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Plastics, the circular economy and Europe's environment — A priority for action

European Environment Agency

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You can reach us

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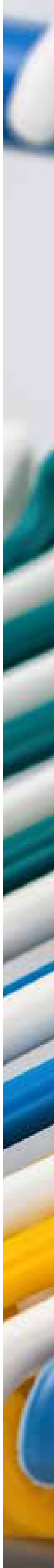

Plastic items and products surround us every day © Pixabay

Summary

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. This report tells the story of plastics, and their effect on the environment and climate, and looks at their place in a European circular economy.

Plastics comprise a range of materials, each with its own unique characteristics, properties and applications — 99 % of plastics are made from carbon from fossil fuels (CIEL, 2019). The consumption and production of plastics have grown exponentially since the 1950s, with the resulting products (including packaging, kitchenware, electronics, textiles, car components and furniture) constituting an important part of everyday life. Plastics are light, cheap, durable and can be made in an infinite number of variations, and the plastics industry contributes to growth and job creation.

Plastic packaging is the largest sector of the plastics industry, representing almost 40 % of total plastic consumption. Among other things, plastics provide new transport solutions for the logistics sector, and they are important for improving hygiene in healthcare (e.g. in virus protection) and for reducing food waste by keeping food fresh for longer. Plastics are also used in cars and aeroplanes, reducing weight and improving fuel efficiency, in synthetic fibres in clothing and other textiles, and in furniture and kitchenware.

In recent years, plastic has been subject to increased focus and attention from an environmental perspective. Being lightweight and durable are two key strengths of plastic, but this also means that plastic spreads easily and can persist in the environment for many years. Plastic waste can now be found in our parks, on our beaches, at the bottom of the oceans and seas, on top of mountains and even inside our bodies. The leakage of plastics into the environment poses a significant problem for current and future generations, and there are significant gaps in our knowledge about the kind of effects that this exposure can have. The potential magnitude of impacts on the environment and human health varies a lot depending on the type of plastics and the chemical additives they contain. The negative effects of plastics go beyond littering and leakage: 7 % of crude oil output is used to make plastics, a proportion set to grow rapidly as consumption of plastics is expected to double in the coming 20 years (EC, 2020). The energy and fossil feedstock used to produce and transport plastics and manage plastic waste creates a large and growing carbon footprint.

Today, plastics are too often used as single use products, then discarded, then too often littered. The current linear models of production and consumption of plastics are failing nature and our economy at the same time, which is why we need a circular plastics economy. Reducing the environmental and climate impacts of plastics, while retaining the usefulness of plastics in society, requires making the systems of plastic consumption and production more circular, resource efficient and sustainable, thereby enabling longer use, reuse and recycling. Adequate policies and the scaling of circular business models can, together with changes in the behaviour of producers and consumers, enable a more circular and sustainable plastics system.

This report introduces the wide family of plastics and briefly explores the main challenges involved in transitioning towards a circular plastics economy. It shows that, although the production, use and trade of plastics continue to grow, significant differences exist between Europe and other regions of the world. Furthermore, it explains the environmental and climate impacts that occur across the life cycle of plastics, including the leakage of plastics into natural environments and the growing demand for oil and emissions of greenhouse gases. Finally, it shows that an increasing number of EU initiatives are already in place to address some of these issues, but that more coordination and scaling up is needed. Three pathways (smarter use; increased circularity; and use of renewable raw materials and decarbonisation) are discussed, which together can help ensure the continued longer term move towards a sustainable and circular plastics system.


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About plastics and the circular economy

Plastics are a large family of different materials, each with its own unique characteristics, properties and applications. To address the environmental and climate challenges associated with the production, use and disposal of these various types of plastics, a circular economy offers a promising strategy for a more sustainable plastics system in which materials and products never become waste.

Plastics: one name, many types

Plastics are composed of polymers (large molecules comprising many repeated subunits called monomers) combined with chemical additives. A common feature of plastics is that, depending on which chemical additives are used, they can be easily turned into many different forms during production. Chemical additives may, for instance, improve the flexibility of plastics or reduce their flammability.

Despite their distinct composition, all plastics are based on carbon. Whereas fossil-based plastics use carbon derived from oil and natural gas (petrochemicals), bio-based plastics use carbon derived from renewable materials, such as agricultural products, cellulose and even carbon dioxide (CO_2). Plastics, whether derived from oil or sugar, for example, can have identical properties.

Plastics can also be divided into different types according to what they are made of (Figure 1), whether they are natural or synthetic, whether they can be remoulded or not, and how they can be recycled without causing contamination.

A more circular plastics economy

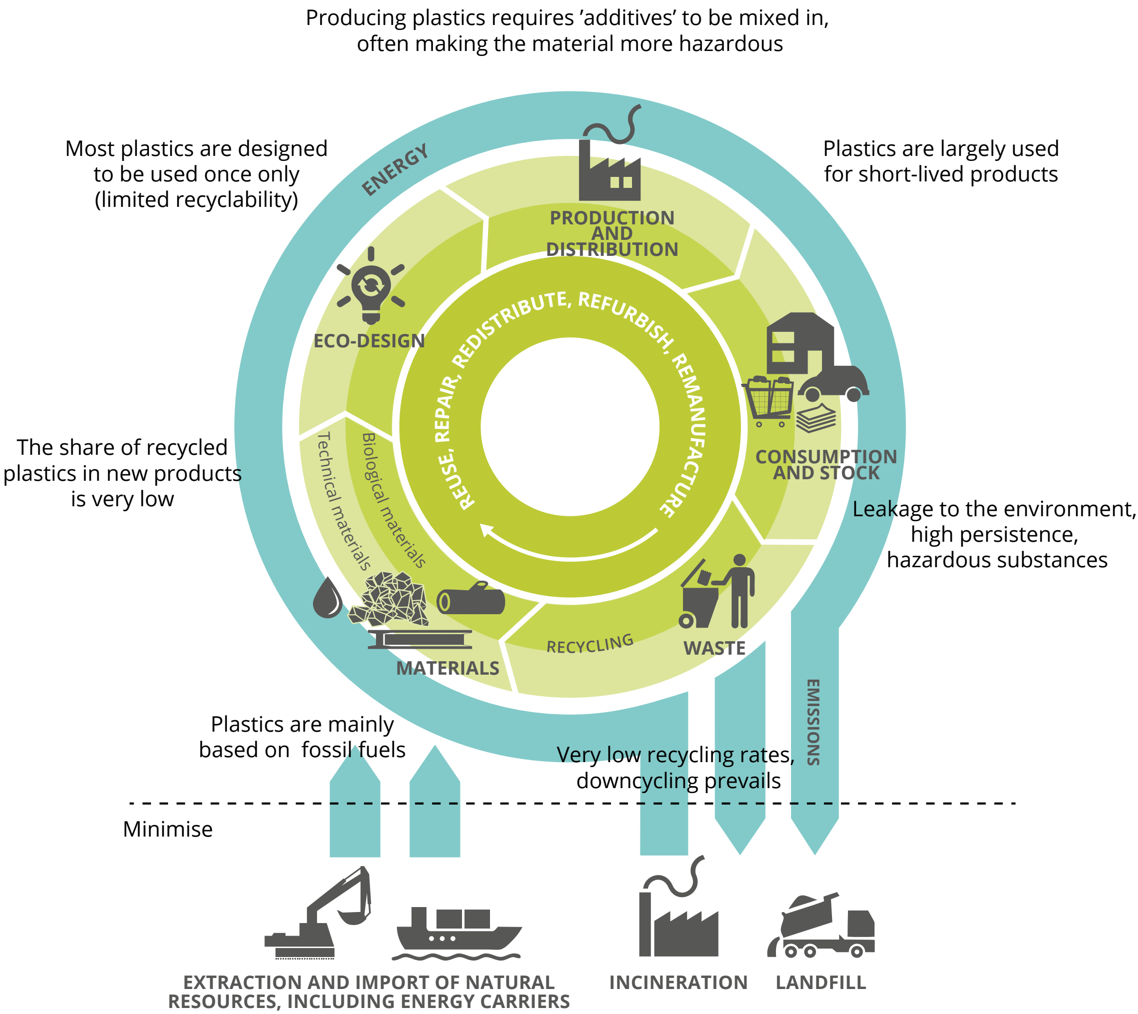
A more circular plastics economy seeks to minimise the need for virgin material and energy in the production of plastics while ensuring that environmental pressures linked to resource extraction, production, consumption and waste are reduced. By improving design, adopting higher quality plastics, and encouraging and enabling reuse, repair, remanufacturing and recycling, a circular plastics economy aims to retain the value and utility of products within the economy for as long as possible to ensure that plastics never become waste (EEA, 2016; Ellen MacArthur Foundation, 2016). This is as opposed to the current linear system of plastic production and use (dominated by low-value, low-cost and short-life plastics) in which all phases of the value chain consume finite resources and cause environmental impacts. Figure 2 shows the current challenges in achieving a shift from a linear plastics economy to a circular plastics economy.

Figure 1. Seven common types of plastics, with symbols and applications

Types of plastics	Symbol	Applications
Polyethylene terephthalate (PET)	1 PET	Beverage bottles, medicine jars, rope, clothing and carpet fibre
High-density polyethylene (HDPE)	2 HDPE	Containers for milk, motor oil, shampoos and conditioners, soap bottles, detergents and bleaches
Polyvinyl chloride (PVC)	3 V	All kinds of pipes and tiles
Low-density polyethylene (LDPE)	4 LDPE	Cling-film, sandwich bags, squeezable bottles and plastic grocery bags
Polypropylene (PP)	5 PP	Lunch boxes, margarine containers, yogurt pots, syrup bottles, prescription bottles, plastic bottle caps and plastic cups
Polystyrene (PS)	6 PS	Disposable coffee cups, plastic food boxes, plastic cutlery and packing foam
Polyethylene (PE) Acrylonitrile butadiene styrene (ABS) Polyamide (PA) or nylons Polybutylene terephthalate (PBT)	7 OTHER	Baby bottles, compact discs and medical storage containers

Source: IVL and EEA.

Figure 2. Challenges in shifting from a linear to a circular plastics system



Source: Adapted from EEA (2019b).

Plastics and COVID-19

The coronavirus disease 2019 (COVID-19) pandemic has caused significant changes in the production, consumption and wastage of plastics.

The pandemic led to a sudden surge in global demand for personal protective equipment, such as masks, gloves, gowns and bottled hand sanitiser. During early efforts to stop the spread of the virus, the World Health Organization estimated that 89 million medical masks per month were required globally, together with 76 million examination gloves and 1.6 million sets of goggles (WHO, 2020).

As a result of lockdown measures across most of Europe, coupled with stringent hygiene requirements, COVID-19 has had a significant effect on the consumption of single-use plastic packaging and products such as plastic cutlery. As most restaurants in Europe were closed for on-site dining, many shifted to offering takeaway and delivery services using single-use plastic containers. Several large coffee retailers stopped allowing customers to bring refillable containers, using disposable cups in their place. Meanwhile, online shopping outlets have seen a surge in demand, with many products packed in single-use plastic.

Although disposable plastic products have played an important role in preventing the spread of COVID-19, the upsurge in demand for these items may challenge EU efforts in the shorter term to curb plastic pollution and move towards a more sustainable and circular plastics system. The production, consumption and disposal of additional single-use plastics will have led to greater impacts on the environment and climate than otherwise, such as increased air pollution and greenhouse gas emissions, waste generation and the risk of littering. In cases where the cleanliness of multiple use products cannot be guaranteed, single use products may be preferred, but without undermining or delaying the objectives and rules of the Single Use Plastics Directive.

In addition to the direct effects stemming from increased demand for single-use plastics, other factors related to the pandemic are important to note. Reduced economic activity has seen sharp falls in global oil prices. In turn, this has made it significantly cheaper for manufacturers to produce plastic goods from virgin, fossil-based materials than to use recycled plastic materials. The economic viability of the European and global plastics recycling market is presently under significant pressure. Lower market demand for recycled plastics has also complicated the efforts of many of Europe's municipalities to manage their waste practices sustainably, and less desirable waste disposal options are being used for significant quantities of plastic waste.

The consumption, production and trade of plastics

With an exponential increase in the production and consumption of these versatile and cheap materials ever since the 1950s, plastics have become an integral part of modern society. However, significant differences in the demand for, production of and trade in plastics exist between Europe and other regions of the world.

Plastic consumption and use

Global plastic use has increased very rapidly, from almost zero around 1950 to 359 million tonnes worldwide in 2018. Plastic use in Europe alone was 61.8 million tonnes in 2018, but it seems to have stabilised somewhat, while its use in other parts of the world is still increasing rapidly (PlasticsEurope, 2019).

The global average use of plastics is 45 kg per person per year. Western Europe (Europe excluding central Europe and the Commonwealth of Independent States) uses three times as much — around 136 kg per person (Plastics Insight, 2016).

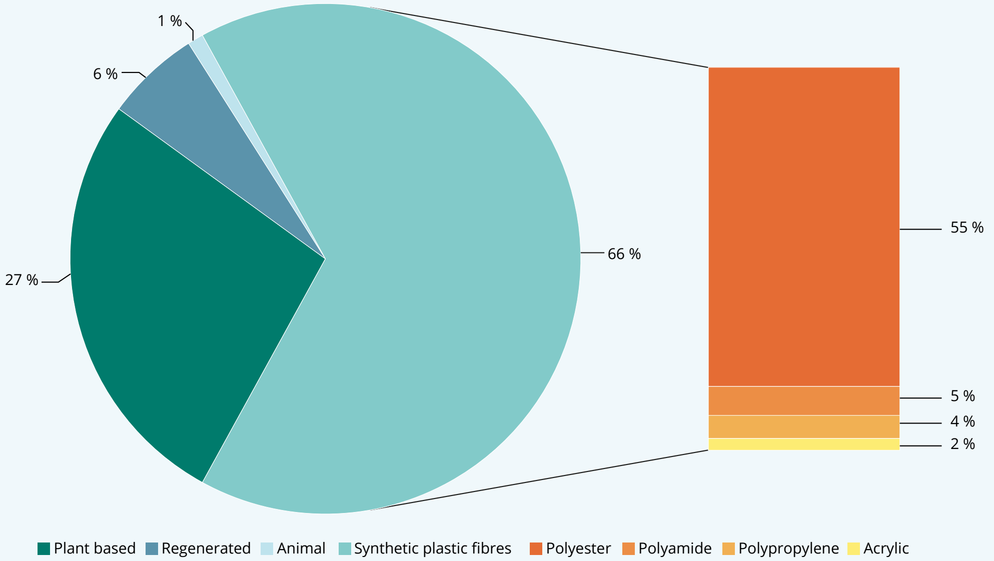
The three largest end-use plastic markets are (1) packaging, (2) building and construction, and (3) the automotive industry, accounting for almost 70 % of all plastics used in Europe. The single largest end-use market for plastics is packaging, which constitutes almost 40 % of European demand. Although synthetic textile fibres are also made from plastics, they are not included in the official statistics for plastics.

Box 1. Plastics for textiles

A significant proportion of plastics goes into synthetic fibres, such as polyester and nylon, used for textiles. Plastic fibres are used for clothing, as well as furniture upholstery, carpets and other applications. Although this is one of the largest end-use markets, textile fibres are usually not included in the statistics for plastics. Synthetic fibres constitute the largest share of all textile fibres used today. Almost two thirds of all textile fibres are synthetic, and one third are plant based (mainly cotton), regenerated fibres (mainly viscose) or animal fibres (mainly wool).

Whereas the production of natural fibres has grown slowly over the past 30 years, the use of synthetic fibres has grown rapidly. Over the past 25 years, synthetic fibres have become the most common type of fibre for textiles, and production amounts to around 65 million tonnes per year. Synthetic fibres are dominated by polyester, which is almost always the same as the plastic which is known as polyethylene terephthalate (PET) when used for water bottles or packaging. However, other plastics are also used for textiles — see Figure 3. More details on textiles and their environmental impact can be found in a recent EEA briefing and underpinning report (EEA, 2019c; ETC/WMGE, 2019).

Figure 3. Distribution of global textile fibre production by type



Source: Based on data from Sandin et al. (2019).

Box 2. Plastics for building and construction

The second largest application of plastics (after packaging) is also one of the most invisible. The building and construction industry is responsible for 20 % of plastic use in Europe. Plastic pipes are used to supply water and remove sewage, as well as for cables and other technical installations. Plastic membranes are used as moisture-proof layers in walls and ceilings. Plastic window frames and profiles have become popular, as they are energy efficient and do not require paint; plastic insulation is used extensively. Plastic flooring is common, especially in public buildings (Agarwal and Gupta, 2017).

The building and construction sector has special requirements (including for durability and strength) for the plastics it uses. The most commonly used plastic is polyvinyl chloride (PVC), accounting for 43 % of plastic used in the sector. In fact, 69 % of all PVC produced is used in building and construction (Häkkinen et al., 2019).

Whereas plastics for packaging are designed and produced for a lifetime of weeks or months, plastics intended for building and construction are designed for a lifetime of decades. This introduces significant challenges when it comes to recycling. Since the plastics from buildings that we want to recycle today are often 30-50 years old, they contain substances that are no longer permitted. This means that new plastic products must be designed today to be recyclable in 30-50 years' time.

Plastic water and sewage pipes used in building and construction © Pixabay

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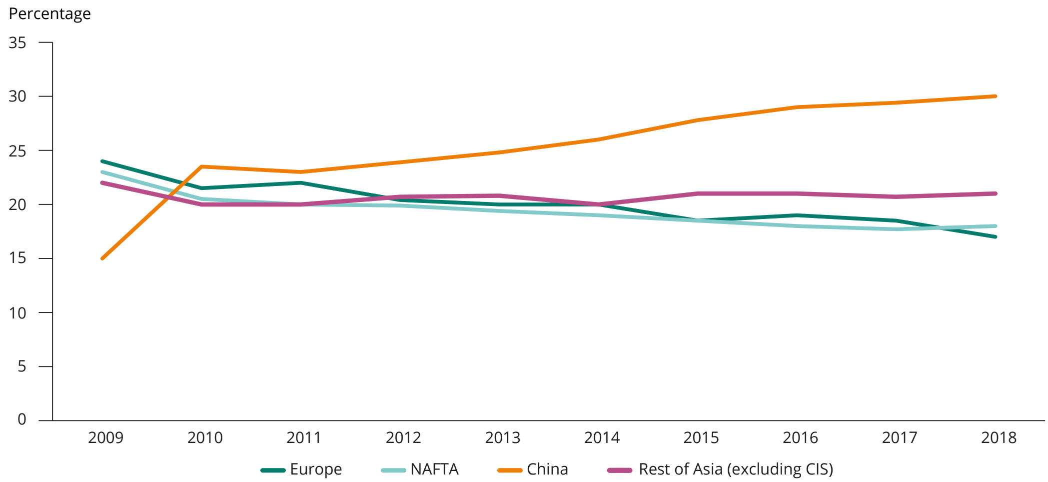
Production of plastics

With its numerous uses and growing supply and demand since the 1950s, the plastic sector has become a very large industry. It employs over 1.6 million people in Europe — including in raw material producers, plastic converters, recyclers and machinery manufacturers — and had an annual turnover in 2018 of EUR 360 billion (PlasticsEurope, 2019).

Global production of plastics has been growing at an average rate of 4.6 % per year over the past decade (PlasticsEurope, 2019). The geographical distribution of plastics production around the world has changed considerably in that time, as shown in Figure 4. Although production in the 28 EU Member States as of 1 July 2013 (EU-28), and in Norway and Switzerland, has only increased by about 1.2 % per year, production elsewhere has grown, leading to a falling market share for European plastics production from about 24 % to 17 %. The growth has primarily been in China, which has doubled its share of the global market from 15 % to 30 %. North America has also lost some of its market share, but less so than Europe because of recent US investments in production based on shale gas.

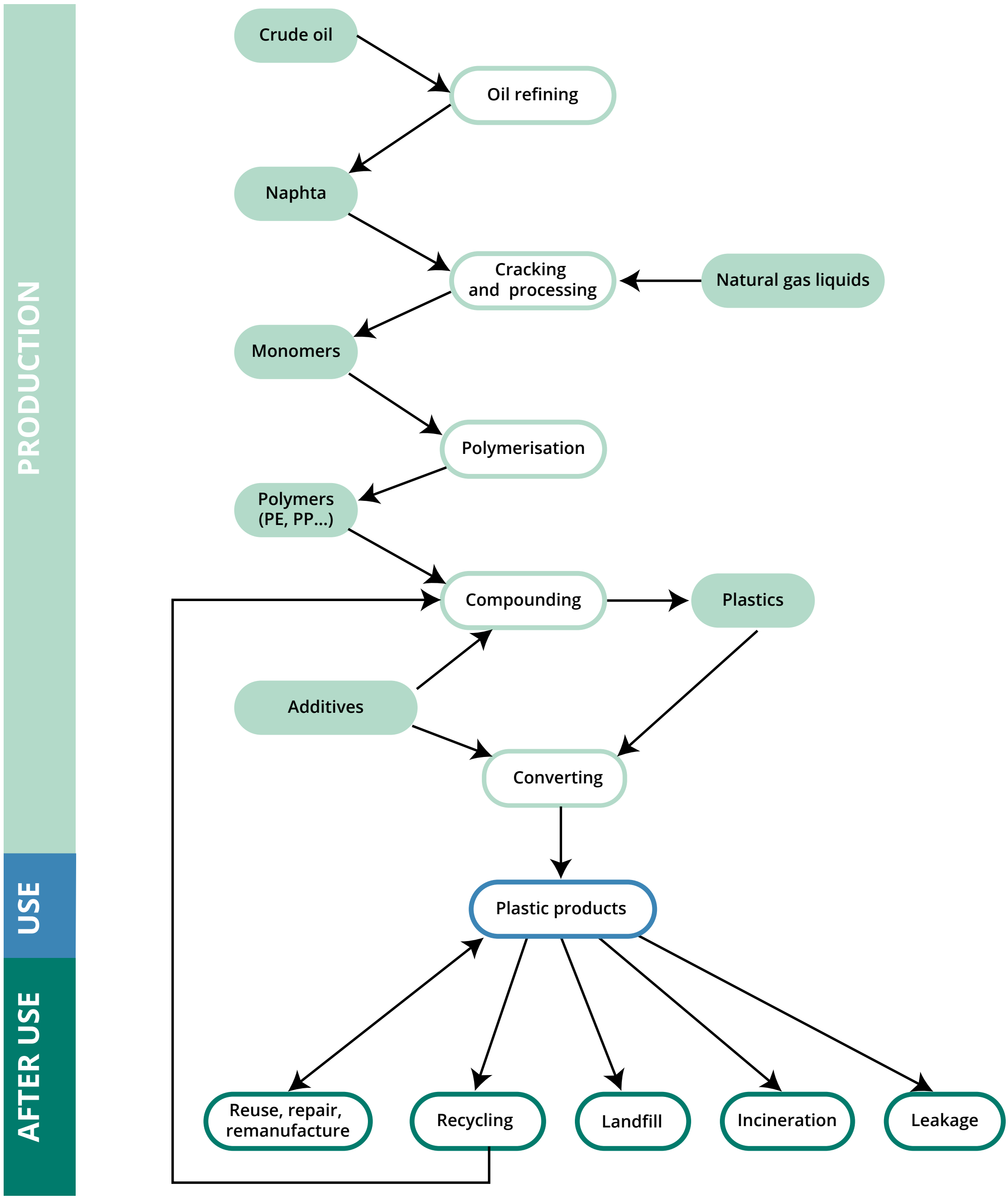
Figure 4. Share of global plastics production in regions with the largest output



Note: Europe, EU28, Norway and Switzerland; CIS, Commonwealth of Independent States; NAFTA, North American Free Trade Agreement.

Source: Based on data from Plastics Europe (2010-2019).

Figure 5. The value chain for plastics



Source: Adapted from Nielsen and Bauer (2019).

Plastics and chemical production has seen faster growth than other markets for oil in recent years, some of which are expected to decline as electric transport gains share from fossil fuel-based propulsion. This has resulted in increased interest in plastics from oil companies, which are investing in plastics and chemicals firms, and production capacity.

The value chain for plastic is long and complicated. As shown in Figure 5, crude oil fractions, such as naphtha and natural gas liquids, are cracked to produce monomers — the building block molecules for polymers. During the polymerisation stage, the monomers are linked together to form larger molecules called polymers. The polymers are then mixed with various chemical additives that give the plastic its desired properties. This is done during a process called compounding. After compounding, the plastic material is used by a converter to produce the final plastic products, such as bottles, water pipes and interior panels for cars. Although approximately one third of these products is collected for recycling in Europe once they become waste, the majority is leaked into the environment, incinerated or landfilled. Only a small fraction is circulated for reuse, repair and remanufacturing (PlasticsEurope, 2019).

The production of primary plastics is dominated by large multinationals in the petrochemical industry. Many of them are subsidiaries to or partially owned by large oil firms, some of which are controlled by national governments. Production usually takes place in large industrial clusters in which oil refineries, steam crackers, polymerisation units and other chemical production facilities are co-located. Some of the world's largest chemical clusters are found in various parts of Europe, such as the areas around Rotterdam (the Netherlands), Düsseldorf (Germany), Antwerp (Belgium), Lyon (France) and Cheshire (United Kingdom) (Ketels, 2007).

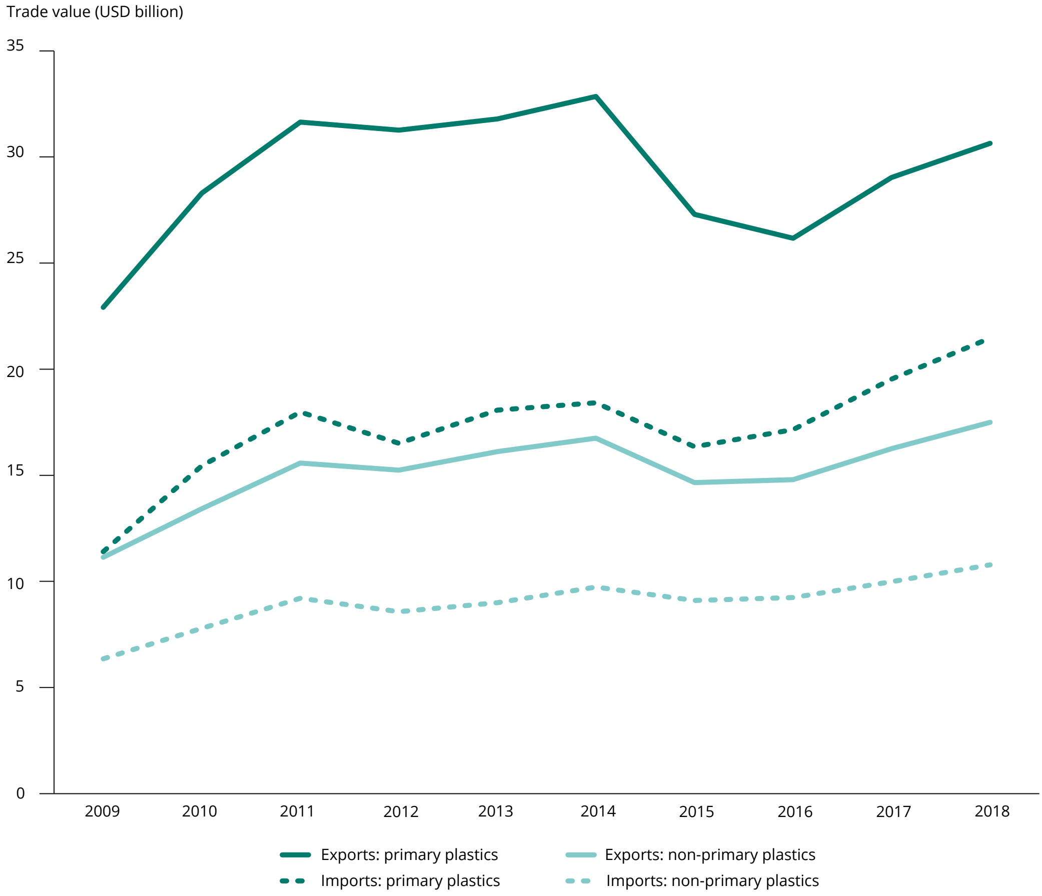
In contrast, the downstream plastics industry, namely plastic compounders (adding chemical additives) and converters (converting into specific products), are mostly smaller firms distributed throughout Europe and other regions of the world.

The plastics trade

Plastics are traded globally, and Europe imports and exports large amounts of both primary and non-primary plastics every year. Primary plastics are the plastic materials themselves, such as pure polymer granulates and compounded plastics. Non-primary plastics are plastic components for later assembly, such as car interior panels, and finished products, for example tubes and bags, as well as products containing plastics, such as electronics, furniture and cars.

The EU has a trade surplus in both primary and non-primary plastics, meaning that the value of the exports for both categories is larger than the value of the imports, as shown in Figure 6. Europe had a positive trade balance of EUR 15 billion in 2018 (PlasticsEurope, 2019).

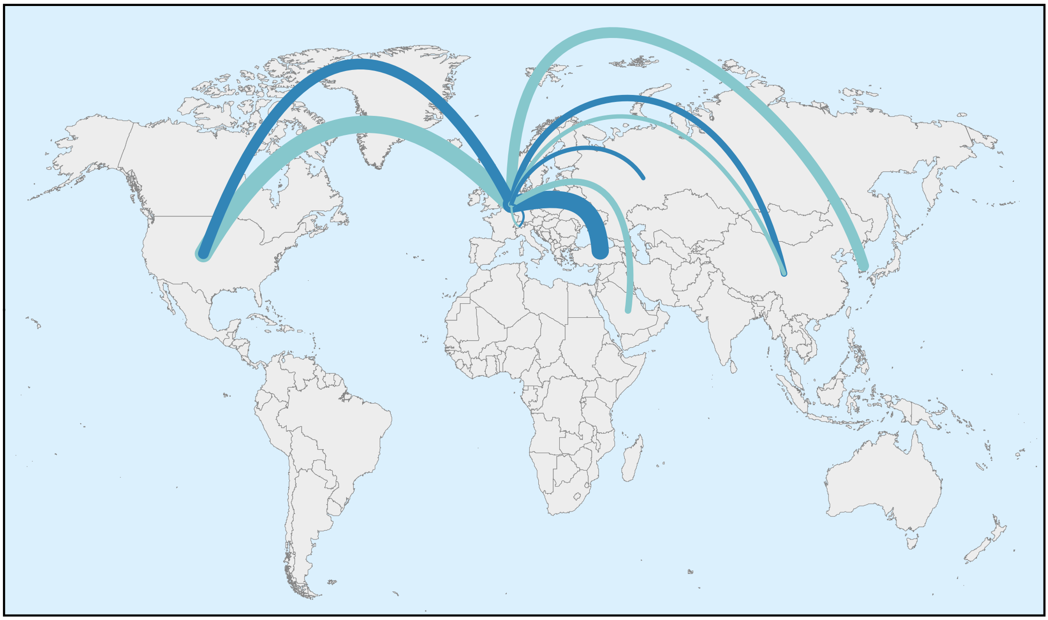
Figure 6. EU imports and exports of primary and non-primary plastics, 2009-2018 (EU-28)



Source: Based on data from UN Comtrade (2019a).

Map 1 shows the EU-28's trade flows in primary plastics with its most important trade partners in 2018. The top five trade partners represent about 50 % of EU plastic exports and approximately 65 % of imports in each category. The EU's strongest trade partner in terms of plastics is the United States.

Map 1. EU-28 exports and imports of primary plastics to and from the EU's five largest trade partners in 2018



Exports and imports of primary plastics to and from the EU's five largest trade partners in 2018

Export flow (USD million)

1 852 | 2 070 | 3 698 | 3 807 | 4 013 | Total 15 442

Import flow (USD million)

1 422 | 1 646 | 2 547 | 3 157 | 4 949 | Total 13 723

Source: Based on data from UN Comtrade (2019a).

Box 3. Polyethylene and its trade

Polyethylene (PE) is the most commonly used plastic worldwide, especially for packaging in the form of bottles or film, as well as for pipes and cable insulation. About 100 million tonnes of PE are produced every year.

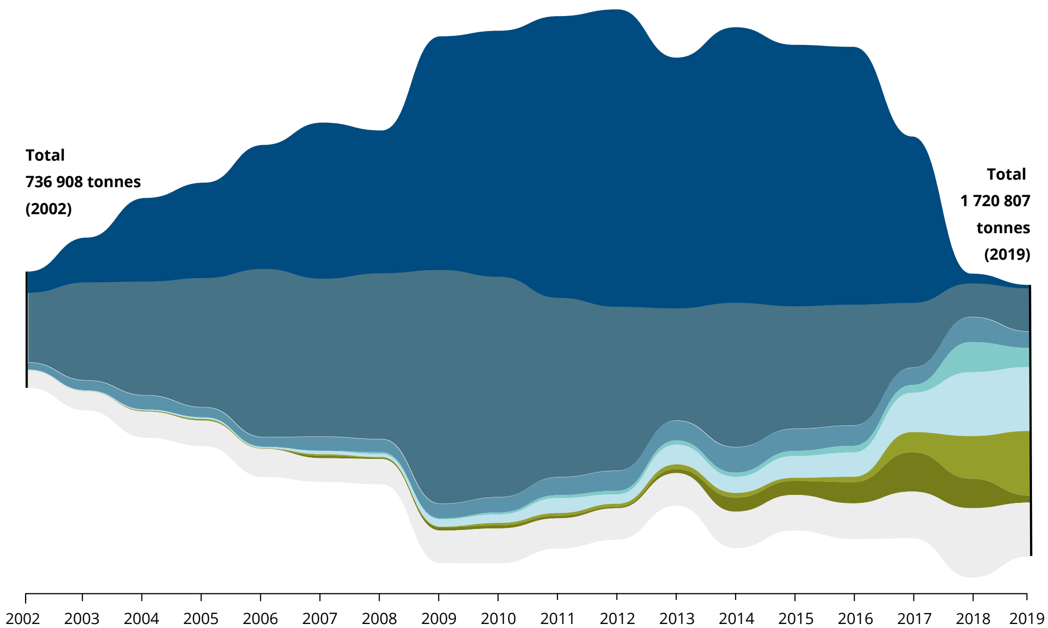
A significant amount of PE is traded worldwide. Saudi Arabia and the United States are significantly larger exporters than most others, and the EU countries Belgium, Germany and the Netherlands are also large exporters. China is by far the largest importer, as the massive manufacturing industry in China demands considerable volumes of plastics. Of the EU countries, Germany, Belgium, Italy and France are those with the largest imports.

The trade in plastic waste

Following policy requirements to collect certain waste streams separately as well as demands for plastic waste for reuse and recycling, more plastic waste became visible and available during the 1990s, leading to rapid growth in international trade in plastic waste.

The EU-28 represents the largest source of export of plastic waste, accounting for around one third of all exports of plastic waste from 1988 to 2016 (Brooks et al., 2018). Most of this waste was previously exported to China and Hong Kong, as can be seen in Figure 7.

Figure 7. EU-28 plastic waste exports, 2002-2018

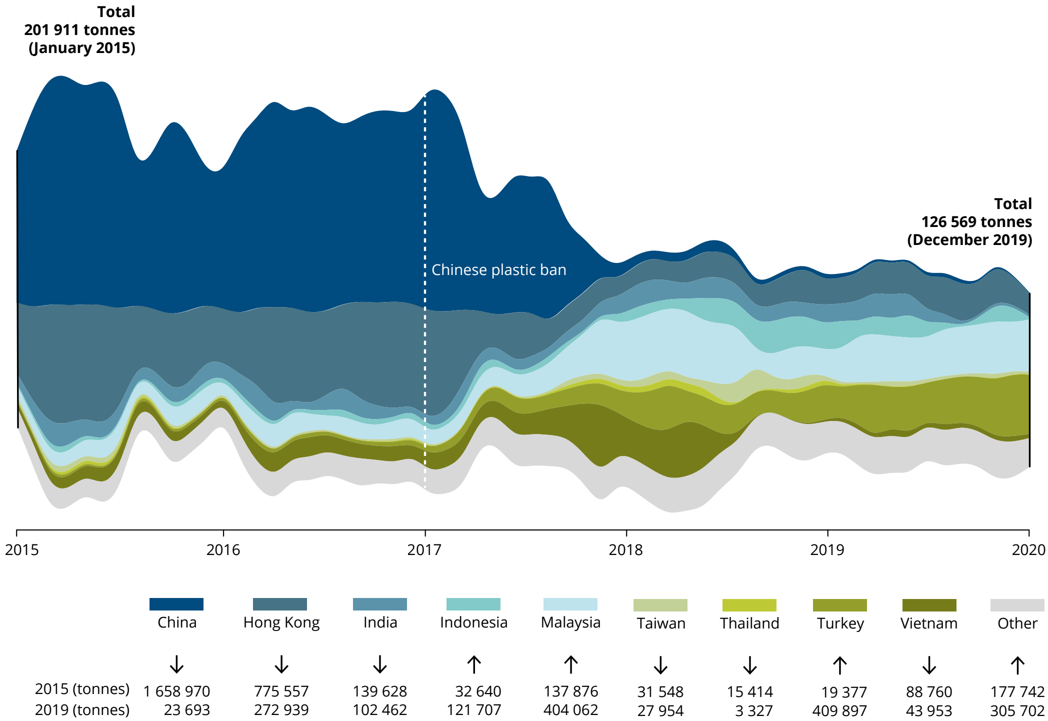


	China	Hong Kong	India	Indonesia	Malaysia	Turkey	Vietnam	Other
	↓	↓	↑	↑	↑	↑	↑	↑
2002 (tonnes)	136 310	440 736	44 575	1 176	3 223	579	232	110 074
2019 (tonnes)	23 690	272 999	102 511	121 707	404 659	409 843	44 182	341 211

Source: Based on data from UN Comtrade (2019b).

The quantities and patterns of exported plastic waste have shifted, following an initial temporary Chinese restriction in 2013 and then new regulations in China banning the import of non-industrial plastic waste in 2017. European plastic waste exports have halved and at the same time been re-routed to other countries in South East Asia, such as Vietnam, Thailand and Malaysia — see Figure 8.

Figure 8. EU-28 exports of plastic waste by receiving country, tonnes per month, January 2015 - December 2019



Source: Reproduced from EEA (2019d).

The export of plastic waste from the EU is likely to decrease and possibly halt in the coming years. In the short term, this may lead to more landfilling and incineration.

In the longer term, it is an opportunity to improve capacities for reusing and recycling plastic waste within the EU (EEA, 2019d).

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Offshore oil rigs, pictured here in the North Sea, are used to extract oil © Pixabay.

Environmental and climate impacts of plastics

Awareness of plastic litter, including its effect on nature (especially the marine environment) and human health, has risen rapidly in recent years. However, litter is just one of the negative environmental impacts that occur throughout the life cycle of plastics, as can be seen in Figure 9. All of these must be addressed to create a circular and sustainable plastics economy. This chapter focuses on impacts occurring throughout the resource extraction, production, consumption and end-of-life phases of plastics. The most significant impacts from each phase are discussed below, recognising that many impacts occur in all phases, but to a varying degree.

Impacts of extracting oil and gas resources for plastics

- If the production and use of plastics continue to increase as projected, the plastic industry will account for 20 % of global oil use by 2050, an increase from today's 7 %.

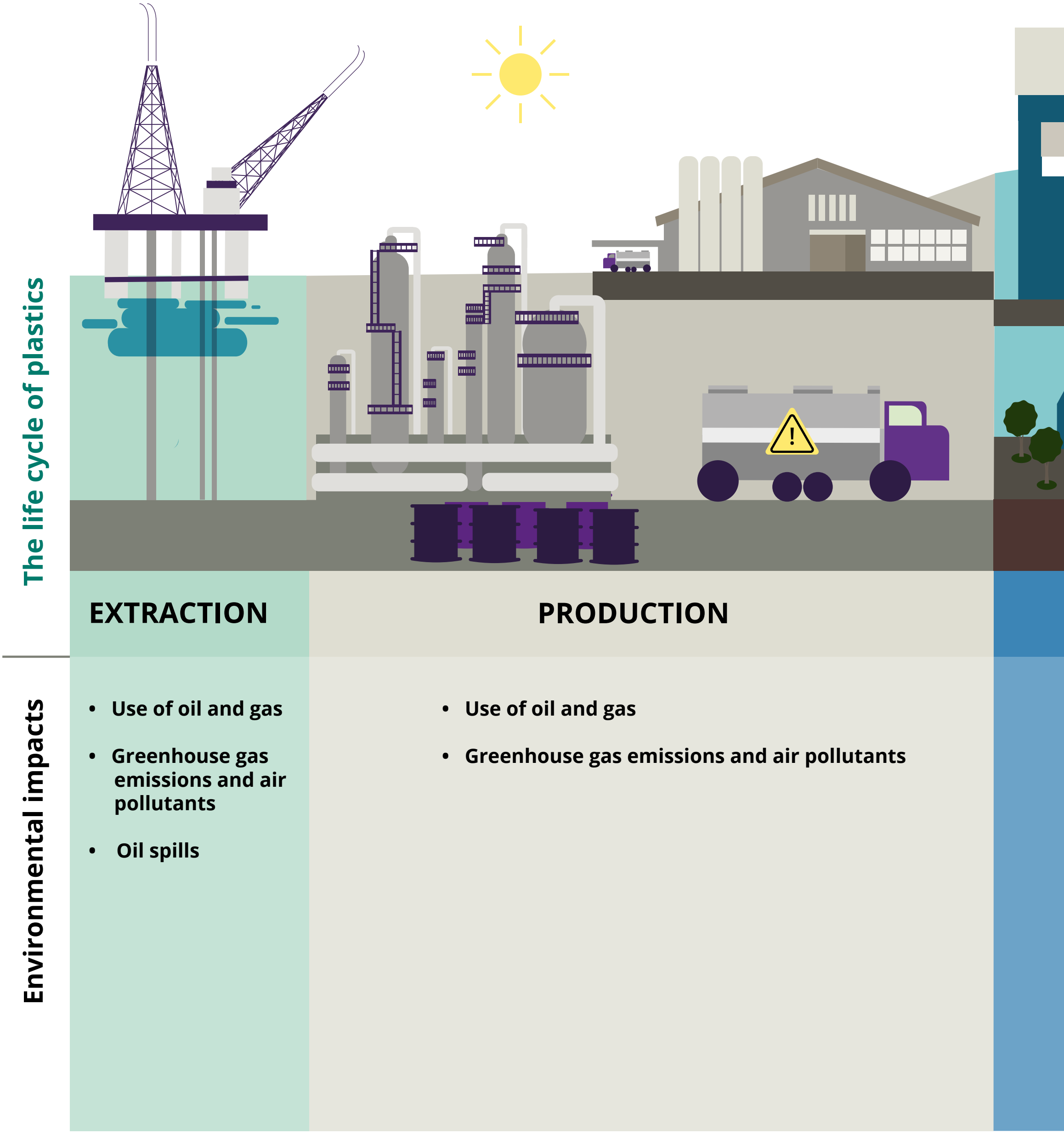
- During the extraction of oil and gas for plastic production, greenhouse gases and multiple pollutants are emitted to the air, and large volumes of waste water containing dispersed oil, hazardous substances and other harmful chemicals are leaked into the environment.

Extraction of oil and gas

The system of consumption and production of plastics implies significant resource use, mainly of fossil fuels, which has implications for the environment and climate. Over 99 % of plastics (CIEL, 2019) are produced from fossil fuel resources, mainly oil and gas. Approximately half of the oil used for plastic is feedstock locked into the plastic products, whereas half is used as fuel in the plastic production process (Ellen MacArthur Foundation, 2016).

If the use of plastics continues to grow as expected, it is projected that the plastics industry will account for 20 % of global oil use by 2050, an increase from today's 7 %. The growth rate of plastic production (3.5-3.8 % per year) is much faster than the growth in demand for oil (0.5 % annually) (Ellen MacArthur Foundation, 2016). Although the vast majority of oil is currently used for fuels, this share is expected to decrease in the coming years as cars and trucks are increasingly electrified, leading to reduced demand for petrol and diesel in developed economies. The International Energy Agency projects that plastics and other petrochemicals will be the largest driver of the growth in the demand for oil up to 2030 (OECD and IEA, 2018).

Figure 9. The environmental impacts across the life cycle of plastics



Source: EEA.

USE	AFTER USE
• Human exposure to toxic substances	• Litter on land and in oceans, seas and freshwater • Greenhouse gas emissions from incineration and landfill

In the past decade, there has also been a global shift in the choice of feedstocks used to produce plastics. Whereas the main feedstock historically was naphtha, a product derived from oil refining, natural gas liquids are increasingly being used. These are lighter hydrocarbons, mainly ethane and propane, found in natural gas reserves in some regions such as the Middle East and in shale gas reserves in the United States.

Shale gas extraction, in particular, is known to have significant impacts on natural areas, as large areas are used and contaminated in the process. US ethane exports have grown rapidly following the expansion of shale gas production, and since 2016 a significant share of exports goes to Europe (US EIA, 2020). Thus, the EU is increasingly using environmentally damaging shale gas imported from the United States to produce plastics.

Box 4. US shale gas extraction affects European plastics production and use

Shale gas extraction in the United States, which uses hydraulic fracturing ('fracking'; see Figure 10), grew very quickly during the beginning of the 21st century. Shale gas production constituted only 1 % of US domestic natural gas production in 2000; however, in just 10 years the share increased to 20 % (Stevens, 2012). The rapid growth in production led to an oversupply of gas on the North American market. At the same time, technologies were developed for managing liquefied natural gas to enable a global trade in gas, as there has been in oil for decades.

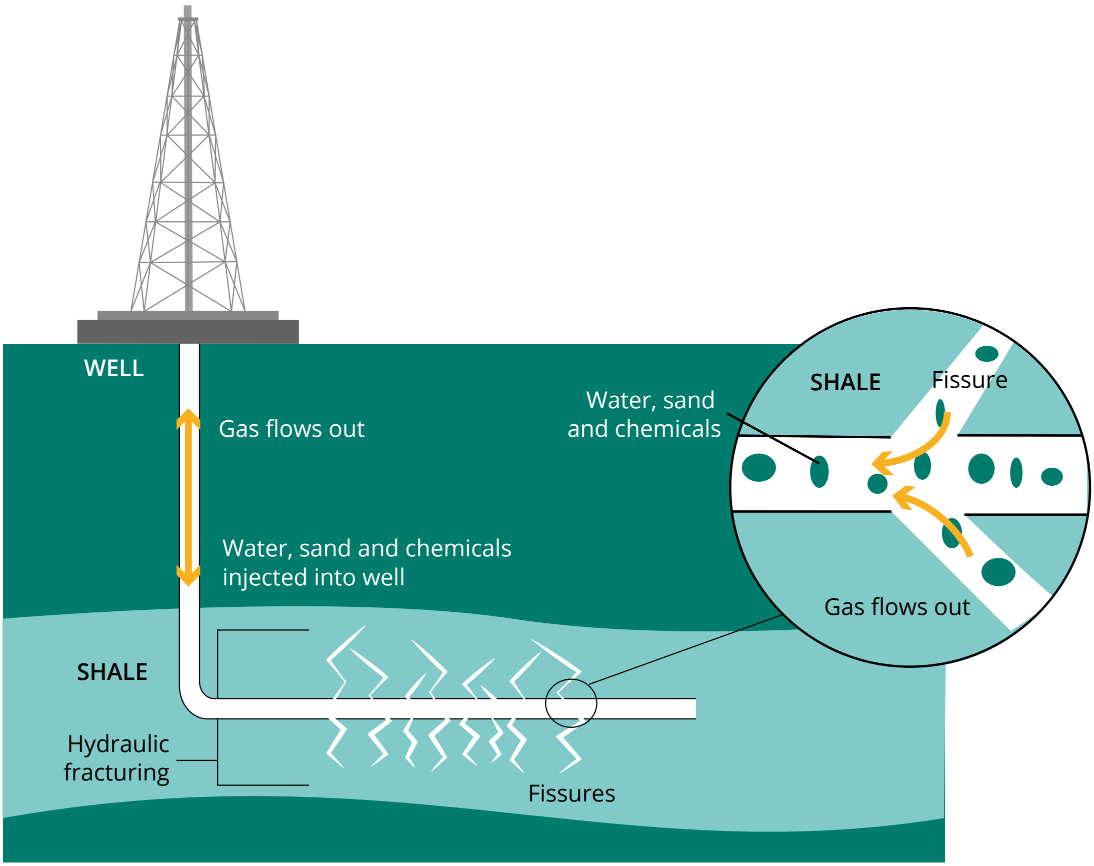
By making use of technologies similar to those developed for liquefied natural gas, a global market for ethane has been established. Several European firms have signed contracts for US ethane, which is being shipped across the Atlantic in large specialised ships. European production of plastics is thus now relying on shale gas products from the United States.

Shale gas extraction and hydraulic fracturing continue to be contentious issues, as they use large volumes of water and chemicals, while issues regarding leakage of potent greenhouse gases and chemicals remain unanswered.

Greenhouse gas emissions and climate change arising from oil and gas extraction

Plastics cause greenhouse gas emissions, mainly due to their current dependence on the fossil fuels oil and gas. Greenhouse gas emissions from plastics start with the extraction of oil and gas, because it requires large amounts of energy. Greenhouse gas emissions are a result of the combustion of natural gas in turbines and diesel in engines to fulfil the energy demands of the drilling machinery and pump and compressor operations (Norwegian Environment Agency, 2020a). Large numbers of trucks emitting greenhouse gases are also needed at the well sites to transport water and waste (CIEL, 2019).

Figure 10. Shale gas extraction through hydraulic fracturing



Note: Horizontal holes are drilled in deep shale layers. Using high pressure water and chemicals, fissures are opened in the shale so that gas is released and can be extracted.

Source: IVL.

In addition to emitting the most common greenhouse gas, CO_2, the extraction of oil and gas is also a significant emitter of methane. Methane emissions occur when natural gas moves through the system, from production to distribution. Examples of activities that may cause methane emissions are intentional venting and unintentional leaks from pipelines and gas engines (US EPA, 2018).

As oil and gas fields get older, the greenhouse gas emissions generally increase, as more energy is needed to clean greater quantities of contaminated water or for injecting more water into the bedrock (Norwegian Environment Agency, 2020b). In some places, onshore oil and gas extraction causes land disturbance and indirect greenhouse gas emissions, as forests and fields are removed to make way for oil fields, and consequently no longer absorb greenhouse gases. Refining crude oil to oil products such as naphtha, still the dominant route for plastics in the EU, consumes large amounts of energy, as does steam cracking (CIEL, 2019).

Pollution of air, water and land arising from oil and gas extraction

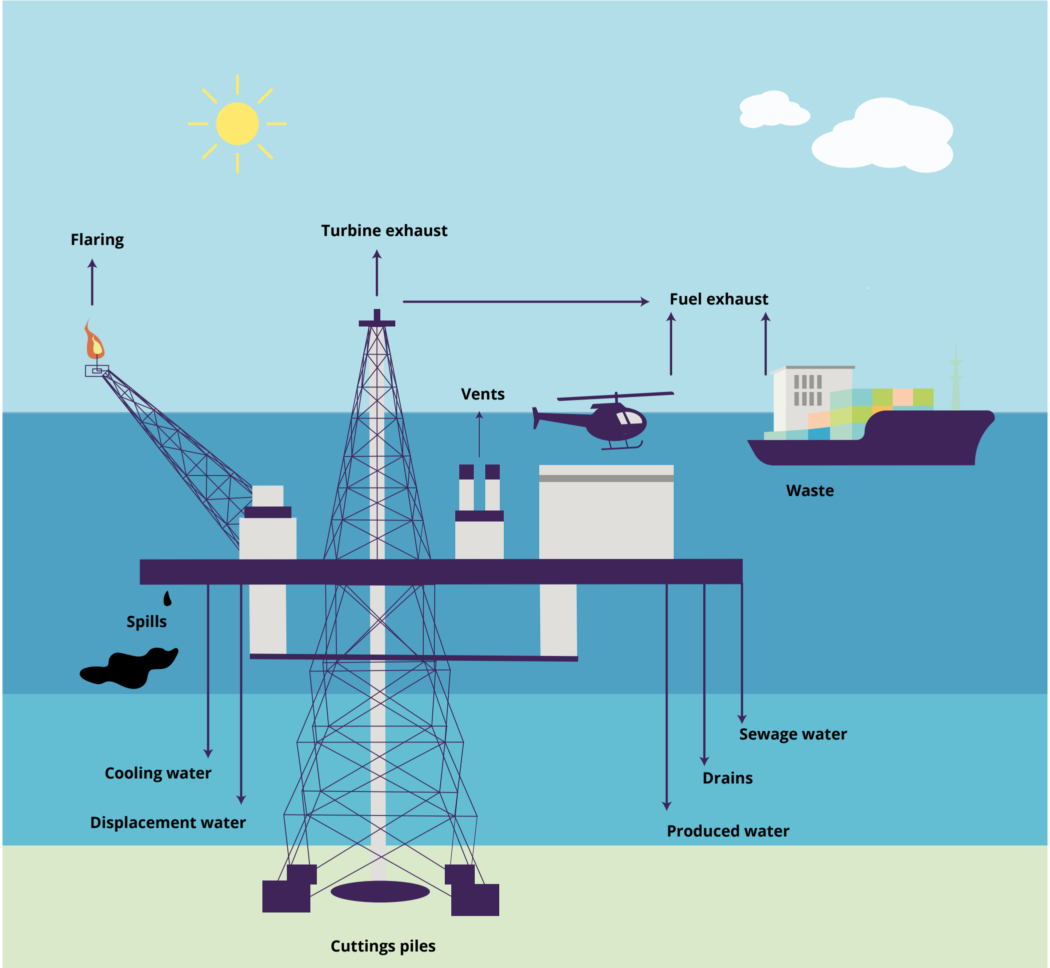
Oil and gas extraction for plastic production emits air pollutants, such as nitrogen oxides (NO_x), sulphur oxides (SO_x), particular matter (PM), volatile organic compounds (VOCs), heavy metals, and a wide range of chlorinated and other toxic organic chemicals (US EPA, 2016). The emissions are mainly a result of fuel combustion in gas turbines and diesel engines that generate energy for drilling operations, treatment of the extracted oil and gas, and transport of oil and gas to reception stations. Flaring or venting excess gases when extracting oil and gas likewise releases toxic chemicals to the atmosphere (CIEL, 2019).

Both onshore and offshore oil and gas extraction result in large amounts of waste water coming from the reservoirs. This is called produced water, and it contains dispersed oil and hazardous substances that occur naturally in the reservoir, such as heavy metals, aromatic hydrocarbons, alkyl phenols and radionuclides. It also contains added process chemicals, some of which are considered harmful in terms of toxicity, bioaccumulation and biodegradation. For example, chemicals are needed when drilling to lubricate and cool the drilling bit (OSPAR, 2017). Although the concentrations of dispersed oil and hazardous substances are generally low in the produced water, the large amounts of water make the quantities relevant. For example, produced water and shipping are the largest emitters of oil into the North Sea. The amount of produced water increases as the oil and gas fields get older (Norwegian Environment Agency, 2020b).

The emissions of oil and toxic chemicals from produced water may have negative impacts on sea animals, but the consequences at ecosystem level are not fully understood (Figure 11). Another environmental risk is oil spill, as this may cause both acute and long-term effects on life at sea. The installation and removal of oil platforms, as well as drilling operations, also affect the local environment, depending on how sensitive the area in question is (Norwegian Environment Agency, 2020b).

Hydraulic fracturing, a technique to improve the flow of the oil or gas from the well, is further associated with risks such as degrading groundwater and surface water quality due to waste fluid disposal, spills of chemicals and the reducing water availability (USGS, 2020). Over 170 fracking chemicals are known to cause health problems such as cancer and damage to the immune system, especially for those living near fracking sites (Heinrich Böll Foundation, 2019).

Figure 11. Emissions to air and water from an oil platform

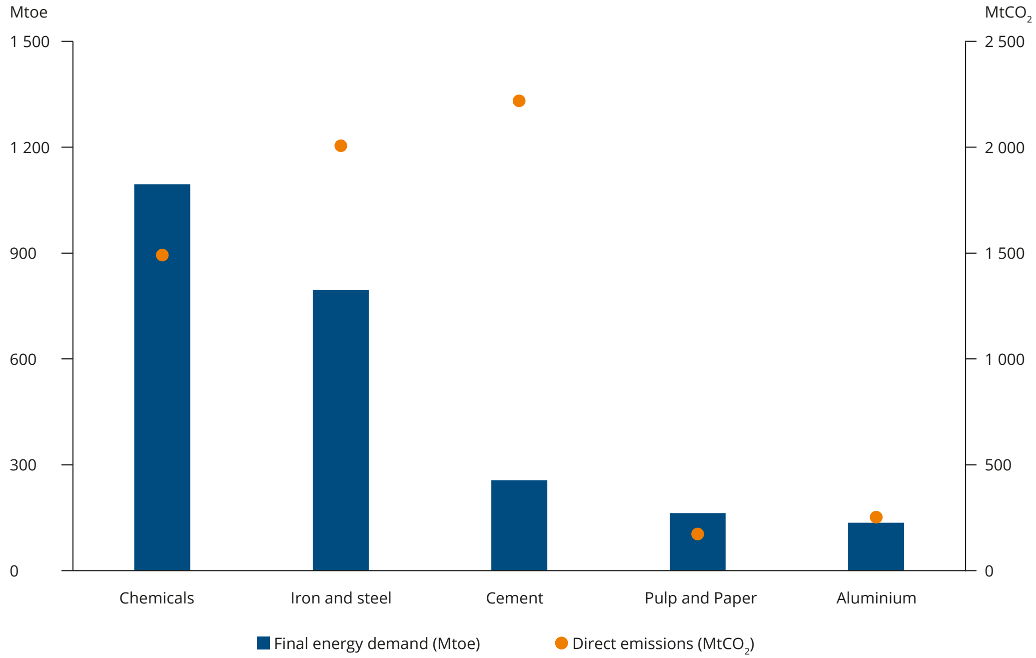


Source: Adapted from OSPAR (2017).

Impacts of plastic production

- Every year, the production of plastics in the EU is responsible for emitting 13.4 million tonnes of CO_2, which is about 20 % of the chemical industry's emissions EU-wide.
- The production of plastics emits substances such as toxic metals and organic compounds, which accumulate in animals and plants and may negatively affect their health.

Figure 12. Global final energy demand and direct CO2 emissions by sector in 2017



Notes: Final energy demand for chemicals includes feedstock, and for iron and steel it includes energy use in blast furnaces and coke ovens. Direct CO_2 emissions includes energy and process emissions in the industry sector; Mtoe, million tonnes of oil equivalent; MtCO$_2$, million tonnes of carbon dioxide.

Source: Reproduced from OECD and IEA (2018).

Greenhouse gas emissions and climate change arising from plastic production

Plastic production is the largest part of the chemical sector, constituting about one third of chemicals production worldwide and about one fifth in Europe (Zheng and Suh, 2019; EEA, 2020a). The chemicals sector is the production sector using the most energy in the world, ahead of the iron and steel, cement, pulp and paper, and aluminium industries, as shown in Figure 12 (OECD and IEA, 2018), and is the third largest source of industrial CO_2 emissions. With about one third of the energy used for plastic production, producing chemicals for plastics has the second largest sectoral energy demand in the world.

In Europe, data from the EEA Greenhouse Gas Inventory shows that annual greenhouse gas emissions related to plastic production in the EU (i.e. the share of direct emissions from petroleum refineries and chemical manufacturing) amount to around 13.4 million tonnes of CO_2, which is about 20 % of the chemicals industry's emissions EU-wide (EEA, 2020a).

Greenhouse gas emissions from plastics production in the EU are, not surprisingly, much higher when emissions over the whole lifecycle are considered i.e. including direct and indirect emissions and upstream activities such as oil extraction and refining/cracking. In this different perspective, greenhouse gas emissions related to the EU plastic value chain for resin production have been estimated to be as high as 132 million tonnes CO_2e in 2018 (ETC/WMGE, forthcoming). Converting these polymers to plastic components and products accounts for an additional 46 million tonnes (ETC/WMGE, 2020).

Pollution of air and water arising from plastic production

NO_x and SO_x are emitted by the plastic polymer manufacturing sector in significant quantities and are well known for their effect as acidifying substances. Acidification may lead to the spread of toxic metals, as it increases the mobility of the metals in the environment. Toxic metals such as lead, cadmium and mercury, as well as toxic organic compounds, are also emitted to air and water during plastic production. These may accumulate in animals and plants and are of concern, mainly because of their undermining health effects. They also persist in the trophic webs, leading to higher concentrations further up the food chain (EEA, 2019a). VOCs in combination with NO_x also participate in the atmosphere's chemistry, leading to various environmental phenomena, the generation of toxic tropospheric ozone being the most important.

Plastics production and waste is also responsible for increased levels of nutrients in water systems, which lead to an ecosystem alteration known as eutrophication. When nutrients increase in a water body, the balance across species changes, fostering increased algal growth. When the algae die, they are degraded in the water body, which causes a reduction in its oxygen concentration and leads to a very significant decrease in biodiversity (EEA, 2019a).

Impacts of plastic consumption, littering and micro-plastics

- When using plastic products in their daily lives, consumers may be exposed to toxic substances through the migration of particles, additives, impurities and degraded chemicals.

- Abundance of plastic litter on land and in oceans, seas and freshwater is one of the most visible aspects of the increasing production and use of plastics. 40 % of plastic items found in European freshwater environments are consumer-related products, such as bottles, food wrappers and cigarette butts.

- Plastic pollution in the environment can have detrimental effects on wildlife, primarily because of entanglement, injuries and ingestion. More research is needed into the effects of micro-plastics, including on marine biota and human health.

Chemical toxicity to humans and nature arising from plastic use

Many negative health impacts including reproductive disorders, behavioural disorders, diabetes and obesity, asthma and cancers have been associated to exposure to various chemicals used in plastics, such as flame retardants, endocrine disrupters and phthalates (HEAL, 2020).

Consumers and users can be exposed to toxicity through the migration of particles, additives, impurities and degraded chemicals, mostly during the first use but also during subsequent uses of plastics. Only limited risk assessments have been performed for chemicals authorised to be used in, for example, food contact plastics, and several materials used in multilayer plastic materials do not have specific legislation that requires authorisation before use.

For single-use plastics, exposure is typically higher than for repeated-use plastics. This is because it is mainly the chemicals that are not bound to the plastic that migrate, and most of the migration happens the first time the plastic is used.

Although additives play an important role in improving the properties of plastics, we know that chemicals used as additives can migrate from macro- and micro-plastics into the environment and lead to human exposure (Hahladakis et al., 2018). For many of the substances used as additives, there are still uncertainties about their hazardous properties and risks to human health and the environment (ECHA, 2019).

The migration of chemicals into nature and humans depends on a number of factors: the type of substance, the concentration of the substance in the plastic, the surface area of the product, and how and where the plastic product is used, for example the temperature (ECHA, 2019). Additives are usually not chemically bound to the plastic structure, so they can potentially migrate/leach from the plastic product into a medium in contact with the product or migrate through the plastic to its surface (Hahladakis et al., 2018).

In nature, environmental factors such as temperature and the availability of microorganisms influence the leaching of chemical substances from plastics (Teuten et al., 2009) including resin pellets, fragments and microscopic plastic fragments, contain organic contaminants, including polychlorinated biphenyls (PCBs. In addition, there are considerable differences between macro- and micro-plastics. Macro-plastics are of key concern for marine animals that may, for example, get tangled in fishing nets or eat plastics. There is less known about the risks of micro- and nano-plastics to humans, animals and the environment. Chemicals from plastics may enter animals directly, if they mistake plastics for food, or indirectly via the food chain. This may result in a higher chemical concentration than that of the source and is common in animals higher up the food pyramid, such as birds and marine mammals. At lower trophic levels, for example plankton, fish, bivalves and molluscs, the major intake of chemicals occurs passively via the surface of the body or via respiratory organs by diffusion (Blastic, 2018).

Plastics in the environment

Plastics end up everywhere in the environment: in air, soil, freshwater, seas, biota and some components of our food. Plastics of various sizes are released into the environment, from large plastic items such as plastic bags and bottles to smaller particles found in textiles and cosmetics or released from car tyres. It has been shown that that plastic waste enters the ocean at a rate of 11 million metric tons per year, harming mariner life and damaging habitats (The Pew Charitable Trusts and SYSTEMIQ, 2020). Over 200.000 tonnes of plastic waste enters the Mediterranean Sea every year, a number that is expected to double if significant measures are not taken (IUCN, 2020).

Larger plastic items in the environment may fragment and degrade into micro-plastics. Recent research estimates that at least 14.4 million tonnes of microplastics have found its way to the bottom of the world's oceans (Barrett et al., 2020). The extent and speed of this fragmentation depends on the type of plastic and the exposure to sunlight, high temperatures, wind and waves. The majority of plastics are not biodegradable in marine conditions but will gradually break down into micro- and nano-plastics through wear and tear and other mechanical action (Velis et al., 2017). In general, knowledge of ecological and health risk of microplastic is surrounded by considerable uncertainly (EC, 2019b).

Plastics on a beach / © Pixabay

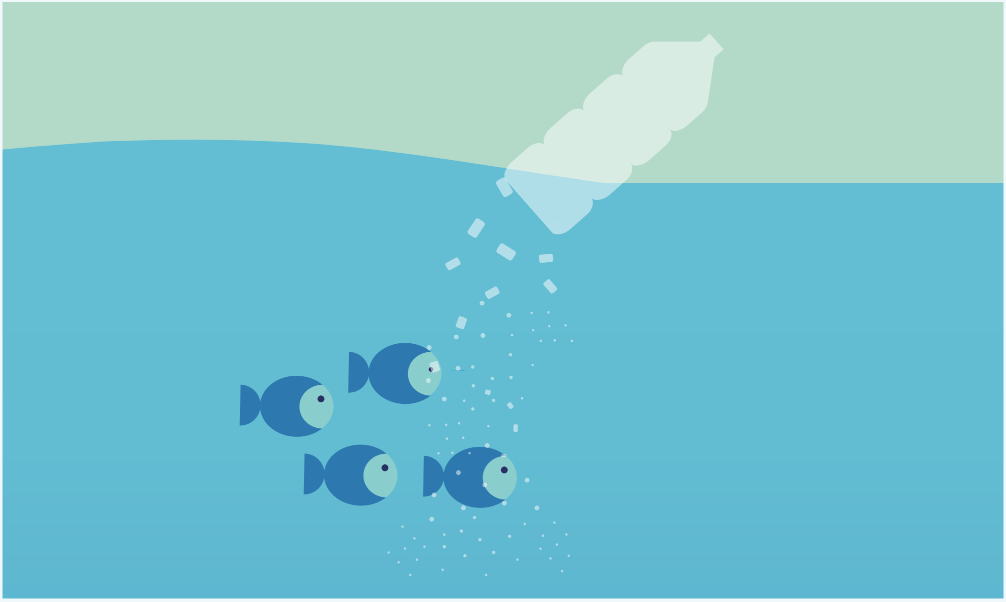
Box 5. Different sizes of plastics in the environment

Plastics in the environment are usually categorised into macro-plastic, micro-plastic and nano-plastic.

Macro-plastics are generally referred to as plastic particles larger than 5 mm. Particles smaller than 5 mm are called micro-plastics, and plastics smaller than 0.1 mm are called nano-plastics. Knowledge about the fate, risks and effects of nano-plastics in the environment is very limited (SAPEA, 2019).

Micro- and nano-plastics can be released either as so-called primary micro-plastics or as secondary micro-plastics. Primary micro-plastics are emitted to the environment in their original shape, for example from washing textiles and as microbeads in cosmetics and personal care products. Micro-plastics can also originate from the fragmentation of macro-plastics (secondary micro-plastics; see Figure 13), for example from the wear and tear of plastic litter or abrasion of car tyres (UNEP, 2018).

Figure 13. The breakdown of a plastic bottle into smaller fragments, eventually ending up as micro- and nano-plastics



Source: IVL.

Figure 14. Sources and pathways of plastics in the environment

Source: EEA.

The majority of plastics found in the marine environment in Europe and elsewhere are carried there by rivers. Litter studies in European freshwater environments show that around 40 % of the identifiable plastic litter items were consumer-related products, mostly consisting of bottles, food wrappers and cigarette butts (Earthwatch Institute, 2019). Results from modelling show that most micro-plastics exported by rivers to seas in Europe are synthetic polymers from car tyres and plastic-based textiles from laundry (SAPEA, 2019).

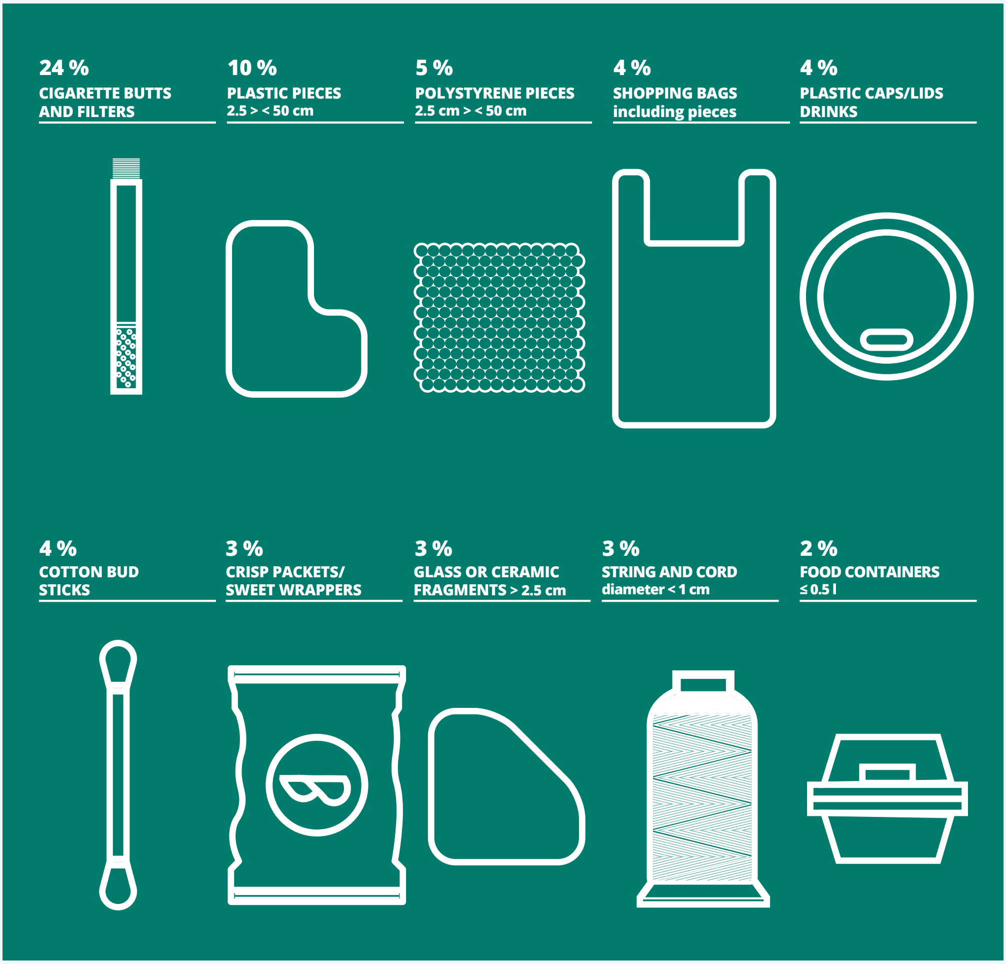
The effects of plastics in the environment are not fully known. Risks are associated with the size of plastics. Macro-plastics such as plastic bags, lost fishing gear and ropes may have detrimental effects on animals because of entanglement, injuries or ingestion. To some species, plastics resemble their ordinary feeding sources, for example for sea turtles transparent plastic bags look similar to jellyfish (UNEP, 2018).

Seabird nesting on fishing nets ©Pixabay

Box 7. Marine Litter Watch

Marine Litter Watch is an ongoing EEA initiative launched in 2014 to better understand the composition, movement and origin of beach litter and to combat plastic litter. By using the Marine Litter Watch app, communities and the public can organise beach clean-ups and record the litter they find on beaches using specific guidelines. The data are used to increase the knowledge base on beach litter and support policymaking under the Marine Strategy Framework Directive and the Single Use Plastics Directive. The top 10 litter items reported to Marine Litter Watch between January 2014 and October 2020 are displayed in Figure 15 below. The percentages are calculated based on the total number of items collected. Together, these items represent 60 % of the litter reported (EEA, 2020c).

Figure 15. Top 10 items reported to Marine Litter Watch (January 2014 and October 2020)



Source: EEA (2020c).

Many marine animal species have been documented as being entangled in and injured by plastics, but the consequences on a population level are not fully known. The animals most often studied include seabirds, turtles and mammals, but fish and invertebrates are receiving increasing attention. Smaller plastic items may be mistaken for food or enter organisms through filtration (e.g. in fish and mussels). All species of marine turtles, almost 60 % of whale species, 36 % of seal species and 40 % of seabird species have been documented as ingesting plastics (Kuhn et al., 2015).

There is some knowledge of the concentrations of micro-plastics in ocean surface waters and freshwaters, but similar information regarding air and soil is very limited. However, there are indications that microplastics in air, freshwater and soil are in need to be addressed similarly to marine microplastics (SAPEA, 2019). Micro-plastics have a negative effect on food consumption, growth, reproduction and survival. High levels of exposure to micro-plastics may cause inflammation and stress, as well as blockage of the gastrointestinal or respiratory tracts, reducing energy uptake or respiration. However, the extent to which this is happening in nature is not known. The concentrations of micro-plastics used in laboratory studies are much higher than those found in the environment (SAPEA, 2019).

The intake of micro- and nano-plastics through food and drink could pose a threat to human health. It is, however, not possible to assess human exposure to micro- and nano-plastics because of a lack of validated and standardised methods. At present, the impacts of micro- and nano-plastic contamination of food and beverages is largely unknown (Toussaint et al., 2019).

Impacts of plastic waste management

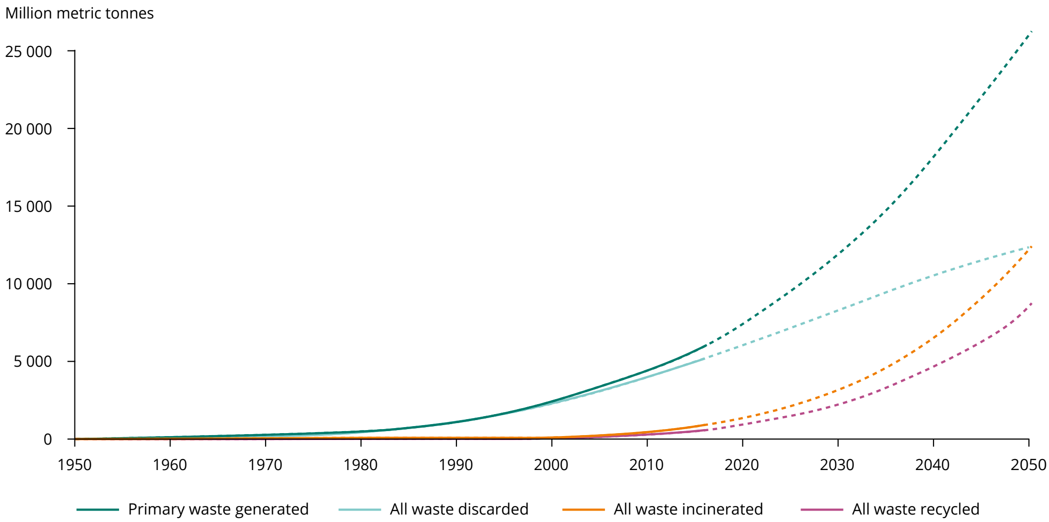
- Estimates suggest that 20-30 million tonnes of plastic waste is incinerated in Europe annually, leading to CO_2 emissions of around 50-80 million tonnes per year.

- Of the 29 million tonnes of plastic waste collected in Europe in 2018, 32 % was collected for recycling. Recycling rather than incinerating plastics can reduce emissions by 1.1-3.0 tonnes of CO_2 equivalent (CO_2e).

In addition to the growth in production, use and consumption of plastics — and the resulting direct environmental and climate impacts — the generation of plastic waste is also an issue, as it constitutes a considerable problem for waste management systems globally. Plastics today constitute a significant part of the total waste generated in Europe.

Humans have already produced a cumulative global total of over 8 billion tonnes of plastics since 1950, of which 6.3 billion tonnes became waste in 2015 (Figure 16). It has been projected that over 25 billion tonnes of plastic could be generated by 2050, much of which could end in landfills or the natural environment (Geyer et al., 2017).

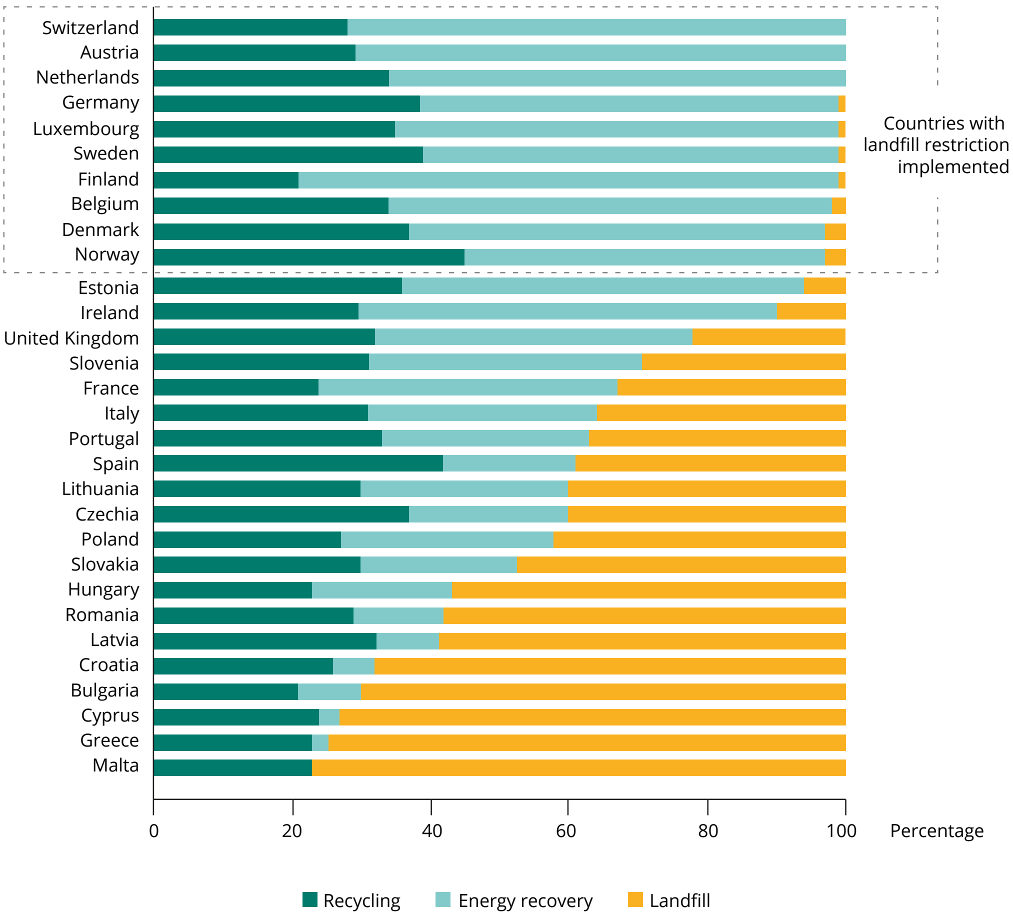
Figure 16. Cumulative global plastic waste generation and disposal



Source: Adapted from Geyer et al. (2017).

In 2018, 29 million tonnes of plastic waste was collected in Europe (EU-28, Norway and Switzerland), of which it has been estimated that 32 % was sent for recycling, 43 % was incinerated and 25 % was landfilled (PlasticsEurope, 2019). Whereas countries in north-western Europe have banned or restricted landfilling and thus incinerate the majority of plastic waste generated, landfilling is still the dominant treatment strategy for plastic waste in southern Europe, as shown in Figure 17.

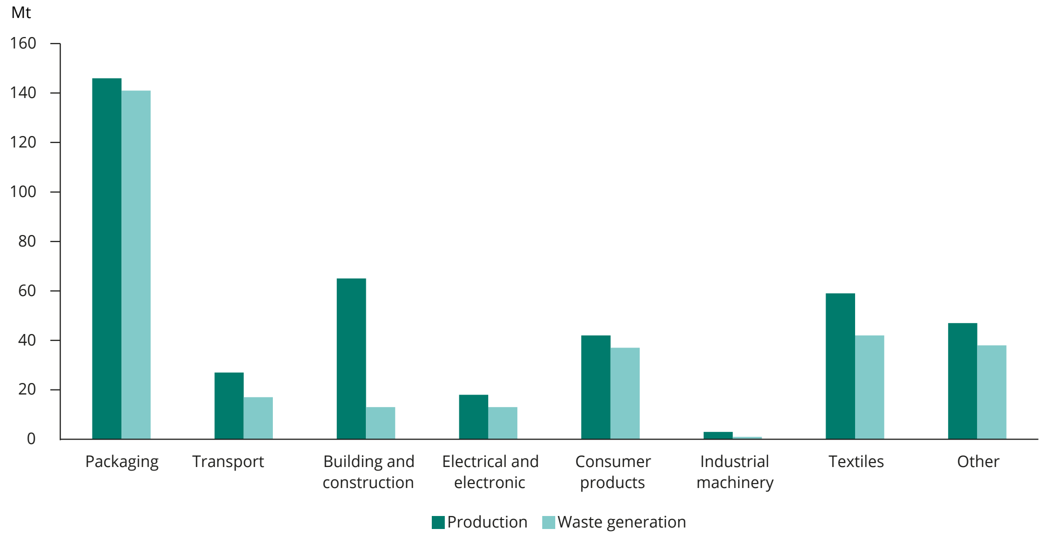
Figure 17. Rates of recycling, energy recovery and landfill for post-consumer plastic waste in 2018 (EU-28, Norway and Switzerland)



Note: The underlying data supporting this graph was not made available to the EEA.
Source: Reproduced from PlasticsEurope (2019).

Whether used for a short or long period, plastic products eventually end up as waste. Plastic packaging is usually discarded within days or weeks, whereas plastic car parts last for years, and water pipes for several decades. Figure 18 shows the global production of plastics for different end-use segments and the plastic waste generated in each of these. End-use segments in which products have short lifetimes, such as packaging and textiles, generate the majority of plastic waste.

Figure 18. Global plastic production and waste generation by end-use market in 2015



Source: Based on data from Geyer et al. (2017).

At the end of their lifetime, plastics are recycled, incinerated or landfilled (if not leaked into the environment). Of these options, recycling is far more beneficial to the environment and climate than incineration or landfilling, the last option being the least favourable. Overall, waste prevention is the most preferable option (EEA, 2019b).

Impacts of recycling plastic waste

The recycling of plastics reduces raw material extraction and the production of virgin plastics and therefore leads to reduced greenhouse gas emissions. Recycling instead of incinerating plastics could reduce emissions by 1.1–3.0 tonnes of CO_2e, compared with producing the same amount of plastics from virgin fossil fuel feedstock (Ellen MacArthur Foundation, 2016). At the same time, recycling requires waste to be collected, sorted and processed, which in turn requires fuel consumption (OECD and IEA, 2018).

Collection for recycling of plastic waste range from about 20 % in Bulgaria and Finland, to more than 40 % in Spain and Norway. Although many types of plastics can be recycled in principle, they are most often not because of the complexity involved, including issues such as the sorting of many different types of plastics and the combination of various plastics in one plastic material. As a result, a large share of the plastics that are collected for recycling are later discarded in the recycling process.

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From the 21 million tonnes of plastic waste collected annually in the EU between 2016 and 2019, 5.2 million tonnes of recycled plastics were used in new products each year (Circular Plastics Alliance, 2020).

As packaging is the segment with the largest demand for plastics, it is also the largest plastic waste stream, as shown in Figure 18. Recycling rates for plastic packaging have steadily improved over the past decade. At the same time, however, the amount of plastic packaging waste has also increased, which means that the overall quantity of non-recycled material has remained stable (ECA, 2020). Today, only about 40 % of plastic packaging waste is recycled in the EU-28, Norway and Switzerland (PlasticsEurope, 2019).

When recycling end-of-life vehicles and electronic waste, more valuable metals are prioritised over plastics, leading to a low recycling rate for plastics from these products. Furthermore, these products often contain types of plastics or additives that create barriers to recycling, such as composite materials and flame retardants, which are not allowed in other applications. Also, some of the additives in plastics are hazardous and therefore these plastics cannot be recycled as they would recirculate the hazardous substances.

Apart from traditional mechanical recycling, there is currently growing interest in different processes for the chemical recycling of plastics. Chemical recycling can be done in different ways, with different impacts on the plastic material — from purification to feedstock conversion.

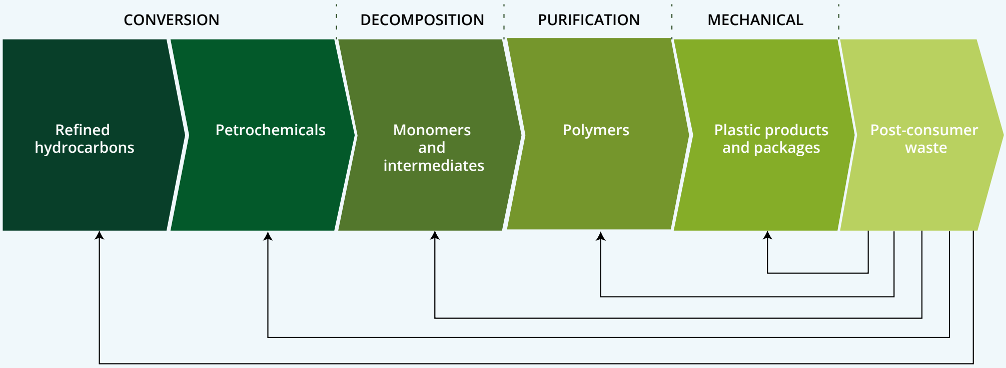
Box 8. Chemical recycling

Plastic recycling is dominated by mechanical recycling, that is, processes in which plastics are sorted by polymer type and colour and then re-melted and undergo regular conversion processes for the production of plastic goods. A new type of recycling process and technology, grouped together under the umbrella term 'chemical recycling' (Figure 19), has gained traction and given rise to discussions in recent years, in terms of business and recycling opportunities, as well as environmental risks and the lack of a sufficient knowledge base.

Chemical recycling offers potential new ways of expanding recycling so that it includes types of plastics and products that are difficult to recycle mechanically. Examples include plastics that are mixed with other materials or types of plastics, or are contaminated by hazardous chemicals. In chemical recycling, plastics can be converted, decomposed or purified by advanced chemical processes into their building blocks (monomers) or oil, which can be purified and used again, as shown in Figure 19 (Crippa et al., 2019; PlasticsleMag, 2019).

There is a significant lack of knowledge about the overall life cycle impacts of chemical recycling on the environment. There are indications, however, that chemical recycling works only under very specific and narrow conditions and that it consumes energy, water and chemical resources that increase the pollution of water, air and land. Volatile chemicals may also be generated during the pyrolysis and purification steps, and, if not carefully captured, they may be emitted to the air as pollution. If chemical recycling is to become a more widely used technology, it will be important to explore the environmental and climate implications and risks as well as the financial costs in more detail to determine whether there is an overall benefit to this type of recycling.

Figure 19. Chemical recycling process



Source: IVL and EEA.

Impacts of incineration of plastic waste

If plastics are incinerated, with or without energy recovery, the carbon locked into the plastics is directly released into the atmosphere in the form of CO_2. The carbon content typically represents 50-80 % of the weight of plastics, depending on the type (OECD and IEA, 2018).

On average, 2.7 tonnes of CO_2 are released for every tonne of incinerated plastics (not taking into account the potential carbon savings of replacing it with another source of energy) (Material Economics, 2019). The total amount of plastic waste incinerated in the EU is uncertain, but estimates suggest that it is 20-30 million tonnes annually (Material Economics, 2019). This means that the total CO_2 emissions from the incineration of plastics in the EU would be somewhere in the region of 50-80 million tonnes per year.

Impacts of landfilling of plastic waste

The third and least favourable waste treatment option from an environmental perspective — landfilling — could, at least in theory, be regarded as a way of storing and postponing the release of carbon present in plastics. The fate of plastics in landfills is not fully understood, and the potential decomposition of plastics over hundreds of years may eventually lead to a leakage of greenhouse gases into the atmosphere. Fires on landfills (legal or illegal) also lead to uncontrolled greenhouse gas emissions. The EU has adopted a zero-landfill target to be achieved by 2030 for recyclable waste such as plastics. The future options for plastic waste in the EU will therefore favour recycling and reuse over landfilling and incineration.

Waste incineration plant Spittelau, Vienna © Pixabay

Box 9. Bio-based, biodegradable and compostable plastics

Recently, the EEA (2020b) has shown that more and more plastic products are labelled as 'compostable', 'biodegradable', 'oxo-degradable' or 'bio-based'. Biodegradable, compostable and bio-based plastics need clearer labelling and repeated awareness-raising campaigns targeting users to ensure their correct disposal and treatment.

Bio-based plastics are fully or partly derived from biomass, such as maize, sugarcane and cellulose. Many of the conventional plastics, such as polyethylene, polypropylene and polyethylene terephthalate, are available on the market as bio-based or partially bio-based. They can be designed to have the same chemical structure and properties as fossil-derived versions, making them technically equivalent to their fossil counterparts. The production of feedstock for bio-based plastics requires land, which is closely linked to direct and indirect environmental impacts on soil, biodiversity, greenhouse gas emissions and water (Spierling et al., 2018).

Plastics marketed as biodegradable or compostable can be made from biomass or fossil resources or from a combination of the two. Compostable plastics can biodegrade under the conditions of an industrial composting plant, but they do not fully compost in home composting bins or the natural environment. Biodegradable plastics can biodegrade in the environment, but only under certain conditions. These conditions depend on, for instance, temperature, the duration of the process, and the presence of microorganisms, nutrients, oxygen and moisture. Given this, many plastics labelled as compostable or biodegradable do not biodegrade if they end up in the open environment or they don't degrade quickly enough to avoid being harmful to marine life or the accumulation of plastic in the environment (EEA, 2020b).

The fact that bio-based and biodegradable plastics are often mistaken for being biodegradable in the natural environment is highly problematic. Today, an increasing number of plastic products are labelled as compostable or biodegradable, and a myriad of different labels and claims of biodegradability or compostability exists. Together with the uncertainty around different plastic types, the many labels risk confusing citizens as to how they should dispose of such products. This confusion may even increase littering if consumers misinterpret these labels as a 'licence to litter'. A clearer labelling system, as well as enhanced awareness-raising and communication with consumers, is therefore important to ensure proper disposal.

The demand for bio-based, biodegradable and compostable plastics is continuously increasing. However, so far, they only make up around 1 % of global plastic production, with packaging the largest field of application (European Bioplastics, 2019). Although biodegradable and compostable plastics can technically be circulated within the economy through recycling, they currently are not.

Source: EEA (2020b).

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The road ahead: towards a circular plastics economy

Innovation, business models, societal awareness and new policies are gradually changing the way we produce, use, recycle and dispose of plastics. Many barriers to achieving circular and more sustainable production and consumption of plastics remain. Given the multiple environmental and climate impacts that exist across the life cycle of plastics, the shift towards a circular economy requires circular business models, changed consumption patterns and policies. These should address all stages in the plastic product life cycle and consider the many different types of and uses of plastics.

Policies and business models

Policies towards a circular plastics economy

Plastic has received growing EU policy attention in recent years. In 2018, the European Commission presented the world's first comprehensive strategy on plastics in a circular economy, which lays out the EU's approach to addressing the challenges of plastics. The strategy aims to curb plastic leakage into the environment and to ensure that plastic products are designed and produced in a way that allows for circularity, including through reuse and recycling. Emphasising the strong business case for European industries to take the lead towards a circular plastics economy, the strategy introduces four overarching aims of the initiative. These include the aim to improve the economics and quality of plastics recycling, curb plastic waste and littering, drive investments and innovation towards circular solutions, and harness global action.

As a main component of the European Green Deal, the new Circular Economy Action Plan (EC, 2020), put forward in March 2020 by the European Commission, presents a range of policy initiatives that will move the EU towards a more circular economy. Building on the efforts of the EU Plastics Strategy, the Action Plan targets plastics as a key product value chain. It contains concrete commitments to develop mandatory requirements for recycled content and waste reduction measures for selected products, to restrict the presence of micro-plastics in the environment, to create a policy framework on bio-based and biodegradable plastics, and to ensure the timely implementation of the Directive on Single Use Plastics (EU, 2019; EC, 2020).

The increased focus on plastics and circularity in EU strategies has also resulted in the adoption of new directives and the amendment of existing ones. In line with increased awareness of the negative environmental impacts associated with single-use plastics, the European Council adopted the Single Use Plastic (SUP) Directive (EU, 2019) in May 2019. With the objectives of preventing single use plastic waste and increasing recycled content in the products, the SUP Directive bans, from 2021 onwards, 10 of the most common plastic objects found polluting European beaches for which alternatives exist. These items include cotton bud sticks, cutlery, plates, straws, stirrers, sticks for balloons, certain food and beverage containers and all products made of oxo-degradable plastics. The SUP Directive also introduces economic incentives to reduce consumption and establish higher collection rates, along with extended producer responsibility (EPR) schemes.

EPR schemes increase producers' responsibility when their product turns into waste. The aim is to incentivise producers to improve collection and waste management of their products and to close the loop through better design and higher recyclability/reusability of their products. Such EPR schemes are also implemented through EU directives on batteries and accumulators (EU, 2006), electrical and electronic waste (EU, 2012), end-of-life vehicles (EU, 2000) and packaging (EU, 2018b). The last three cover product categories with a high plastic content and also represent some of the largest demand segments for plastics. These products are thus collected separately, which allows dedicated recycling systems.

In addition, several waste management directives have been revised to include new targets specifically on plastics. These include the 2015 EU Directive 2015/720 on lightweight plastic carrier bags, which stipulates that Member States should reduce the consumption of lightweight plastic bags by setting a target of 40 bags per person by 2025 and/or introducing measures that prevent carrier bags being provided free of charge by 2018 (EU, 2015). The Waste Framework Directive (EU, 2018a) has likewise been revised with new recycling targets for municipal waste and packaging, and landfill reduction targets. By 2025, 55 % of municipal waste needs to be recycled (60 % by 2030), and by 2025 50 % of plastic packaging must be recycled (55 % by 2030).

In response to the growing awareness around marine plastic pollution, there has also been a range of international actions. These come first and foremost from a growing number of civil society initiatives aimed at limiting the consumption of single-use plastic items and cleaning up waste items. In recent years, business and governments have also begun to discuss how they may take stronger, more coordinated action addressing marine plastic pollution specifically, for example through voluntary action and global agreements.

In relation to this, trade in plastic waste has also risen up the international political agenda. As discussed in the section on trade in plastic waste, the effects of the 2017 Chinese ban on imports of certain types of plastic waste led to significant changes in the international plastic trade. In addition, the revision of the Basel Convention (2019) encourages countries to take greater ownership of and give more consideration to their plastic waste.

In the context of this plethora of initiatives, coordinated action is needed to enable best practice to be shared between countries and regions and to scale up circular and more sustainable plastics initiatives. To this end, the EU has a unique opportunity to play a

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leading role when it comes to promoting sustainable plastic production and consumption in the global arena. The new circular Economy Action Plan sets out an ambition to create a global circular economy alliance that can identify knowledge and governance gaps in transitioning towards a global circular economy.

Circular and sustainable business models

Current business models in the plastics industry are dominated by traditional and very linear business models enabling the extraction, production, consumption and waste management of plastics, with little or no focus on circularity. Resource extraction is dominated by large multinational companies in the oil and gas industry with high levels of international trade and imports and exports to and from Europe. The many production phases related to plastics involve companies of many different sizes operating in Europe and elsewhere, and the same is the case in the waste management phase.

Moving towards more circular and sustainable business models in the plastics production and consumption system — often enabled through social and technological innovation — has huge potential for reducing environmental and climate impacts.

During resource extraction and use of materials for plastic production, innovation and circular business models can enable a gradual move from sourcing entirely virgin raw materials (mainly from oil and gas) to renewable resources and secondary resources from the recycling and recovery of plastics. More circular product design is also important. The choice and organisation of materials, including plastics, are the main determining factors for product and material circularity. Basically, the aim should be to keep the materials in the economy for as long as possible.

Along with the environmental and climate impacts of production, the logistics of the plastics supply chain, including transport, storage and retail, affect circularity significantly.

Circular business models can enable longer use, reuse and repair of materials, while at the end-of-life phase these business models are crucial to enable the sorting, recycling and remanufacturing of plastics.

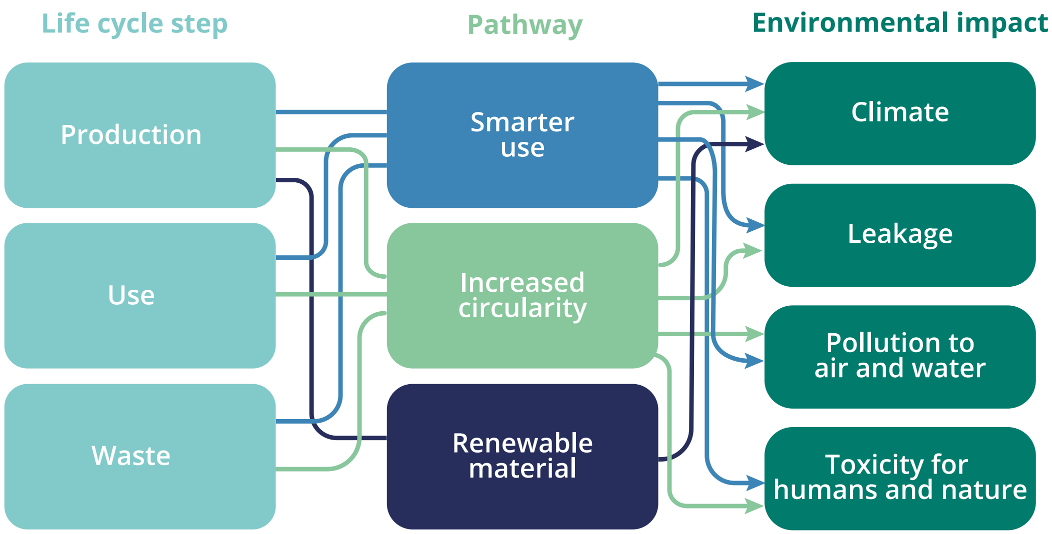
Pathways towards circularity in the longer term

Despite increasing initiatives to change the current plastics system, various stakeholders in business, policy and civil society often promote specific solutions aimed at addressing particular problems, such as littering and low recycling rates. However, given the challenges associated with different plastic applications and different stages of the life cycle, as explained in the previous section, a single initiative will not suffice to facilitate the trajectory towards a circular plastics economy.

Rather than searching for a silver bullet solution, this section presents three pathways that may together ensure the continued longer term move towards a sustainable and circular plastics production and consumption system. These pathways should be seen not as alternative options but rather as pathways that are in line with current policies and that offer options for continued policy development towards circularity and sustainability in the longer term.

The three pathways are smarter use, increased circularity and renewable material (Nielsen et al., 2018). Figure 20 illustrates that each pathway addresses different stages of the plastics value chain, as well as different environmental and climate impacts. For each pathway, the following section explores the problems it seeks to address, the types of solutions it promotes, its limitations, and the possibilities for further action. Policy action, circular business models and a changing role for consumers are important to all three pathways.

Figure 20. Scope of different pathways towards a more sustainable plastic system



Source: Based on (Nielsen et al., 2018).

The smarter use pathway

Through policy, circular business models and consumer action, the smarter use pathway aims to reduce the use of unnecessary plastics by ensuring that the right plastic is used for the right purpose and by substituting plastics with more resource-efficient materials when this is beneficial and possible.

Problems it addresses

This pathway addresses the environmental impact of plastic pollution and the exponential growth rates in plastic production and consumption, which far outpace our ability to manage the waste generated. Rather than merely relying on technological fixes such as better recycling systems, this pathway aims to reduce the projected growth curve of plastic production and consumption by using plastics in a smarter way.

Types of solutions it promotes

A 'smarter use' of plastics entails a reduced use of plastics when this is beneficial, coupled with a more effective use of the plastic that is consumed. Achieving this requires significant changes in current consumption patterns. Not only is it important for consumers to consider the types of materials, products and services they use, but products should also be used for longer, through reuse and repair, as enabled by circular business models.

It is also crucial to consider which types of plastics are used for which types of applications. For instance, reducing the number of different plastic types used for packaging through circular business models can reduce complexity further down the value chain. It also means, in some cases, exchanging plastics with other materials while making sure that these materials do not have higher environmental impacts. A smarter use likewise entails limiting the number of toxic elements in plastics.

In line with this pathway, there is a growing number of initiatives that aim to make users more aware of how much plastic they consume and the negative effects that this can have. These initiatives range from civil society actions aimed at changing consumer habits, such as encouraging reusable takeaway coffee cups (Freiburg cup), to global efforts to clean up the large plastic patches in oceans (Ocean Cleanup) and more local efforts to clean beaches (Ocean Conservancy) or harbours (GreenKayak in Denmark). Several circular business models that promote longer life cycles of plastic products have also come to light in recent years.

A significant number of public and policy initiatives aimed at curbing plastic waste and reducing consumption (of single-use plastics) also exist. These range from the Single Use Plastics (SUP) Directive to bans and taxes on plastic bags. In addition, there are an increasing number of initiatives aimed at dealing with toxic elements in plastics, from bans on specific additives, such as bisphenol A in baby bottles (EU, 2011), to bans on micro-plastics in rinse-off cosmetics in France, Italy and Sweden, for example.

Example of a reusable coffee cup © Pixabay

Box 10. Seven recommendations of the European Academies' Science Advisory Council to transform the plastics system

The European Academies' Science Advisory Council recently published a report on plastics packaging in a circular economy that shows that fundamental changes along the entire value chain are required to slow and reverse environmental and climate impacts. The report includes seven messages for EU policymakers on how to transform the plastics system.

1. Ban exports of plastic waste to third countries

Rather than shipping huge amounts of plastic waste to third countries that often do not have the necessary capacity to deal with it in a sustainable way, Europe should manage its own plastic waste. This is better from both an environmental and an ethical perspective, even if part of the waste has to be recovered for energy.

2. Adopt a target of zero plastic waste to landfill, and minimise consumption and one-way use

In addition to adopting a target of zero plastic waste to landfill and making reduction in consumption an explicit objective, policymakers should extend deposit refund schemes to cover a wider range of containers and single-use beverages.

3. Extend producer responsibility (EPR)

Ambitious EPR schemes should include measures that facilitate product design choices that consider end-of-life use and environmental impacts, such as toxicity, durability, reusability, repairability and recyclability/compostability.

4. End misleading information about bio-based alternatives

At present, scientists see very limited potential for biodegradable plastics, as only a few products meet biodegradation tests in the natural environment. Furthermore, consumers may be misled by the diversity of existing labelling schemes and are often not aware of the environmental impacts associated with bio-based alternatives. A uniform European labelling scheme that relates to the actual rather than theoretical recyclability of bio-based plastics should therefore be created.

5. Advanced recycling and reprocessing technology

To extract more value from plastic waste, advanced recycling and reprocessing technology must be developed. In addition, recycling for use in the same product (closed-loop recycling) must be prioritised over other options, such as recycling for use in the production of different products (open-loop recycling) or energy recovery.

6. Limit additives and types of resin to improve recyclability

To increase the recyclability of plastics, the use of additives must be reduced and the number of polymers that can be used for specific products simplified.

7. Price regulations and quotas for recycled content

The current cost of virgin plastic feedstock is very low and does not include costs to the environment and climate. Policymakers should therefore adopt a regulatory and financial framework, including, for instance, a plastics tax or a requirement for minimum recycled contents, that takes into account adverse impacts across the plastic product life cycle.

Source: EASAC (2020).

Information encouraging more sustainable consumption of plastics is also found in environmental product declarations, on labels about types of plastic used in packaging and in guidelines for green public procurement.

Constraints

Plastics are very useful materials and substituting them with alternative materials is not always straightforward. It can be difficult to determine the negative impact of specific plastic products compared with alternative materials (Spierling et al., 2018) a review on available data from life cycle assessment (LCA). This, in turn, makes it difficult to choose which plastic items to tax, ban or redesign.

Similarly, using fewer types of plastics in certain applications may also lead to unintended negative impacts. For instance, although laminates used in plastic food packaging can complicate recycling, they offer advanced food protection, thereby reducing food waste while also reducing the overall amount of plastic used. The value of food protection is likely to outweigh the cost of poor mechanical recyclability in most cases, but such assessments may be difficult to make.

Possibilities for further action

Initiatives to reduce the use of plastics tend to focus on packaging, such as straws, cups and bottles. However, future initiatives could look at other key plastic sectors, such as the automotive industry (car tyres), textiles (synthetic textiles) and agricultural film, that also pose significant challenges. In addition to widening the scope of action, standards and guidelines on how to achieve a 'smarter use of plastics' could be further developed and used as part of, for example, green public procurement or corporate social responsibility initiatives. An overall goal would be to make plastic a more 'valuable' product, both in economic terms, whereby the price reflects its environmental impacts, and in terms of how consumers use and relate to it.

The increased circularity pathway

The main ambition under the 'increased circularity pathway' is to transition from a linear plastics economy to a circular plastics economy, in which the value and utility of plastics is maintained within closed loops through, for example, circular business models enabling improved end-of-life management and enhanced product design.

Problems it addresses

A key problem with the current take-make-dispose plastics system is that it leads to low resource efficiency and high material and economic value losses, with a continuous input of virgin materials derived from the Earth's finite resources. This pathway therefore addresses the (material) inefficiency of the plastics system, in which only a limited amount of plastics is currently conserved.

Types of solutions it promotes

Proponents of this pathway focus on technical and systemic solutions, along with circular business models that help unlock material and energy savings by enabling plastic waste to re-enter the system after use, thus replacing virgin raw materials in new products. This includes improving the design of products and services, reducing the toxicity and complexity of applications, improving collection and sorting, and promoting a market for recycled and reused plastics.

Box 11. The 'New Plastics Economy': a vision for an economy in which plastics never become waste

Launched by the Ellen MacArthur Foundation in 2016, the New Plastics Economy initiative envisages a circular economy in which plastics never become waste. Instead, unnecessary plastics should be abolished, and innovation should ensure that all necessary plastics can be circulated within the economy through reuse, recycling or composting. For plastic packaging specifically, the initiative defines a circular economy by the following six characteristics:

1. Eliminating problematic or unnecessary plastic packaging through redesign, innovation and new delivery models is a priority.
2. Reuse models are applied when relevant, reducing the need for single-use packaging.
3. All plastic packaging is 100 % reusable, recyclable or compostable.
4. All plastic packaging is reused, recycled or composted in practice.
5. The use of plastic is fully decoupled from the consumption of finite resources.
6. All plastic packaging is free of hazardous chemicals, and the health, safety and rights of all people involved are respected.

Together with a wide set of stakeholders, the initiative takes a systemic approach to creating a shared vision and a common set of actions that can set an irreversible path towards creating the New Plastics Economy.

It does so through several accompanying initiatives, such as the Global Commitment initiative, which was launched in collaboration with the United Nations Environment Programme. The Global Commitment initiative gathers more than 450 businesses, governments and organisations behind a set of targets aimed at tackling plastic waste and pollution at its source by 2025.

To contribute to reaching these targets across all regions, the Plastics Pact network brings together national and regional initiatives that implement solutions towards a circular plastics economy. The network also works as a platform for sharing knowledge and best practices related to the transformation of the plastics system.

Source: Ellen MacArthur Foundation (2019).

Examples of these types of solutions and circular business models can be found in the growing number of initiatives on a circular (plastics) economy that have been embraced by both the European Commission and a wide range of companies and Member States. This includes the increasing number of companies that present voluntary commitments to using recycled plastics in their product lines or new design specifications that increase recyclability. It also includes policy tools, such as deposit refund systems for PET (polyethylene terephthalate) bottles that are common in the Nordic countries, and EPR schemes on plastic packaging in, for instance, France, the Netherlands and the United Kingdom. There is also a growing amount of investment going into improving waste management infrastructures.

Box 12. The Circular Plastics Alliance

In 2018, the European Commission launched the Circular Plastics Alliance as part of the European strategy for plastics. It aims to boost the EU market for recycled plastics to 10 million tonnes by 2025. The Alliance covers the full plastics value chain and includes over 175 organisations representing industry, academia and public authorities (EC, 2019a).

Constraints

The constraints of this pathway include challenges related to (mechanical) recycling and how to integrate the different steps along the value chain. Key obstacles to plastic reuse and recycling include toxic elements in recycling streams, quality loss in the recycling process (downcycling), lack of transparency regarding polymers and additives in plastic products, complexity of collecting and sorting, difficulties in recycling laminate and thermoset plastics, and concerns over low market demand for recycled plastics.

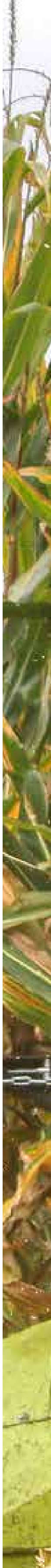
Possibilities for further action

To improve the traceability of all the different elements in plastics, new techniques such as mass-balance measurement could be scaled up. This would improve product information, including how much of a product is made from recycled content, and enable a more gradual shift towards the use of recycled plastics. Moreover, recycling could be improved if current fragmented waste management practices were more harmonised across regions, countries and the EU, and if deposit return systems were expanded to a broader range of products and sectors.

However, circularity should not be reduced to simply improving recycling rates. It also necessitates reuse, redesign of products and rethinking of the entire value chain.

The use of renewable raw material and decarbonisation pathway

The central idea of this pathway is to reduce the amount of plastics that is derived from fossil fuels (today more than 99 %) by switching to renewable raw materials.



Maize harvesting © Pixabay

The problem it addresses

This pathway highlights the plastic sector's dependence on fossil feedstock and the implications of this in terms of energy and resource security, greenhouse gas emissions and a situation of 'petrochemical lock-in'.

Types of solutions it promotes

Solutions promoted under this pathway focus on decoupling plastics from fossil feedstock by switching — when more beneficial — to renewable feedstock, in line with the broader EU actions on climate change and the bioeconomy. In doing so, it focuses more attention on the early stages of the value chain, compared with the other pathways. A key solution is promoting a market for plastics made from alternative raw materials, often called bio-based plastics. These are plastics made fully or partly from biological feedstock, typically oils, starches and sugars from agricultural crops. Feedstocks can also include cellulose, bio-waste and even CO_2.

The benefits of using renewable feedstock include reduced dependency on imports, reduced dependency on fossil resources, reduced greenhouse gas emissions and, if locally sourced, increased rural development.

There are fewer examples of current initiatives for this pathway than for the previous two pathways. However, the new Circular Economy Action Plan will develop a policy framework on bio-based plastics to assess in which cases bio-based feedstock leads to genuine environmental benefits beyond the simple reduction in fossil fuel use. In the EU Plastic Strategy, research and development projects are used as a policy instrument to promote renewable raw material for plastics at the EU level (EC, 2018). In addition, there are also a number of civil society and private sector initiatives that promote plastic products such as packaging and toys made from renewable feedstock.

Constraints

A key concern for this pathway is the discussion around feedstock scarcity and the implications for land use. A significant scaling up of bioplastics would, using current production patterns, take up a significant part of global arable land, leading to competition for food, feed and other bio-based products.

In addition to issues concerning land use, consumers often confuse bio-based plastics with biodegradable and compostable plastics. Bio-based plastics are fully or partly derived from raw materials other than fossil fuels, while the term 'biodegradable plastics' indicates that a plastic application is compostable (under certain conditions). Another central limitation is price. Currently, virgin fossil-based plastics are relatively cheap, and producers have to pay a premium for alternative raw materials. Finally, bio-based plastics such as bio-polypropylene (PP) and bio-polyethylene (PE) are identical to regular fossil-based PP and PE, which means that they do not solve problems further down the value chain, such as leakage and recyclability.

Possibilities for further action

When it comes to land use competition and availability of feedstock, it is necessary to diversify the source of non-fossil feedstocks to include second- and third-generation biomass and carbon capture and use, for example using captured CO_2 to produce new plastics.

Subsidies and upscaling initiatives from the bioeconomy strategy could help provide a more level playing field when it comes to price. Alternatively, a tax/levy on fossil-based plastic could be considered. It is also necessary to develop more knowledge of the environmental impacts and energy demand from a scale-up of bio-based plastics production. Moreover, clearer information, standards and labels are needed to address consumer confusion.

There are pathways but no silver bullets

To reach a sustainable and circular use of plastics, different stages of the value chain as well as different types of environmental and climate impacts must be addressed. A combination of the three pathways described above therefore offers a way forward for the longer term.

- **Smarter use** focuses on production and use to alleviate problems connected to leakage and toxicity, but it focuses less attention on the impacts on climate change and other negative externalities.

- **Increased circularity** aims to integrate the entire value chain to improve the circularity of plastics. This promises to deal with many of the environmental impacts highlighted in this report. However, circular plastic economy initiatives often do not address the expanding levels of consumption or the dependence of plastics on fossil resources.

- **Renewable material** takes up the fossil lock-in of plastics but does not focus on their use and waste management. Switching to renewable materials would not in itself do much for the leakage problem of plastics.

As is often the case with sustainability shifts and transitions, there are no silver bullets for solving the challenges of plastics. We need to consider multiple pathways to address all the challenges of plastics in the longer term. This includes not only improving synergies between them but also acknowledging potential trade-offs (Nielsen et al., 2018). In order to implement a sustainable transition in the plastics economy, there is a need to reduce knowledge gaps on the negative impacts of plastics and facilitate more coordinated efforts along the value chain and across multiple sectors.

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What can you do as a consumer?

We are all consumers of plastics. Although the environmental and climate impacts of plastics are to a very large extent the result of the current production, consumption and waste management system — with linear value chains, dependency on oil and gas, impact of chemicals, insufficient infrastructure, etc. — there are also a number of things citizens can do, either in organised ways or as individuals.

To directly prevent the use of unnecessary or replaceable plastics (often for single use), consumers can think twice before buying or using them. They may, for instance, support stores offering packaging-free goods, or choose packaging made from alternative and perhaps reusable materials, such as wood, cotton and metal. Using less single-use plastics — for example for cutlery, plates and cups — is also an option. However, choosing a product from a different material may not always be the most environmentally friendly solution, as discussed under the smarter use pathway.

As plastics are an omnipresent part of our daily life, it is virtually impossible to avoid them altogether. Sometimes plastic is preferable to other materials because of its lightweight nature and durability. If the use of plastics cannot be avoided, consumers can instead opt for purchasing reusable plastic products and thus contribute to increased circularity by keeping materials out of the waste stream. Whereas reusability depends on several factors, such as a product's design and compliance with hygiene requirements, the willingness of consumers to favour reusable over single-use products is essential. Another option is to purchase products made from recycled plastics if a more sustainable alternative material does not exist.

In the after-use phase when plastics have become waste, consumers play a central role in determining the fate of plastics and ensuring that they are not leaked into the environment. High-quality waste management systems are crucial for enabling the proper separation of waste. But consumers also need to make an effort to contribute to collection and recycling systems by ensuring that recyclable plastics are not thrown into the residual waste bin, or by using available take-back systems for different products, such as empty cans and bottles, electronic equipment and vehicles. In addition, avoiding littering of plastics in the environment is an obvious option for all consumers and citizens.

As discussed in the previous chapter, large amounts of plastics have already escaped proper waste management and ended up as litter. There is a growing number of initiatives that aim to involve users in capturing what has already been leaked. These initiatives range from global efforts to clean up the large plastic patches in the oceans (e.g. Ocean Cleanup) to more local efforts to clean beaches (e.g. Ocean Conservancy) or harbours (e.g. GreenKayak in Denmark). Citizens and consumers can choose to join such initiatives.

Although consumers can do a lot, it is the current systems of plastic production and consumption that are the major reason for unsustainable use of plastics. Businesses, policymakers and other stakeholders in the plastics system have a responsibility to make it more sustainable and circular.

Box 13. GreenKayak

GreenKayak works to reduce the amount of rubbish floating in our coastal waters. The idea is simple: volunteers get free GreenKayak trips in return for collecting waste. GreenKayak also shares knowledge and helps people of all ages to get out on the water and take action. GreenKayak operates in Copenhagen and other regions of Denmark and in some other European countries (GreenKayak, 2020).

GreenKayak in action in Copenhagen © GreenKayak

List of abbreviations and acronyms

BPA	Bisphenol A
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COVID-19	Coronavirus disease 2019
EEA	European Environment Agency
EPR	Extended producer responsibility
EU	European Union
EU-28	The 28 EU Member States as of 1 July 2013 to 31 January 2020
NO_x	Nitrogen oxides
PE	Polyethylene
PM	Particulate matter
PP	Polypropylene
PVC	Polyvinyl chloride
SO_2	Sulphur dioxide
SO_x	Sulphur oxides
SUP	Single-Use Plastics
VOC	Volatile organic compound

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European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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