2050 bio-based plastics (expected)	-2.2	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2050 CCU+H2 based plastics (expected)	-1.5	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 low-carbon H2 steam cracker	0.2	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 electric steam cracker	1.1	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 steam cracker + CCS	0.5	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 steam cracker	0.8	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 polymerisation	0.4	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 incineration	2.2	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2021 conversion	0.2	tCO_2e/t polymer produced	Reshaping Plastics (2022)
2050 energy savings (expected)	5.0	%	OECD (2022)
2021 emission intensity European electricity mix	275.0	gCO_2e/kWh	EEA (2022)
2030 Europe emission intensity electricity mix (expected)	114.0	gCO_2e/kWh	EEA (2022)
2050 residual emission intensity European electricity mix (expected)	11.0	gCO_2e/kWh	IPCC (2014)

Penetration rate of levers to reduce Scope 1-2 emissions			
2030 renewable fuels (expected)	0.47	%	Reshaping plastics (2022)
2030 electrification of monomer production (expected)	0.47	%	Reshaping plastics (2022)
2030 capturing emissions (CCS) (expected)	2.4	%	Reshaping plastics (2022)
2030 steam cracker (expected)	96.7	%	Reshaping plastics (2022)
2050 renewable fuels (expected	55.0	%	Reshaping plastics (2022)
2050 electrification of monomer production (expected)	14.0	%	Reshaping plastics (2022)
2050 capturing emissions (CCS) (expected)	32.0	%	Reshaping plastics (2022)
2050 steam cracker (expected)	-	%	Reshaping plastics (2022)
Financial implications			
Inflation 2021-2022	12.4	%	Eurostat (2023)
Annualised CAPEX			
Mechanical recycling	102.0	EUR/t polymer produced	Material Economics (2019)
Chemical recycling[1]	157.0	EUR/t polymer produced	TNO (2021)
Bio-based plastics	216.6	EUR/t polymer produced	Reshaping Plastics (2022)
Bio-attributed plastics	96.1	EUR/t polymer produced	Reshaping Plastics (2022)
CCU+H2	475.0	EUR/t polymer produced	TNO (2021)
Renewable fuels	94.5	EUR/t polymer produced	Reshaping Plastics (2022)
Electrification monomer production	175.8	EUR/t polymer produced	Reshaping Plastics (2022)
Capturing emissions (CCS)	102.1	EUR/t polymer produced	Reshaping Plastics (2022)
Steam cracker	84.0	EUR/t polymer produced	Reshaping Plastics (2022)

1 Includes cost of hydrotreating

Polymerisation	50.0	EUR/t polymer produced	Reshaping Plastics (2022)
Conversion	176.9	EUR/t polymer produced	Planet Tracker (2022)
Transport of waste	23.0	EUR/t plastic waste transported	PlastiCircle (2021)
Landfill	17.8	EUR/t plastic waste landfilled	Eunomia (2020)
Incineration	28.1	EUR/t plastic waste incinerated	Reshaping Plastics (2022)
OPEX			
Mechanical recycling	892.9	EUR/t polymer produced	CE Delft (2022)
Chemical recycling	889.4	EUR/t polymer produced	Reshaping Plastics (2022)
Bio-attributed plastics	1,084.0	EUR/t polymer produced	Material Economics (2021)
Bio-based plastics	2,414.9	EUR/t polymer produced	Reshaping Plastics (2022)
CCU+H2	2,383.1	EUR/t polymer produced	Reshaping Plastics (2022)
Renewable fuels	1,91.0	EUR/t polymer produced	Reshaping Plastics (2022)
Electrification monomer production	1,091.5	EUR/t polymer produced	Reshaping Plastics (2022)
Capturing emissions (CCS)	1,057.7	EUR/t polymer produced	Reshaping Plastics (2022)
Steam cracker	929.8	EUR/t polymer produced	Reshaping Plastics (2022)
Polymerisation	232.5	EUR/t polymer produced	Deloitte analysis (2023)
Conversion	50.3	EUR/t polymer produced	Planet Tracker (2022)
Transport of waste	57.3	EUR/t plastic waste	Deloitte analysis (2022)
Landfill	11.0	EUR/t plastic waste landfilled	Eunomia (2020)
Incineration	183.1	EUR/t plastic waste incinerated	Reshaping Plastics (2022)
Cost decline mature technology	10.0	%	Harvard Business Review (1985)
Cost decline innovative technology	15.0	%	Harvard Business Review (1985)

A non-exhaustive list of about 100 publicly available business cases, actions and commitments by members of Plastics Europe that make plastics more circular, drive life cycle emissions to net-zero or foster sustainable use of plastics

CASE	COMPANY
Additional sales ambitions circular plastics solutions 2030 Evonik	Evonik
Additive sustainability footprint	VinylPlus member companies
Agiplast; Virtucycle	Arkema
Ambitions circular solutions Ineos O&P	INEOS O&P
Amodel Bios	Solvay
APK Dissolution process & Circulen Recover	LyondellBasell
Arkema Climate Plan	Arkema
BASF 2050 net-zero ambitions and 2030 investments	BASF
Bio Polyolefins	REPSOL
Bio-attributed PVC	Westlake Vinnolit
Bio-based polyamides capacity and additives	Arkema
Biodegradable Mater-Bi	Novamont
Blockchain projects	SABIC
BlueAlp	Shell Chemicals
BLUEHERO™	SABIC
Borcycle™ M	Borealis
Carbios	Solvay
Catena-X	BASF
Cazoolo	Braskem
CCS project	Röhm
ChemCycling; Ccycled	BASF
Circle project for advanced recycling of PVC	INOVYN
Circularity ambitions	Trinseo
Circular and bio-based Surlyn for more sustainable perfumes/ cosmetics packaging	Dow
Circular Flooring	Westlake Vinnolit
Coolbrook RDR	SABIC
Ducor carbon footprint reduction plan	Ducor Petrochemicals
Ducor circularity ambitions on mechanical recycling	Ducor Petrochemicals
Ducor circularity ambitions on renewable feedstock	Ducor Petrochemicals
Ecoplanta	REPSOL
Energy Transition Campus Amsterdam e-cracking furnace experimental unit	Dow, Shell
EOL Tyres to Auto Materials	REPSOL
EPS insulation portfolio focusing on alternative resources	BASF
Food contact standards for mechanically recycled polystyrene	INEOS Styrolution

Fortescue Future Industries	Covestro
GHG and Volatile organic compounds (VOC) emissions reduction commitments	VYNOVA
Grandpuits zero-crude platform	TotalEnergies
Green electricity	Ducor Petrochemicals
GreenVin® PVC	Westlake Vinnolit
H2/electrolyser project	INOVYN
H2-Reallabor Burghausen; ChemDelta Bavaria	Westlake Vinnolit
Heathland acquisition	Trinseo
Hoop	Versalis
Hydrogen Import Alliance Bavaria	Westlake Vinnolit
I'm green portfolio	Braskem
Indaver; Agilyx	INEOS Styrolution
La Mède Refinery	TotalEnergies
Large-scale electrically heated steam cracker furnace demonstration plant	BASF, SABIC, Linde
Low Carbon Solutions	LyondellBasell
Makrolon	Covestro
Marlex Anew	Chevron Phillips
Mater-Bi	Novamont
Mepol recycled compounds	LyondellBasell
Moerdijk pilot	Shell Chemicals
MoReTec & Circulen Revive	LyondellBasell
Mura Technology	Dow
Niaga tag	Covestro
Novamont decarbonisation strategy	Novamont
OCS Kallo & Antwerp	Borealis
Oxygea Sustainable Investments	Braskem
Ostium	Solvay
Project Greensand	INEOS O&P
Project ONE	INEOS O&P
ProTerra	Röhm
PVC recycling	INOVYN
QCP & Circulen Recover	LyondellBasell
rABS; ECO family of solutions for the circular economy	INEOS Styrolution
R-Cycle Digital Product Passport	Dow
Rafnes Vinyl Chloride	INOVYN
RE:clic	TotalEnergies
Recelerate entity	Borealis
Reciclex	REPSOL
RecoMed and VinylPlus Med, initiatives to recycle PVC Healthcare waste	VinylPlus
RecyClass	INEOS Styrolution

Renasci Smart Chain Processing	Borealis
Renewable-based feedstock & Circulen Renew	LyondellBasell
Revive PS	Versalis
REVOLOOP™ traceability and recycled content certification	Dow
Röhm 2030 and 2050 decarbonisation commitments	Röhm
SABIC Circular solutions ambition 2030	SABIC
SABIC Plastic Energy Advanced Recycling Unit	SABIC
Safer Chemistry Program	SABIC
Sales ambitions circular solutions 2030 BASF	BASF
SourceOne advanced sorting	LyondellBasell
Steel2Chemicals	Dow
Sustainea bio-MEG	Braskem
Synova & Plastic Omnium	TotalEnergies
SyschemIQ	SABIC
Terneuzen decarbonization ambition	Dow
Terneuzen pilot	Trinseo
Trucircle	SABIC
Upsyde	Braskem
Valoregen	Dow
Verbund	BASF
Victrex net-zero aspirations	Victrex
VinylPlus 2030 commitment	VinylPlus member companies
Voqen Sustainable Energy	Braskem
Wenew recycling solutions	Braskem
Window profile case	INOVYN
Wise Plasticos; Valoren	Braskem

Plastics Europe and our members recognise the severity of the climate crisis and the challenge of plastic waste. Faster systemic change is essential to successfully meet the EU's net-zero and circularity objectives.

In this roadmap, developed with the support of Deloitte, we lay out a potential pathway for a circular and net-zero plastics industry in Europe. The roadmap provides a framework, milestones for 2030 as well as for 2050 and indicators to monitor progress, identify bottlenecks and find solutions to keep moving forward.

Our data-driven roadmap is a living document that will be progressively updated based on new insights and changes to our industry environment. It aims to guide, incentivise and accelerate industry action and performance, and provide an evidence base to inform value chain dialogue and policy-making.

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