ETC CE Report 2023/1

Pathways to circular plastics in Europe: Good examples from countries, businesses and citizens

Authors:

ETC experts: Ive Vanderreydt (VITO), Alexandra Almasi (IVL), Emma Strömberg (IVL), Anna Tenhunen-Lunkka (VTT), Mona Arnold (VTT)

EEA experts: Lars Fogh Mortensen, Tobias Nielsen, Freja Paulsen

European Environment Agency
European Topic Centre
Circular economy and resource use

Cover design: EEA
Cover image © iStock.com/Thomas Faull
Layout: ETC CE

Publication Date: 20 February 2023

EEA activity Circular economy and resource use

ETC CE coordinator: Vlaamse Instelling voor Technologisch Onderzoek (VITO)

ETC CE partners: Banson Editorial and Communications Ltd, česká informační agentura životního prostředí (CENIA), Collaborating Centre on Sustainable Consumption and Production (CSCP), Istituto Di Ricerca Sulla Crescita Economica Sostenibile, Istituto Superiore per la Protezione e la Ricerca Ambiantale, IVL Swedish Environmental Research Institute, PlanMiljø, Universita Degli Studi Di Ferrara (SEEDS), German Environment Agency (UBA), Teknologian Tutkimuskeskus VTT oy, Wuppertal Institut für Klima, Umwelt, Energie gGmbH, World Resources Forum Association.

European Topic Centre on
Circular economy and resource use
https://www.eionet.europa.eu/etcs/etc-ce

Contents

Acknowledgements 1
Summary 2
1 Introduction: pathways to circular plastics in Europe 4
2 The smarter use pathway 7
  Introducing the smarter use pathway 7
  Business 8
  Policy makers 11
  Citizens 14
  Wrap up on the smarter use pathway 15
3 The increased circularity pathway 16
  Introducing the increased circularity pathway 16
  Business 17
  Policy makers 20
  Citizens 22
  Wrap up on the increased circularity pathway 23
4 The renewable material pathway 24
  Introduction to the renewable material pathway 24
  Business 25
  Policy makers 28
  Citizens 29
  Wrap up on the renewable material pathway 29
5 Conclusions 31
References 32
Annex 1: Workshops 34
Annex 2: Criteria for selecting good examples 36

Acknowledgements

The report has been produced within the task on ‘Pathways toward circular plastics: good examples from countries, business and citizens’ of the 2022 ETC/CE work programme. Lars Fogh Mortensen and Tobias Nielsen (EEA) have been the project leaders, supported by Freja Paulsen (EEA). Ive Vanderreydt (VITO) has been the task leader, supported by Alexandra Almasi (IVL), Emma Strömberg (IVL), Anna Tenhunen-Lunkka (VTT) and Mona Arnold (VTT) for the elaboration of the report and by Francesca Grossi (CSCP) for the organisation of the workshops.

The review by Kia Rose Egebæk substantially proved the quality of the report. Bart Ullstein (BEC) provided careful editing of the report.

The authors are grateful to all experts and organisations for providing feedback and comments during or after the organisation of the workshops within the context of this task.

Summary

If we want to avoid plastics becoming a victim of its own success, there is a clear need for further changes in the way it is produced, used and managed. This relates to their extraction, production, use and end-of-life treatment.

The heterogeneity of plastics, their use and corresponding impacts require a diversified approach to move towards circularity and sustainability, combining an application specific focus and a systemic view on the way forward. The diversity of polymers, their applications and geographical contexts makes it challenging to provide all-inclusive solutions.

Using the smarter use, increased circularity and renewable materials pathways, previously analysed and explained in an earlier EEA report (EEA, 2020b), as a starting point, main trends and challenges for each pathway are described in this report, interspersed with existing good examples from across Europe that are already addressing these issues and challenges.

These good examples are meant to inspire stakeholders, from policy makers to businesses and citizens, on how they can improve/increase their role in making plastics more circular and sustainable, with the aim of protecting the environment and climate from the detrimental effects of plastics production, consumption and management.

Reduced plastics production, consumption (prevention) and reuse systems have an important role to play in increasing the circularity of plastic and in lowering plastics' environmental footprint. Both the current price of (fossil based) bulk products as well as the current design of most products do not, however, intrinsically motivate longer use or less use, repair, reuse and sharing approaches from a resource cost perspective.

On a smarter use pathway to plastics circularity and sustainability, upstream policy instruments, such as recycled content targets and durability requirements for plastic components could create incentives to reduce use and foster circularity and sustainability. Adapting their business model to circular economy strategies, such as higher quality and longer use, reuse, repair and remanufacturing requires companies to change their business approach and investment models.

Good examples identified for smarter use not only relate to higher quality and longer use, reuse, repair and remanufacture, but also to the implementation of circular business models, such as product-as-a-service, sharing and leasing.
On an increased circularity pathway, several measures are important such as circular product design, more and better collection of waste, further developed sorting and recycling technology, in a coordinated way, as well as a well-developed market for secondary materials. On top of that, qualitative recycling ensuring effective closure of material loops is a prerequisite to drive the transition to a real circular economy. To be able to increase material circularity, cooperation of involved stakeholders along the value chain is key. However, it remains challenging to set up this cooperation on a large scale, to preserve it and to improve it. A chain is only as strong as its weakest link.

On a renewable materials pathway, the quest to reduce society's dependency on fossil-based plastics by bio-based plastics is further explored. Bio-based plastics can, under the right circumstances, provide environmental benefits, in particular in the production stage. These advantages may, however, come with trade-offs, such as less favourable effects on the availability of land for agriculture, increased plastic pollution, rivalry with food production, vague end-of-life management and greater expense.

To expand from specialty polymers to large-scale bio-based plastic market applications, sustainable sourcing combined with the possibility of effectively closing material loops at the end-of-life phase seem to be the crucial challenge for bio-based plastics.

1 Introduction: pathways to circular plastics in Europe

Plastics and plastic-containing products play a critical role in the transition to a circular economy: how they are designed, manufactured, used and become waste has a significant impact on the economy, society, the environment and the climate today and in the future. By reusing, recirculating and recycling plastics and plastic-containing items rather than discarding them, not only is the value of the products and components preserved, but the need for virgin materials and corresponding energy for extraction of these virgin materials, as well as the production of waste, is reduced, leading to a decrease in the related environmental (including climate) impacts.

In recent years many studies have been published explaining both the advantages and the challenges in the way plastics are produced, used and managed in society. Although some action has already been taken in Europe and around the world to prevent plastics from damaging the environment, it does not yet entail a comprehensive and systemic response to the need for responsible and improved management of plastics and products containing them.

To facilitate the transition to the circular use of plastics in Europe, as well as in other regions of the world, a balanced and systemic set of solutions addressing all specific issues of the currently linear plastics system, should be considered. This will enable producing and using plastics in a more effective and efficient way by doing more with less plastic, while at the same time managing the plastics in use in a circular way.

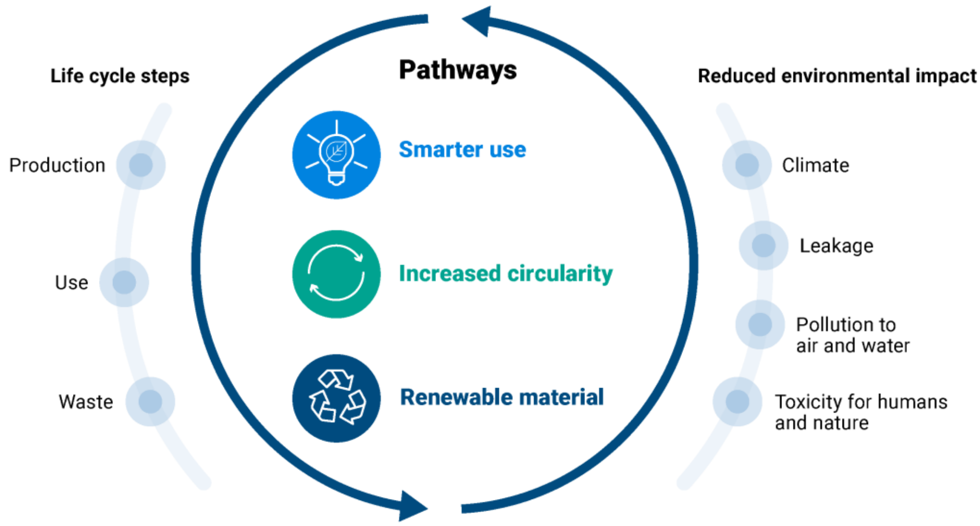
A combination of approaches to make plastics management more circular could be adapted/tailored to the specific context in which they are applied. No single solution exists when it comes to circular plastics.

Three main pathways that could contribute to the circularity of plastics in Europe have already been explained and explored in a previous EEA report. (EEA, 2020b)

1. **Smarter use:** the focus of the smarter use pathway is to reduce the use of unnecessary plastic, including by effective design of plastics and products containing them thereby preventing waste; extending their lifetime by improving quality and increasing reuse and repair; or adapting the type of material used, resulting in less environmental pollution caused by plastic use and management, and a decrease of the growth rate of plastic production and consumption.
2. **Increased circularity:** the increased circularity pathway refers to solutions that improve the circularity of plastics by focusing on maintaining the value and utility of plastics in closed loops. This preservation of functionality should provide specific as well as systemic solutions, helping to close material loops leading to higher resource efficiency and low(er) materials and value losses.
3. **Renewable material:** to reduce society's dependency on fossil fuels for plastics, the renewable materials pathway offers options to switch to renewable feedstock, helping society to escape from the petrochemical lock-in.

Each pathway, as shown in Figure 1, targets distinct stages of the plastics value chain as well as diverse environmental and climate impacts.

Figure 1 The scope of different pathways to a circular plastic system



Source: Developed by the EEA and the ETC CE — illustration by the Collaborating Centre on Sustainable Consumption and Production (CSCP) and the EEA.

These three pathways are not alternatives, but rather complementary pathways in line with current EU policies, offering options for continued policy development towards circularity and sustainability in the long term. Policy action, circular business models and a changing role for consumers are important to all three pathways.

The remainder of this report describes trends and challenges for each pathway, interspersed with good examples from countries and businesses across Europe that are already addressing these issues and challenges. The role of the good examples is to inspire stakeholders – policy makers, businesses and citizens – on how they can improve/increase their role to make plastic more circular and sustainable.

Underlined text with a light grey background indicates that a box explaining the corresponding good example follows.

The good examples of circular plastics should be regarded as an obligation-free menu, leaving it up to the reader to pick out the ones that best suit their local situation, context and goals.

Two complementary entry points were used in the preparation of this report.
Firstly, good examples of circular plastics in Europe were gathered by the project team and categorised according to their respective pathway and main stakeholder – business, policy makers or citizens. The collection of good examples was presented during a first workshop and was expanded based on inputs from workshop participants (Annex 1: Workshops). Secondly, good examples were gathered for each pathway based on a shortlist of the main challenges to managing plastic in a more circular way. Good examples addressing these specific challenges were gathered and documented, and then discussed at a second workshop. The criteria applied for selecting the good examples are described in Annex 2.

The following good examples are described in this report, accompanying the analyses in each chapter.

- For the smarter use pathway:
  - Access-based products (examples: washing machines, jeans, headphones and toys);
  - Reusable plastic products (example: business-to-business (b2b) packaging systems);
  - Reusable plastic products (example: refillable by bulk dispenser);
  - Reusable plastic products (example: collection system for toys);
  - Extending lifetimes through repairability (examples: mobile phone, electronics);
  - Requirements for prolonged product use (examples: reusable products, repairable products, durable products);
  - Public procurement (example: reduction of single-use plastics at events);
  - Green deals for reduced consumption (example: reduction of plastic bag consumption);
  - Product sharing (examples: sports and leisure equipment, car sharing, electronics, tools and equipment, baby gadgets).

- For the increased circularity pathway:
  - Better/more collection (example: centralised/better collection of (agricultural) plastic waste);
  - Better/more collection (example: collection system for residue from the installation of plastic flooring);
  - Improved recycling (example: closed-loop plastic furniture);
  - Improved recycling (example: closed loop food-grade polyethylene terephthalate (PET) recycling);
  - More and better collection+sorting+recycling (example: collaborative value chain approach for packaging);
  - Reduce impacts of substances of very high concern (SVHC) (example: recycling hazardous plastic waste);
  - Carbon dioxide as a feedstock for plastics (example: carbon capture and utilisation);
  - Eco-modulation of extended producer responsibility (EPR) fee of plastics packaging;
  - Public procurement (example: sustainable plastic use within public sector);
  - Dissemination of information (example: national and/or regional knowledge hubs for the circularity of plastics);
  - Better/more collection (example: increased collection for recycling).

- For the renewable material pathway:
  - Third generation feedstock for bio-based plastics (examples: ocean algae, citric peels, lignin and cellulose);
  - Feedstock efficient solutions for bio-based plastics;
  - Sustainably sourced bio-based plastic alternative (example: recyclable bio-based packaging material);
  - Sustainably-sourced bio-based plastic alternative (example: biodegradable agricultural mulch);
  - Alternative labels for unpacked fruit and vegetables (example: biodegradable solution, laser-based marking);
  - Sustainably-sourced bio-based plastic alternative (example: bio-based flocculant aids in water treatment);
  - Sustainably managed forests – forest policies and certification (examples: Forest Stewardship Council (FSC), Programme for Endorsement of Forest Certification (PEFC)).

2 The smarter use pathway

Introducing the smarter use pathway

In general, the relatively low cost of fossil feedstock, coupled with the diverse functionality of plastic as a material, has led to the ubiquitous and growing global supply and demand for plastics. Through functionalised and specific design, plastic and plastic-containing products, including packaging, have supported a faster lifestyle characterised by takeaway services, single-use and disposable items, etc.

Petrochemicals, i.e., chemicals obtained from petroleum and natural gas, are by far the most significant driver of the global growth in the demand for oil and are both the largest industrial consumer of energy and the third-largest industrial emitter of greenhouse gases. The International Energy Agency (IEA) estimates that global direct greenhouse gas emissions from petrochemicals will increase 20 % by 2030 and 30 % by 2050, with plastic production as the main driver of the petrochemical industry's growing climate footprint.(IEA, 2018).

Without action to curb the supply and demand for plastics, increased product lifespans, and better waste management and recyclability, plastic pollution and related emissions will rise concurrently, with an almost threefold increase in plastics use driven by growing global population, production and incomes. The Organisation for Economic Co-operation and Development (OECD) estimates that nearly two-thirds of plastic waste in 2060 will be from short-lived items such as packaging, low-cost products and textiles (OECD, 2022).

The smarter use pathway aims to reduce the projected growth curve of plastic production and consumption by using plastics in a smarter way. It focuses on reducing unnecessary plastics by ensuring that they are used more effectively, by improving resource efficiency – less plastic providing the same functionality, and by extending the lifetime of plastic products. Action supporting changes in production, consumer behaviour, and increased reuse and repair is important and inherently linked to this pathway. With such measures, the pathway intends to decrease the supply and demand for plastics and, therefore, the corresponding environmental impact of plastic production and consumption (EEA, 2020b).

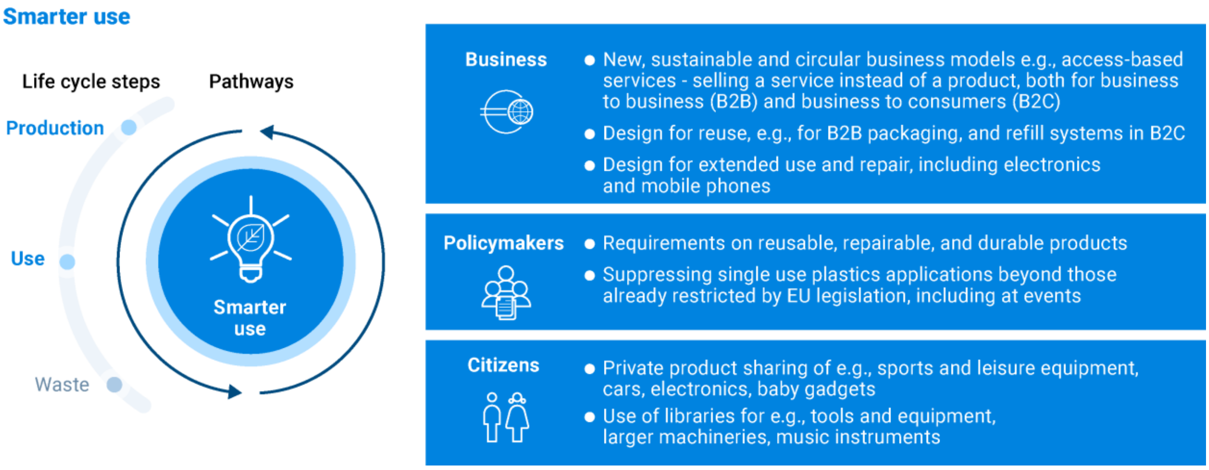
According to Bauer et al. (Bauer et al., 2022), breaking the increasing trend of plastic use is likely to start with disposable single-use plastic products and packaging. The goal is to use fewer resources and materials by enhancing product quality and lifetimes through design, reuse and repair – especially for more complex applications and in applications for which reduction is challenging.

Plastics are shipped across the world as materials, products and waste streams through global supply chains. At the same time, the current policy landscape for plastics worldwide is fragmented and could be strengthened. Policy responses would be more effective were they better coordinated internationally, including through a possible new global treaty on plastics that is currently being developed and negotiated.

Curbing the supply and demand for plastics brings the largest environmental gains (OECD, 2022). Lower supply and demand for plastics means fewer greenhouse gas emissions from extraction and production, fewer plastics-related health risks and less plastic waste to deal with. The choice of the best and most efficient policy option for achieving this is, however, not clear. Data gaps and monitoring issues on plastics in society, especially non-waste-related information, make it difficult to develop policies.

On the pathway towards smarter use of plastics, businesses, policy makers and citizens have different but complementary roles to play. Examples for each of these stakeholders are included in the discussion below and in Figure 2.

Figure 2 Examples of the smarter use pathway



Note: The life cycle steps highlighted in blue are the ones most relevant for the smarter use pathway, but are not necessarily the only ones that can be found.

Source: Developed by the EEA and the European Topic Centre on Circular Economy and Resource Use (ETC CE) — illustration by the Collaborating Centre on Sustainable Consumption and Production (CSCP) and the EEA.

Business

Generally, businesses have taken note of the problems and challenges with plastics, and some have responded with efforts to reduce excessive plastics use or launch products made of recycled or bio-based plastic. Start-ups and entrepreneurs have also capitalised on public attention; one well-known example is luxury goods, such as sunglasses, made from recovered ocean plastic (Dijkstra et al., 2020).

Access-based products

One way that (plastic-containing) products can be used smarter is by shifting mindsets from the owning products to having access to products or their functionality. Access-based products and business models, commonly known as product service systems or producer ownership models, provide access to services that meet customer needs without the necessity of owning the product itself. By increasing utilisation of the products through, for example, leasing or renting solutions, these models can reduce the production of new products. They offer a value proposition of user experience and product performance without the (cost of) ownership. This model makes high-quality products accessible and affordable to a broader audience by minimising the upfront investment for consumers; a much lower, periodic use fee is charged instead. Examples are the rental of clothing for special occasions or camping gear, and the leasing of jeans, printers, headphones and washing machines. Such business models, however, currently have a marginal share of the plastic-related markets in Europe and around the world.

Access-based products (example: washing machines, jeans, headphones, toys)	
Issue addressed	Avoidance of excess consumption and ownership of products
Solution description	Provide access to products and functionality in a more efficient way. The solution provides incentives for products of higher quality and longer service lives.
Constraints	To decouple profit generation from the production and sales volume requires the right conditions and incentives for lifetime-extension and resource-saving strategies, such as more durable products, maintenance, reparability, and design-for-repair and take-back systems. Whether actual environmental benefits occur, however, depends highly on the specific solution, for example, the product type, the business model, circulations achieved, logistic setup, etc.

Examples of solution providers	• Washing machines: Belgium, Coolblue https://www.coolblue.be/en/washing-machines/subscriptions; • Jeans: Netherlands, Mud Jeans https://mudjeans.nl/pages/lease-a-jeans; • Headphones: Netherlands, Repeat® https://gerrardstreet.nl/; • Toys: Denmark, Dear Baby www.dearbaby.dk.

Reusable plastic product

Related to this, the design for reusable (plastic) packaging has gained interest, supported by the European Parliament's call for an increase in the share of packaging reuse to 10 % by 2030 and covenants or EPR schemes that include the reduction of single-use packaging. In practice, the impacts will depend on the specific design and implementation of the reusable packaging systems. Well-designed refill/reuse systems can result in material savings and various producers have developed refillable packaging, providing refills that use less material or reusable packaging for, amongst others, the ecommerce sector. More radical approaches, such as packaging-free shops, have not been very successful. Switching to reusable packaging has, however, to be weighed against, for example, increased transport movements, complex logistics, cleaning, food safety and other factors (Coelho et al., 2020).

Reuse and repair centres turn out to be examples of how to extend the lifetime of products and preventing them from becoming waste. Also, business initiatives exist for collecting (plastic) toys to extend their actual lifetimes.

Reusable plastic product (example: business-to-business packaging systems)	
Issue addressed	The use of large amounts of single-use secondary and tertiary packaging with short lifespans in, for example, the food industry and e-commerce.
Solution description	A system that enables the distribution of fresh produce and goods in standardised and reusable plastic crates and pallets within the food industry. Actors from the entire value chain, from producers through wholesalers to stores, can become members and use the system. Members pay a user fee and a deposit to use the crates and pallets. After every use, the crates and pallets are taken back for quality control and washing. It is estimated that using reusable crates instead of disposable packaging reduces carbon dioxide emissions by more than 70 % compared to single-use packaging. In addition, it is also estimated that a medium-sized store can save about 160 hours of labour every year by using reusable crates and pallets rather than single-use ones.
Constraints	The system is dependent on a managing organisation and a well-developed logistical model. It is financed by a membership fee. To be truly sustainable, the solution needs to be aligned with the anticipated number of times that the packaging is used.
Examples of solution providers	• Smart circular system for the food industry: Sweden, Svenska Retursystem https://www.retursystem.se/en/; • Packaging for eCommerce: Finland, Repack https://www.repack.com/; Denmark, Rezip, www.rezip.dk; • Personal care products: Norway, Påfyll https://pafyll.com; • Packaging for takeaway food: Finland, KamuPak https://en.kamupak.fi/; Denmark, Newloop www.thenewloop.dk (in Danish).

Reusable plastic product (example: refillable by bulk dispenser)	
Issue addressed	Shops and department stores providing bulk dispensers so that customers can use their own containers and pay pby weight instead of pre-defined products.
Solution description	Reusable packaging for perishables is often limited to dry products such as cereals, nuts, and sweets but can also be used for liquids and other non-dry products.
Constraints	Manufacturers' preferences for their own individual packaging design and branding. The inconvenience for customers having to bring their own packages to the store.
Examples of solution providers	• Cleaning products: Global, Ecover https://www.ecover.com/global/; • Packaging-free solutions: Europe, MIWA https://www.miwa.eu/; • Packaging-free stores: Germany, Unverpackt https://original-unverpackt.de/; • Packaging-free goods: UK, Waitrose Unpacked https://www.waitrose.com/ecom/content/about-us/sustainability/unpacked; • Packaging-free goods: UK, Asda https://corporate.asda.com/newsroom/2020/10/20/asda-opens-new-sustainability-store.

Reusable plastic product (example: collection system for toys)	
Issue addressed	The products have a low separate collection rate or are incinerated at end of life.
Solution description	To prolong the use of the products, a simple-to-use platform is in place that allows customers to pass on toys to children in need. After the use of the products is finished, by private citizens send the toys back to the producer, who then redistributes them. This prolongs the service life of the products and decreases the need for new product is.
Constraints	The system is easily scalable for many producers of toys, depending on the durability of the materials in the product.
Examples of solution providers	Toys: Denmark, Lego Replay https://www.lego.com/en-us/sustainability/environment/replay

Extending lifetimes through repairability

At base, eco-design aims to minimise the use of natural resources as far as possible without compromising the functions of a product. Eco-design for plastic products generally includes making products lighter and substituting materials. Recent emphasis on reusable food packaging has also turned design towards increased durability, combined with hygienic aspects of the final product. For packaging, it should be noted that the protective function of the package is always the top priority and that the environmental footprint of the packed goods is typically much higher than that of the packaging.

In general, plastic product designers need to solve complex trade-offs between the sustainability of a product; necessary functions such as. quality, durability, and safety; and costs and revenue (Watkins et al., 2020). For many products, designers have a choice between using plastics or other materials, such as wood, metal or glass, or the combination of different materials – which is often the case in multi-layered packaging. Substituting plastics for alternative materials can be an option for addressing sustainability issues. However, in the drive to reduce plastics, there is a risk that the alternative materials or the material combinations are less recyclable and/or have greater environmental or climate impacts when taking a lifecycle perspective.

One of the goals of eco-design is to boost repairability, which enables extending the lifetimes of products. Interesting examples of repair have already been demonstrated for mobile phones, typically 40 % of which are plastic, and electronics in general. Some companies have specialised in the refurbishment and resale of used electronics ensuring reliable data erasure, battery lifetimes and product guarantees to help extend the lifetime of these products.

Extending lifetimes through repairability (example: mobile phones and electronics)	
Issue addressed	Sometimes valuable products reach their end of life due to the malfunction of only one component or part of the product or because its software is no longer functioning as desired.
Solution description	Designing electronics and smartphones to be easily dismantlable and offering repair services could considerably extend their lifetimes.
Constraints	Adaptation of business models.
Examples of solution providers	• Smartphone: Europe, Fairphone www.fairphone.com/en/; • Electronics repair guidance: Global, iFixit www.ifixit.com/; • Repair and refurbishment of used electronic: Scandanavia, Refurb® www.refurb.eu (in Danish, Norwegian and Swedish).

Policy makers

Public policies are key levers for reducing the environmental consequences of the amounts of and way plastics and plastic products are produced, used and their wastes managed. A steady increase in awareness of the environmental, economic, public safety and individual health risks posed by plastic pollution has led to the development of numerous and diverse sets of regulatory tools at national, regional and international levels.

Requirements for prolonged product use

Existing EU legislation and policy targets, such as the Single-Use Plastics (SUP) Directive and the sustainable product policy, support the use of substitute materials in Europe and reducing the use of some plastic products and their environmental impact. For instance, it has been estimated that the ban on single-use plastic products will avoid the emission of 3–4 million tonnes of carbon dioxide equivalent each year by 2030, avoid environmental damage which would cost the equivalent of more than EUR 30 billion by 2030 to repair, mainly related to avoided impacts associated with terrestrial and marine litter, and will save consumers almost EUR 8 billion (ICF Eunomia, 2019).The SUP Directive includes waste prevention measures such as providing information to consumers, market-based instruments and product design requirements.

According to an EEA study from 2019, the major part of policy measures currently applied focuses on post-consumption plastic waste, while waste prevention action relating to production, such as eco-design and measures to reduce the presence of hazardous substances, is in the minority. Most policy instruments employed by countries are soft measures, such as information/public communication programmes and voluntary agreements. Another group of measures are market-based instruments, most of which refer to legal obligations to reduce the consumption of plastic carrier bags (EEA, 2019).

At the same time, new EU policy initiatives are currently being developed, including initiatives for reducing pollution from microplastics and promoting alternative plastics, including bio-based, biodegradable and compostable plastics.

Globally, bans and taxes on certain single-use plastic items exist in more than 120 countries, but their effectiveness in reducing plastic pollution could still be improved everwhere. Most regulations are limited to single-use plastic bags or other streams that are relatively small in volume. This means that these instruments are mainly effective in reducing leakage as a result of littering rather than restraining the overall consumption of plastics (OECD, 2022).

In a recent report on the future of petrochemicals, the IEA predicted that the combination of a growing global economy, rising population and technological development will translate into increasing global demand for petrochemical products. Although there are substantial increases in recycling and efforts to curb the use of single-use plastics, these efforts will be outweighed by a sharp increase in plastic consumption in developing economies. The IEA also predicted that the supply of robust alternatives to petrochemicals will be challenging considering the overall demand growth for petrochemical products (IEA, 2018).

Also, environmental labelling and certification help communicate the characteristics of substitute materials and the potential benefits to consumers, and are therefore an essential element for the viability of such alternatives (OECD, 2016).

Upstream policy instruments, such as recycled content targets, durability and repairability requirements for plastic components and EPR schemes with fee modulation, can create financial incentives to reduce use and foster the circularity of plastics. However, only some countries are experimenting with these instruments and targets. Their impact could be improved considerably by showcasing the results more widely and thus extending them to more product types, countries and regions.

Requirements for prolonged product use (examples: reusable products, repairable products, durable products)	
Issue addressed	Policy makers could promote prolonged product use by including requirements in relevant legislation and regulations.
Solution description	Several existing regulations already include requirements for prolonged product use. These requirements often could be strengthened and replicated for other products and product categories.
Constraints	Preferably done on international and regional levels; to be effectivity assessed for all products.
Examples of solutions	• Electric and electronic equipment: Article 4 of Waste Electrical and Electronic Equipment (WEEE) Directive, “*facilitating reuse, dismantling and recovery*”; • Household washing machines and household washer-dryers: Commission Regulation 2019/2023, Annex II, “*availability of spare parts*”; • Furniture: Commission Decision 2016/1332, “*promoting a durable and high-quality product that is easy to repair and disassemble*”; • Televisions: Commission Decision 2009/300/EC, Annex, Criteria 4, Design for disassembly.

Public procurement

Public procurement could incorporate bans on single-use plastic items, as well as targets and incentives to promote repair, reuse and/or plastic-free alternatives, enabling procurement teams to include a sustainable product line. Green public procurement (GPP) provides powerful opportunities to reduce the environmental impact of public services and, importantly, to leverage investment in greener products.

Public procurement (example: reduction of single use plastics at events)	
Issue addressed	Single-use plastic represents a major source of waste at public events such as festivals or concerts.
Solution description	Stakeholders and events in different countries have taken initiatives to either ban single-use plastics or to replace certain articles, such as cups, cutlery and water bottles with reusable ones.
Constraints	The need to develop or identify alternative solutions.
Examples of solution providers going beyond the SUP requirements	Ban on single-use plastics at several festivals: UK, Glastonbury Festival https://www.iq-mag.net/2019/02/no-more-plastic-bottles-glastonbury/ - .XLCFLOtKii5; Belgium, • ban on disposable plastic products at public events in Brussels https://www.brussels.be/ban-disposable-plastic-products-events; • how to organise a green event? https://ovam.vlaanderen.be/groen-event; Denmark, Aarhus municipality: plastics strategy to minimise unnecessary use of plastic and ensure better recycling https://www.aarhus.dk/demokrati/politikker-og-planer/klima-energi-og-forsyning/plaststrategi/.

Green Deals for reduced consumption

The European Plastic Pact brings together governments and frontrunners across the plastic value chain. They work together towards four goals: design, responsible use, recycling capacity, and the use of recycled content. The Pact supports this work by offering a platform to exchange ideas, display good practice and discuss challenges needed to build a new circular default for all to follow. It was initiated by France and the Netherlands and today covers more than eighty organisations –governments, companies, non-governmental organisations (NGOs) and business associations – from across Europe (European Plastics Pact, 2020).

As a complement to legal action, policy makers can play an essential role as initiators of green deals in collaboration with businesses. A national green deal can be a voluntary agreement between the government and business, bringing together the parties that play key roles in bringing about the desired change. With the help of agreements, the implementation of current legislation can be enhanced or supplemented. Agreements can also set goals that are stricter than legislation and achieve certain goals without additional regulation. Compared to legislation, agreements sometimes offer a more flexible operating model to search for the most effective, functional and up-to-date or new solutions to achieve common goals.

Green Deals for reduced consumption (example: reduction of plastic bag consumption)	
Issue addressed	Single-use plastic represents a major source of waste from plastic shopping bags.
Solution description	Green deals between public authorities and industry that go beyond current legislation and official targets
Constraints	The need to develop or identify alternative solutions.
Examples of solution	An agreement has been made between the Ministry of the Environment and trade unions for 2016–2025 aims to ensure that the reduction targets of the EU's Packaging Waste Directive regarding the consumption of plastic bags and food packaging at events in Finland. The goal was that a maximum of 40 bags per person per year would be used by the end of 2025. Action included fees for bags and giving a bag to the customers only after confirmation of the need ([1]). The consumption of plastic bags covered by the reduction

[1] The EU Packaging Waste Directive reduction goal for 2019 was maximally 90 bags per person per year

	goal decreased from 68 in 2018 to 63 bags per person in 2019. Despite the increase in client visits, the disconnection between the number of visits and the consumption of plastic bags occurred approximately one year it was signed (YM 2022a).

Citizens

Citizens' behaviour and action are key to reducing plastic production, use, and waste. Over the last few years, the level of public awareness has grown considerably. In 2020, 89 % of European citizens were worried about the environmental impact of everyday plastic items (European Commission, 2020). Problem awareness by itself, however, does not change the levels of or the way plastic is used and treated. Despite pro-environmental attitudes, situational factors and lock-ins, such as infrastructure, social and cultural factors and the economic situation, can impede behavioural change, leading to an increasing gap between attitudes and behaviour. However, the most important situational barrier that impedes plastic-free consumption is found to be the lack of convenient alternatives to plastic products (Heidbreder et al., 2019).

Product sharing

An evolving but still small offering/supply of sharing economy services, using renting or library services instead of purchases, encourages consumers towards a more circular economy. While sharing services do not offer all the answers for a circular economy, they do offer choice and an alternative to the current way of consuming. Peer-to-peer sharing allows consumers to use only what they need when they need it. The key is efficient redistribution and accessibility of products, while at the same time offering economic savings to the consumer (Kimberley, 2020).

Complementary to businesses offering product sharing, examples exist of platforms that have been set up as citizen initiatives.

Examples of plastics containing products which are offered through sharing platforms include sports and leisure goods, textiles, electronics, tools and baby gadgets, such as car seats, cots and pushchairs.

Product sharing (examples: sports and leisure equipment, car sharing, electronics, tools and equipment, and baby gadgets)	
Issue addressed	The time-limited use of several common products.
Solution description	Promotion of sharing of products, set up by citizens or businesses, enabling the more efficient use of products over longer periods of time and providing access to these products. Easily replicable to other regions.
Constraints	Need for initial investment; structured collection points; citizens' engagement needed.
Examples of solution providers	• Sports and leisure equipment library: Sweden, Fritisbanken https://www.fritidsbanken.se/en/; • Car sharing; Belgium Cozywheels (https://www.cozywheels.be/) is a cost-sharing platform on which individuals and organisations can share cars. Other similar platforms are Getaround (www.be.getaround.com (in Dutch)) and Dégage (https://www.degage.be/ (in Dutch)) which claims that one Dégage car makes an average of 11 other cars redundant. • Electronic equipment: Finland's public libraries offer borrowing possibilities for sports, exercise and leisure equipment as well as saws, pushchairs, headsets, musical instruments, energy metres, computers, etc. for free across municipalities and cities in Finland https://directory.libraries.fi/services • Equipment: Netherlands, Peerby https://www.peerby.com/ • Baby gadgets: Finland, Zaki Baby Club (https://zakibabyclub.com/) offers, car seats, highchairs, travel cots, baby carriers and baby baths for short- or longer-term rentals,

including an optional delivery service. Similar services are provided also by, amongst others, Tiny Library (https://tinylibrary.nl/)

Wrap up on the smarter use pathway

Reduced production and consumption (prevention) and better reuse systems have an important role to play in increasing circularity of plastic and in lowering plastics' environmental footprint. The relatively low price of (fossil-based) bulk products and the current design of most products do not, however, intrinsically motivate longer use, repair, reuse or sharing approaches.

Upstream policy instruments, such as recycled content targets and durability requirements for plastic components could create incentives to reduce the use and foster circularity, but currently their application is limited. A more consistent approach in countries and regions could significantly boost the smarter use of plastics. Existing legislation and policy targets in the EU, including the SUP Directive and the Sustainable product policy support the use of substitute materials in Europe and their focus is on shifting from plastics to substitutes.

Adapting their business models to reuse requires companies to fundamentally change their business approaches and investment models. Furthermore, a long-term policy framework supporting this is required.

Although there are hardly any economic incentives for citizens when it comes to reuse, they are often motivated to reuse packaging and goods containing plastics for environmental and climate reasons. However, there is a clear potential for further awareness-raising measures focused on reducing consumption, the environmental and health impacts of single-use plastics and available reusable alternatives to be able to change citizens' behaviour in the long term.

3 The increased circularity pathway

Introducing the increased circularity pathway

The use of plastics in many different products continues to increase and the production of the materials and the accumulated waste are predicted to triple by 2060 (OECD, 2022). As a result, there is a need for well-developed infrastructure to handle both current and future products and waste fractions. The increase in the collection and recycling rates of plastics after their use is essential to meet the goals for plastic waste management. To achieve resource-efficient and circular plastic flows, there is a need to develop the market for recycled plastics while promoting the expansion of recycling capacity and efficiency in the collection and recycling of plastics as well as the circular design of products.

The way plastics have been managed until now has led to high levels of waste plastic and microplastic materials in terrestrial and marine environments. The EU's SUP Directive (EU 2019/904) addresses this issue by banning several single-use plastic products from the market as well as establishing several EPR schemes, including ones covering the costs of cleaning up litter and awareness raising for specific products. To increase circularity, there is a need to improve policy and infrastructure worldwide to incentivise both citizens and organisations/companies to improve design, increase the durability of materials and increase collection rates of plastics after use. The increased circularity pathway relates to the production, use and end-of-life management of plastics and should reduce the corresponding environmental impacts such as climate effects, leakage and toxicity for humans and nature.

Innovation along the entire plastics value chain will be critical if the environmental impacts of plastics are to be reduced. The sector is characterised by an upsurge of mostly technological innovation and patented environmental plastics technologies increased more than threefold between 1990 and 2017. This could also be supplemented by social and business model innovation (European Environment Agency, 2021). Active and ambitious research and innovation support is needed to bring more circular solutions to the market to increase the demand for circular solutions while reducing plastic consumption overall (OECD, 2022).

The Circular Plastics Alliance (CPA) initiative was established by the European Commission under the Strategy for plastics (2018) to boost the EU market for recycled plastics to 10 million tonnes a year by 2025. The Alliance covers the whole plastics value chain and comprises 311 signatories representing industry, academia, NGOs and public authorities, who have signed a declaration committing to the Alliance's shared vision and contributing to its operational work.

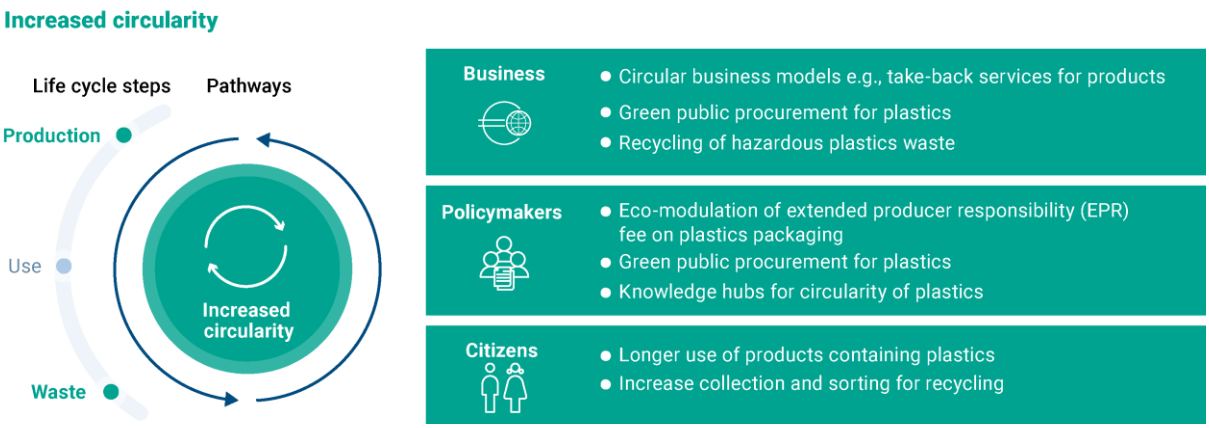
Currently, a significant part of collected plastic waste is lost as residue, both in the sorting and recycling processes. One of the promising options to increase recycling possibilities is to apply traceability solutions. Many plastics contain additives that might disturb the recycling process or contaminate the resulting recyclates when using mechanical or other recycling methods. Uncertainty about the homogeneity and the composition of the waste material often leads to disposal by incineration, which contributes to greenhouse gas emissions. Some hope, but also a lot of uncertainty and lack of sufficient knowledge, is placed on emerging chemical recycling technologies addressing this challenge by allowing the removal of contaminating additives and degradation products, as well as promoting the production of a recycled fraction that is similar or identical to the virgin materials, thus avoiding use of new fossil resources. The technology is, however, still facing several challenges (EEA, 2020a) and the methods should only be considered as contributing to the circular schemes if they are complementary to mechanical recycling – processing the fractions that cannot be mechanically recycled – and only if the feedstock is used for the production of new materials rather than fuels. Efficient sorting and pre-treatment are essential for both chemical and mechanical recycling and result in rather homogeneous material fractions that should primarily be mechanically recycled. The environmental and climate impacts of the methods are currently being debated due to, among other things, high energy consumption in the recycling processes.

There is a major issue with the quality of the recycled material on the market today, as only a fraction of the recyclates can be used for high-value products; most materials are part of downcycling processes. There are some examples of closed-loop recycling, where producers ensure the collection of their own products and recycle the materials, resulting in high-quality recyclates that have the same functionality as primary materials and can, therefore, be used in the production of new applications. These examples are, however, still limited in scale.

There is also a wide variety of products on the market that consist of endless combinations of different materials, for examples, various plastics, such as laminates and composites or other materials in combination with plastics. Separating the different material fractions is often difficult or even impossible, resulting in either low value recyclates with uncertain material properties, incineration of the products or landfilling. Product designs promoting recycling should include a design for dismantling or stipulating increased use of mono-materials. The goal is to maintain the materials in the system for several recycling loops, ensuring resource efficiency.

The examples described for the increased circularity pathway are summarised in Figure 3.

Figure 3 Examples of the increased circularity pathway



Note: The life cycle steps highlighted in green are the ones most relevant for the increased circularity of plastics pathway, but are not necessarily the only ones that can be found.

Source: Developed by the EEA and the European Topic Centre on Circular Economy and Resource Use (ETC CE) — illustration by the Collaborating Centre on Sustainable Consumption and Production (CSCP) and the EEA.

Business

There are several business strategies that focus on closed material loops for standardised plastic-containing products on the market or products that are used by several stakeholders. Some companies are offering take-back services for their own products at the end of life. This enables qualitative recycling and sometimes reuse of the products because companies have full traceability of materials and the components in them. Other companies develop collaborations with relevant stakeholders to develop separate collection and recycling schemes for a product category.

In these cases, the companies involved have invested to expand their activities in the broader value chain in which they are operating, by integrating additional activities such as waste collection (horizontal integration), and by better cooperation with companies already active upstream or downstream the value chain. This often results in the collection of a larger fraction of the materials, a higher rate of recycling and better quality of the recyclates.

Better/more collection	
Example: centralised/better collection of (agricultural) plastic waste	
Issue addressed	Low recycling rates for plastic waste.
Solution description	Decentralised solutions for collection of plastic waste can generate fragmentation of management practices and low recycling rates. Collaborative solutions for the collection, management and recycling can increase separate collection of different plastic waste fractions and thus increase recycling. Centralised solutions are often structured as member organisations and financed by membership fees. This is a common solution for the collection, management and recycling of plastic packaging waste, electronics and other products covered by EPR schemes, as well as other products such as plastic used in the agricultural sector.
Constraints	Requires collaboration between different stakeholders and a managing organisation.
Examples of solution providers	Sweden, Svepretur https://svepretur.se/en/; Belgium, Valipac https://www.valipac.be/en/; Germany, RIGT https://www.rigk.de/en/; European level solution applied in Norway: https://www.grontpunkt.no/ (in Norwegian)
Example: collection system for residue from the installation of plastic flooring	
Issue addressed	Up to 10 % of plastic flooring is wasted during installation. As this is new material with known content, the potential to recycle it back into production is high.
Solution description	To enable recycling, there is a need for separate collection of the residual material at source on the construction site. Contractors can register and a book pick-up and transport of the material free of charge. They also receive information on how much material they have collected on an annual basis. The flooring producers cover the costs of operating the system and they can take back the residual material originating from their own flooring products. Some of the flooring manufacturers use the material in the production of new plastic flooring.
Constraints	The system is easily scalable, but dependent on cooperation between the flooring producers. There is also a need to increase awareness among building contractors that such a system is available and a need to collect the residue separately from the construction site.
Examples of solution providers	Sweden, Swedish Flooring Trade Association (*Golvbranschens Riksorganisation*, (GBR)) https://www.golvbranschen.se/hem/about-us

Improved recycling	
Example: closed-loop plastic furniture	
Issue addressed	Lack of traceability and varying quality of conventional plastic-containing waste stream
Solution description	Closed-loop of recycled plastic-based furniture leading to use of less virgin plastic. The company buys back their furniture and reuses/recycles it into new products.
Constraints	Scalability and the buy-back loop challenging to establish.

Examples of solution providers	Closed-loop demonstration in furniture sector by Durat. The company uses less virgin plastics as it uses recycled materials. They also provide reuse, repair/restoration and recycling services prior to recycling. Use-phase maintenance also prolongs service-life. Uses recycled polyesters in production. Available on the market (business to consumer). Finland, Durat https://www.durat.com/
Example: closed-loop food grade PET recycling	
Issue addressed	(Perceived) lower quality of conventional plastic containing recycled plastics.
Solution description	An integrated recycler of PET pots, tubs and trays, which offers recycling on an industrial scale. Used PET food packaging is taken back by the producer and recycled into new food grade pots, tubs and trays of the same quality – without compromising on any functional properties.
Constraints	The solution is limited to PET.
Examples of solution providers	Denmark, Faerch https://www.faerch.com/

Ideally initiatives to increase the circularity of plastics combine more than one approach to better close the plastic material loop, for example, by combining better and more collection with improved recycling. In this way, the synergy of individual examples is combined.

More and better collection+sorting+recycling (example: collaborative value-chain approach for packaging)	
Issue addressed	Low recycling rates for plastic waste.
Solution description	Coordinated collection and automatic sorting of household plastic packaging waste in homogenous fractions to enable recycling. High collection rates for both flexible and rigid plastic packaging, high purity of plastic fractions for recycling, sorting large amounts of various homogenous plastic fractions to improve recycling. Already applied in several regions (such as Sweden), high potential for replicability, for example for construction and demolition waste (CDW).
Constraints	Currently only implemented for consumer plastic packaging; high investment costs; dependent on well-structured collection systems.
Examples of solution providers	Sweden, Swedish Plastic Recycling https://www.svenskplastatervinning.se/en/ Belgium, FostPlus https://www.fostplus.be/en/about-fost-plus

There is a vast number of plastics (containing) products on the market that include additives that could hinder qualitative mechanical recycling at the end of life. Stricter product regulation and limit restrictions for substances of very high concern (SVHC) in products put on the market prevent these products from being qualitatively recycled at their end of life.

To increase the recyclability of these waste fractions, specific technological solutions are required. Although there are still several challenges that need to be addressed, for example, retaining the quality of the material after the treatment from which additives have been removed, there are already some methods that are currently applied, promoting retaining materials in the system.

Reduce impacts of substances of very high concern (example: recycling hazardous plastic waste)	
Issue addressed	Removal of additives in collected plastic waste, allowing qualitative recycling.
Solution description	Recycling plastic waste that contains hazardous substances such as brominated flame retardants.
Constraints	Effective debromination technologies are still in development, higher bromine-containing plastic waste feedstock is currently not recycled. Challenges in maintaining polymer properties and effective debromination.
Examples of solution providers	• Netherlands, Coolrec (https://www.coolrec.com/en/) recycles WEEE plastic waste into high-grade secondary raw materials such as acrylonitrile butadiene styrene (ABS), polypropylene (PP)/polyethylene (PE), and polystyrene (PS). Coolrec is the largest recycler of waste plastics in Europe with three high-tech production plants, annually treating 50 000 tonnes of plastics. • Italy, TREEE (https://treee.it/) recycles WEEE plastic waste at their five treatment plants. • Germany, Fraunhofer IVV (https://www.ivv.fraunhofer.de/en.html) is a research centre developing mechanical pre-treatment and solvent-based technologies (CreaSolv® Process) to debrominate plastic waste by selective extraction.

Carbon capture and utilisation (CCU) is an interesting and promising future feedstock for plastics. Many CCU techniques are not yet economically feasible, and industrial application of CCU technologies for plastics is limited. It based on capturing carbon dioxide, which is then utilised f as a building block to be converted into polymers. For example, carbon dioxide can be converted to syngas, a mixture of carbon monoxide and dihydrogen, which can be further processed into polymers such as PE and PP (olefins). Carbon dioxide utilisation is, however, constrained by the need for high stability of the carbon dioxide molecule and the high energy demand for most of its transformation processes – catalysts are commonly needed (Pires da Mata Costa et al., 2021).

Carbon dioxide as feedstock for plastics (example: carbon capture and utilisation)	
Issue addressed	Utilising excess carbon dioxide as a feedstock for plastics.
Solution description	CCU can be used as a feedstock for plastics.
Constraints	Still in the research and development phase, not commercially available. For CCU energy intensity is an issue.
Examples of solution providers	• Utilisation of carbon dioxide and development of catalysts for production of polyether polyols and PE from polyether carbonate polyol by polymerisation, by , for example,. Covestro (https://www.covestro.com/en) (Pires da Mata Costa et al., 2021); • Utilisation of carbon dioxide to build polyols with epoxides and PE, by, for example, Econic Technologies (https://econic-technologies.com/) (Pires da Mata Costa et al., 2021); • Copolymerisation of carbon dioxide and epoxide to produce polycarbonate, and reaction between alkylene oxide and carbon dioxide to produce ethylene carbonates, by, amongst others, Lotte Chemicals (https://www.lottechem.com/en/index.do) (Pires da Mata Costa et al., 2021).

Policy makers

There is a need for continued development of incentives from political systems for transitions to circular solutions for plastics. Policy makers have a very important role to play in continued development of policy initiatives which contribute to better product design for reuse and recyclability, increased collection of plastic waste fractions, further development of sorting and recycling technology, as well as a well-developed market for secondary materials.

During the past decade, policy targets on plastic have to some extent shifted from mainly focusing on a waste management perspective – volumes collected and sent to recycling – to a broader circular economy or resource perspective, including on the amount of the recycled content in new products and the effective closure of the material cycle. This shift is needed to increase and improve circularity of the materials.

Extended producer responsibility schemes can promote circularity in product design, collection of end-of-life products and circular recycling of high-value materials through differentiation of fees for specific products/materials put on the market together with increased taxes on landfilling and incineration. Another important tool that policy makers can implement to support circular use is to set demands for recycled content in suitable applications, such as packaging, vehicles, construction and electronics.

Eco-modulation of extended producer responsibility fees for plastics packaging	
Issue addressed	This can lead to more/better recycling of plastic waste from corresponding end-of-life products and/or more absorption of secondary materials in corresponding products.
Solution description	Variation of existing EPR fees for plastic packaging according to sortability, recyclability and/or recycled content
Constraints	The concept is easily replicable in other regions and for other products containing plastics, and even other materials. Collection and recycling schemes might differ between regions and countries, so there could be difficulties to just copying existing schemes.
Examples of solution providers	• Belgium • France • Germany • Italy • Netherlands • Portugal • Sweden

There is an opportunity to support and accelerate the transition to circular solutions through public procurement. However, procuring organizations need guidance on what and how to ensure that the set criteria for circular products and services contribute to positive environmental impacts. The guidelines can, for example, identify relevant products and product groups and an analysis of the requirements for specific applications.

Public procurement (example: sustainable plastic use within the public sector)	
Issue addressed	Single-use plastics and packaging represent a major source of waste within the public sector.
Solution description	Specific guidelines have been set to help the organisations map the needs of specific products and materials and to support the choice of materials that contribute to circularity.
Constraints	The need to develop or identify alternative solutions.
Examples of solution providers	• EU, green public procurement (GPP) criteria https://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm; • Sweden, National Agency for Public Procurement (*Upphandlings myndigheten*) https://www.upphandlingsmyndigheten.se/om-hallbar-upphandling/miljomassigt-

	hallbar-upphandling/upphandling-for-att-framja-cirkular-ekonomi/hallbar-plastupphandling/ (in Swedish); • Flanders (Begium), Circular Flanders https://vlaanderen-circulair.be/nl/doeners-in-vlaanderen?form=casesIndexForm&q=&themas%5B%5D=9&provincies=#casesIndexForm (in Dutch).

To be able to evaluate the contribution of potential solutions and practices to more circular and sustainable plastics, it is essential for both policy makers and businesses to have a good understanding of how plastics flow through the economy and insights into the relationship between the flows of polymers, products (partially) made of plastic and waste containing plastic. This availability of data and knowledge on plastics enables obtaining a view of the current situation, following up on change, and facilitating decision making. Preferably this information should not be limited to one pathway but rather gather and provide information on the broader topic of plastics in society.

Dissemination of information (example: national and/or regional knowledge hubs for the circularity of plastics)	
Issue addressed	In many regions a lot of information on circularity of plastics is already available, but it is often dispersed among many stakeholders – policy makers, companies, research organisations, etc.
Solution description	Coordination of information on sustainability and circularity of plastics, including recycling, collection, fossil dependency, substances of concern, microplastics. Organisation and coordination of seminars, dialogues with research agencies, collection and dissemination of new knowledge, enabling dialogues between all partners involved along the plastics value chain – policy makers, businesses, citizens, etc. Easily replicable to other regions.
Constraints	National policies, recycling schemes and strategies might differ between regions

Examples of solution providers	• Sweden, Swedish Environmental Protection Agency https://www.naturvardsverket.se/amnesomraden/plast/nationell-samordning-for-en-hallbar-plastanvandning/;
	• Finland
	  ○ Circwaste https://www.materiaalitkiertoon.fi/en-US (broader than plastic);
	  ○ New Plastics Centre: Muivipoli https://www.muovipoli.fi/briefly-english/;
	  ○ Finnish plastics roadmap https://muovitiekartta.fi/in-brief/;
	• Flanders (Belgium), Pack it better https://www.fostplus.be/en/projects/pack-it-better;
	• EEA https://www.eea.europa.eu/ ;
	• Organisation of Econmic Co-opertaion and Development (OECD) https://www.oecd.org/
	• UK, Ellen Macarthur Foundation https://ellenmacarthurfoundation.org/
	• Denmark, Plastindustrien https://plast.dk/wp-content/uploads/2019/12/Design-Guide-Reuse-and-recycling-of-plastic-packaging-for-private-consumers-english-version-1.pdf

Citizens

Citizens' engagement in circular solutions varies in countries and regions. Many initiatives promote engagement either through public awareness campaigns or financial incentives. Simple solutions that can be easily applied in everyday life are the critical factors identified as driving forces contributing to circularity and reducing the environmental footprint.

To contribute to increased circularity, citizens mainly depend on the systems and solutions offered regionally and locally by policy makers and businesses. Increased circularity requires an integrated approach over the plastic value chain and stakeholders cooperating to close material loops. It is therefore hard for citizens to set up stand-alone action contributing to increased circularity. On the other hand, for all consumer products, citizens' cooperation is key to closing material loops, be it for the proper separation and collection of waste or for awareness in purchasing products containing (more) recycled content.

Better/more collection (example: increased collection for recycling)	
Issue addressed	Incentivisation of citizens for more and better source-separated collection.
Solution description	Monetary deposit for plastic packaging with a digitalised mobile app. An app. that allows citizens to scan barcodes on packaging and receive compensation when the products are delivered to a recycling station or collection point, including household systems. One major issue today is the collection of the post-consumer fraction; this app. enables the collection of increased volumes, creating inducements for citizens and companies to engage in more and better sorting and collection. Social/community-based innovation through which local community, policy/decision makers and companies have come together to boost the collection of plastic packaging waste. Easy and rather cheap method to replicate in other regions.
Constraints	Dependent on the EPR systems in different regions; it might need education of the population and companies that are interested in contributions.
Examples of solution providers	Sweden, Bower app https://en.getbower.com/; Finland, MuoviSampo https://projektit.seamk.fi/kestavat-ruokaratkaisut/muovisampo/ (in Finnish).

Wrap up on the increased circularity pathway

Several measures need to be in place to increase circularity, such as adapted product design, increased collection rates, further coordinated development of sorting and recycling technology, and a well-developed market for secondary materials. The quality of recyclates is important to drive the transition.

A variety of initiatives provide solutions for increased circularity, many of which could be transferred to other countries and scaled up national and international levels. Plastic products are marketed across the global, and the demands along the value chain for circularity, including product design, need to be extended. True circularity has, therefore, to be promoted within value chains.

One of the important factors for the resource-efficient use of the materials is to design products for several circular recycling loops, allowing the separation of the materials into homogeneous fractions, and increasing the quality of recyclates for high-value products. There is also a need for further development of technological solutions for sorting and recycling collected fractions.

Although it is clear that the involvement of stakeholders along the value chain is key to increasing material circularity, it still is a major challenge to set up this cooperation, preserve and improve it. A chain is only as strong as its weakest link.

4 The renewable material pathway

Introduction to the renewable material pathway

The renewable material pathway promotes renewable feedstock-based solutions such as bio-based plastics, which support decoupling from fossil-based feedstock. This pathway focuses on the beginning of the value chain, on feedstock choices and supply, but also relates to the use and end-of-life phase. The benefits of using renewable feedstocks include reduced dependency on fossil resources, reduced greenhouse gas emissions and, if locally sourced, increased rural development, and possibly reduced dependency on imports. Several challenges are, however, associated with bio-based plastics, such as pollution during cultivation and production due to the use of pesticides, fertilisers, and, in general, competition for water and land with food production. Currently, 26 % of the global bio-based (and biodegradable) plastic production capacity is in Europe. The current global share of bio-based plastics is less than 1 % of total plastics produced annually (European Bioplastics, 2021)

The finite nature of fossil-fuel resources and their link to environmental issues, especially climate change, have boosted the uptake of bioeconomy initiatives in which bio-based plastics are used to replace fossil-based ones. Bio-based plastics are promising alternatives that have the potential to reduce dependency on finite fossil-fuel resources. The shift from fossil-based to bio-based plastics could also mitigate climate change by reducing greenhouse gas emissions in the extraction of fossil-based resources. It needs to be noted, however, that the production of raw materials for bio-based plastics requires the use of land and water, in competition with food production and other applications. Additionally, the reduction in emission varies from one feedstock to another (Bauer et al., 2022).

The market for bio-based plastics is growing – in 2021, the global bio-based, biodegradable and non-biodegradable, plastics production capacity was 2.42 million tonnes. The production of bio-based plastics is expected to continue to grow and is estimated to go beyond 2 % of total plastics produced annually by 2026 (European Bioplastics, 2021) (Nova Institut, 2021).

The environmental benefits of bio-based plastics lie in sustainable sourcing. Bio-based plastics are made from renewably sourced raw materials – mainly carbohydrate-rich, agri-based sources, such as maize or starch, and non-edible lignocellulosic feedstock from, for example, wood-based sources.

Bio-based plastics can be either:

1) non-biodegradable – for example, bio-polyethylene and bio-polypropylene;
2) biodegradable – for example, polyhydroxy alkanoates and starch blends ([2]).

It is important to note that bio-based is not a synonym for biodegradable. Biodegradation is a complex process that can either be industrial compostable or home compostable. In both cases, biodegradation occurs only under very specific conditions. However, this pathway focuses on bio-based, non-fossil feedstock and not biodegradable plastics.

It has been estimated that 0.7 million hectares out of of 5 billion hectares of global arable land is currently used for the current production of bio-based plastics (European Bioplastics, 2021). For biomass, there are several ways for further refining and processing the raw material, and in many cases, the bio-based monomers can be produced through several routes. Typically, the raw material is refined further to precursors for the monomer production phase, which are further polymerized.

The three main production approaches are:

- use of natural polymers, such as starch-based plastics;
- polymerisation of bio-based monomers and oligomers through fermentation or conventional chemical processes, such as PLA; and

[2] Fossil-based and biodegradable plastics are not included in this study.

- polymerisation through bacterial fermentation, for example, polyhydroxyalkanoates (PHA).

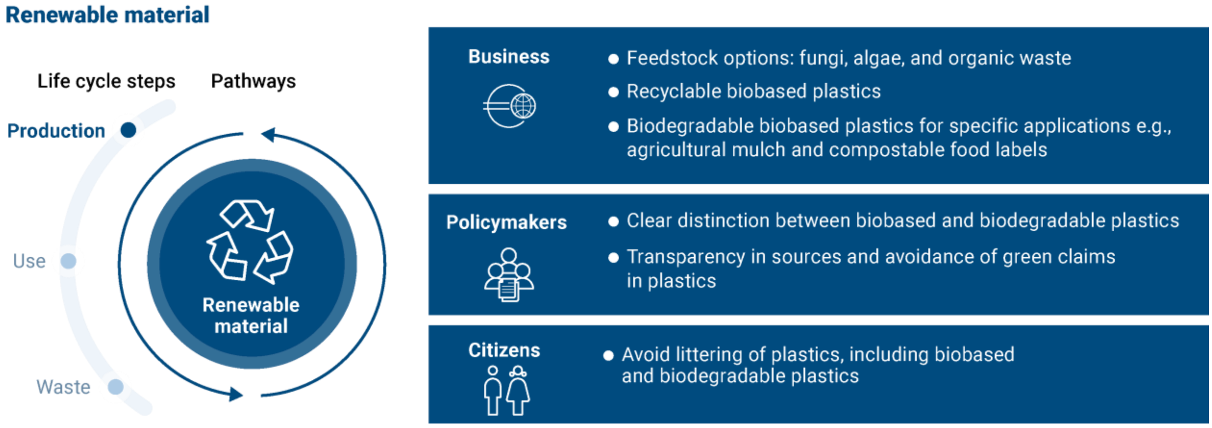
There is a considerable amount of research looking into how to address the issues of land use competition and the availability of feedstock. This research includes second- and third-generation biomass, biotechnical production methods and CCU.

The resource sufficiency is dependent on whether the material is reused and recycled. There are concerns on how biodegradable bio-based plastics fit into waste management systems as they require industrial composting facilities (ETC WMGE, 2021). This is not an issue, however, for bio-based but non-biodegradable polymers as they can be used in the same recycling processes as their conventional plastic counterparts, such as bio-PE and PE. Reuse is of course also an option to enhance circularity for both biodegradable and non-biodegradable plastics.

Negative impacts of bio-based plastics relate to the sourcing of the feedstock, for example, in case of unsustainable deforestation or other agriculture practices and the use of pesticides, fertilisers, water and land, or competition with food production. Tropical deforestation for agriculture is a key source of greenhouse gas emissions. It is estimated that 29–39 % of the deforestation-related emissions were caused by international trade and that Europe is, together with China, the major importer of the related goods. The deforestation emissions are estimated to be responsible for 15 % of the total carbon footprint of food consumption in EU countries (Pendrill et al., 2019). On the other hand, bio-based materials can also be considered as a carbon storage – for example, a substantial amount of carbon is stored in woody biomass and hence utilising wood in long-lasting applications, such as construction and vehicles, can store carbon. The use of biomass for materials should be favoured over the use of biomass for energy to mitigate climate change.

The examples described for the renewable material pathway are summarised in Figure 4.

Figure 4 Examples of the renewable material pathway



Note: The life cycle steps highlighted in blue are the ones most relevant for the renewable material pathway, but are not necessarily the only ones that can be found.

Source: Developed by the EEA and the European Topic Centre on Circular Economy and Resource Use (ETC CE) — illustration by the Collaborating Centre on Sustainable Consumption and Production (CSCP) and the EEA.

Business

Alternative plastic feedstocks are generally divided into first-, second- and third-generation ones: first-generation feedstock, such as maize and sugar cane, is also suitable for food and feed applications; second-generation feedstocks, such as non-food-crop cellulose or side streams from such first-generation feedstock as maize stover, are not (yet) suitable for food or feed applications; third-generation feedstocks come from such sources as algae and different waste streams.

Third generation feedstock for bio-based plastics (examples: ocean algae, citric peels, lignin and cellulose)	
Issue addressed	Alternative bio-based feedstocks that do not compete with food production.
Solution description	Utilising algae, municipal or industrial waste, or by-products from the food industry as raw materials for bio-based plastics. Little to no competition with food production.
Constraints	Commercial availability still limited; feedstock supply security not guaranteed in the long term.
Examples of solution providers	• Finland, Origin Ocean https://www.originbyocean.com/: a range of products and ingredients created from invasive ocean algae, including packaging and materials. It acts as biodegradable packaging solution; • Switzerland, Sulzer https://www.sulzer.com/en/shared/applications/polyethylene-furanote-pef: polyethylene furanoate (PEF), a next generation polyester that has great properties and can replace fossil-based PET, while decreasing greenhouse gas emissions. 2,5-Furandicarboxylic acid (FDCA), which is the building block of PEF, can be generated from, for example, citric fruit peel. PET is commonly used in bottles, textiles and films – PEF has superior properties compared to PET; • UK, Biome Bioplastics https://biomebioplastics.com/industrial-biotechnology/: production of bio-based and biodegradable aromatic polyesters from lignin and cellulose through novel bio-manufacturing and polymerisation processes.

Additionally, the production of bio-based plastics would benefit from a focus on high-efficiency feedstocks. Feedstock efficiency describes the conversion ratio of feedstock weight to final product weight, essentially describing the yield. The environmental impact is lower if the amount of feedstock required to produce bio-based plastics is as low as possible.

Feedstock efficient solutions for bio-based plastics	
Issue addressed	High utilisation rate/material efficiency through processing.
Solution description	High feedstock efficiency through processing and selection of the feedstock type.
Constraints	Feedstock production is still mostly dependant on the available arable land area.
Examples of solution providers	High feedstock efficiency for polylactide (PLA) production from non-edible sugars – 1.6 kilograms (kg) of fermentable sugar feedstock is needed for the production of 1.0 kg of PLA polymer. Typical feedstock efficiency can range between 2.5–3 (Corbion, 2022).

Besides the sustainability of the feedstock supply, the end-of-life management of bio-based and biodegradable alternatives such as PHA and PLA polymers is also a challenge. While many of these polymers are recyclable, technically they tend not to be recycled due to such systemic challenges as low waste volumes and the decentralised generation of waste. To make this pathway support circularity it is important that the bio-based plastics produced are also recyclable and not only suitable for industrial composting.

Sustainably sourced bio-based plastic alternative (example: recyclable bio-based packaging material)	
Issue addressed	Recyclable bio-based materials.
Solution description	Cellulose-based flexible packaging that is recyclable. Production of raw material used does not compete with agricultural resources for food/feed. Replaces virgin fossil feedstock.
Constraints	Product applications are mostly single-use items. The package needs clear marking on how to recycle it (with paper board) to avoid contaminating plastic recycling.
Examples of solution providers	Production of bio-based packaging, replacing plastic bags, that is recyclable in the fibre-based stream with cardboard, and with the durability of conventional plastics. A light material, which can provide material savings in certain application such as stand -up pouches (Torniainen, 2022), is available in 35 countries from Paptic® (https://paptic.com) and Woopak (https://woopak.fr/).

In some cases and applications, biodegradable plastic solutions have benefits that support their use. Good examples are biodegradable agricultural mulches and biodegradable food labels. Mulches are typically challenging to recover after use and are often ploughed into the ground after the harvest season. Here, a biodegradable solution brings benefits by lowering the macro-, micro- and nano-plastic pollution in the ground. It is, however, important to pay close attention to the conditions in which the biodegradable materials are effectively compostable – they need to be compostable under the conditions to which they are subjected – cold, wet, a lack of enzymes, etc. If this is not factored in, decomposition can be insufficient, meaning that the material does not break down completely and leads to, for example, microplastic pollution. Biodegradation of plastics can release harmful substances. Moreover, biodegradation can also reinforce single-use behaviour.

Sustainably-sourced bio-based plastic alternatives (example: biodegradable agricultural mulch)	
Issue addressed	Decreasing plastic pollution of agricultural land.
Solution description	Biodegradable polyesters which have been developed commercially for the specific application of mulching.
Constraints	According to standard EN-17033, mulch may be classified as biodegradable when it has a biodegradation threshold of 90 % in 2 years. For many farmers this is too long as one crop lasts only 3–6 months in the field (EIP-AGRI, 2019). Limited applicability in Europe. In the Nordic countries, biodegradation is very slow. Biodegradable plastics are typically not recyclable and some biodegradable plastics can only degrade in industrial facilities Lower cost compared to starch-based mulch films which are 100 % biodegradable in the soil (IBERS, 2018).
Examples of solution providers	Italy, Novamont https://www.novamont.com/eng/mater-bi: polyhydroxyalkanoates (PHA), polyhydroxy butyrate (PHBs) and polybutylene succinate (PBS) produced from the fermentation of plants using micro-organisms.

Alternative labels for loose fruits and vegetables (example: biodegradable solution, laser-based marking)	
Issue addressed	Replacing fossil-based and non-biodegradable fruit labels.
Solution description	1. Bio-based and biodegradable solutions, which can be put into organic waste streams. 2. Laser-based marking of fruits and vegetables, replacing the need for any sticker labels.
Constraints	1. Still single-use items – can the plastic be replaced altogether by, for example, the laser option. 2. Possibility of damaging the fruit and labelling speed – highlighted as minimum risks. 3. Confusion among consumers on labelling related to home as opposed to industrial composting.
Examples of solution providers	1. Certified home compostable labels: worldwide, Sinclair Home Compostable Hand Labelling https://www.sinclair-intl.com/produce-labeling-solutions/label-categories -compostable. 2. Laser-based marking: worldwide, natural branding by JBT https://www.jbtc.com/foodtech/products-and-solutions/products/fresh-produce-technologies/identification/laser-labeling-system/jbt-laserfood/; Spain, LaserFood https://laserfood.es/natural-branding/.

Another good example of optimal use of the specificities of biological materials is the use of bio-based flocculant aids in water treatment.

Sustainably-sourced bio-based plastic alternatives (example: bio-based flocculant aids in water treatment)	
Issue addressed	Replacing synthetic flocculants and inorganic coagulants with non-toxic and biodegradable solutions.
Solution description	Chitosan and starch-based flocculant aids to replace synthetic, water-soluble and charged polymers and polyacrylamides. The monomer acrylamide, which may be included in commercial polyacrylamide products, is reportedly toxic to humans and animals (Vogt, 2021).
Constraints	Lower availability compared to conventional products. The cost of bio-based alternatives is averagely higher, although not constantly. Currently not yet certified for biological degradation in soil.
Examples of solution providers	France, Hydrex by Veolia https://www.veoliawatertechnologies.com/en/vegetal-based-coagulants-wastewater-treatment; Germany, Emfloc by Emsland.

Policy makers

In November 2022, the European Commission published a communication on a policy framework for bio-based, biodegradable and compostable plastics. This was done to respond to the current policy gaps and create a coherent policy framework for bio-based plastics, as well as for biodegradable and compostable plastics. The target is to improve the understanding of the complexities around these types of materials, and, by clarifying the conditions, aim to deliver a genuine environmental impact. Increasing the level of understanding and simplifying the complexity is necessary for several stakeholders. Additionally, the aim is to promote research, innovation and sustainable investment.

Bio-based plastics are made from a number of different feedstocks can impact sustainability topics, such as (in)direct land and water use, biodiversity, (in)direct greenhouse gas emissions, and create competition with food production for resources. Hence, sustainable sourcing of renewable materials for bio-based plastics is key. Different certification schemes for feedstock sustainability are available and widely used, for example, sustainably managed forests, there are FSC and PEFC certificates.

Sustainably managed forests – forest policies and certification (examples: Forest Stewardship Council and Programme for Endorsement of Forest Certification)	
Issue addressed	Sustainable production/management of bio-based raw materials.
Solution description	The sustainable management of raw materials is not only important to ensure availability of raw materials, but also make sure biodiversity is fostered, there is no competition with food production and climate change can be effectively adapted to and mitigated. Sustainable forest management leads to growing stock volumes – more is grown than harvested – despite high rates of harvesting.
Constraints	Sustainable management related policies are however based on a compromise between economic, ecological, social and cultural sustainability. For economic gains, there are typically trade-offs with environmental sustainability.
Examples of solution providers	• Sustainable forest management: Forest Act in Finland https://www.finlex.fi/en/laki/kaannokset/1996/en19961093. • Forest certification: Finland's forest owners can enter their forests into a forest certification scheme, the criteria of which impose requirements on forest management and use that go beyond what is laid down by law. The certification of forests is a voluntary, market-driven system to verify the compliance with these requirements. Currently, more than 90 % of Finland's forests are certified under Finland's PEFC scheme and 10 % is FSC certified. • Forest certification: Programme for the Endorsement of Forest Certification https://www.pefc.org/; https://www.pefc.org/discover-pefc/our-pefc-members/national-members. • Forest certification: Forest Stewardship Council https://fsc.org/en; https://fsc.org/en/local-fsc-teams.

Citizens

European citizens and consumers are increasingly aware of plastics and their environmental and climate impacts. This has increased interest in and demand for bio-based alternatives and products made from other materials. There is, however, widespread confusion about the sustainability and environmental impacts, such as pollution and land use, of plastics that is only reinforced by inconsistent use of and sometimes misleading terminology.

Wrap up on the renewable material pathway

Bio-based plastics have potential in the quest to reduce society's dependency on fossil-based virgin resources to produce plastics. Bio-based plastics can, under the right circumstances, provide environmental benefits, particularly in the production stage. These advantages may, however, come with trade-offs, such as less favourable effects on agriculture, water and land use, increased plastic pollution, rivalry with food production, vague end-of-life management and greater expense.

To expand from specialty polymers to large-scale bio-based plastic market applications with truly sustainable and circular impacts, sustainable sourcing combined with the possibility of effectively closing material loops at the end-of-life phase seem to be the critical challenges for bio-based plastics.

Utilising renewable resources does not guarantee sustainability on its own. That depends more on the material production process, application and recycling capabilities than on its constituent parts.

Policies that emphasise full circularity will compel businesses to examine every step of a product's anticipated lifecycle and can increase consumers’ awareness of the environmental friendliness of plastic products and plastics in products.

5 Conclusions

It is clear that no single pathway will lead to full circularity and that a balanced combination of pathways and solutions is needed, addressing both smarter use and increased circularity as well as a shift to renewable materials, and that these are the common responsibility of all stakeholders. Furthermore, the described pathways are linked and do not operate independently.

The most sustainable plastic is still the one that is not produced or used in the first place. The smarter use pathway intrinsically provides the highest potential to decrease the environmental and climate impacts of plastics management, but it is also the most difficult to apply. The current industrial setting, characterised by a linear production and consumption model that has been optimised for decades, needs to shift to circular production and consumption and corresponding circular business models. Although several good examples are available, it will still require a considerable shift from both producers and consumers, and a long-term policy framework to support this.

Increased circularity seems to be the most used pathway both among policy makers and private actors. The transition to this increased circularity is complex, and further efforts are needed to accelerate it. The time is ripe for industry to adapt its (long-term depreciable) infrastructure and business models to include secondary materials in their production, supported by policy.

Bio-based plastics seem to offer potential in the quest to reduce society's dependency on fossil resources to produce plastics. Bio-based plastics can, in some cases, be more climate friendly and offer a route to more resource independence and rural development. Bio-based plastics, which are non-biodegradable (drop ins), are compatible with current recycling streams. Switching to bio-based feedstocks may come with trade-offs, such as less favourable effects on water and land use, agriculture, competition with food and feed production, and hazy end-of-life management if bio-based and biodegradable.

The complexity of and links between these pathways should not prevent proceeding their implementation. Overwhelmed by an avalanche of information on the potential of several solutions for circular plastics, both policy makers and companies are, in some cases, reluctant to take additional steps towards circularity, fearing making the wrong choice(s), creating a lock in or thinking that it would be better to wait for the next emerging solution with even more potential, finally leading to a standstill.

As this study demonstrates, a lot is happening in each pathway. These, and many other examples, enable a circular transition for plastic. A complete systematic transition will, however, need further effort as well as a scaling up of the many good examples highlighted. Businesses, policy makers and consumers need to work together for this to happen. The transition to a circular economy will lead to a better environment, increased employment and more resource independence.

References

Bauer, F., et al., 2022, 'Plastics and climate change—Breaking carbon lock-ins through three mitigation pathways', *One Earth* 5(4), pp. 361-376 (DOI: 10.1016/j.oneear.2022.03.007).

Coelho, P. M., et al., 2020, 'Sustainability of reusable packaging–Current situation and trends', *Resources, Conservation & Recycling: X* 6, p. 100037 (DOI: 10.1016/j.rcrx.2020.100037).

Corbion, 2022, Sustainable sourcing of feedstocks for bioplastics, (https://www.totalenergies-corbion.com/media/ijpb1qzl/totalenergiescorbionpla_whitepaper_foodstock_1-3.pdf).

EEA, 2019, 'Resource efficiency and the circular economy in Europe 2019 — European Environment Agency' (https://www.eea.europa.eu/publications/even-more-from-less) accessed 15 September 2022.

EEA, 2020a, 'How green are the new biodegradable, compostable and bio-based plastic products now coming into use? — European Environment Agency',.

EEA, 2020b, *Plastics, the circular economy and Europe's environment — a priority for action*, No 18/2020, European Environment Agency (https://www.eea.europa.eu/publications/plastics-the-circular-economy-and/) accessed 4 June 2021.

EIP-AGRI, 2019, 'Nuevas ténicas para facilitar y acelerar la degradación de los materiales degradables de acolchado', EIP-AGRI - European Commission (https://ec.europa.eu/eip/agriculture/en/find-connect/projects/nuevas-t%C3%A9nicas-para-facilitar-y-acelerar-la) accessed 14 September 2022.

ETC WMGE, 2021, *Greenhouse gas emissions and natural capital implications of plastics (including biobased plastics)*, Eionet report (https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-wmge-reports/greenhouse-gas-emissions-and-natural-capital-implications-of-plastics-including-biobased-plastics) accessed 1 February 2023.

European Bioplastics, 2021, Global production capacities of bioplastics 2021-2026, (https://www.european-bioplastics.org/wp-content/uploads/2021/11/Global_Prod_Capacity_Total_2020to2026.jpg).

European Environment Agency, 2021, *A framework for enabling circular business models in Europe*.

European Plastics Pact, 2020, European Plastics Pact, Roadmap, (https://europeanplasticspact.org/wp-content/uploads/2020/12/wrap-european-plastics-pact-roadmap_hr.pdf), European Plastics Pact.

Heidbreder, L. M., et al., 2019, 'Tackling the plastic problem: A review on perceptions, behaviors, and interventions', *Science of The Total Environment* 668, pp. 1077-1093 (DOI: 10.1016/j.scitotenv.2019.02.437).

IBERS, 2018, 'Biodegradable Plastics for Agriculture', Farming Connect (https://businesswales.gov.wales/farmingconnect/news-and-events/technical-articles/biodegradable-plastics-agriculture) accessed 14 September 2022.

ICF Eunomia, 2019, 'Investigating Options for Reducing Releases in the Aquatic Environment of Microplastics Emitted by Products', Eunomia (https://www.eunomia.co.uk/reports-tools/investigating-options-for-reducing-releases-in-the-aquatic-environment-of-microplastics-emitted-by-products/) accessed 15 September 2022.

IEA, 2018, *The future of Petrochemicals: Towards more sustainable plastics and fertilisers. International Energy Agency, Paris, France*,.

Kimberley, G., 2020, 'The environmental benefits of product as a service' (https://productasaservice.net/the-environmental-benefits-of-product-as-a-service/) accessed 30 June 2022.

Nova Institut, 2021, *Bio-based Building Blocks and Polymers – Global Capacities, Production and Trends 2020-2025* (http://bio-based.eu/downloads/bio-based-building-blocks-and-polymers-global-capacities-production-and-trends-2020-2025/).

OECD, 2016, Environmental labelling and information schemes, (https://www.oecd.org/env/policy-persectives-environmental-labelling-and-information-schemes.pdf).

OECD, 2022, *Global Plastics Outlook: Policy Scenarios to 2060* (https://www.oecd.org/publications/global-plastics-outlook-aa1edf33-en.htm) accessed 1 February 2023.

Pendrill, F., et al., 2019, 'Agricultural and forestry trade drives large share of tropical deforestation emissions', *Global Environmental Change* 56, pp. 1-10 (DOI: 10.1016/j.gloenvcha.2019.03.002).

Pires da Mata Costa, L., et al., 2021, 'Capture and Reuse of Carbon Dioxide (CO2) for a Plastics Circular Economy: A Review', *Processes* 9(5), p. 759 (DOI: 10.3390/pr9050759).

Torniainen, E., 2022, Personal communication/interview.

Vogt, D., 2021, 'BioSinn - Products for which biodegradation makes sense (PDF)', Renewable Carbon Publications (https://renewable-carbon.eu/publications/product/biosinn-products-for-which-biodegradation-makes-sense-pdf/) accessed 8 June 2022.

Watkins, E., et al., 2020, 'Support to the Circular Plastics Alliance in establishing a work plan to develop guidelines and standards on design-for-recycling of plastic products', JRC Publications Repository (https://publications.jrc.ec.europa.eu/repository/handle/JRC122453) accessed 17 June 2022.

Annex 1: Workshops

Within the course of the elaboration of this report, two workshops were organised to gather feedback of relevant stakeholders involved in circular plastics. The agenda for both workshops can be found below.

Expert workshop 1 Pathways towards circular plastic: examples from countries and business, 26 April 2022, online

Meeting aims:

Plastics play an essential role in modern society, but also lead to significant impacts on the environment and climate. Reducing such impacts while retaining the usefulness of plastics requires a shift towards a more circular and sustainable plastics system. Against this background and by building on existing analytical work, the aim of this meeting is to further explore, analyse and discuss trends and good examples across Europe focusing on three pathways towards a more sustainable plastic system: 1) smarter use; 2) increased circularity and; 3) renewable material.

Background and preparatory guidance

We invite participants to take a look at the background document shared in the e-mail for more information on the workshop.

Agenda 26 April 2022, 10:00 – 12:00 CEST		
Time	**Item**	**Speakers**
09:45-10:00	Log in to Zoom	IT support
10:00-10:20	**Setting the scene**	
	Opening & Welcome	Lars Mortensen, EEA
	Background and aim of the project	Tobias Nielsen, EEA
	Agenda & Housekeeping rule	Francesca Grossi, ETC/CE
10:20-11:00	**Three pathways towards a more sustainable plastic system**	
	Good examples for each of the three pathways + Q&A and plenary exchange	Ive Vanderreydt ETC/CE
11:00-11:55	**Interactive breakout groups exchange**	
	Brief introduction: • Feedback on applied case studies criteria • Identification of possible additional elements and gaps • Gathering of good examples and practices	Francesca Grossi, ETC/CE
	Group 1: Smarter use	EEA & ETC/CE Team
	Group 2: Increased circularity	
	Group 3: Renewable material	
11:55-12:00	**Final reflections & next steps**	Ive Vanderreydt ETC/CE Lars Mortensen, EEA Tobias Nielsen, EEA

Expert workshop 2 Pathways towards circular plastic: examples from countries and business, 26 October 2022, online

Aim

During this expert workshop we will present and share our results on analyses of good examples for pathways towards circular plastics with the aim of gathering feedback before publication of our results in early 2023. The European Environment Agency supported by the European Topic Centre on Circular Economy and Resource Use (ETC CE) have been conducting an analysis focusing on plastic and the environment in Europe´s circular economy. The output of this analytical work is the collection and exploration of trends and good examples across Europe for these pathways to move towards a circular plastic system. The work is a continuation of previous studies and takes as a starting point three pathways towards a more sustainable plastic system: 1) smarter use; 2) increased circularity and; 3) renewable material identified as seen in the report: *Plastics, the circular economy and Europe's environment* (EEA, 2020b)

Background and preparatory guidance

We invite participants to take a look at the draft report in order to maximize the outcomes of exchanges and discussions during the workshop.

Agenda 26 October 2022, 10:00 – 12:00 CEST		
Time	**Item**	**Speakers**
09:45-10:00	Log in to Teams	IT support
10:00-10:20	**Setting the scene**	
	Welcome & agenda for the meeting	Lars Mortensen, EEA
	Aims of the meeting and brief recap of the project objectives & the outcome of the previous meeting	Tobias Nielsen, EEA
	The three pathways in a nutshell	Ive Vanderreydt, ETC CE
10:20-11:35	**Three pathways towards a more sustainable plastics system**	
	Deep dive into each pathway: an overview and joint exchange • Smarter use • Increased circularity • Renewable materials	EEA / ETC CE & Participants
11:35-11:55	**The interlinkages between the pathways – continuing the exchange**	
	A brief impulse on the interlinkages between the pathways	Ive Vanderreydt, ETC CE
	Joint reflection	All
11:55-12:00	**Meeting close and next steps**	Lars Mortensen & Tobias Nielsen, EEA

Annex 2: Criteria for selecting good examples

This report brings together a collection of good examples of increasing the circularity of plastics from countries and businesses across Europe . The role of these is to inspire stakeholders – policy makers, businesses and citizens – to improve/increase their role in making plastic more circular and sustainable. This collection of good examples was gathered through brainstorm sessions with the project team and during a workshop.

The criteria for selecting the good examples were that they:

- were readily available on the market;
- showed clear environmental benefits;
- were accessible;
- showed potential for replication to other product groups or polymers;
- showed potential for replication in other regions.

European Topic Centre on
Circular economy and resource use
https://www.eionet.europa.eu/etcs/etc-ce

The European Topic Centre on Circular economy and resource use (ETC CE) is a consortium of European institutes under contract of the European Environment Agency.

European Environment Agency
European Topic Centre
Circular economy and resource use