



Report

Phasing out plastics

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Acronyms and abbreviations

2DS	two degrees scenario
BAU	business as usual
CIEL	Center for International Environmental Law
CO₂e	carbon dioxide equivalent
EEE	electrical and electronic equipment
ETC	Energy Transitions Commission
ETP	energy technology perspectives
GEA	global energy assessment
GHG	greenhouse gas
GT	gigatonnes
HDPE	high-density polyethylene
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LED	low energy demand
LLDPE	linear low-density polyethylene
LDPE	low-density polyethylene
MaaS	mobility as a service
Mt	million tonnes
OECD	Organisation for Economic Co-operation and Development
PE	polyethylene
PET	polyethylene terephthalate
PHA	polyhydroxyalkanoate
PLA	polylactic acid
PP	polypropylene
PP&A	polyester, polyamide and acrylic
PS	polystyrene
PUR	polyurethane
PVC	polyvinyl chloride
RTS	reference technology scenario
SSP2	shared socioeconomic pathway 2

Executive summary

Plastics today feature in every part of our lives and are found everywhere. The global realisation that plastics are an environmental problem has focused on plastic waste and pollution, but plastics are also problematic in terms of the global climate emergency, because almost all plastics today are made from fossil fuels. By 2050, on current trends, greenhouse gas (GHG) emissions from plastics will increase threefold and could account for as much as 20% of total oil consumption (World Economic Forum et al., 2016). To achieve net zero emissions globally by 2050, it is critical that the plastics sector reduce its GHG emissions to zero by that date.

Building on recent literature about plastics and climate change, this report explores the potential for extensive emission reductions in the plastics sector. Using a scenario approach, we present an assessment of the technical feasibility of phasing out the production of new fossil plastics by 2050, based on detailed analysis of the potential to transform the use of plastics in four sectors – automotive, construction, packaging and electrical and electronic equipment (EEE). The report also discusses the implications of much lower plastics consumption for the upstream oil and gas sector.

Our analysis shows that a large reduction in the use of plastics will be necessary to phase out fossil plastics and their associated GHG emissions. This is technically feasible, but achieving it will require different approaches in different sectors of the economy, as well as a large expansion of plastics recycling. In 2050, the use of oil and gas for plastics production could be 50% of what it is today and GHG emissions from plastic almost one-third today's level with the right approach.

Plastics today

Six types of plastic account for three-quarters of plastics production, which totalled 407 million tonnes (Mt) in 2015 (Geyer et al., 2017). This study focuses on these six plastics, namely: polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET) and polyurethane (PUR). The largest use of plastic is for packaging, which accounted for 36% of total output in 2015. Construction is the second-largest use of plastic products (16% of total plastics output), followed by textiles (14%). The automotive sector accounted for 7% of plastics consumption in 2015, while EEE consumed 4% (Geyer et al., 2017).

There are large regional differences in the consumption of plastics. North America, Europe and East Asia together consume almost two-thirds of the world's plastics. Globally, per capita consumption of plastics is 47 kilograms (kg) per year, but in Africa and South Asia, it is less than 10 kg per year. Plastics production is concentrated in North America, Europe and East Asia, and there is often a high degree of integration between the manufacture of plastic resins and oil and gas production.

Plastics in 2050

Our assessment compares a business-as-usual (BAU) scenario with a low-plastic-consumption scenario for 2050. The former is based on a projection of plastics consumption, met by current patterns of production, modified to reflect current trends, while the latter reflects actions that reduce the consumption of plastics and increase recycling, consistent with keeping the rise in average global temperature below 1.5°C.

The BAU scenario in this study assumes an annual growth rate for plastics production and

consumption of 3%, resulting in 1,145 Mt of plastics produced in 2050. In the low-plastic-consumption scenario, plastics consumption would total 400 Mt in 2050. The largest proportional changes in consumption would be in the packaging and construction sectors (with 78% and >95% reductions, respectively).

About 54% of the plastics produced in our 2050 low-plastic-consumption scenario would be made from recycled plastic. The production of new plastics would, therefore, be about half today's level. Plastic waste in 2050 would total 301 Mt and 75% of this would be collected for recycling (compared with 20% today).

Routes to reducing fossil plastics

To achieve the transformation implied by the low-plastic-consumption scenario, it will be necessary to reduce the consumption of plastics, change production processes and overhaul the way that plastic waste is managed and recycled.

Reducing consumption

There are two main strategies to reduce plastics consumption: 'dematerialisation and reuse', which reduces the consumption of goods made from plastics, and 'substitution', or the replacement of plastics with other materials.

The low cost of plastic materials has not incentivised the efficient use of plastics. However, product design could reduce the quantity of materials used, or extend the lifespans of products and parts (for example, with more durable plastics or products that can be disassembled), in addition to enhancing the reuse of plastic products. Products such as cars can be designed to provide tailored services rather than a range of services, increasing product utilisation and materials efficiency. Consumers can also extend the life of plastic products by reusing them for the same purpose rather than discarding them after using them once or twice.

Dematerialisation and reuse can also be achieved through changes in business models and consumer behaviour (for example, businesses providing services rather than goods and consumers reusing packaging and increasing recycling rates).

Many plastic products can be made from other materials, such as metal, wood, natural fibres and ceramics. For example, glass bottles for beverages or glass jars for other foodstuffs can be used and reused after collection and cleaning. The substitution of plastics would need to consider the environmental and economic effects of producing and using alternative materials.

The potential for dematerialisation, reuse and substitution to reduce the consumption of plastics varies from sector to sector and across plastic types. In the four sectors examined in detail for this study, consumption in the low-plastic-consumption scenario is reduced (compared with BAU) by more than 95% in the construction sector, 78% in the packaging sector, 17% in the automotive industry and 57% in the EEE sector. Figure 1 shows the overall and sectoral reductions through dematerialisation, reuse and substitution in our low-plastic-consumption scenario.

Recycling

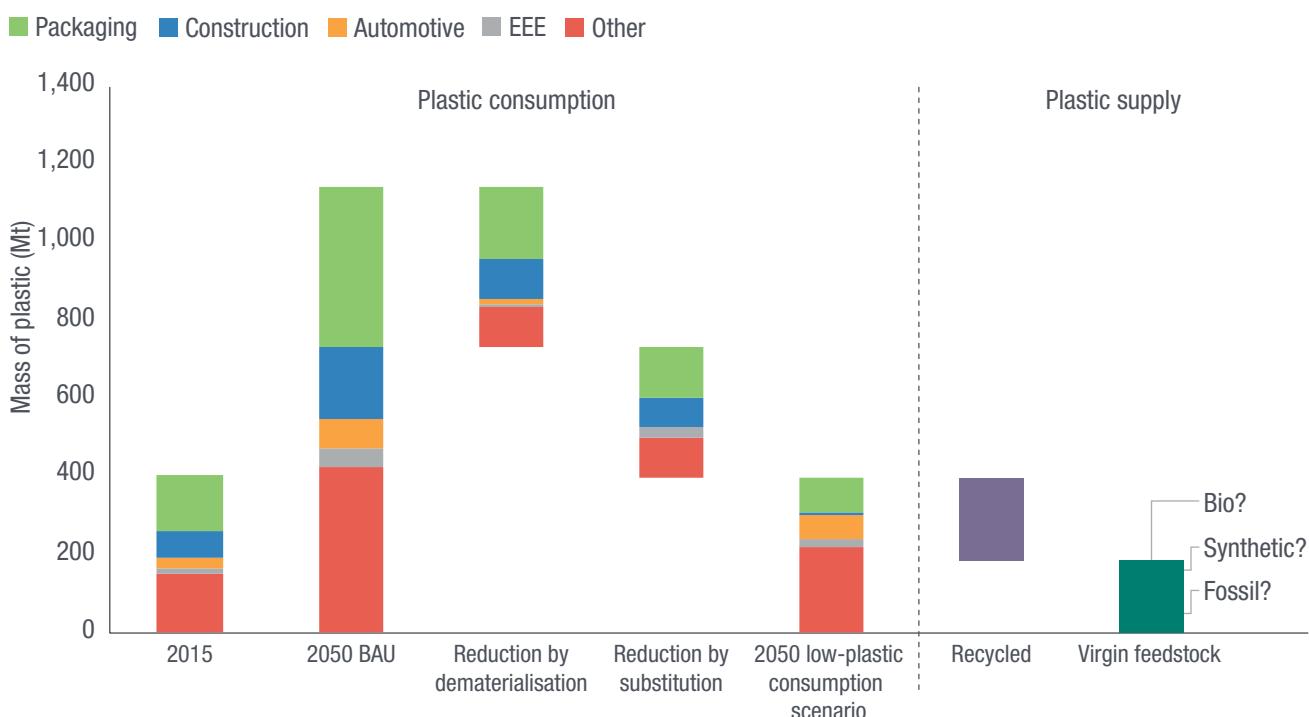
About 20% of plastic waste is recycled today (Conversio, 2019). For mechanical recycling, which is the predominant technology, plastic waste is collected, sorted and cleaned before being cut into chips and then melted. However, mechanically recycled plastics may retain impurities, limiting the scope for recycled plastic to replace new plastic (IEA, 2018). Chemical recycling transforms plastic waste back into monomers, which are then polymerised to produce plastic resin, but the technology is still being developed.

In our low-plastic-consumption scenario, recycling provides 54% of plastics output in 2050 (Figure 1). This does not do away with the need for other forms of plastic waste management, nor the need for some new plastic to meet the projected level of plastics consumption in 2050.

Alternative feedstocks

About 200 Mt of new plastics would be produced in 2050 under the low-plastic-consumption scenario, roughly half the quantity produced today. The raw material for new plastics could be fossil fuel (oil and gas), biomass or synthetic feedstock. Plastics made from

Figure 1 Reductions in the demand for virgin plastic materials from changes in consumption and production in 2050



Sources: Authors; Geyer et al. (2017)

biomass feedstock tend to emit fewer GHGs during resin production than fossil plastics. However, plastics made from biomass feedstock currently account for less than 1% of all plastics production and their potential to replace fossil plastics would depend on greatly expanding production capacity and reducing the cost per tonne, which was double the cost of fossil plastics in 2015 (ETC, 2019).

Synthetic feedstock, which is produced by combining hydrogen (H_2) and carbon dioxide (CO_2), is technologically possible, but currently far from being commercially feasible (ETC, 2019).

Climate impacts of phasing out fossil plastics

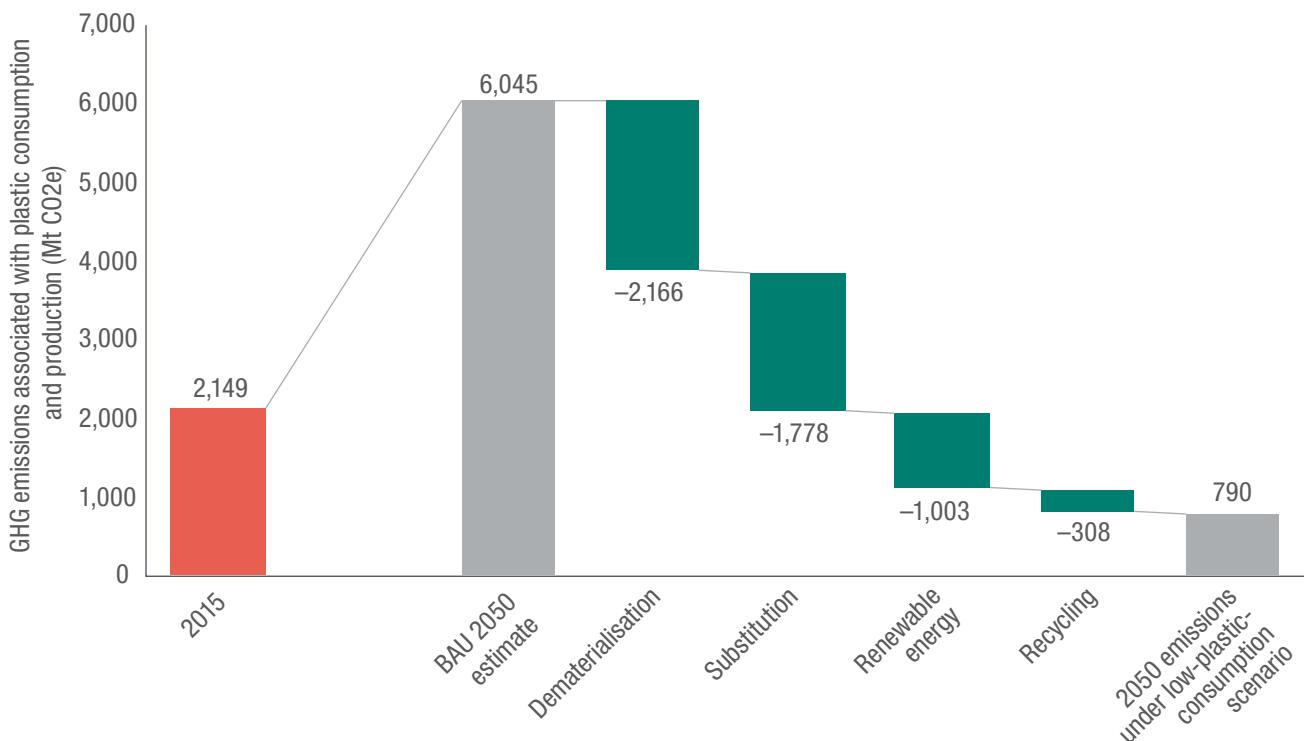
Our 2050 low-plastic-consumption scenario would reduce GHG emissions from plastics, both relative to BAU and in absolute terms compared with current levels. Emission reductions would be achieved through lower consumption of oil and gas for feedstock, changes in the production process and an overhaul of plastic waste management.

Greenhouse gas emissions

Under the BAU scenario, GHG emissions from plastics production and use would grow more than threefold, to about 6 gigatonnes (Gt) of carbon dioxide equivalent (CO_2e) by 2050. In our low-plastic-consumption scenario, there would be an absolute reduction in GHG emissions from plastics, as shown in Figure 2, from an estimated 2,149 Mt CO_2e in 2015 to 790 Mt CO_2e in 2050 (without taking into account any indirect changes in emissions associated with substitution).

Compared with the BAU scenario, dematerialisation and reuse would reduce consumption by 2,166 Mt CO_2e , accounting for 41% of the total reduction. Substitution would cut consumption by another 1,778 Mt CO_2e (34% of the total reduction) and the decarbonisation of energy would trim it by 1,003 Mt CO_2e (19% of the total). The higher rate of recycling in our low-plastic-consumption scenario would reduce emissions further, by 308 Mt CO_2e , thus making a relatively small contribution to total emissions cuts (6% of the total) compared with other actions.

Figure 2 Reductions in greenhouse gas emissions from plastics consumption and production



Sources: Authors; Geyer et al. (2017)

Demand for oil and gas

Plastics production currently accounts for about 9% of global oil consumption and 3% of natural gas. By one estimate, plastics could account for 20% of global oil consumption in 2050 (World Economic Forum et al., 2016). However, our low-plastic-consumption scenario would put demand for plastic feedstocks in 2050 at about half the level it is for oil and gas for plastics today.

Our low-plastic-consumption scenario, therefore, implies a reduction in the required capacity of petrochemical plants by 2050. Although the total capacity of petrochemical facilities globally is expanding in anticipation of growth in plastics consumption, our scenario suggests only half of current capacity could be needed in 2050. The expectation that plastics production will provide an expanding market for oil and gas, stimulated in part by low gas prices, would thus be confounded by a pathway towards low plastic consumption consistent with limiting global heating to 1.5°C.

Management of plastic waste

The quantity of plastic waste generated in our 2050 low-plastic-consumption scenario would

be about the same as that generated in 2015, but with one key difference: a significantly higher level of recycling – 75% waste collected for recycling in 2050 compared with about 20% in 2018. The 25% of plastic waste not collected for recycling in 2050 would be either incinerated or sent to landfill. The scenario thus implies a fourfold increase in global capacity for collecting, sorting, cleaning and recycling plastic waste, presenting a potential opportunity for businesses.

Conclusions

Under our BAU scenario, current consumption trends could triple emissions from plastics by 2050 and prevent us from achieving the goal of keeping global heating below 1.5°C. However, the low-plastic-consumption scenario at the heart of this study assumes action can be taken to substantially reduce the consumption of plastics, through measures to reduce the overall quantity of materials consumed and to substitute other materials for plastics.

It would be technically feasible to achieve a level of plastics consumption in 2050 that is 65% lower than the BAU projection. The

total quantity of plastics consumed globally in 2050 could be about the same level as it is today, despite increases in population and prosperity. The quantity of virgin (new) plastics produced could be about half today's level, with recycled plastic accounting for half of all plastics produced.

Combined with shifts to renewable electricity and enhanced recycling, this could reduce emissions from plastics to about 0.8 Gt CO₂e in 2050 – an absolute reduction from current levels.

Reduced consumption of plastics could be achieved through changes in product design (incorporating principles of sustainability and circular economy into the design process), business models and consumer behaviour (including increased reuse of products). It would require changes in government regulation, price incentives and social attitudes to help reduce the consumption of plastic products.

Plastic recycling would need to be scaled up and transformed to achieve the rate of recycling that is technically feasible in 2050. A high rate of recycling may also call for more integration of the businesses of waste management and recycling with those of monomer and polymer manufacture. However, by 2050, enhanced recycling could provide about half of the material needed to produce plastic resins.¹ This would roughly halve the amount of oil and gas used to make plastics from today's level.

Change will be necessary in almost every market sector to achieve a reduction in GHG emissions from plastics consistent with a 1.5°C global heating goal. Policies to transform the plastics sector will need a system-wide perspective to simultaneously drive reductions in plastics consumption and in the use of oil and gas to produce virgin fossil plastics.

Key messages

- Plastics are hampering international action to combat the climate crisis because they are almost all made from fossil fuels and contribute significantly to greenhouse gas emissions. Contrary to the aims of the Paris Agreement, greenhouse gas emissions from plastics are due to increase threefold by 2050. Achieving net zero emissions means reducing plastics emissions to zero.
- Although plastics permeate our lives and every corner of our planet, it is technically possible to largely phase them out. ODI's analysis reveals we could halve plastic consumption in 2050 compared to business as usual, recycle 75% of the plastic that remains and increase the amount of plastic produced without fossil fuels. This would reduce greenhouse gas emissions from plastics from 1,984 Mt CO₂e in 2015 to 790 Mt CO₂e in 2050.
- The world needs a system-wide reboot that simultaneously drives reductions in consumption while reducing the use of oil and gas to produce new plastics. Improved product design and changes to consumption patterns would reduce the quantity of materials used, extend the lifetimes of products and enhance their reuse. Meanwhile, other materials could be substituted for plastics – including metal, wood, natural fibres and ceramics – and recycled plastics used elsewhere.
- These actions would boost global efforts to build a stronger, greener recovery from Covid-19 by reducing plastic consumption by more than 95% in the construction sector, 78% in the packaging sector, 57% in the electrical and electronic equipment sector and 17% in the automotive sector.
- Reducing plastics' emissions to zero and phasing out new plastics made from fossil fuels would halve plastics' current demand for oil and gas and lower existing petrochemical production capacity.

¹ Under the low-plastic-consumption scenario, the quantity of plastic waste recycled in 2050 would be 241 Mt. After losses during processing, the quantity of resin produced from recycled plastic would be about 232 Mt.

1 Introduction

Plastics are ubiquitous in the true meaning of the word. Plastics feature in every part of our lives – our food system, clothing, buildings, transport, communications, healthcare, leisure and entertainment. Plastic particles have been found in the remotest corners of the world, in the deepest parts of the ocean, on mountain peaks and in the rain. But the world has begun to realise that plastics are problematic. Currently, the dominant narrative on the negative aspects of plastics focuses on waste and pollution from microplastics. The fate of about 60% of the 250 Mt of plastic waste generated globally in 2018 was unknown, improperly disposed of or leaked into the environment (Conversio, 2019). Concerns about the toxicity and impacts on human health of plastic microfibres found in the air, water and soil are now added to broader environmental pollution concerns.

Plastics are also problematic in terms of the global climate emergency. They were the source of about 4% of global GHG emissions in 2015 (Zheng and Suh, 2019) – more than the whole continent of Africa. By 2050, on current trends, the quantity of emissions from plastics will triple. But global GHG emissions need to reach net zero by 2050 if the world is to have a chance of averting catastrophic climate change (IPCC, 2018). Almost all plastics today are made from fossil-fuel raw materials (oil, gas and coal) and use fossil-fuel energy in their manufacture. They account for about 9% of total demand for oil and gas and, by 2050, could account for 20% of oil demand (World Economic Forum et al., 2016). To achieve net zero emissions globally by 2050, it is critical that the plastics sector reduce its GHG emissions to zero by this date.

This report explores the potential for extensive emission reductions in the plastics sector, which is currently forecast to continue growing. It presents an assessment of the technical possibility of phasing out or reducing the use of fossil plastics in 2050 and outlines what might be required to achieve this. Our research builds on recent literature, such as the Energy Transitions Commission study (ETC, 2019), which suggests that the demand for plastics could be 30% lower in 2050 as a result of dematerialisation, reuse and materials substitution. Our report is based on detailed analysis of potential shifts in four market sectors – automotive, construction, packaging and EEE – which have different characteristics and opportunities to change how plastics are used. We calculate that by 2050, a 65% reduction in overall plastics production (against BAU) may be technically feasible. This could allow around a 50% reduction in new fossil plastics production from today's levels.

Chapter 2 outlines our analytical approach to estimating the potential to reduce emissions from plastics. Chapter 3 presents the current state of plastics production and consumption. We outline our two mid-century scenarios (BAU and low-plastic-consumption) in chapter 4 to illustrate the extent and nature of change that is possible in the plastics sector. Chapter 5 examines how transformation in the plastics sector could be achieved, and the effect these changes could have on GHG emissions from plastics, while we discuss the demand for fossil-fuel raw materials in chapter 6. Chapter 7 considers the key challenges to achieving our low-plastic-consumption scenario and chapter 8 presents our conclusions.

2 Approach

The purpose of this study is to illustrate the technical and political feasibility of phasing out or substantially reducing the production and consumption of virgin (new) plastics made from fossil fuels in 2050. The aim is to demonstrate the impact this would have on climate change by assessing the effect a phase-out (or scaling back) of plastics production would have on GHG emissions.

The study set out to answer three questions.

- What are the technical opportunities to phase out (or reduce) plastics production and consumption in the short, medium and long term?
- What are the emission-reduction effects of phasing out plastics production and use?
- What are the high-level political-economy considerations for phasing out plastics production and use?

Our overall approach was to compare two alternative scenarios for 2050, one based on a BAU projection of plastics consumption and the other based on assumptions about technically feasible reductions in plastics consumption. Our analysis focused on the six main types of plastic (PE, PP, PS, PVC, PET and PUR), which accounted for about 80% of total plastics production in 2015 (Geyer et al., 2017).

The BAU scenario assumed 3% average annual growth in total plastics consumption between 2015 (the baseline year) and 2050. Our low-plastic-consumption scenario was based on detailed assumptions for plastics consumption in four sectors (packaging, construction, automotive and EEE). These sectors were selected for practical reasons, including the availability of information and

the potential to build on analysis in previous studies (such as World Economic Forum et al., 2016; Material Economics, 2018). Together, these sectors accounted for 63% of all plastics consumption in 2015 (Geyer et al., 2017). For all other sectors, the low-plastic-consumption scenario incorporated conservative general assumptions about the potential to reduce plastics consumption.

The first step in our analysis was to determine a baseline for plastics production and consumption. We chose the 2015 data of Geyer et al. (2017), which have also been used in other studies, including IEA (2018) and Zheng and Suh (2019).

The second step was to forecast plastics consumption in 2050 under BAU assumptions. The study assumes plastic consumption grows by 3% per year under BAU assumptions between 2015 and 2050.

In the third step, we developed a forecast of plastics consumption in 2050 under a low-plastic-consumption scenario. The quantity of plastics consumed in any year is determined by two factors: activity and (plastics) intensity. Activity is a quantity equivalent to the demand for goods wholly or partially made from plastic, such as the number of cars or electronic devices produced. Intensity is the quantity of plastic used to produce the goods to meet that demand (kilograms of plastic per car or electronic device).

Drawing on the low energy demand (LED) scenario developed by Grubler et al. (2018) (see Box 1), this analysis considered ways to reduce activity and intensity in each sector. The potential to reduce the consumption of fossil plastics through recycling or alternative feedstocks was considered in aggregate across all sectors, as the action required was beyond an individual market sector.

Box 1 The low energy demand scenario

The low energy demand (LED) scenario sets out feasible energy end-use and efficiency transitions to 2050 that are consistent with the 1.5°C global heating goal of the Paris Agreement. It considers four broad categories of energy end-use and five upstream sectors (sectors involved in supplying end-use services). These end-use sectors – thermal comfort (spatial heating and cooling), consumer goods, mobility and food – broadly relate to the plastics consumed by the sectors selected for this study (packaging, construction, automotive and EEE). The LED scenario's analysis of commercial buildings also ties in with the construction sector, and the upstream industry sector includes petrochemical (including plastics) manufacture.

The LED scenario considers how changes in consumer demand (driven by quality of life, urbanisation, innovations in energy services, end-user behaviour and information innovation) affect the quantity, type and quality of goods manufactured in 2050 as well as changes in manufacturing processes and organisation. These changes provide the basis for a 'dematerialisation factor', reflecting demand reduction, and a 'materials efficiency factor', reflecting reuse, longer product lifespans and changes in product design. For the petrochemicals industry (including plastics), the LED scenario estimates a 25% reduction in demand in 2050 due to dematerialisation and no change in materials efficiency.

Source: Grubler et al. (2018)

To estimate the feasibility of reducing plastics consumption in each sector, we developed a narrative vision for each sector in 2050, drawing from literature on trends and technological developments in each sector and more broadly.² The development of these visions considered what could be done immediately to reduce the use of plastics in the sector by using available technologies; what could be done in the medium-term (2035) by using technologies that are expected to become available over the next decade; and what could be done in the longer term (2050) through technological development, changes in market structure or behavioural change. The sectoral visions for 2050 enabled us to identify the potential to reduce sectoral consumption of virgin plastics in four steps, considering the scope for:

1. **dematerialisation and reuse** (avoiding the consumption of goods made from virgin plastic)
2. the **substitution** of plastics with non-plastic materials in goods that remain in demand

3. **enhanced recycling** of plastic waste to replace virgin plastics for residual demand
4. the use of **alternative feedstocks** to produce virgin plastics.

This analysis determined the 2050 low-plastic-consumption scenario for each sector, including the quantities of different plastics produced, the level of recycling and other end-of-life treatment of plastic waste, and the level of plastics production required to satisfy residual demand. We aggregated our analyses of the four sectors with a generalised analysis of the other sectors to provide an overall estimate of plastics consumption.

A high-level political-economy analysis complemented our assessment of the technical feasibility of phasing out or reducing plastics consumption in each of the four sectors. This considered key stakeholder groups and ways of changing plastics consumption in the sector, and identified political-economy factors with the potential to block change, as well as possible coalitions that could drive change.

2 The four accompanying sectoral reports provide more detail about these narrative visions.

The final step in our analysis was to estimate GHG emissions from plastics in 2050 and the difference in emissions between the BAU and low-plastic-consumption scenarios. This built on the work of Zheng and Suh (2019), who offered the most recent analysis of emissions from plastics production and use based on global data,³ including emissions at end of life. Our analysis also estimates upstream emissions from the production of oil and gas, which are not included in Zheng and Suh (2019), and provides an estimate of lifecycle emissions per tonne of plastic. This allows us to estimate the effects of dematerialisation and reuse, substitution and

enhanced recycling on GHG emissions in each sector and in total.

It was beyond the scope of our analysis to include an assessment of GHG emissions from non-plastic materials that may be used to substitute plastics. The wide variety of products and parts currently made from plastics would require individual assessment for potential substitute materials and the emissions from the production of each material. It would also require an understanding of the technological trends in the production of substitute materials, in order to reflect changes that would affect their emissions in 2050.

³ Other studies have relied on data from one region (such as Europe or North America) and do not reflect regional differences in production technology.

3 Plastics today

The global market for plastics was valued at \$523 billion in 2017 and was forecast to grow to \$721 billion by 2025 (Grand View Research, 2019). Taking the whole value chain into account (for an example from the automotive sector, see Figure 3), from raw-material production to waste management, revenue in the sector was estimated to be equivalent to 3% of the global economy in 2015 (Ryberg et al., 2018).

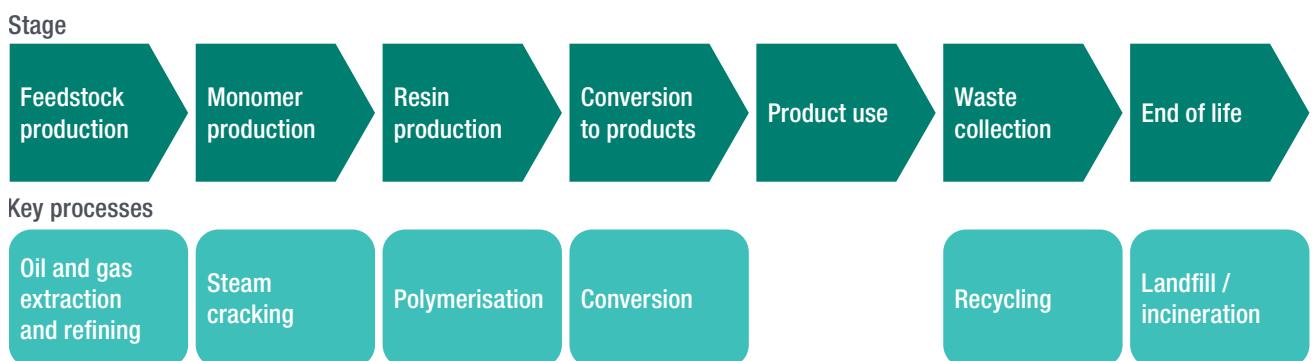
The industry globally produced 407 Mt of plastics in 2015, our baseline year (Geyer et al., 2017).⁴ Although there are many types of plastic, six types account for three-quarters of total output: PE, PP, PVC, PS, PET and PUR. Their share of total output is shown in Figure 4. These six plastics are the focus of this study and the accompanying technical reports on the four sectors.

3.1 Plastic categories and manufacturing processes

Plastics fall into two broad categories, thermoplastics and thermosets. The former can be recycled easily because they melt when heated. Thermosets, in contrast, are permanently hardened during processing and are difficult to recycle mechanically. They tend to be used for products with a specific purpose, while thermoplastics have general uses, such as bottles, storage containers and furniture.

Figure 3 shows the steps in the plastics manufacturing process for the automotive sector. The principal raw materials, naphtha and ethane, which are derived from crude oil and natural gas, are converted into monomers in a process known as steam cracking. Two categories of monomer are produced at this stage, olefins (ethylene, propylene and butadiene) and aromatics (mainly benzene, toluene and xylene). Polymerisation in the next stage converts them into plastics resins (polymers), ready for conversion or for use in making thermoset plastics. In the final manufacturing

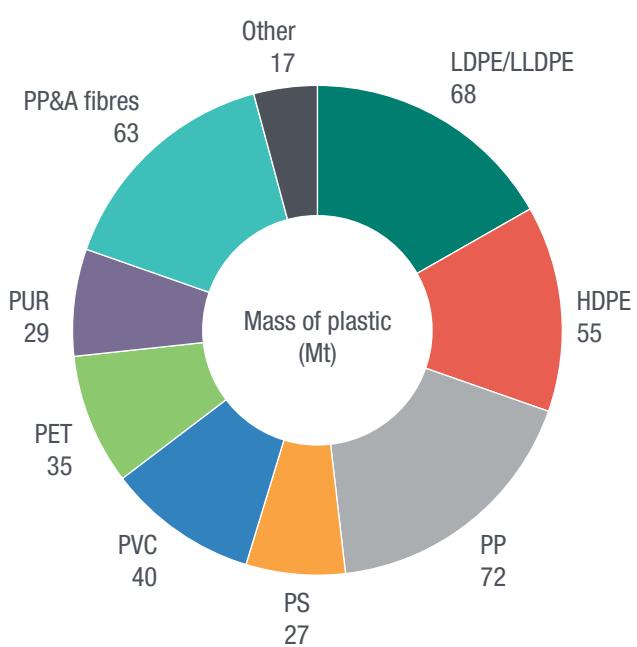
Figure 3 Plastics value chain for the European automotive sector



Sources: Adapted from value-chain diagrams in Ryberg et al. (2018) and ETC (2019)

4 The total and disaggregated quantities for plastics production in this report include additives.

Figure 4 Production of plastics by type, 2015



Note: LDPE, low-density polyethylene; LLDPE, linear low-density polyethylene; HDPE, high-density polyethylene; PP&A, polyester, polyamide and acrylic. The quantity of additives is distributed proportionally.

Source: Geyer et al. (2017)

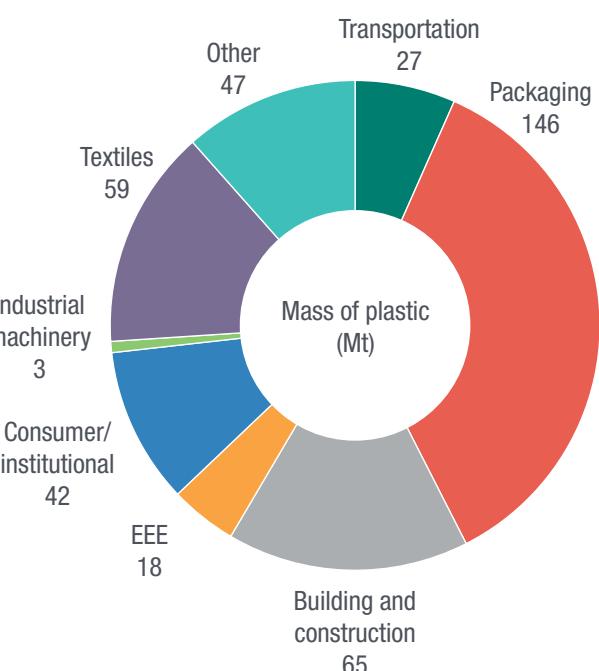
stage (conversion in Figure 3), resins are moulded or extruded into plastic products (Levi and Cullen, 2018; Material Economics, 2019; Zheng and Suh, 2019).

The lifespan of a plastic product depends on its purpose. Single-use plastic products reach the end-of-life stage of the value chain in their year of manufacture, while some plastics used in the construction sector have lifespans of decades. In 2015, the total quantity of plastic waste generated globally was estimated at 302 Mt, equivalent to 74% of production that year (Geyer et al., 2017; Figure 4). At the end of their useful life, plastics are recycled, incinerated, sent to managed landfill or disposed of in an unmanaged way.

3.2 Plastic consumption by sector and region

The largest use of plastic products is for packaging, which accounted for 36% of global plastic output in 2015 (Geyer et al., 2017). Because plastic packaging is predominantly single-use plastic, packaging was responsible

Figure 5 Plastic consumption by sector, 2015



Source: Geyer et al. (2017)

for about half of all plastic waste the same year. The construction sector is the second-largest consumer of plastics (16%), followed by textiles (14%). Figure 5 shows the breakdown of consumption by sector in 2015. Detailed descriptions of the packaging, construction, automotive and EEE sectors can be found in the four accompanying technical reports prepared for this study.

There are large regional differences in the consumption of plastics (Figure 6). Whereas per capita consumption of plastics in Africa and South Asia is less than 10 kg per year, in some rich countries, it is over eight times more. In 2017, the global average was 47 kg per person. While demand is growing rapidly in aggregate and per capita terms in lower-income countries, in some high-income countries, per capita consumption may be falling, suggesting a saturation level of around 60 kg per person per year (IEA, 2018).

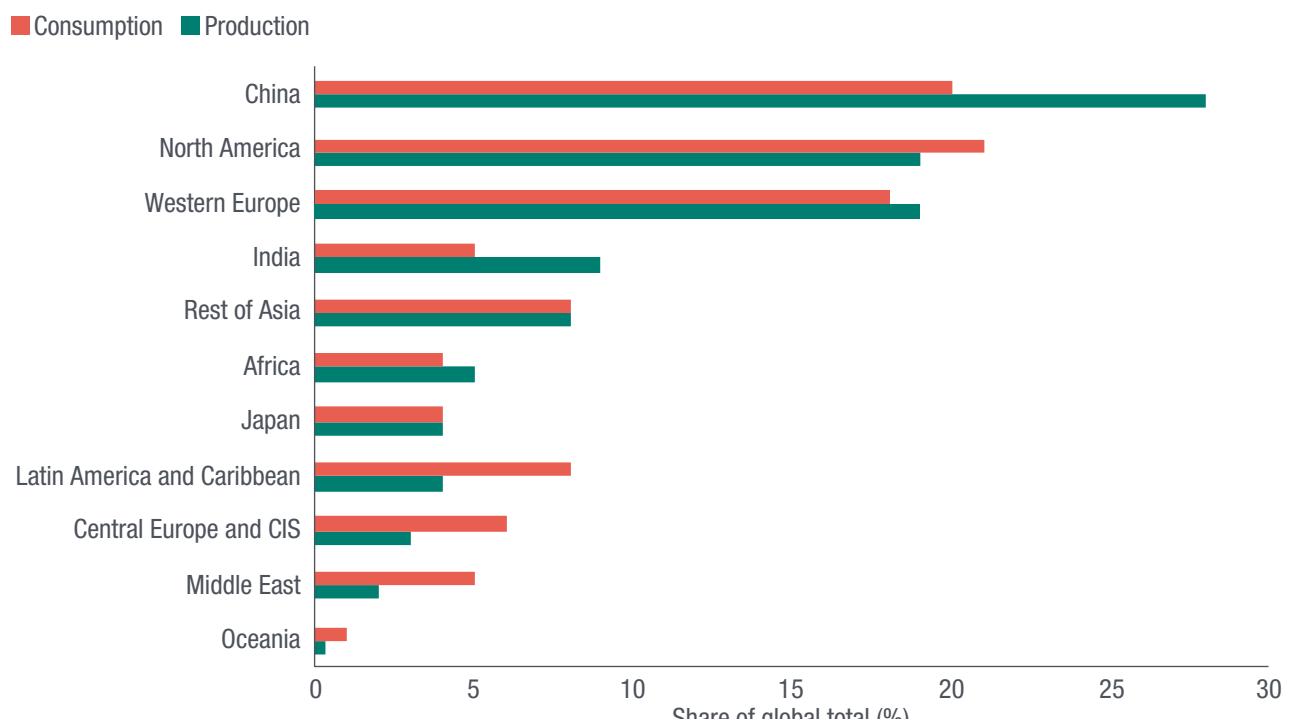
In aggregate terms, three regions – East Asia (China and Japan), North America and Western Europe – account for almost two-thirds of plastic consumption. They also produce 70% of the world's plastics (Figure 6). These regional aggregates, however, do not reveal the extent of

international trade within the global value chain. In 2017, for instance, global trade in ethylene was valued at \$7.5 billion, with exports from 67 countries and imports to 97 countries. Trade in PE was valued at \$27.3 billion, with imports to 179 countries (Observatory of Economic Complexity, 2019). Even so, ethylene production capacity is concentrated in a small number of countries – the United States alone has about 20% of global ethylene capacity, followed by China and Saudi Arabia, with over 9% each.

The structure of the plastics sector varies along the value chain. In the petrochemical stages, including feedstock (naphtha and

ethane), monomer (ethylene and propylene) and polymer production, there is often a high degree of vertical integration. Feedstock production may be integrated with oil and gas extraction and refining, within the same facility as well as within the same company. The conversion of resins to plastic products, through moulding or extrusion, for example, is undertaken by a wider variety of companies than those involved in feedstock production. Many producers of plastic products or components are suppliers to original equipment manufacturers, but the latter may also convert polymers for their own use.

Figure 6 Share of global plastic production and consumption by region



Note: CIS, Commonwealth of Independent States.

Source: Ryberg et al. (2018)

4 Plastics in 2050

The production and consumption of plastics will need to change substantially if we are to phase out fossil plastics by the middle of the century. To understand the extent of this change, including the differences in GHG emissions, we compare a BAU scenario with a low-plastic-consumption scenario for 2050. The BAU scenario is based on a projection of plastics demand that is met by current patterns of production, modified to reflect current trends. The low-plastic-consumption scenario demonstrates the technical feasibility of phasing out new fossil plastic, through actions that both reduce the consumption of plastics and increase recycling, and is consistent with a goal of curtailing the rise in global temperatures to 1.5°C. This chapter describes the two scenarios and the assumptions behind them. Summaries of the findings for each of the sector studies are available in Annex 2.

4.1 BAU scenario

Since the beginning of the century, the production of plastics has grown globally at an annual rate of about 4%. Short-term market forecasts suggest this rate of growth may continue for a few years (see, for example, Grand View Research, 2019). Projecting this rate of growth results in an estimated annual consumption of 1,600 Mt of plastic by 2050. However, there are grounds to believe the BAU trajectory for plastics consumption will be more modest than this. Concerns about plastic waste alone are likely to change consumer and business preferences, reducing demand for single-use plastic products.

According to the International Energy Agency's (IEA) reference technology scenario (RTS), global production of plastics will increase by 60%

between 2017 and 2050 under BAU assumptions (IEA, 2018). More than half of this growth will occur before 2030. Plastics production in 2050 will total 589 Mt and the average annual growth rate will be about 2% (half recent annual growth rates), under RTS assumptions.⁵ The RTS sees plastics demand growing 3.7% per year between 2017 and 2030 and by just 0.7% per year between 2030 and 2050 (IEA, 2018).

The rate of growth in plastics production assumed by the IEA is lower than in other studies. The Centre for International Environmental Law (CIEL) (2019) assumes a rate of 3.8% per year to 2030 and 3.5% per year between 2030 and 2050, as do the World Economic Forum et al. (2016). We assume an annual growth rate of 3% for our BAU scenario, resulting in 1,145 Mt of plastics produced in 2050. This rate of growth reflects detailed analysis of plastics-market sectors.

In 2015, the total quantity of plastic waste was estimated at 302 Mt (Geyer et al., 2017). Under BAU conditions, this would grow in proportion to the quantity of plastics produced. The quantity of waste is directly related to the lifespan of plastic products, which remains unchanged under BAU. However, waste-collection rates are expected to increase. Despite this, the average plastic recycling rate globally would be lower in 2050 than it is in Europe today, with less than 20% of recyclable plastic waste collected (IEA, 2018).

Biomass feedstock does not make up a significant share of plastics production in 2050 under BAU (IEA, 2018). This and the relatively low recycling rate in 2050 suggest that demand for oil and gas for feedstock will continue to grow under BAU assumptions. In the IEA's RTS scenario, the demand for fossil fuels for feedstock (non-energy demand) increases threefold.

⁵ When the total increase in production is averaged over the period 2017–2050, the RTS in IEA (2018) indicates a growth rate of 2.1%.

4.2 Low-plastic-consumption scenario

This study focuses on a 2050 low-plastic-consumption scenario that is compatible with and draws on the LED scenario of Grubler et al. (2018), which describes feasible energy end-use and efficiency transitions consistent with restricting global heating to 1.5°C. Developed from detailed sectoral analysis, our 2050 low-plastic-consumption scenario is based on observable trends and is technologically feasible.

The low-plastic-consumption scenario considers the drivers of change and other key trends identified in the LED scenario (see Box 2) in relation to four key sectors in the global market for plastics – packaging, construction, automotive and EEE. Together, these four sectors account for more than 60% of plastics consumption.

In our low-plastic-consumption scenario, plastics consumption in 2050 would total 400 Mt, compared with 407 Mt in our baseline year of 2015. This is almost two-thirds lower than the level of consumption under our BAU projection (1,145 Mt). We outline how this large reduction could be achieved in chapter 5 and examine its effects in chapter 6.

The largest proportional changes in plastic consumption would be in the packaging and construction sectors (78% and >95% reductions, respectively). Figure 7 shows the consumption in all sectors in 2050 under our BAU and low-plastic-consumption scenarios (details are provided in Annex 1).

The consumption of different types of plastic in the low-plastic-consumption scenario differs from that of the BAU scenario (Figure 8). The largest reductions in consumption would come from PS and PVC. PUR would see the smallest proportional reduction in consumption.

Box 2 Forecasting the future consumption of plastics

The low energy demand (LED) scenario is based on the global energy assessment (GEA) efficiency scenario and is consistent with the moderate demographic and economic changes (continuation of current trends) of the shared socioeconomic pathway 2 (SSP2) (Grubler et al., 2018). For energy end-use and efficiency in industry, including plastics manufacture, the LED scenario relies on the 2 degrees scenario (2DS) in the IEA's *Energy technology perspectives 2017* (ETP) (IEA, 2017).

The LED scenario assumes that half of petrochemicals output (fertilisers and plastics) is used in final consumption and half in upstream sectors. Final consumption in 2050 is 50% lower than in 2020 because of changes in consumption associated with consumer aspirations for a better quality of life (such as reduced pollution). Total petrochemicals output in 2050 is estimated to be 753 Mt in the LED scenario, 25% lower than the LED reference level for total petrochemical consumption in 2050 of 1,003 Mt, which is based on ETP 2DS.

Compared with projections in other studies, ETP 2DS has a lower level of plastics consumption in 2050. Total petrochemicals output grows by around 1.18% a year on average in ETP 2DS, from 576 Mt in 2014 to 1,003 Mt in 2050. High value chemicals (plastics) accounted for 337 Mt (59%) of all petrochemicals in 2014, growing to 553 Mt in 2050 (55% of the total), before applying LED scenario assumptions for reduced consumption.

An IEA study on the future of petrochemicals (IEA, 2018) estimates total plastics production in 2017 at 350 Mt, growing to 589 Mt by 2050 (about 7% higher than the ETP 2DS). Applying the LED dematerialisation factor to this figure suggests total plastics production of about 442 Mt in 2050.

Some estimates of plastics consumption in 2050 assume a significantly higher rate of growth. World Economic Forum et al. (2016) and CIEL (2019) assume a 3.8% annual growth rate to 2030, then 3.5% to 2050, taking total plastics consumption in 2050 to more than 1,100 Mt. ETC (2019), drawing on the analysis of Material Economics (2018), estimates around 800 Mt of plastics consumption in 2050.

Today, plastic products are made almost entirely from virgin plastic resin. In our low-plastic-consumption scenario for 2050, about 54% would be made from recycled plastics.⁶ To completely phase out the production of new fossil plastics by 2050, the other 46% would

have to be made from non-fossil-fuel raw materials (Figure 1). Plastic waste in 2050 would total 388 Mt, and 265 Mt of this (68%) would be recycled, either mechanically or chemically. The remainder would be disposed of as well-managed landfill.

Figure 7 Plastic consumption in 2050 by scenario and sector

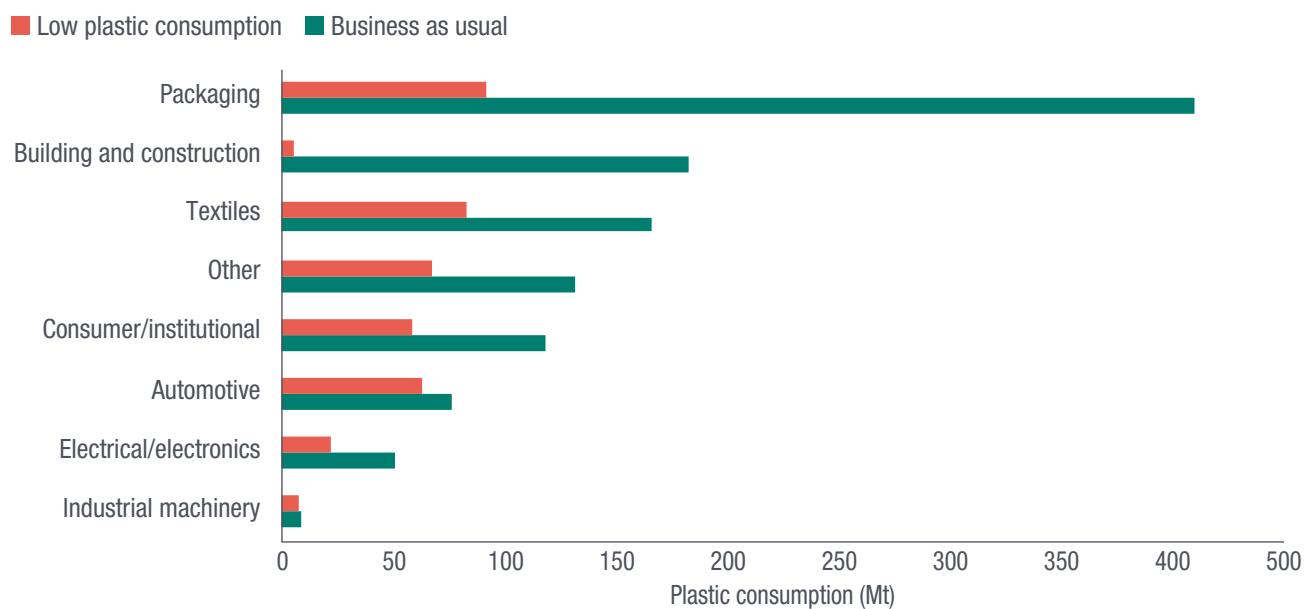
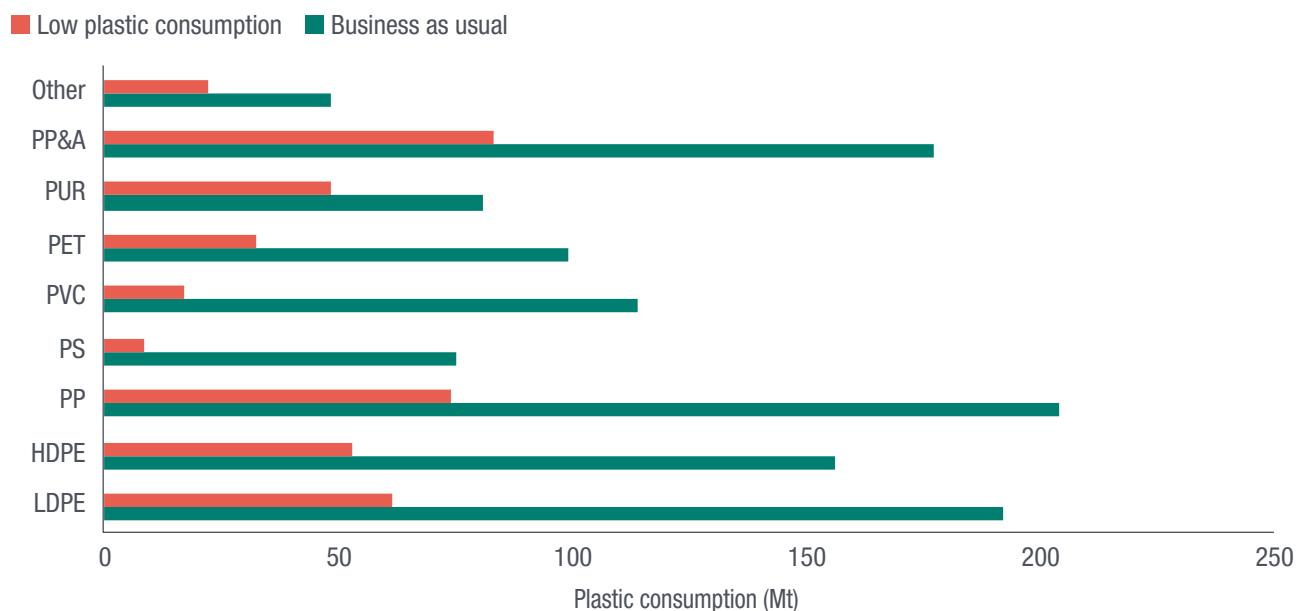


Figure 8 Plastic consumption in 2050 by scenario and type of plastic



⁶ Hundertmark et al. (2018) also forecasts that 60% of plastic products consumed in 2050 will be made from recycled plastics.

5 How to phase out fossil plastics

The phase-out of new fossil plastics by 2050 will require a global transformation of the production and consumption of plastics. Consumers, manufacturers, retailers and public services need to radically change how they use plastic products to achieve the reduction implied by our low-plastic-consumption scenario. How plastic waste is managed and recycled also needs to be overhauled.

There are two main strategies for reducing the consumption of plastics. The first is ‘dematerialisation and reuse’, which involves reducing the consumption of goods (material objects) made from plastics. This includes reducing the use of materials to provide services in general and reducing the amount of plastic required when its use is essential. The second strategy is ‘substitution’ – replacing plastics with other materials. Section 5.1 elaborates on these strategies.

To reduce the production of virgin plastics, producers of plastic will need to greatly increase the use of recycled plastic as a raw material. Currently, only 12% of plastic resin output is made from recycled plastics (Hundertmark et al., 2018). Higher rates of recycling will require changes in plastics manufacture and product design, as well as improved waste collection and management. Plastics production will also need to change to use sustainable alternatives to fossil fuel-based feedstock. These changes in production processes are detailed in section 5.2.

5.1 Reducing consumption

5.1.1 Dematerialisation and reuse

Changes in materials consumption are integral to emissions pathways consistent with the goal

of limiting global heating to 1.5°C (IPCC, 2018). The LED scenario, for example, factors in a 25% reduction in materials consumption (Grubler et al., 2018). In the case of plastics, consumption could be reduced by delivering services in a different way, avoiding the use of material goods or by using less plastic to provide the same services (dematerialisation). Reusing plastic goods can reduce the need for new material goods and thus plastic consumption.⁷ Our detailed sector analyses suggest that dematerialisation and reuse could, in some cases, reduce plastics consumption more than the LED scenario suggests, through changes in product design, business model, consumer behaviour and materials efficiency (Material Economics, 2019). However, detailed analysis of the potential for this in the main plastic-consuming sectors has rarely been undertaken.

Sustainability principles have not been inherent in the design of many products in daily use and the low cost of plastic materials has not been an incentive to use plastics efficiently. The climate crisis and the devastation of plastic pollution point to the need to rethink the design of products made entirely from plastic and incorporating plastic components. More sustainable designs could cut the quantity of plastic used in a product, extend the lifetime of products and parts, and enhance the reuse of plastic products. Product designs could, for example, use more durable plastics or ensure products can be disassembled so parts can be reused or replaced.

Dematerialisation could also be achieved through changes in business models, including the continuation and embedding of some current trends. The consumption of plastic packaging

⁷ Reuse here refers to the repeated use of goods for the same purpose.

could be reduced by changes in consumer behaviour and business-to-consumer interaction, for example, by dispensing from bulk containers into reusable cartons and reusing other forms of plastic packaging. The ‘sharing economy’, for instance, could reduce the number of physical assets (such as cars, floor space and machinery) required to meet demand for the services they provide. Businesses providing services, such as mobility, rather than products, may need fewer material goods (such as appliances or cars) because they have an incentive to maximise asset life and reuse parts. Shared goods, such as cars, could be designed to provide specific services instead of a range of services, reducing downtime and increasing product utilisation. Electronic appliances, meanwhile, could be designed to provide several services, reducing the need for multiple devices. Manufacture by 3D printing could reduce demand for plastic goods in the delivery chain, as well as reduce waste during the manufacturing process. Regulations and standards for products and the wider systems they serve (mobility or the urban environment, for instance) could promote changes in business and consumer behaviour.

5.1.2 Substitution

The consumption of plastics has grown rapidly because of their desirable properties (versatility, durability and light weight) and low cost. Many plastic products can be made from other materials, such as metal, wood, natural fibres or ceramics. Indeed, before the widespread use of plastics, many of the products now made from plastic were made from those materials. Recognition of the negative side of plastics – GHG emissions, pollution and toxicity – is increasing interest in the substitution of other materials for plastics, although this also needs to consider the environmental and economic effects of producing and using alternative materials.⁸

In the construction sector, for example, plastics are used in thousands of different products. Many of them can be made from wood or metal (for example, windows, doors and pipes). Although it may be difficult to find a suitable substitute for

plastic sheathing to insulate electricity and data cables, alternatives are already available for many other construction products.⁹

Materials substitution in packaging also has significant potential. Natural fibre-based alternatives could replace up to 25% of plastic packaging (Material Economics, 2019). Glass bottles and jars for beverages and other foodstuffs could be used and reused after collection and cleaning. Similarly, there could be a return to cardboard and paper for packaging. Plant-based packaging materials, such as mycelia derived from fungi could be used, instead of extruded polystyrene foam while seaweed-based food containers are examples of potential alternative packaging materials.

The potential to reduce the consumption of plastics through dematerialisation, reuse and substitution varies from sector to sector and across plastic types. In the four sectors examined in detail for this study, consumption is reduced (against BAU) by more than 95% in the construction sector, 78% in the packaging sector, 57% in EEE and 17% in the automotive industry.

5.2 Changing production

5.2.1 Recycling

Despite the significance attached to recycling and products made from recycled plastics by consumers and businesses concerned about plastic waste, the proportion that is recycled is far lower than for other materials, such as metals and paper (OECD, 2018). About 20% of plastic waste is recycled today (Conversio, 2019). According to the IEA’s base scenario, average waste-collection rates will increase marginally in most regions of the world. The collection rate for the main thermoplastics will be about 25% higher in 2050 than it is today, but plastics consumption will be 70% higher (IEA, 2018). Recycling will need to expand significantly to phase out new fossil plastics.

Mechanical recycling is the predominant technology for recycling plastics today. Plastic waste is collected, sorted and cleaned before being cut into chips and then melted. The plastic

8 Assessment of the environmental and economic effects of alternative materials is beyond the scope of this study.

9 See *Phasing out plastic: the construction sector* for more detail.

retains its polymer chemical structure and can be re-moulded into (recycled) plastic products. Mechanically recycled plastics may retain impurities, such as additives and colourings used to make the original products, which can limit the scope for recycled resin to completely replace virgin resin (IEA, 2018).

Chemical recycling transforms plastic waste back into monomers, which are then polymerised to produce plastic resin. This requires chemical processing facilities and is thus more capital-intensive than mechanical recycling. Plastic waste could also be recycled back to feedstock material (naphtha or natural gas) by pyrolysis, although its value may be limited to waste that cannot be recycled in other ways (Hundertmark et al., 2019). The technology of chemical recycling is still in development and it has potential as a complement to mechanical recycling in the longer term.

Together, mechanical and chemical recycling could increase rates of plastic waste recycling to the equivalent of over 60% of plastics production (Material Economics, 2019). In our low-plastic-consumption scenario, we conservatively assume 75% of plastic waste is collected for recycling in 2050 and that recycling provides 54% of plastics output in 2050. However, high rates of plastic recycling may not remove the need for some virgin plastic to meet demand in 2050.

A significant increase in plastics recycling is a good start, but there is still a need for other forms of plastic waste management. More secure (closed) and better managed landfill will remain necessary for some waste (ETC, 2019), while some hazardous waste (such as plastics used in healthcare) may need to be incinerated.

5.2.2 Alternative feedstocks

The choice of feedstock for plastics production affects GHG emissions. Using ethane instead of naphtha, for example, can reduce emissions by as much as 50% per tonne of ethylene (Material Economics, 2019). Alternatives to fossil feedstocks, namely biomass or synthetic feedstocks, could also reduce total emissions from plastics. Plastics made from biomass feedstock have lower emissions at the resin production stage of the value chain

than fossil plastics (Zheng and Suh, 2019).¹⁰ Synthetic feedstock, which is produced by synthesising hydrogen (H_2) and carbon dioxide (CO_2), is a technological possibility, but far from commercially feasible (ETC, 2019).

Although biomass-based plastics could replace most conventional polymer types without changing their properties (Zheng and Suh, 2019), their potential to replace fossil plastics will depend on expanding production. Global production capacity for plastics produced from biomass is currently around 2 Mt per year and expected to expand to 2.6 Mt by 2023 (European Bioplastics, 2018). This is less than 1% of all plastics production. Biomass-based plastics are projected to grow by about 4% a year between 2017 and 2022 (Zheng and Suh, 2019). At this rate, their output in 2050 would be around 7 Mt, equivalent to less than 2% of total consumption in our low-plastic-consumption scenario.

The six plastic types on which we focus in this study account for less than half of the plastics produced from biomass today. Growth in output of biomass-based plastics is currently driven by production of innovative polymers, such as polylactic acid (PLA) and polyhydroxyalkanoates (PHAs), which are substitutes for PP and PS (European Bioplastics, 2018). However, the cost per tonne of plastics made from biomass feedstock was double the cost of fossil plastics in 2015 (ETC, 2019). Scaled-up production and technological developments may reduce this difference. Biomass-based plastics will have a part to play in emissions reduction in our low-plastic-consumption scenario.

5.2.3 Process energy

A combination of renewable energy, improved energy efficiency and the electrification of manufacturing processes (such as steam cracking) that currently use thermal energy would reduce GHG emissions from plastics manufacture. Zheng and Suh (2019) found that 100% renewable energy in 2050 would reduce lifecycle emissions per tonne of plastic by 62%. Energy-efficiency measures could reduce emissions moderately (ETC, 2019; Material Economics, 2019).

¹⁰ Zheng and Suh (2019) estimate 3 tonnes CO_2e per tonne of plastic made from sugarcane, compared with 4.1 tonnes CO_2e per tonne of fossil plastic.

6 Effects of phasing out fossil plastics

A detailed assessment of the effects of reduced fossil plastic production in our low-plastic-consumption scenario is made challenging by the sheer variety and extent of plastics use in almost all social and economic activities. Moreover, projections for scenarios in 2050 are inherently subject to multiple assumptions. This chapter, therefore, focuses on a high-level assessment of three key aspects of phasing out new fossil plastics and the effect this would have on climate change: GHG emissions, the use of oil and gas for plastics production, and the management of plastic waste.

6.1 Greenhouse gas emissions

Unabated growth in the production and consumption of plastics would be inconsistent with the objective of net zero emissions by the middle of the century, which is necessary to avert catastrophic climate change. As climate action progresses in other sectors (such as energy and transport), expansion in the plastics sector would increase the share of global emissions attributable to plastics. Material Economics (2018) has estimated that emissions from plastics could increase 188% by 2050. Reducing emissions from plastics by reducing plastic consumption, the use of low-carbon energy, recycling and the use of biomass-based feedstocks (Zheng and Suh, 2019) could reduce GHG emissions from plastics by 56% by 2050, according to the Energy Transitions Commission (ETC, 2019). In our low-plastic-consumption scenario, emissions from plastics would be lower than they are today.

Under the BAU projection in this study, which assumes 3% annual growth in plastics consumption and an increase in the level of incineration of plastic waste, GHG emissions from plastics would grow almost threefold to

about 6 Gt CO₂e by 2050. This is more than seven times the estimated emissions in the low-plastic-consumption scenario.

Under the low-plastic-consumption scenario, there would be an absolute reduction in GHG emissions from plastics, from an estimated 1,984 Mt CO₂e in 2015 to 790 Mt CO₂e in 2050. This reduction in emissions from plastics would be the result of reduced plastic consumption, the use of renewable energy for processing and a higher recycling rate, but it does not take into account changes in emissions associated with substitution.

The sources of emission reduction in the low-plastic-consumption scenario are shown in Figure 2. Under BAU assumptions, emissions from plastics production and consumption would reach 6,045 Mt CO₂e in 2050. In our low-plastic-consumption scenario, dematerialisation and reuse would reduce these emissions by 2,166 Mt, substitution with other materials would reduce them by another 1,778 Mt and fully renewable energy for processing would reduce them by a further 1,003 Mt. The higher rate of recycling in the low-plastic-consumption scenario would further reduce emissions, by 308 Mt CO₂e.

The pathway to lower GHG emissions from plastics will need to entail simultaneous action in all four areas. The decarbonisation of energy systems, for example, which is necessary to achieve a 1.5°C global heating goal, will be a key factor in lowering emissions from plastics (Zheng and Suh, 2019). Although the use of renewable energy for processing could reduce emissions by around half, it would not reduce non-process emissions, i.e. those from plastic consumption.

GHG emissions from the end-of-life stage of the plastics value chain could become more significant if the energy system has been decarbonised. However, this would depend on the proportions

of plastic waste that were recycled, incinerated or sent to landfill. Incineration generates more emissions per tonne of plastic waste than either recycling or landfill (see Box 3). In the low-plastic-consumption scenario, we assume 5% of plastic waste is incinerated, recognising that some residual waste will need to be disposed of this way.¹¹

While recycled plastic generates lower processing emissions than the use of raw feedstock, Figure 2 shows that a high rate of recycling makes a relatively small contribution to reducing emissions from plastics compared with other areas of action.

Action will be required at all stages of the value chain to achieve the absolute reduction in GHG

Box 3 Estimating the greenhouse gas emissions from plastics

Recent studies provide a variety of estimates for the quantity of greenhouse gas (GHG) emissions generated by plastics. The differences between estimates are due to differences in scope (for example, the boundaries of the value chain, geographies and plastic types) and assumptions (such as the carbon-intensity of process energy, feedstock and end of life).

Material Economics (2019) estimates total lifecycle emissions at 5 tonnes CO₂e per tonne of plastic and includes emissions from oil and gas production. Hestin et al. (2015) omit emissions from feedstock production, but provide estimates by type of plastic and end-of-life fate for production in Europe. Posen et al. (2016; 2017) do the same using data for the United States. Zheng and Suh (2019) take a similar approach, but with a global perspective, and include estimated emissions by type of plastic at the conversion stage. The table below compares the estimated emissions for production and end-of-life fate discussed in these key studies.

Our analysis uses the emission factors estimated from global data by Zheng and Suh (2019) and adds upstream emissions from oil and gas extraction and feedstock production. Emissions per tonne of plastic produced in 2015 are estimated to average 4.9 tonnes CO₂e per tonne of plastic. Emissions per tonne of plastic produced in 2050 are estimated at 5.3 tonnes CO₂e under BAU and 2.0 tonnes CO₂e in the low-plastic-consumption scenario.

Emission estimates (kg CO₂e per tonne of plastic)

	Hestin et al.	Posen et al.	Zheng and Suh
Production			
HDPE	1,800	1,430	1,949
LDPE	1,870	1,700	1,962
PET	2,150	2,340	3,332
PP	1,630	1,490	1,983
PP&A	N/A	N/A	3,625
PS	3,300	3,080	3,517
PUR	N/A	N/A	4,900
PVC	1,900	2,140	2,066
Other	4,800	N/A	2,837
Landfill	56	N/A	89
Incineration	2,743	N/A	1,324
Recycling	762	N/A	906

Notes: (1) The emissions per tonne of plastic resin by plastic type are for the production stage. They exclude emissions from feedstock production and the conversion stage. (2) Posen et al. (2016) figures assume hydrogen is from steam cracking by system expansion. (3) N/A, data not available. 1 tonne = 1,000 kg.

Sources: Hestin et al. (2015); Posen et al. (2016); Zheng and Suh (2019)

¹¹ This is in line with Zheng and Suh (2019; supplementary table 10), who assume that 5% of conventional plastic waste is incinerated and 44% recycled in 2050.

emissions from plastics implied by our low-plastic-consumption scenario. No strategy to reduce these emissions will be enough on its own (Zheng and Suh, 2019). It will require the use of renewable energy for plastics processing, a reduction in the consumption of plastics, enhanced recycling of plastic waste, less incineration of waste and the increased use of biomass-based feedstocks.

6.2 Demand for oil and gas

Today, the primary raw materials for plastics production are oil and natural gas, from which naphtha and ethane feedstocks are derived. Plastics production consumes around 9% of global oil and 3% of natural gas.¹² BAU forecasts indicate that plastics' share of total oil and gas consumption is expected to increase. According to the IEA, half of the expected increase in oil and gas consumption to 2050 will be from the petrochemical industry (IEA, 2018) and, by one estimate, plastics could absorb 20% of global oil production in 2050 (World Economic Forum et al., 2016).

In our low-plastic-consumption scenario, total production of plastics in 2050, at 400 Mt, would not be very different to today. But about half of this output would be made from recycled plastic. Therefore, assuming limited uptake of non-fossil feedstocks and lower demand for new feedstock (naphtha and ethane), demand for oil and gas to produce virgin plastics in 2050 would be about half of what it is today. Rühl (2019) similarly suggests that the effect of reduced consumption of plastics combined with high recycling rates could see a 20% reduction in petrochemical demand for oil by 2040.

Our low-plastic-consumption scenario also implies a reduction in the required capacity

of petrochemical plants in 2050 from current levels. There is less need to produce ethylene and propylene for plastics, because the total consumption of plastics is lower and recycling rates are much higher. Yet, global oil-refining capacity is expected to expand by 15% between 2018 and 2025 (Chatterton et al., 2019) and much of this new capacity will be integrated with petrochemical processing. The capacity of petrochemical facilities is expected to grow by more than 4% a year to 2022 (Deloitte, 2019), partly in response to the increased availability of natural gas liquids and ethane from hydraulic fracturing in the United States.¹³

Recent and planned expansion of petrochemical facilities worldwide has been undertaken in anticipation of growth in plastics consumption and to replace the shrinking market for fossil fuels for transport and electricity generation. However, reduced consumption of plastics combined with high recycling rates could see a reduction in petrochemical demand for oil and gas. Some companies are responding to restrictions on single-use plastic products by investing in recycling facilities and financial analysts are already highlighting the risks to large petrochemical investments (Kaskey, 2019; Block, 2019). The expectation that plastics production will provide an expanding market for oil and gas would be confounded by a pathway towards low plastic consumption that is consistent with the 1.5°C global heating goal.

6.3 Management of plastic waste

The quantity of plastic waste in our low-plastic-consumption scenario would be about the same as the quantity generated in 2015 (our baseline year), assuming the ratio of plastics produced to

12 According to the IEA, petrochemicals account for 14% of primary demand for oil and 8% of natural gas (IEA, 2018).

Rühl (2019) estimates that two-thirds of the crude oil consumed by petrochemicals is used to make plastics. Levi and Cullen (2018) indicate that more than 90% of the oil and 49% of the natural-gas inputs to petrochemicals production are used to make high-value chemicals, including plastics.

13 For example, nine petrochemical projects in the US, with a combined total investment of \$59 billion, will increase feedstock production capacity by 19 Mt a year (Monk, 2019).

the quantity of plastics reaching end of life did not change significantly.¹⁴ In 2015, there were 302 Mt of plastic waste globally (Geyer et al., 2017), while our low-plastic-consumption scenario assumes 301 Mt in 2050. However, a key feature of this scenario is a significantly higher level of recycling and a transformation of the way in which end-of-life (waste) plastic is managed.

In 2015, about 18% of plastic waste was collected for recycling, almost 59% went to landfill and 24% was incinerated (Geyer et al., 2017). The most recent survey of global plastic waste estimated similar proportions for 2018: 20% collected for recycling, 20% incinerated and 60% to landfill or unmanaged disposal (Conversio, 2019). This survey also showed that waste-management practices varied from region to region. In the United States and Canada, for instance, 75% of plastic waste was disposed of through managed landfill and 11% was recycled, while in Europe 31% went to managed landfill, 11% to recycling and 33% was incinerated. Africa and Latin America had the highest shares of improper disposal or leakage into the environment (at 60% and 42%, respectively).

Our low-plastic-consumption scenario assumes 75% of plastic waste is collected for recycling, with the quantity increasing from

around 54 Mt in 2015 to 226 Mt in 2050. This implies a fourfold increase in global capacity to collect, sort, clean and recycle plastic waste. The potential business opportunity this represents has been outlined by McKinsey & Co. (Hundertmark et al., 2018) and Material Economics (2019), but low prices for fossil-fuel feedstock may undermine the commercial incentive in the absence of a supportive policy framework.

The 25% of plastic waste that is not collected for recycling in the low-plastic-consumption scenario is either incinerated or sent to landfill. The scenario assumes 60 Mt of plastic waste (20% of the total) in 2050 is disposed of in well-managed landfill. This is one-third of the quantity sent to landfill, disposed of improperly or leaked to the environment in 2015. To ensure this smaller quantity does not result in plastic waste pollution of land or water, improved collection and effectively managed landfill systems will be required.

The low-plastic-consumption scenario also assumes that a small proportion of plastic waste (5%) is incinerated. More effective waste-management practices could ensure that incineration is limited to plastics containing toxic chemicals or those that have become hazardous through use (such as medical waste).

¹⁴ The reduction in single-use plastics inherent in our low-plastic-consumption scenario may increase the average lifespan of plastic products and thus affect the quantity reaching end of life in 2050.

7 Key challenges to phasing out fossil plastics

7.1 Technical

Our low-plastic-consumption scenario assumes radical changes of business model and product design that reduce the use of plastics. It also assumes the substitution of plastics by other materials, such as metals, wood and natural fibres, further cutting the use of plastics. It is beyond the scope of this study to explore in detail the economic and policy levers necessary to realise this reduction in plastics consumption. In many cases, these will be related to sectors consuming plastic and not directly to the production and consumption of plastics. Regulation and product standards, as well as fiscal measures (such as a carbon price)¹⁵ may help drive the reduction in the production and consumption of plastics. Changes in producer and consumer responsibilities for waste and recycling will be influential, as will efforts to raise public awareness and change behaviour.

Our low-plastic-consumption scenario further assumes that the energy used to manufacture plastics will be decarbonised by 2050.¹⁶ This will require the electrification of steam cracking, polymerisation and the processing of by-products using electricity from renewable sources. Most steam-cracking facilities currently use some of the raw material in hydrocarbon feedstock to provide heat in the production of monomers (Koottungal, 2015). By 2050, the use of fossil fuels for process

energy in plastics production must be eliminated. Technological developments may be necessary to bring about the adoption of (renewable) electric steam cracking and to avoid emissions from hydrocarbons not incorporated in monomers.

The transformation of recycling, integral to the low-plastic-consumption scenario, will require investment in infrastructure for waste collection and processing, as well as mechanical and chemical recycling facilities. High rates of recycling will be enabled by changes in product design and the elimination of additives that would inhibit the recycling of plastic waste. Economies of scale and better efficiency may also make mechanical recycling more attractive to businesses. Chemical recycling, which is currently not widespread, may require further technological advancement to play a significant role by 2050 and complement mechanical recycling.

7.2 Political economy

Phasing out fossil plastics and reducing the consumption of plastic by 2050 will require a transformation in the markets for plastics products and the manufacture of plastics. Changes at a similar rate and scale to the rapid expansion of plastics over the past two decades will be necessary in business models, the organisation of businesses along the plastics value chain and consumer behaviour. The reduced demand for

¹⁵ For example, the Energy Transitions Commission (ETC, 2019) suggests that a carbon tax equivalent to \$140 per tonne of plastic could make chemical recycling economic today.

¹⁶ This would be consistent with the LED scenario of Grubler et al. (2017) and the low-carbon-energy scenario of Zheng and Suh (2019). Our low-plastic-consumption scenario follows Grubler et al. by assuming carbon capture, utilisation and storage technology will not be used.

fossil fuel-based feedstock will also have significant implications for oil and gas producers and companies invested in petrochemicals.

The drivers of change in the different sectors of the market for plastics are likely to vary. In the packaging sector, for instance, a shift in consumer preferences away from single-use products, combined with business efforts to attract customers, which is already occurring, could rapidly result in lower demand from this sector.¹⁷ Changes in consumer preference may also drive change in the diverse market for plastic in consumer goods (for example, toys, sports equipment, household goods and furniture). In the building and construction sector, in contrast, final users of buildings are not the main market for construction plastic products. Here, building regulations, standards and urban planning may play a strong role, based on national climate-change policy objectives. In the automotive sector, plastics demand may be affected by new business models (such as mobility as a service (MaaS) and vehicle-sharing), bringing about changes in consumer behaviour and new business interests that could support the phase-out of plastics (see the sector reports for more discussion).

Recycling could be a major source of future profit in the plastics value chain and be integral to the business of plastics producers. They will have an interest in ensuring that a plastics production system that relies on recycled plastics as an input will be able to optimise recycling rates (for example, through product design,

waste collection and reduced degradation). Plastics companies themselves may need to become involved in waste management to ensure they have a supply of plastic waste to recycle (Hundertmark et al., 2018).

Reducing the consumption of plastics, as implied by our low-plastic-consumption scenario, would affect all stages of the plastics value chain. The effects would be felt in the reduced production share of virgin plastics, as well as overall production. There would be less need for monomer production using naphtha and ethane, presenting a challenge for petrochemical companies with significant investment in steam-cracking facilities. New investment in some facilities is predicated on growth in the consumption of plastics made from low-cost fossil feedstock. Some large oil and gas companies currently depend on the sale of petrochemicals for a quarter of their revenue, while 80% of the output of some chemical companies is for the production of plastics (Block, 2019). Companies operating steam crackers are often closely tied to oil and gas companies, and new refinery capacity is often integrated with petrochemical processing. Although the oil and gas sector has regarded petrochemicals as its principal growth area, the reduction in oil and gas consumption implied by the low-plastic-consumption scenario – necessary to achieve a goal of 1.5°C global heating – has major implications for the oil and gas sector's future operations.

¹⁷ Over 60 countries had introduced restrictions on single-use plastic products by the end of 2018 (Scott, 2019).

8 Conclusions

Unless action is taken to reduce the consumption of plastics and increase the recycling of plastic waste, the quantity of plastics produced globally in 2050 could be more than 180% higher than in 2015, and GHG emissions from plastics could more than treble from 1.9 Gt CO₂e a year to about 6 Gt CO₂e a year. An increase in plastics consumption of this scale would prevent us from keeping global heating to less than 1.5°C, which requires net zero CO₂ emissions by 2050.

The low-plastic-consumption scenario at the heart of our analysis assumes action reduces the consumption of plastics, uses renewable energy to manufacture plastics and greatly increases the recycling of plastic waste. Together, technically feasible action in these areas could reduce GHG emissions from the production and consumption of plastics in 2050 to 0.8 Gt CO₂e. Plastics consumption in 2050 could be 65% lower than a BAU projection – about 400 Mt instead of 1,145 Mt – and marginally lower than consumption in 2015.¹⁸ This technically feasible reduction could be achieved through action to reduce the overall quantity of materials consumed and to substitute other materials for plastics.

Reduced consumption of plastics could be achieved through changes in product design (incorporating principles of sustainability and circular economy into the design process), business models and consumer behaviour (including increased reuse of products). Plastics are not essential to many products that now include them, while the reorganisation of businesses and the way they interact with their

customers could reduce the consumption of material goods. Achieving this requires changes in government regulation, price incentives and social attitudes that would help to reduce the consumption of plastic products.

Plastic recycling would need to be scaled up and transformed to achieve the rate of recycling in 2050 that could technically be achieved. Our low-plastic-consumption scenario assumes 75% of plastic waste will be collected for recycling, more than double the rate in Europe today and more than seven times that in other high-income countries (OECD, 2018). Although the reduced consumption of plastics makes the recycling challenge more manageable than it would be under BAU, this would still require scaling up infrastructure for waste collection and sorting, as well as for the recycling processes themselves. Chemical recycling technology could complement mechanical recycling for hard-to-recycle and degraded plastics. A high rate of recycling may also call for closer integration of the businesses of waste management and recycling with those of monomer and polymer manufacture. However, by 2050, enhanced recycling could provide more than 50% of the material needed to produce plastic resins.¹⁹

Renewable electricity in 2050 could be the primary source of processing energy at all stages of the plastics value chain. Renewable electricity would also reduce the emissions from materials that replace plastics. Adopting renewable electricity could reduce emissions from plastics by 50%, but renewable electricity and recycling alone would not be enough to achieve the

¹⁸ The estimated quantity of plastic produced in our low-plastic-consumption scenario is based on conservative assumptions about dematerialisation, reuse and substitution in the sectors that we did not analyse in detail, including textiles and general consumer goods. Further research could generate a lower estimate.

¹⁹ Under the low-plastic-consumption scenario, the quantity of plastic waste recycled in 2050 would be 241 Mt. After losses during processing, the quantity of resin produced from recycled plastic would be about 232 Mt.

emission reductions necessary to meet the 1.5°C global heating goal.

Approximately half of the plastic products produced in 2050 could be made from recycled plastics. The other half, amounting to about 200 Mt, would be made from virgin plastics. Although biomass-based feedstock could technically be used to substitute for most types of fossil plastic, it would require a hundredfold increase in production capacity to meet the demand for virgin plastics in 2050. The challenge of expanding production on this scale, as well as the potential implications for land use, suggest the low-plastic-consumption scenario would still need some virgin fossil plastics production in 2050.²⁰ Therefore, closed-loop production systems (a truly circular economy) would be necessary to capture waste and by-products during the manufacturing

stages of the value chain, combined with tightly managed landfill and recycling at the end-of-life stage.

The pervasiveness of plastic products today means change will be necessary in almost every market sector to achieve a reduction in GHG emissions from plastics that would be consistent with a 1.5°C global heating goal. Achieving our low-plastic-consumption scenario depends on change from BAU throughout the economy and transformation in the plastics value chain. Incentives for consumers and businesses, new business models, regulation and policy will play a role, to varying degrees, in different product markets. Policies to transform the plastics sector will need a system-wide perspective to simultaneously drive reductions in plastics consumption and in the use of oil and gas to produce virgin fossil plastics.

²⁰ It is possible that analysis of other market sectors and more in-depth research for the low-plastic-consumption scenario could reduce this need.

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Annex 1 Consumption by plastic type and sector

Table A1 Consumption of plastics (Mt) in 2015

Sector	Type of plastic										Total
	LDPE	HDPE	PP	PS	PVC	PET	PUR	PP&A	Other		
Packaging	44	30	27	8	3	33	1	0	0	146	
Construction	4	11	4	8	28	0	8	0	2	65	
Automotive	0	3	10	0	1	0	6	0	6	27	
Electronics	2	1	4	3	2	0	2	0	5	18	
Consumer goods	10	6	13	6	2	0	4	0	1	42	
Industrial machinery	1	0	1	0	0	0	1	0	0	3	
Textiles	0	0	0	0	0	0	0	59	0	59	
Other	6	3	15	3	5	0	9	0	6	47	
Total	68	55	74	27	41	33	31	59	19	407	

Source: Geyer et al. (2017)

Table A2 BAU consumption of plastics (Mt) in 2050

Sector	Type of plastic										Total
	LDPE	HDPE	PP	PS	PVC	PET	PUR	PP&A	Other		
Packaging	124	86	76	21	8	93	2	0	1	411	
Construction	11	32	12	21	79	0	23	0	5	183	
Automotive	1	9	29	0	3	0	18	0	16	76	
Electronics	6	3	11	8	5	0	5	0	13	51	
Consumer goods	29	17	37	18	6	0	10	0	2	118	
Industrial machinery	2	1	2	0	0	0	3	0	0	8	
Textiles	0	0	0	0	0	0	0	166	0	166	
Other	17	9	42	7	14	0	25	0	17	132	
Total	190	157	209	75	115	93	86	166	54	1154	

Table A3 Low plastic consumption (Mt) in 2050

Sector	Type of plastic									
	LDPE	HDPE	PP	PS	PVC	PET	PUR	PP&A	Other	Total
Packaging	25	26	14	0	2	26	0	0	0	92
Construction	3	0	0	0	2	0	0	0	0	5
Automotive	1	7	24	0	3	0	15	0	13	63
Electronics	3	1	5	3	2	0	2	0	6	22
Consumer goods	15	7	15	0	0	0	22	0	0	59
Industrial machinery	2	1	2	0	0	0	3	0	0	8
Textiles	0	0	0	0	0	0	0	83	0	83
Other	13	11	14	5	8	7	6	0	3	67
Total	62	53	74	8	17	33	48	83	22	400

Table A4 Low plastic consumption (Mt) in 2050 by source of reduction

Sector	BAU total	Type of plastic		Total
		Dematerialisation	Substitution	
Packaging	411	-187	-131	92
Construction	183	-108	-77	5
Automotive	76	-13	0	63
Electronics	51	-6	-22	22
Consumer goods	118	-30	-29	59
Industrial machinery	8	0	0	8
Textiles	166	-42	-41	83
Other	132	-33	-32	67
Total	1,145	-412	-333	400

Note: Columns and rows may not add up exactly due to rounding of numbers.

Annex 2 Summaries of sector technical analyses

This annex summarises the analyses in the four detailed sectoral studies that informed this report. The summary of each sector presents the key characteristics of the 2050 vision for low plastic consumption in the sector and the estimates for technically feasible reductions in consumption against BAU projections.

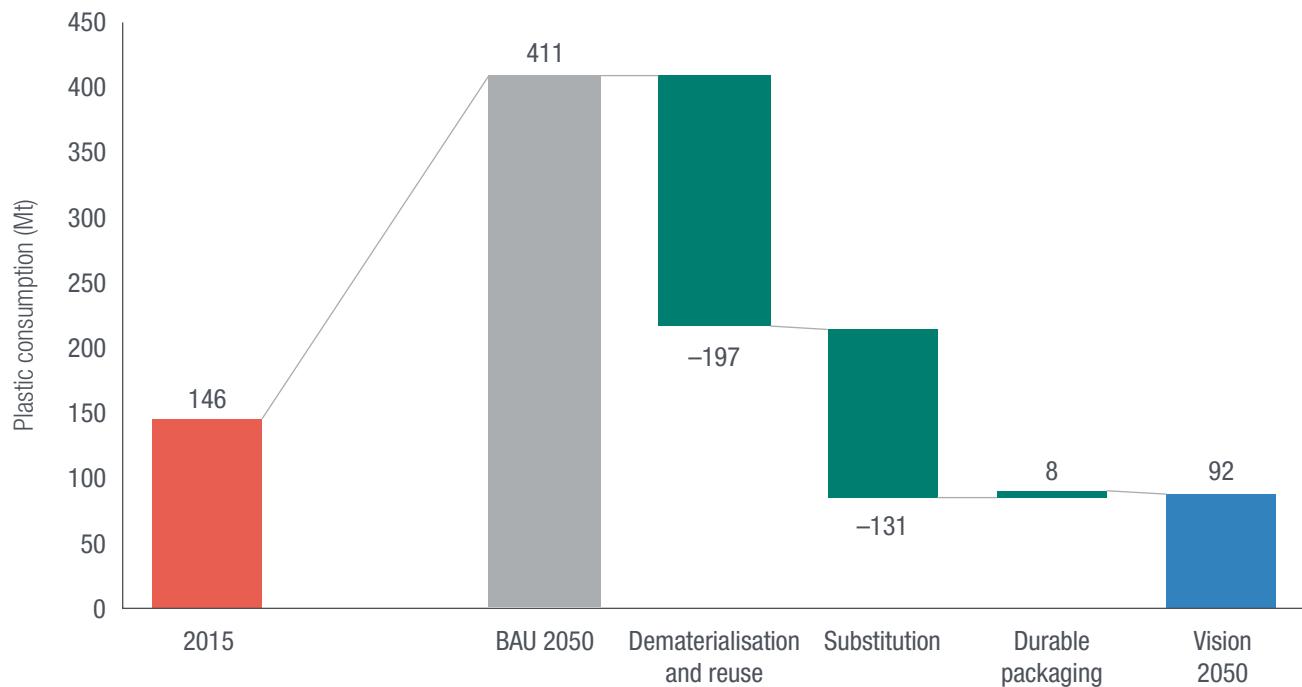
A2.1 Packaging

The packaging sector consumed 36% of global plastics production in 2015, a total of 146 Mt (Geyer et al., 2017). Under BAU projections, 411 Mt of plastics would be produced for packaging in 2050 (Figure A1). This would be primarily for single-use packaging that reaches the end of its life in its year of manufacture.

In our low-plastic-consumption scenario for 2050, total production of plastics for packaging would be 92 Mt. This is less than a quarter (22%) of the BAU level of consumption. It is the result of an 80% reduction in single-use plastic packaging (compared with BAU), offset by an increase in the production of durable, reusable plastic packaging.

In our low-plastic-consumption scenario, packaging in 2050 primarily performs a functional service, namely the safe delivery of products. The use of packaging to attract consumers is less important due to a substantial shift to online purchasing. Packaging would be durable and reusable, designed to

Figure A1 Reduction in plastics consumption for the packaging sector



Source: Authors and Geyer et al. (2017)

transport goods in a way that minimises space and prevents damage. Most packaging would remain the property of the retailer or delivery company. Consumers may use their own reusable packaging to collect goods, or pay a deposit for returnable packaging.

Shops in 2050 could act more as delivery hubs for the collection of goods and to provide lifestyle experiences. Additive manufacture (3D printing) could allow many products to be made closer to consumers. Supermarkets could provide an extensive range of products through self-dispensing into standardised reusable containers, available in-store or brought by consumers. Some packaging for perishable products may be replaced by edible coatings, while some liquid products (such as detergents) may be sold in highly concentrated form, requiring minimal packaging.

The expansion of product-as-a-service business models leads to an increase in product rental, which may involve strong reusable packaging, optimised for multiple deliveries and returns of the same product. This durable packaging remains with the service provider. The lifespan of products is longer, as there is an incentive for businesses to design for longevity and the easy replacement of parts.

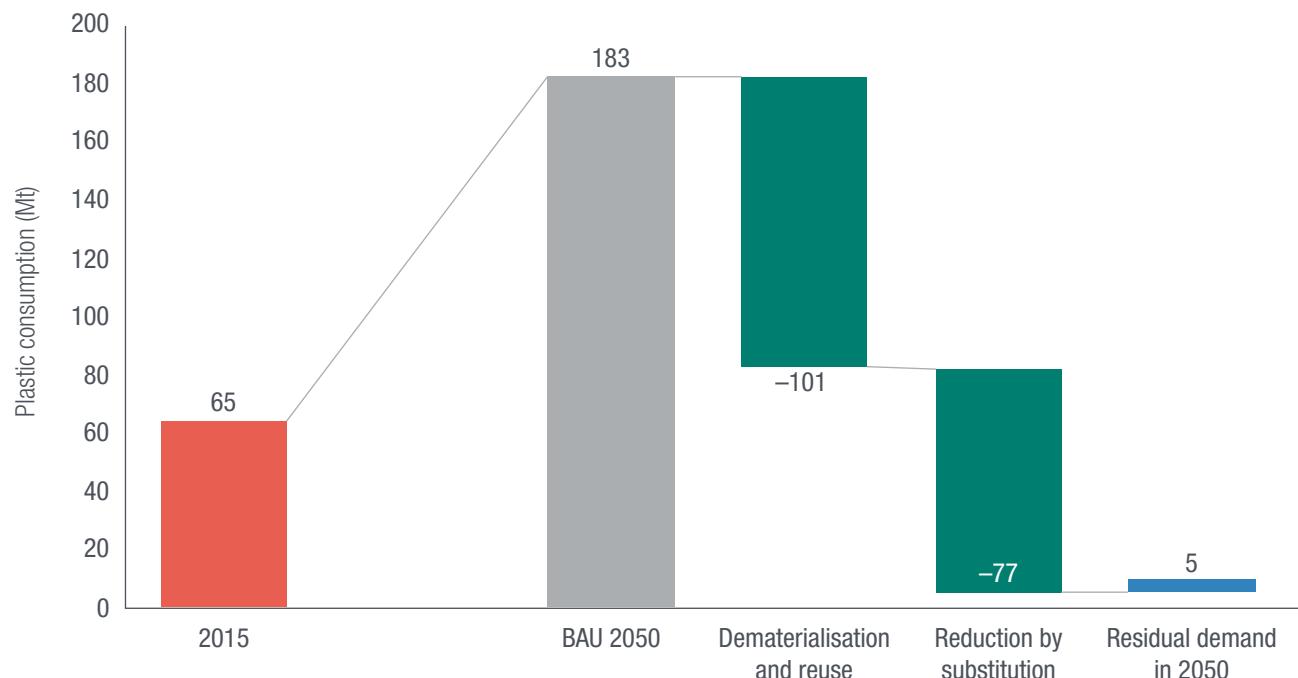
Single-use plastic bottles could be obsolete by 2050, partly through regulations banning their use. Deposit and collection schemes for the remainder of single-use plastic packaging provide incentives for consumers and significantly increase collection rates.

A2.2 Construction

Under BAU projections, 183 Mt of plastics would be produced for the construction sector in 2050 (Figure A2). This would primarily be for profiles (such as windows and doors), pipes, tubes and insulation. Other notable uses include electrical cables, waterproof barriers and municipal or industrial pipe systems. Most of these products have long in-use lifetimes, averaging 35 years across the sector (Geyer et al., 2017).

In our low-plastic-consumption scenario, total production of plastic for the construction sector would be 5 Mt. This is the result of a reduction in demand for construction materials – driven by a move towards longer building lives and more compact urban areas – and the substitution of many existing products that incorporate plastics with non-plastic alternatives.

Figure A2 Reduction in plastics consumption for the construction sector



Sources: Authors and Geyer et al. (2017)

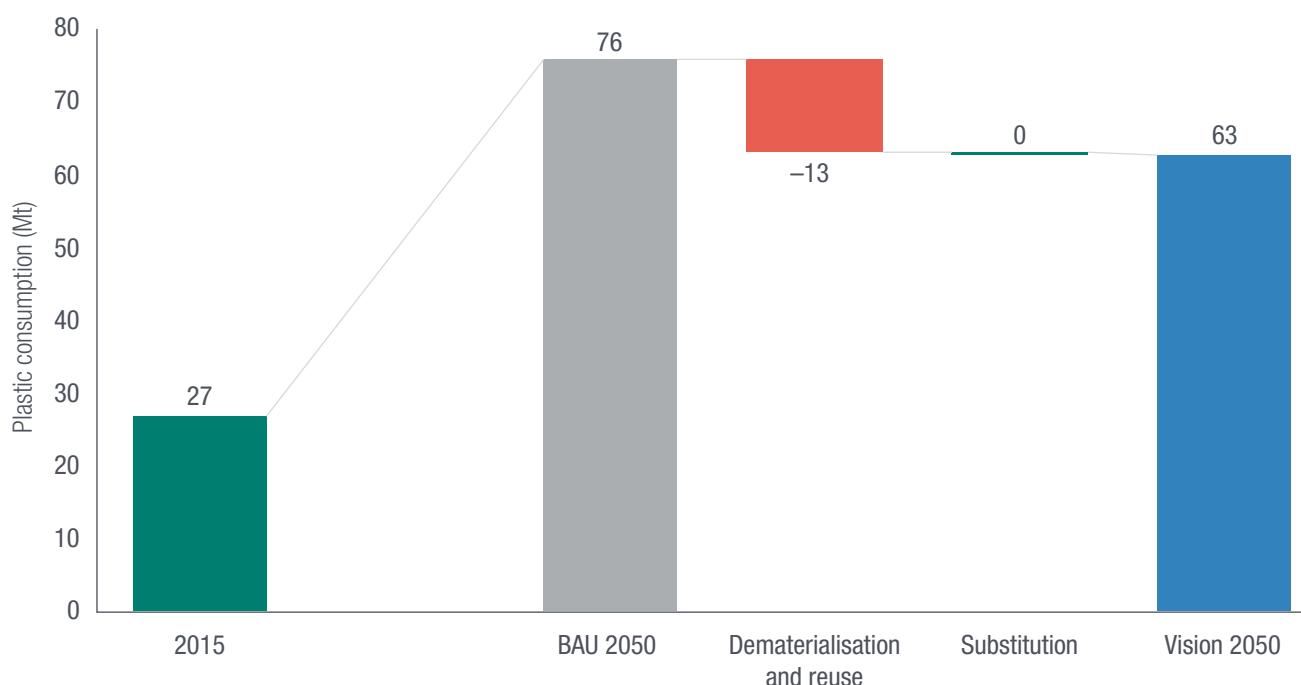
Achieving the low-plastic-consumption scenario is largely possible with today's technologies, but requires a broad and deep-rooted redirection of the industry. Reversing the growth in plastic materials in recent decades is challenging, but need not be seen as a negative path. Broader public policy decisions that align with the Sustainable Development Goals could concomitantly reduce the demand for plastic materials. Urban planning that promotes compact cities would help to reduce the demand for services that plastic materials provide per building unit, while also offering the potential for better transport options, cleaner environments and better-quality housing. The use of plastic in construction is typically a choice, rather than a necessity. Plastic components are often cheaper to buy, easier to install and hidden from view once buildings are constructed. This creates strong incentives for construction companies to choose plastic materials over alternatives that may be more costly and laborious to use, even if the alternatives are preferable to the user or society at large because they, for example, last longer or create fewer GHG emissions. Correcting this market failure will also be paramount.

The emerging sustainability agenda within the construction industry is beginning to find ways to make the lifetime costs and impacts of plastic materials more salient. However, the combination of powerful vested interests and a sector that is often seen as slow to adapt pose notable barriers to disrupting the forecast growth of plastics in the sector. Voluntary and mandatory standards, better-quality and more comparable full-lifecycle data, as well as shorter supply chains that would arise from a major shift to pre-fabrication, could focus attention on more sustainable construction choices and reduce plastic demand. Various sectoral actors are already promoting action on each of these themes; the challenge will be to coordinate and scale up these efforts to move them from the fringes to the new status quo.

A2.3 Automotive

Globally, the automotive sector consumed 27 Mt of plastics in 2015, about 7% of global plastics production (Geyer et al., 2017). Under BAU projections (3% annual growth) the sector will consume 76 Mt of plastics in 2050 (Figure A3).

Figure A3 Reduction in plastics consumption for the automotive sector



Sources: Authors and Geyer et al. (2017)

In our low-plastic-consumption scenario, the production of plastics for the automotive sector in 2050 would total 63 Mt globally. This is equivalent to more than double the consumption in 2015, but a reduction of about 17% on BAU. The reduction would be primarily through dematerialisation.

Although the overall demand for passenger and freight transport services is expected to grow by 2050, especially in emerging economies, the number of passenger vehicles, both in use and sold annually, could increase at a much lower rate. The widespread uptake of ride-sharing, car-sharing and mobility-as-a-service (MaaS) business models, combined with improved public transport, could drive a reduction in the number of passenger cars in 2050 compared with BAU. This could be facilitated by changes in urban physical environments and digital technologies to ease transfers between modes of transport, including low-impact ones, such as bicycles and (electric) scooters. Reduced private passenger-vehicle ownership would be the result of changes in the organisation and operation of transport services.

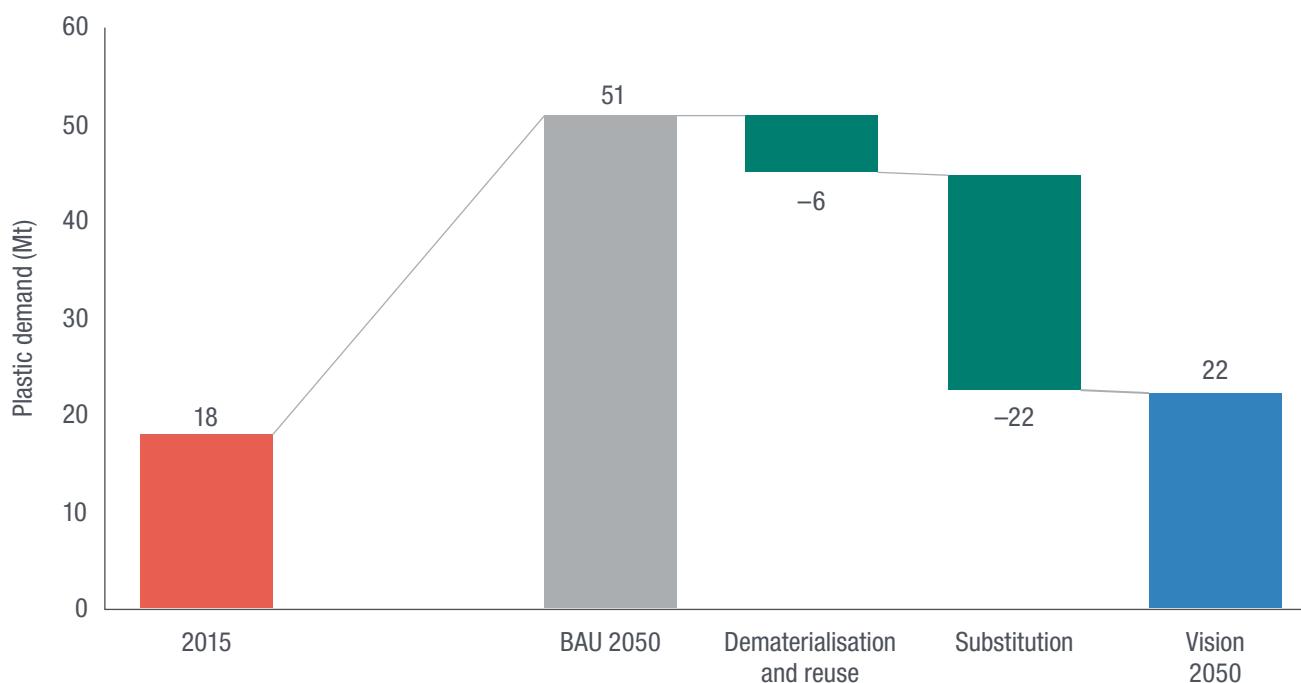
However, the quantity of plastics incorporated into an average vehicle is expected to increase by 50% in cars. The use of plastics reduces overall vehicle weight and helps to improve fuel efficiency and reduce GHG emissions. In electric vehicles, which will largely replace vehicles with internal combustion engines, lower vehicle weight helps to extend battery life.

Our low-plastic-consumption scenario reflects changes that could mitigate growth in plastics consumption in addition to reduced private vehicle ownership. Professionally managed shared vehicle fleets and MaaS businesses would provide an incentive for manufacturers and service operators to optimise vehicle efficiency and durability. This could result in radical changes in vehicle design (such as an increase in modular components) and size, which reduce average vehicle weight and affect plastics consumption.

A2.4 Electrical and electronic equipment (EEE)

The EEE sector was responsible for the consumption of around 18 Mt of plastics in 2015, equivalent to 4% of total plastics consumption (Geyer et al., 2017) (Figure A4). Plastics in the sector fall into two broad categories: specialist engineering plastics that have an intrinsic role in the operation of EEE, and bulk plastics used for structural support and protective casings.

Figure A4 Reduction in plastics consumption for the electrical and electronic equipment sector



Sources: Authors and Geyer et al. (2017)

In our BAU scenario, we assume 3% annual growth, with total plastics consumption by the sector reaching about 51 Mt in 2050. The LED scenario (Grubler et al., 2018) projects the number of electrical devices globally to be lower than BAU because of trends towards shared appliance ownership, devices providing multiple services and virtualisation (content stored elsewhere).

Our 2050 low-plastic-consumption scenario suggests a substantial shift towards modular design for EEE. This would enable them to be disassembled and repaired, facilitating reuse and extending product life. By 2050, recycling rates for plastics in the sector would be much higher than today, driven by regulations to incentivise recycling and consumer preference for recycled materials. This could be facilitated by regulations on additives (for example, only permitting the use of additives that are non-toxic and allow complete recycling) and product labelling (for instance, on carbon footprint and recycled content).

The substitution of other materials (such as metals, wood and ceramics) for plastics in the EEE sector could replace the use of PP and PE for structural uses and casings and the use of PUR and PS for insulation.

By 2050, the consumption of plastics in the sector could be reduced by almost 60% compared with the BAU projection through a combination of dematerialisation and materials substitution. The increase in the prosperity of lower-income consumers under the LED scenario suggests that these consumers have the greatest potential to reduce plastics consumption in the sector compared with BAU.



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