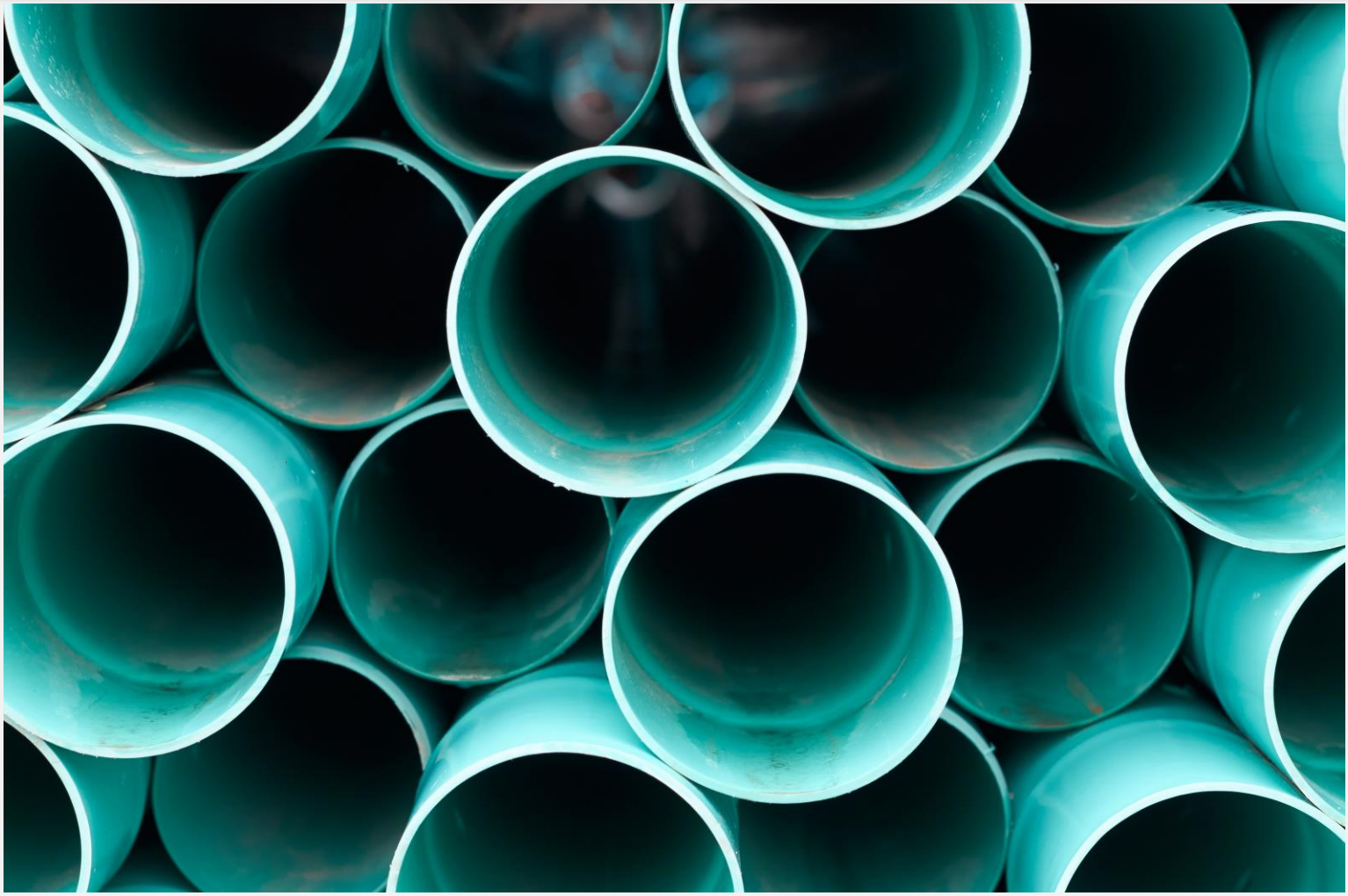
ETC CE Report 2022/7

Non-packaging plastics in Europe



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Circular economy and resource use

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1 Scope and objective

This report is a contribution to EEA's work on plastic and the environment in Europe's circular economy, building on reports and briefings published in 2021. In particular, this publication seeks to develop knowledge on the availability of information about the types and amount of plastic streams, other than packaging, with a focus on data availability and gaps. In a previous EEA report, three pathways to ensure a long-term move towards a sustainable and circular plastics production and consumption system were presented. The three pathways are (i) smarter use; (ii) increased circularity; and (iii) renewable material, addressing different stages of the plastics value chain, as well as different environmental and climate impacts (Fogh Mortensen et al., 2020). In this report, the need for data to support the three pathways is highlighted, as well as the need to look beyond packaging plastics and focus on non-packaging streams as well.

To be able to assess the contribution of potential solutions and practices to more circular and sustainable uses of plastics, both policy makers and business require a clear overview of plastic flows in the economy and insights into the relationship between the flows of polymers, products (partly) made of plastic(s) and waste flows containing plastic. Data availability facilitates forming this overview of the current situation, following up on change, and decision making.

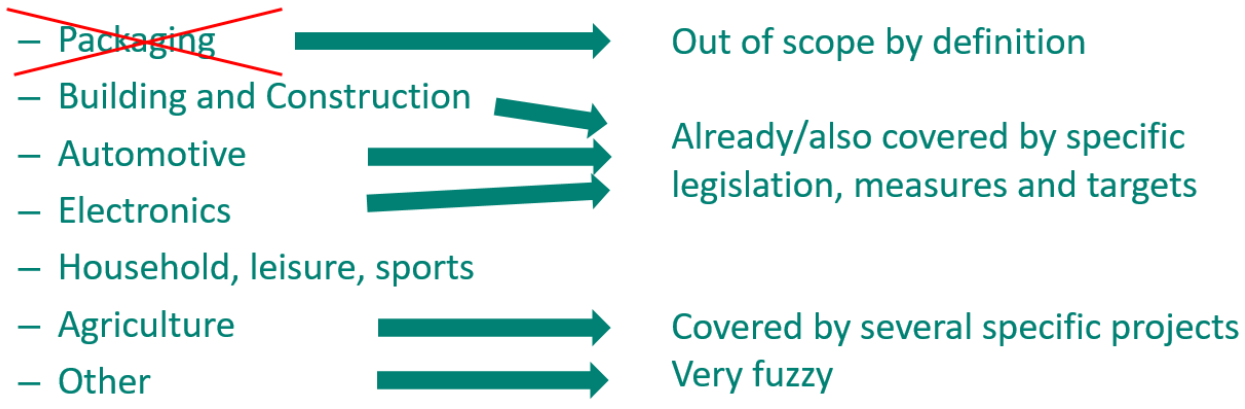
The aim of the task was to map the knowledge base on the material flows of non-packaging plastics in Europe. Specific objectives included:

1. the development of greater knowledge on this material stream to support environmental policymaking and regulation in the EU;
2. an improved understanding of regional and sectoral variance in the availability of data on non-packaging plastics, underpinned by the compilation of an initial set of case studies.
3. articulation of the knowledge gap to highlight where the current lack of data affects policy making.

The packaging sector is probably the most regulated and documented plastic sector. The focus for this report, as shown in Figure 1.1, is the non-packaging plastic, including the automotive, electronics, construction and building, agricultural, and household plastics sectors.

From these plastic demanding sectors, building and construction, automotive and electronics seem to be covered by other than plastic related specific legislation, measures and targets, mainly because of the large share of non-plastic materials in their product categories. Additionally, the use of plastics for agriculture is a very specific application and is the focus of several dedicated projects. The "other" category is the most divers sector by definition. And last but not least, the household, leisure and sports sector is a broad collection of plastic and plastic-containing applications.

Figure 1.1 Scope of this report



2 Introduction and background

Plastics play an essential role in modern society. Today more than 50 types of plastics are used in all sectors including building and construction, automotive, agriculture, healthcare, household, sport and leisure. Because plastics are very cheap in comparison with other materials, highly durable, light weight, impermeable and can be used as isolating materials, they are used in an increasing number of applications. This has resulted in an ever-increasing global demand for plastic. The Organisation for Economic Co-operation and Development (OECD) estimates that the global annual use of plastics reached 460 million tonnes in 2019 (OECD, 2022).

Plastic production, more than 90 % of which uses fossil feedstock, and the poor management of plastic waste lead to significant impacts on the environment and climate. According to OECD about 353 million tonnes of plastic waste was generated globally in 2019, but only 55 million tonnes were collected for recycling (OECD, 2022).

To reduce environmental impacts related to plastic production and consumption, European policy makers and stakeholders have called for accelerating a more circular use of plastics, including the smarter use of the material and the use of biobased feedstocks as well as increased recycling. Fogh Mortensen (et al., 2020) presents five pathways for overcoming challenges related to the plastic sector's dependence on fossil feedstock, insufficient waste management and littering. The pathways presented are (i) using bio-based alternatives to fossil feedstock to reduce greenhouse gas emissions and dependence on fossil fuels; (ii) using biodegradable plastics that mitigate some problems related to leakage; (iii) recycling to reduce the need for virgin feedstock, improving resource efficiency and reducing emissions; (iv) reducing the number of types of plastics to decrease the plastics system's complexity and facilitate recycling; and (v) reducing the use of plastics to reduce plastic littering, the use of resources, and exposure to potentially harmful chemicals (Nielsen et al., 2018).

Although plastic consumption is increasing, there is still a poor understanding of the plastic material streams and waste flows in the economy. Plastics embedded in products and in stocks are poorly documented. There is also a very limited understanding of how, why and how much plastic is leaking from the economy, f.e. through littering or landfilling. This restricts understanding existing and future plastic streams, restricts the possibility to develop better management systems.

The linear economic model makes the plastics management system highly inefficient and problematic. Poor recyclability characterises plastic and plastic-containing products in non-packaging sectors. In comparison, plastic packaging has significantly higher recycling rates due to the characteristics of the products themselves, the management system and policies. Non-packaging plastics are often embedded in complex products or lack a specific product category and management system.

Sustainable business models built on circular economy (CE) principles are expected to impact design and manufacturing, for example, from lightweight to recyclable materials, reusability, recyclability, and repairability (Frost & Sullivan, 2019). The growing significance of the CE is predicted to prevent waste generation and keep materials and their value in circulation through new business models, such as leasing, sharing, reusing and repairing (Dufva, 2020).

2.1 Policy background

The basic principles and general ambitions for circularity in the plastics sector are defined in the European CE policy framework (European Commission., 2018b; European Commission, 2018; European Commission., 2015, 2020). The EU legislation and policies are transposed into national legislation and policies, thus forming the basis for the CE policy framework in EU Member States. EU policies set the framework both for recycling targets for waste (European Commission., 2018b) and for market demand for secondary materials (European Commission., 2020).

The Waste Framework Directive (WFD) (2008/98/EC) sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery and end-of-waste criteria (European Commission., 2018b). Only plastic packaging waste has specific recycling targets – in the Packaging and Packaging Waste Directive: 50 % by 2025 and 55 % by 2030 (European Commission., 2018d). There are also specific collection targets for polyethylene terephthalate (PET) beverage bottles in the Single-Use Plastics (SUP) Directive (2019/904/EC) of 77 % (European Commission., 2019). The other waste directives specify targets for whole waste streams: targets for recycling municipal solid waste (MSW) and construction and demolition waste (C&DW) are set in the WFD, targets for recycling waste electrical and electronic equipment (WEEE) in the WEEE Directive (2012/19/EU) and for end-of-life vehicles (ELVs) in the ELV Directive (2000/53/EC) (European Commission., 2018b, 2018c; European Commission, 2000). The agriculture; houseware, leisure and sports; and other categories (Figure 1.1) have no specific recycling targets. The houseware, leisure and sports, as well as other categories make up for the majority of the non-packaging plastic fraction of MSW (Fråne et al., 2014). To further boost recycling, the 2nd Circular Economy Action Plan (CEAP) has an objective of halving the amount of non-recycled municipal waste by 2030 (European Commission., 2020) while the Landfill Directive presents a target of landfilling a maximum of 10 % of total generated MSW in 2035 (European Commission., 2018a).

The 2nd CEAP calls for the use of secondary materials in products. Its key target is to enhance circularity by supporting the creation of a well-functioning market for secondary raw materials to increase demand for them and ensure the smooth expansion of the recycling sector in the EU. Action to support this include introducing requirements for the recycled content in products and developing EU-wide end-of-waste criteria for certain waste streams. The Action Plan also aims to reduce waste exports and address the EU's overdependence on foreign waste treatment, mobilise the recycling industry to increase its capacity and add value to waste in the EU (European Commission., 2020). So far, binding targets for recycled content have been presented only for packaging, SUP Directive states that PET beverage bottles should include at least 25 % recycled content by 2025 and 30 % by 2030 (European Commission., 2019).

The EU's 1st CEAP had already defined closing the material loops and promoting a CE for plastics as a priority area (European Commission., 2015). Following up on this, in 2018, the Commission adopted the European Strategy for Plastics in a Circular Economy. This aims to support more sustainable and safer consumption and production patterns for plastics by transforming the way plastic products are designed, produced, used and recycled in the EU. A key objective is to improve the recyclability of plastics through upscaling recycling capacity and phasing out poorly sortable plastics and substances that hamper the recycling process, as well as by increasing demand for recycled plastic content through supporting the market for secondary plastics. In total, the Strategy aims to increase European sorting and recycling capacity fourfold between 2015 and 2030, and to increase the demand for recycled plastics fourfold by supporting the market for secondary plastics (European Commission, 2018).

The Circular Plastics Alliance (CPA), a voluntary pledge by the European plastics industry, associated industries and stakeholders, aims to facilitate reaching the Plastic Strategy's targets through a market uptake of 10 million tonnes (Mt) of secondary plastics by 2025 (European Commission, 2022).

Plastic circularity policies mainly focus on waste and recycling, with non-binding targets for the uptake of secondary raw materials. There are significant differences in policies between packaging and non-packaging plastics, with significantly stronger ones for packaging. There are material-specific recycling targets and reporting obligations for packaging that, in most EU Member States, are enforced through extended producer responsibility (EPR) schemes with reporting obligations on materials put on market, and waste collection and treatment. There are also differences between non-packaging plastic sectors: the automotive and electronics sectors have EPR schemes mandated in the respective directives but without material-specific recycling targets (European Commission., 2018c; European Commission, 2000). The construction sector has recycling targets which are also not material specific. The household, leisure and sports sectors lack policy except for general recycling targets for MSW.

3 Non-packaging plastics

3.1 Characteristics of non-packaging plastics

Plastics are a group of materials with similar characteristics but in policies plastics are considered one material stream. Plastics are a wide group of materials, each made up of one or polymers, and modified with different additives. Plastics are materials that, on one hand, are very diverse, but on the other, show very similar characteristics. This makes for some challenges in recycling as different polymers cannot be segregated at source due to the vast number of polymers in use, the similarity of different plastics and the general consumers' inability to distinguish between them. Thus, plastics are collected as a mixed stream, often together with other materials. The heterogeneous nature of collected plastic waste creates recycling challenges, resulting in inferior quality secondary raw material relative to virgin polymers.

Packaging plastics are commonly produced for short lifespans, possibly with ecodesign/design for recyclability having been taken into consideration. Non-packaging products are designed for longer lifespans, with the focus of their design being on functionality, durability and weight. Therefore, materials of non-packaging products tend to be more complex than packaging materials. The complexity of materials – their multilayers, attached materials, reinforcements and complex structures – significantly hinders the circularity of the non-packaging plastics sector.

Some plastic products, mainly in the electronics, automotive and construction sectors, can contain hazardous substances such as flame retardants. The regulatory framework in the EU has set limits for a number of hazardous substances, preventing their recycling. Limits are set in product regulations, such as the Restriction of Hazardous Substances (RoHS) Directive, ELV Directive, and the Persistent Organic Pollutants (POPs) Regulation.

Non-packaging plastics are not one group of products, but rather a variety, from cars that are significant long-term investments, to cheap, single use items, such as diapers and toothpicks. Some non-packaging product categories, including those used in the automotive and electronics sectors, are somewhat uniform products with relatively similar applications, but the household, leisure, sports and others categories contain a very diverse range of products. Challenges related to the management of non-packaging plastics accumulate in these categories, which form an unknown stream of plastics through society.

3.2 Plastics commonly used for non-packaging applications

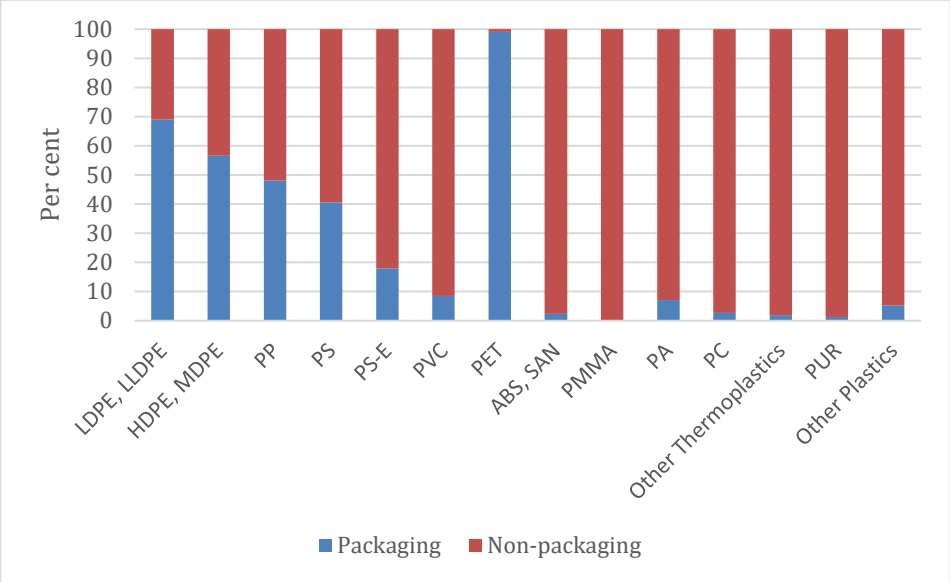
Non-packaging plastic include commodity plastics – polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyvinyl chloride (PVC) – as well as a wide range of special engineering plastics. These have better mechanical and/or thermal properties than commodity plastics. Examples include polymers such as acrylonitrile butadiene styrene (ABS), polyamide (PA), polycarbonate (PC) and polymethyl methacrylate (PMMA). Engineering plastics are used for low-volume applications such as mechanical parts and often replace metal, glass or ceramics.

Fibre-reinforced plastics are also widely used in non-packaging applications. These are composite materials; common reinforcement fibres are glass, carbon, aromatic polyamide (aramid), and basalt. Fibre-reinforced plastics are commonly used in the aerospace, automotive, marine, and construction industries. Fibre-reinforced plastics are difficult to recycle while self-reinforced plastics, also known as single-polymer composites, for example, self-reinforced PP, have better recyclability due to their relative homogeneity.

Non-packaging sectors dominate the demand by converters ([1]) for all major polymers except for PE and PET, which are dominant in the packaging sector (Figure 3.1). The demand of different polymers in the non-packaging sectors range from more than 5 Mt of PP to just 40 000 tonnes of PET (Figure 3.2).

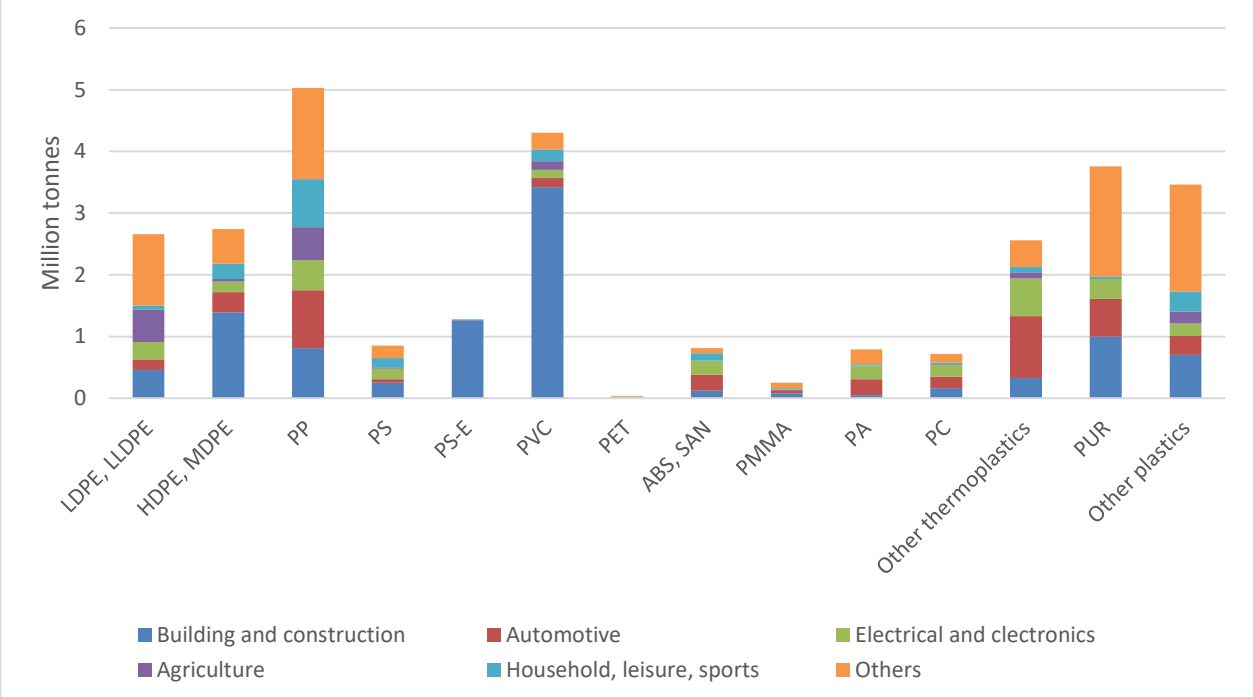
[1] Converters are companies that specialise in modifying or combining raw materials to create new products.

Figure 3.1 Polymer demand for packaging and non-packaging, EU-27+3 2020, per cent



Source: (Plastics Europe, 2022)

Figure 2.2 Polymer demand by converters per polymer and sector, EU-27+3, 2020, million tonnes



Source: (Plastics Europe, 2022)

Low- and linear low-density polyethylene

Low-density polyethylene (LDPE) is a thermoplastic made from the monomer ethylene that is widely used for packaging and similar applications, such as various films and containers. Its most common use is in single-use and reusable plastic bags. Linear low-density polyethylene (LLDPE) is recycled LDPE, differing structurally from LDPE because of the absence of long-chain branching and the presence of legacy impurities. Together LDPE and LLDPE make up 17.4 % of the polymer demand by converters in Europe in 2020, 8.75 Mt in total (Plastics Europe, 2021). The converters demand can be indicative of how the use of LDPE and LLDPE is distributed along the sectors: packaging, 69 %; agriculture, 6 %; building and construction, 5 %; electrical and electronics, 3 %; automotive, 2 %; household, leisure and sports, 1 %; and

others, 14 % (Plastics Europe, 2022). LDPE is mechanically recyclable by being ground into flakes and then granulated.

High- and medium-density polyethylene

High-density polyethylene (HDPE) is also a thermoplastic produced from ethylene. It is widely used for packaging and similar applications, such as food and personal hygiene bottles, pipes, houseware and toys. Medium-density polyethylene (MDPE), which is less common than HDPE, is more flexible and has better cracking resistance properties. It is commonly used for packaging and similar applications, such as pipes, films and containers. Together, HDPE and MDPE make up 12.9 % of polymer demand by converters in Europe in 2020, 6.32 Mt in total (Plastics Europe, 2021). The converters demand can be indicative of how the use of HDPE and MDPE is distributed among the sectors: packaging, 57 %; building and construction, 22 %; automotive, 5 %; household, leisure and sports, 4 %; electrical and electronics, 3 %; agriculture, 1 %; and others, 9 % (Plastics Europe, 2022). Both HDPE and MDPE are mechanically recyclable by being ground into flakes and then granulated.

Polypropylene

Polypropylene (PP) is a thermoplastic of the polyolefin family with properties similar to PE, but slightly harder and more heat resistant. It is inexpensive to produce and has high corrosion, abrasion and impact resistance. As a result, PP is widely used for food packaging, bottle caps, reusable containers and plant pots. It makes up 20 % of the plastics demand by converters in Europe in 2020, 9.7 Mt in total, and is the second-most widely produced commodity plastic, after PE (Plastics Europe, 2021). The converters demand can be indicative of how the use of HDPE and MDPE is distributed along the sectors: packaging, 48 %; automotive, 10 %; building and construction, 8 %; household, leisure and sports, 8 %; electrical and electronics, 5 %; agriculture, 5 %; and others, 15 % (Plastics Europe, 2022). It is mechanically recyclable by being ground into flakes and then granulated.

Polystyrene

Polystyrene (PS), a hard and brittle plastic is commonly used in its rigid form, as expandable polystyrene (PS-E), expanded polystyrene (EPS), extruded polystyrene (XPS), and as a blend with rubber to form high-impact polystyrene (HIPS). It is an inexpensive resin and accounts for 6 % of polymer demand by converters in Europe in 2020, 2.98 Mt in total (Plastics Europe, 2022). It is commonly used in dairy packaging, compact disc (CD) boxes, containers and lids, bottles, trays, and disposable cutlery. EPS is primarily used in insulation boards, fish boxes, food takeaway boxes and protective packaging. HIPS is frequently used in casings of electrical and electronic equipment (EEE). The converters demand can be indicative of how the use of PS and PS-E is distributed along the sectors: building and construction, 51 %; packaging, 29 %; electrical and electronics, 6 %; household, leisure and sports, 5 %; automotive, 2 %; agriculture, 1 %; and others, 7 % (Plastics Europe, 2022). Polystyrene is mechanically recyclable by being ground into flakes and then granulated.

Polyvinyl chloride

Polyvinyl chloride (PVC) comes in two basic forms: rigid and, with the addition of plasticisers, flexible. Rigid PVC is used in construction for pipes and in profile applications, such as doors and windows. It is also used for plastic bottles, non-food packaging and plastic cards – bank or membership cards. Flexible PVC is used in plumbing, cables, inflatable products, imitation leather, flooring, and many applications in which it replaces rubber. It accounts for 10 % of the plastics demand by converters in Europe, 4.7 Mt in total in 2020 (Plastics Europe, 2021). The converters' demand can be indicative of how the use of PVC is distributed across sectors: building and construction, 73 %; packaging, 9 %; household, leisure and sports, 4 %; automotive, 3 %; electrical and electronics, 3 %, agriculture, 3 %; and others, 6 % (Plastics Europe, 2022). Recycling is limited due to the presence of chlorine and some additives such as cadmium and lead.

Polyethylene terephthalate

Polyethylene terephthalate (PET) is a thermoplastic of the polyester family, mainly used in fibres for clothing, and containers for liquids and foods. It is clear, tough, solvent resistant and highly recyclable. It

accounts for 8 % of the plastics demand by converters in Europe, 1.43 Mt in total in 2020 (Plastics Europe, 2021). Excluding its use in polyester in the textile industry, PET is mainly used in packaging – only 1 % of PET use is for non-packaging applications (Plastics Europe, 2022).

Acrylonitrile butadiene styrene and styrene acrylonitrile resin

Acrylonitrile butadiene styrene (ABS), a copolymer of styrene, acrylonitrile and butadiene, is currently the most-consumed engineering plastic, used for, amongst others, car bumpers, dashboard trims and Lego. Styrene acrylonitrile resin (SAN) is a copolymer of styrene and acrylonitrile. They are widely used in place of polystyrene owing to their greater thermal resistance; ABS is also harder, more rigid has improved chemical and fatigue resistance. Together, ABS and SAN account for less than 2 % of plastics demand by converters in Europe, 0.83 Mt in total in 2020 (Plastics Europe, 2021). The converters' demand can be indicative of how the use of ABS and SAN is distributed across sectors: automotive, 31 %; electrical and electronics, 28 %; building and construction, 14 %; household, leisure and sports; 14 %; packaging, 2 %; and others, 10 % (Plastics Europe, 2022). Since ABS and SAN are thermoplastics, they can be recycled mechanically but small waste volumes have hindered large-scale recycling.

Polymethyl methacrylate

Polymethyl methacrylate (PMMA), also known as acrylic glass and plexiglass, is used as a lightweight or shatter-resistant alternative to glass, for example in taillights and protective shields. It accounts for less than 1 % of plastics demand by converters in Europe, 0.26 Mt in total in 2020 (Plastics Europe, 2021). The converters demand can be indicative of how the use of PMMA is distributed across sectors: building and construction, 32 %; automotive, 20 %; household, leisure and sports, 8 %; electrical and electronics, 4 %; and others, 36 % (Plastics Europe, 2022). Since PMMA is a thermoplastic, it can be recycled mechanically but its small waste volumes have hindered large-scale recycling.

Polyamide

Polyamide (PA), also known as nylon, is strong and light, highly abrasion resistant and elastic.
Its major applications include consumer electronics; the automotive industry; packaging; skis and ski boots; and waterproof textiles, such as for umbrellas and raincoats. Polyamide makes up for 2 % of plastics demand by converters in Europe, 0.85 Mt in total in 2020 (Plastics Europe, 2021). The converters demand can be indicative of how the use of PA is distributed across sectors: automotive, 31 %; electrical and electronics, 26 %; building and construction, 6 %; household, leisure and sports, 2 %; and others, 28 % (Plastics Europe, 2022). Since PA is a thermoplastic, it can be recycled mechanically but its small waste volumes have hindered large-scale recycling.

Polycarbonate

Polycarbonates (PCs) are a group of polymers with carbonate groups in their structure. They are durable, high impact-resistant materials that can be easily moulded and thermoformed. However, PCs have low scratch resistance and often need coating. They are generally similar to PMMA, but are stronger and more heat resistant. Polycarbonates are found in many applications, mainly in the construction, automotive and electronics sectors, but also in myriad of smaller applications. They account for 1.5 % of plastics demand by converters in Europe, 0.73 Mt in total in 2020 (Plastics Europe, 2021). The converters demand can be indicative of how the use of PC is distributed across sectors: automotive, 26 %; electrical and electronics, 26 %; building and construction, 22 %; household, leisure, and sports, 4 %; packaging, 3 %; agriculture, 1 %; and others, 19 % (Plastics Europe, 2022). Since PCs are thermoplastic, they can be recycled mechanically but small waste volumes have hindered large scale recycling.

Polyurethane

Polyurethane (PUR) is a class of polymers, made from a wide range of starting materials joined by urethane links. This chemical variety produces materials with different characteristics and applications, such as rigid and flexible foams, varnishes and coatings, adhesives, and fibres such as Spandex and polyurethane laminate (PUL), a soft, flexible, hardwearing and waterproof fabric.

Polyurethane accounts for 8 % of plastics demand by converters in Europe, 3.81 Mt in total in 2020 (Plastics Europe, 2021). The converters demand can be indicative of how the use of PUR is distributed across sectors: building and construction, 26 %; automotive, 16 %; electrical and electronics, 8 %; household, leisure and sports, 1 %; packaging, 1 %; others, 47 % (Plastics Europe, 2022). Recycling is limited due to the thermoset characteristics of PUR, meaning it has an irreversible structure and cannot be mechanically recycled by melting and extruding. It can, however, be chemically recycled and downcycled.

3.3 Material flows and data availability

This section presents an overview of the material flows of non-packaging plastics in Europe. It discusses where major knowledge and data gaps are, as well as what new knowledge is needed to form a better view on the non-packaging plastics material flows in Europe which could promote circularity in the sector.

Circular economy action aims to take commodity and product management strategies to a higher level, with the goal of better protecting the environment from the detrimental effects of resource extraction, production and waste treatment. Recent global events, including the COVID pandemic and Russia's invasion of Ukraine, have demonstrated the critical importance of managing materials more sustainably so that resources are used to their maximum and the EU becomes less dependent on imports.

In terms of plastics, the shift from sustainable waste management, diverting waste from disposal to recycling (waste-push), to sustainable resource management promoting the production of resources, for which there is a market (market-pull), is providing a double benefit. While the waste-push promotes a shift of waste treatment from disposal and incineration to low value recycling, the market-pull effect is driving industry to produce higher value secondary materials from waste. Along the value chain, industrial partnerships, such as Process4Planet (P4P) and the Circular Plastics Alliance (CPA), are being built in Europe to help achieve more circularity and overall climate neutrality while enhancing global competitiveness.

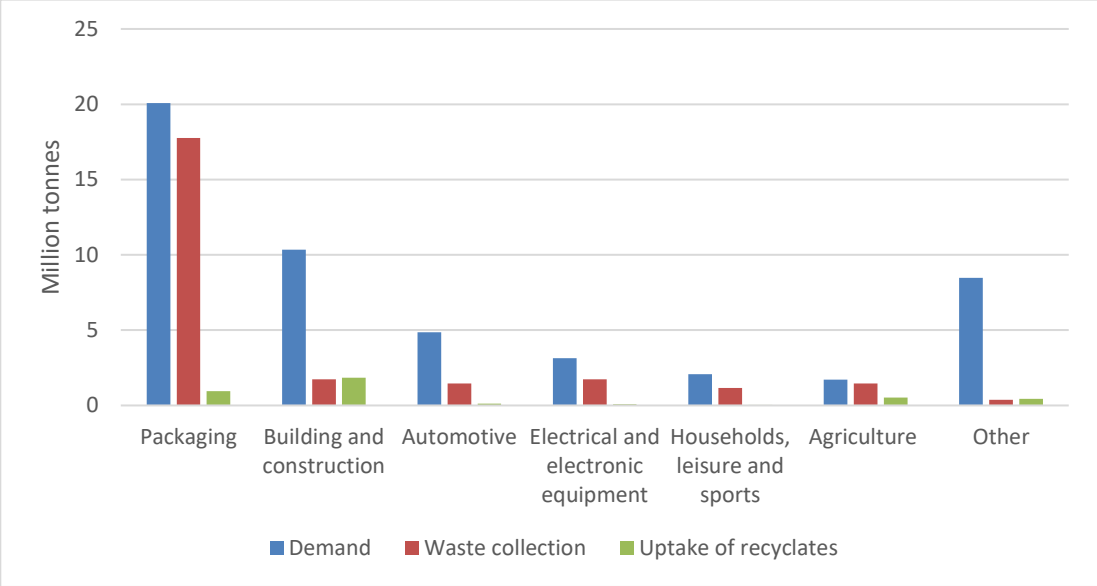
In comparison to plastic packaging material flows, those for non-packaging plastic are poorly documented. The plastic packaging and packaging waste flows in the EU are well-documented in several Member States due to reporting obligations and clear recycling targets within the Packaging and Packaging Waste Directive (PPWD). Plastic packaging and packaging waste data statistics are published by Eurostat (Eurostat, 2022b).

The automotive and electronics sectors also have EPRs mandated in the ELV Directive and the WEEE Directive (European Commission., 2018c; European Commission, 2000). These Directives do not, however, lay down material-specific recycling targets and producers do not have the same reporting obligations for the plastic content of products they put on market. As a result, this data are not collected, but it is likely that manufacturers do have details of plastic volumes used for each product category. The other sectors (construction, and household, leisure and sports, other) also do not have material-specific recycling targets or reporting obligations, so there is little knowledge about their plastic waste generation and treatment.

Although the non-packaging sectors account for 60 % of Europe's total plastics demand, they have a limited contribution when it comes to waste collection and recycling. All the sectors, however, particularly construction, are relevant outlets for recycled plastic packaging waste.

Figure 3.3 presents the demand for virgin raw plastic materials from European converters, generated waste and uptake of recyclates in the packaging and the main non-packaging sectors.

Figure 3.3 Mass flow of plastics: demand (2019), waste collected (2018) and uptake of recyclates (2019), EU27+3, million tonnes



Source: (Plastics Europe, 2020a, 2019)

3.3.1 Plastic demand and use

This section presents information and available data on plastics currently in use and put on the market annually, both at the EU and national level in a few EU Member States. Due to the existing data scarcity, this section also briefly presents potential options for estimating the amount of non-packaging plastics which is used in Europe.

Overview at the EU level

Modelling done by Material Economics indicates that there are around 550 Mt of plastic in use in the EU, the so called 'plastic in stock'. This represents approximately 28 % of the total of 2 billion tonnes ([2]) of plastics used in Europe since the 1950s. The rest has become plastic waste. Material Economics also estimates that the stock of plastic is growing every year by 8–10 Mt (Material Economics, 2022).

According to the plastics industry association, Plastics Europe, the annual demand for virgin plastic polymers is relatively stable at around 50 Mt. Data presented in the annual publication *Plastics- the Facts* show that the demand from European convertors was 49 Mt in 2015, 49.9 Mt in 2016, 51.2 Mt in 2017, 51.2 Mt in 2018, 50.7 Mt in 2019 and 49.1 Mt in 2020. Data presented by Plastics Europe is limited to raw material demand by European converters. Despite this, it is sometimes cited as total consumption of plastic products in Europe.
The total EU plastics conversion demand and the EU plastics consumption are reported to be similar, respectively 53.9 Mt versus 53.6 MT in 2020 for EU27+3 ([3]). The EU(27+3) is a net importer of plastic products and components, mainly for EEE, automotive, houseware, leisure and sports, while being a net exporter for packaging. (Plastics Europe, 2020b)

Data presented by Plastics Europe originate from European and national authorities and sector organisations. Plastics Europe's Market Research and Statistics Group (PEMRG) also provided input on the production of and demand for plastic raw materials and 250 interviews conducted with plastic converters in several European countries. Furthermore, estimates of plastic waste within mixed waste streams is included in the waste generation estimates (Plastics Europe, 2019).(Plastics Europe, 2019)

[2] Billion = 10^9

[3] EU27+3 is the EU plus Norway, Switzerland and the United Kingdom

The Plastics Europe data set is the go-to one for policy making in the EU and globally. It is cited by, among others, the European Commission (Villanueva et al., 2014; European Commission, 2018), the United Nations Environment Programme (UNEP) (UNEP, 2021) and the Ellen MacArthur Foundation (World Economic Forum et al., 2016). In scientific literature, the reliance on Plastic Europe data is as strong as it is in policy making. Out of 20 peer-reviewed scientific articles and policy strategies (Appendix 1), 17 cited Plastics Europe's data directly and three indirectly through other publications that uses Plastics Europe data.

According to Plastics Europe, in 2020, out of the total demand for virgin plastic polymers 40.5 % was used to manufacture packaging, while the remainder was used to manufacture products – 20.4 % by the building and construction sector; 8.8 % by the automotive sector; 6.2 % by the electrical and electronics sector; 4.3 % by the households, leisure and sports sector; and 3.2 % in agriculture. Other uses such plastics for furniture, medical applications, machinery and mechanical engineering, technical parts accounted for 16.6 % of the total demand for raw plastic materials (Plastics Europe, 2021). The figures presented by Plastics Europe do not differentiate between product categories within these end-use markets.

Besides data presented by Plastics Europe, there is very little information and knowledge regarding non-packaging plastic used by European business, industry and private consumers. Trade and production statistics can provide an indication of the total consumption of plastic in Europe, even if these contain major uncertainties. Imports, exports and the consumption of different goods can be tracked using databases such as Prodcom and Comext, which are managed by Eurostat (Eurostat, 2017). This requires a detailed review of all the product categories and will build on estimates of the amount of plastic used in each product category.

Some scientific papers have done this and used the data to analyses of plastic flows in Europe. (Hsu et al., 2021) estimate that the total plastic consumption in the EU generated by the use of plastic products and plastic-containing products is around 73 Mt in 2016. Of this, packaging accounted for 26 %; construction 17 %; transport 14 %; electric and electronic equipment 8 %; textiles 6 %; health care 2 %; paints and varnishes 2 %; and the general category 'other' the remaining 25 %. This last category includes brooms and brushes, diapers, footwear, furniture, goggles, luggage, personal care and cosmetic products, personal safety equipment, sports equipment, sunglasses, tampons and toys.

Status at national level

There are a few examples of European countries which have undertaken the mapping of plastic flows and plastic waste flows at a national level – Denmark (The Danish Environmental Protection Agency, 2019), Sweden (The Swedish Environmental Protection Agency, 2022), Germany (Conversio, 2020), The Netherlands (CE Delft, 2021) and Switzerland (Klotz and Haupt, 2022) ([4]) (Appendix 2).

These studies include packaging and non-packaging plastic flows. The methods used include material flow analyses using trade and production data from national statistics offices and EPR organisations. In some of the countries the studies even include estimates of plastic consumption as well as information from interviews with experts and industry representatives.

These estimates suggest that, of total annual plastic consumption, non-packaging plastic made up 62 % in Switzerland, 63 % in Sweden, 72 % in the Netherlands and 74 % in Germany.
The study in Denmark does not provide information on consumers' plastic use.

The existence of these national studies indicates that there is interest among the European countries in understanding their total plastic material use and to follow its evolution over time. It could therefore be

[4] This is not an exhaustive list and there may be other countries for which similar studies exist.

relevant to develop a harmonised mapping method at the European level, which would also contribute to increasing data availability.

3.3.2 Waste and recycling

The amount of plastic waste generated in Europe every year is influenced by how plastic materials are used and product lifespans. The distribution of plastic waste generation is somewhat different from plastic consumption, as lifespans vary greatly between different product categories – from 0.5 years for packaging to more than 35 years for plastic used in construction (OECD, 2022). Thus, the plastic stock is growing in many sectors as the products reaching their end of life originate from a time of less extensive plastics use.

Availability of data regarding non-packaging plastic waste is rather poor. Eurostat reports data on separately treated plastic waste, extracted either from separate collection or post-collection sorting. Numbers from Eurostat ([5]) indicate plastic waste generation volumes of 17.23 Mt for the EU27 (Eurostat, 2022; 2022a; 2022b). Furthermore, Eurostat reports recycling volumes for all post-consumer plastic waste collected of 10.97 Mt in 2018 (Eurostat, 2022). Packaging represents a major part of these numbers.

Plastics Europe also reports data on plastic waste collection in separated streams and mixed streams. Their published data on total plastic waste collection of 29.1 Mt, of which 61 %, 17.75 Mt, was from the packaging sector; building and construction accounted for 6 %, 1.75 Mt; electrical and electronics 6 %, 1.75 Mt; automotive 5 %, 1.45 Mt; agriculture 5 %, 1.45 Mt; houseware, leisure and sports 4 %, 1.16 Mt; and others 13 %, 3.8 Mt in 2018 (Plastics Europe, 2019).

The difference between Eurostat and Plastics Europe's datasets is related to methodology. While Eurostat only reports separately collected and reported volumes, Plastics Europe accounts for plastics in the residual streams as well. Both, however, indicate losses of plastic, either because of a significant increase in stocks or poor data on waste generation not capturing all generated plastic waste. A study by Material Economics (2022) estimates that the total amount of plastic waste annually generated in the EU27+3 is 45 Mt. The same study estimates that only about 15 % of the plastic waste generated each year is recycled into new products, the rest being incinerated or landfilled (Material Economics, 2022).

Non-packaging plastic makes up 60 % of converters' plastic demand, but yet only around 40 % of collected plastic waste comes from non-packaging sources (Plastics Europe, 2020a). This relates to packaging having a shorter lifespan than many other product categories, and there being more efficient collection systems for plastic packaging. Many EU Member States have separate collections for plastic packaging waste and the PPWD sets binding recycling targets for its recycling.

Of all plastic waste recycling, packaging waste accounts for 80 % ([6]) (Plastics Europe, 2020a). Of the total collected post-consumer plastic waste, 48 % is separately collected and 52 % is collected in mixed streams. Recycling rates are higher for separately collected waste than for mixed collection (Plastics Europe, 2019):

- of the separately collected plastic waste, 62 % is recycled
- of the plastic waste collected in mixed streams, 6 % is recycled.

Of 29.5 Mt post-consumer plastic waste collected in 2020, it is reported that 34.6 % is sent to recycling, 42 % to energy recovery and 23.4 % to landfill (Plastics Europe, 2021). The plastic waste that is generated but not collected, almost 20 Mt in 2020, is lost in mixed wastes and though littering. Kawecki et al. (2018) estimates that 1.15–12.7 Mt of plastic waste ends up in the marine environment each year.

[5] [env_wasgen]dataset, hazardous and non-hazardous plastic waste from all NACE activities plus households

[6] In 2018, total plastic waste collected in EU27+3 is 29.1 Mt, of which 32.5%, 9.5 Mt, is sent to recycling. Collected plastic packaging waste is 17.8 Mt, of which almost 42 %, 7.5 Mt is sent to recycling. Of the total of 9.5 Mt recycled plastics, almost 80 % is packaging plastics (Plastics Europe, 2020a)

In the absence of waste data ([7]), packaging put on market is often used as a basis for waste reporting in the packaging sector, although many EU Member States use other sources as well to adjust data for *de minimis* rules and imports. The automotive, building and electronics sectors also have targets and reporting obligations related to waste collection and treatment, which is why some data are available for these sectors. There is, however, no mandatory data reporting on the fate of specific materials in these waste streams, but case studies shed some light on the plastic content of these. For the other sectors, there are no sector specific targets or reporting obligations, and no data on plastic use or waste generation.

Major data gaps within the data on plastic waste can be identified for all non-packaging sectors. Sectoral plastic waste-collection data are not available in official Eurostat statistics, although Plastic Europe presents sectoral divisions (Plastics Europe, 2019). However, data on plastics in specific waste streams are not available, nor are data on polymer distribution within plastic waste (Plastics Europe, 2019).

3.3.3 Uptake of recycled plastics

Although there is available information and data on the recycling of plastics, most are gathered from a waste perspective – the amount of waste collected, sent to recycling and recycled. When looking at plastic recycling from a material or CE perspective – the volume of secondary plastics produced and used as input for new products – the availability of data is much lower and what is actually happening with these secondary plastics is less transparent. The complexity and variety of different plastics in ever more products and applications makes it impossible to keep up with or have an overview of the use of individual plastics in the economy, especially within non-packaging sectors. Data are, therefore, often only, at best, available on an aggregated level.

Overall uptake of recycled plastics in EU

In 2018, about 11 Mt of EU post-consumer plastic waste was collected for recycling. (EUROSTAT, 2022)
This collected waste is then sorted, some of the sorted waste is recycled in the EU and the remainder exported outside of the EU, resulting around 43 % of the collected waste is transformed into recyclates in the EU ((Joint Research Centre (European Commission) et al., 2020). This corresponds to 4 Mt of plastic recyclates being used in new products in the EU (Plastics Europe, 2020a) out of a total demand from converters of about 50 Mt (Plastics Europe, 2019). The European Commission has estimated that 6 % of new plastic materials come from recycling (EC, 2018).

Linking origin and destination of plastic recyclates

About two thirds of all recycled plastic waste originates from packaging. (EUROSTAT, 2022)
Correspondingly, Plastics Europe reported that packaging contributes 61 % to all recyclates produced. (Plastics Europe, 2019)

In which product category plastic recyclates are actually being absorbed depends from the source consulted, as shown in

[7] Data on separate collection and treatment are reported to Eurostat but plastic packaging waste in other waste streams is not.

Table . It is clear, however, that the packaging, building and construction and ‘other’ product categories absorb the majority of recyclates, in contrast to the EEE and automotive categories.

Table 3.1 Uptake of EU recyclates by product category, per cent

	Deloitte report, 2017 (Deloitte Sustainability, 2017) ([8]) %	Plastics, the facts 2020 (Plastics Europe, 2020a) %	Joint Research Centre (European Commission et al., 2020) ([9]) %
Packaging	33	24	32
Agriculture	-	13	4
Building and construction	25	46	24
EEE	3	2	1
Automotive	7	3	3
Households, leisure and sports	-	1	37
Other	33	11	-

Note: percentages may not sum to 100 due to rounding.

A comparison with the respective plastic demand for these product categories (Table 3.1), demonstrates a recycled content of about 5 % for packaging and a recycled content of more than 5 % for agriculture, building and construction and houseware, leisure and sport combined with 'other'.

The difference between plastic recyclates production and absorption for the packaging sector indicates a low share of closed-loop recycling and implies a significant amount of plastic packaging recyclates going to other product categories.

Table 3.1 Penetration of EU recyclates compared to plastic demand by product category, per cent

	Plastics, the facts 2020 (Plastics Europe, 2020a) %	(Joint Research Centre (European Commission) et al., 2020) %	The Circular Economy for Plastics – A European Overview (Plastics Europe, 2020b) %
Packaging	5	5	7
Agriculture	33	7	23
Building and construction	18	8	17
EEE	3	1	3
Automotive	3	2	3
Households, leisure and sports + Other	5	12	3 4

Recently, the European Commission's Joint Research Centre (JRC) published a study on the origin and fate of recycled EU plastic waste to support the CPA in establishing a workplan on the design-for-recycling of plastic products, providing actual details on plastic recyclate production and absorption by sector. These results are summarized in Table 2.3.

The total recyclate production according to the JRC report of 3 854 kilotonnes (kt) ([10]) corresponds well to the 4 000 kt reported by Plastics Europe. Even more, the figures also confirm that the vast majority, more

[8] The scope of the Deloitte report is a selection of five large plastic-waste producing EU countries (France, Germany, Italy, Spain and the United Kingdom) which, together, represented about 70 % of total EU market.

[9] (Joint Research Centre (European Commission) et al., 2020) does not include all EU plastic volumes, but is limited to a list of priority plastic products and product groups deemed to have the greatest potential of contributing to the 10 Mt CPA target by 2025.

[10] 1 kilotonne = 1 000 tonnes

than 70 %, of recyclates originates from plastic packaging recycling, that packaging, construction and 'other' are the most relevant product categories for absorbing recyclates, and that the total recycled content is below 10 % for all product categories and ranges between 8 % for construction and 12 % for 'other' to 1% for EEE and 2 % for automotive.

Table 2.3 Plastic recyclate production and uptake by sector, 2014-2018, kilotonnes

			Agriculture	Packaging	EEE	Construction	Automotive	Other	TOTAL	
		Demand→	1741	20429	3174	10138	5069	10650	**51200**	% recyclate to own sector
		Recyclate uptake→	122	1074	21	795	105	1253	**3370**	
Origin	Waste	Recyclate production↓								
Agriculture	711	302	122	69	0	56	0	55	**302**	40%
Packaging	13848	2789	0	998	21	406	105	1175	**2706**	36%
EEE	630	72	NA	NA	NA	NA	NA	NA	NA	NA
Construction	1009	362	0	7	0	333	0	22	**362**	92%
Automotive	590	328	NA	NA	NA	NA	NA	NA	NA	NA
Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	
TOTAL	16787	3854	122	1074	21	795	105	1253	**3370**	
		% recycled content	**7%**	**5%**	**1%**	**8%**	**2%**	**12%**	**7%**	
		% closed loop recycling	**7%**	**5%**	**0%**	**3%**	**0%**	**0**	**0**	
		0	4%	32%	1%	24%	3%	37%	100%	

Note: 'Other' here includes households, leisure and sports.
Figures may not sum due to rounding.

Although the non-packaging product categories require about 60 % of demand from converters, they only contribute about 28 % to recyclate production. The major outlet for produced recyclates from non-packaging are the construction and 'other' categories. Almost all, 92 %, of the recyclates originating from the construction setor are used in new construction products again.

In line with the CPA goal of reaching 10 Mt of recycled content by 2025, a roadmap was published including how plastic waste producing and absorbing sectors could or should contribute to reaching the goal against a 2020 baseline of 6.3 Mt of recycling outputs of post-consumer waste origin . This roadmap allocates most of the potential, 2.75 Mt of the potential of 3.37 Mt to the packaging sector. Non-packaging sectors should contribute 0.62 Mt –0.29 Mt by the EEE sector, 0.05 Mt by construction, 0.06 Mt by automotive, 0.22 Mt by agriculture. This potential estimate does not only relate to the amount of plastic that is put on the market and not collected, but takes account of the potential for collection and additional sorting and recycling, including the corresponding cost. So, it actually looks for the most economic way of reaching the 10 Mt target. This information makes clear that the CPA commitment will mainly rely on additional collection and recycling of plastic packaging.

For the availability of data on plastics management in non-packaging sectors, all reports rely heavily on inputs from the plastics sector and hardly any data are available in national or European statistics. More differentiated numbers focussing on the production of recyclates as a starting point for making new products, rather than considering recyclates as a final outcome of waste management operations, could provide a starting point for getting better insights into the way plastics are managed and improve corresponding legislation to evolve to a CE.

3.3.4 Data needs for improved management of plastics

The term non-packaging plastics represents a more complex system than that of packaging due to the variety and complexity of the products involved. In addition, given that the volumes are significantly larger than that of packaging, there is a strong case for these plastics to be better controlled to increase the overall circularity of plastics in Europe.

There is currently a fundamental information gap on the overall magnitude of plastic consumption and plastic waste generation in Europe. The EU's plastic packaging material flow is fairly well documented through EPR systems and the reporting obligations associated with the recycling targets of the PPWD.

Significant amounts of plastics are, however, also used to produce the many items used in every aspect of household, commercial and institutional activities. In some instances, the entire product is composed of plastic(s), or, more often, plastics are embedded in products as part of a complex mix of constituent materials. Much of the debate on plastics demand in Europe is based on assumptions of usage that stem from the demand from Europe's plastic production industry.

There is a lack of detailed knowledge on the nature and extent of this material flow, which comprises not just articles produced in Europe but also the many imported products consumed in Europe.

The policy landscape for non-packaging plastics is less developed than that for plastic used in packaging. A direct consequence of this can be seen in the dearth of data regarding non-packaging plastics, but it is also evident in lower collection and recycling rates for plastic from non-packaging applications. Most EU Member States have EPR systems with reporting obligations for packaging put on market, waste collection and treatment. Producers of non-packaging plastics do not have similar material-specific waste reporting obligations, so data on the plastic content are lacking. Furthermore, the products are extremely diverse and the manufacturers numerous so there is little knowledge about plastic volumes put on the market or waste collected. Nonetheless, policies for improved circularity aim to increase the recycling of these waste streams.

Strong data give information on the current situation and provide the means to follow-up on progress, thus providing the base for supporting the development of recycling. In contrast, unreliable and/or missing data provide a weak foundation for effective policy making, and this is why data on non-packaging need improvement to allow for the development of policies to target these important material and waste streams.

Today packaging is regulated with a specific focus on the waste phase of the product value chain. Waste composition data, however, may not be the best approach for developing better data on non-packaging plastics, due to the heterogeneity in the types and lifespans of plastics in non-packaging applications. Rather, data on plastic content and volumes of products entering the European market might be the best means for understanding total plastic flows in Europe.

The pathways towards a sustainable and circular plastics system

Inspired by the work by Fogh Mortensen (et al., 2020) on overcoming challenges related to the plastic sector's dependence on fossil feedstock, insufficient waste management and littering, Fogh Mortensen et al. (2020) created a vision of three pathways that together could ensure a long-term move towards sustainable and circular plastics production and consumption system. The three pathways, which address different stages of the plastics value chain, as well as different environmental and climate impacts, are:

(i) *smarter use*;
(ii) *increased circularity*; and
(iii) *renewable materials*.

The data availability across the lifecycle stages of plastic use is very different: while data on production, provided annually by Plastics Europe, are detailed at a polymer level for converters' demand for virgin polymers, there is no information on the total use of plastics in Europe. Waste data is restricted to separately collected waste volumes and case studies on the composition of mixed waste streams, excluding a majority of plastics embedded in products.

Data availability will impact policy development for the three pathways. As the pathways represent a target for a sustainable plastics economy, they are not a given, but requires some steering if they are to be reached. Policy support for moving towards the vision of the three pathways requires better data for decision making.

- *Smarter use* of plastics is related to, for example prolonged lifetimes. Current data collection and circularity targets for plastics, however, have a significant focus on waste. To enable the transition

to smarter use, there is a need for the collection of data related to more than waste and recycling, and it also requires policies on production and consumption.

- *Increased circularity* is related to increasing recycling of plastic waste, as well as the uptake of recycled plastics in production. Today, there is a lack data on both consumption and waste management. Targets only related to European demand from converters excludes a significant share of the plastic flows in Europe. Better data can support a better understanding of plastic flows and enable realistic circularity targets for the production sector.
- *Renewable materials* is related to switching away from fossil feedstocks to renewable resources such as biomass. There is a lack of data on the flows of bio-based plastics consumed, as well as transparency into the types of polymers used and how much of a product is made of bioplastics as opposed to conventional plastics. Such data would improve the understanding of this small but growing segment of plastics, and also help waste managers in handling bio-based plastics.

The role of standards

Standardisation activities could support the transition to a CE by revising standards that limit the use of recycled materials by standardising the calculation of recycling content and rates, and subsequent labelling, and by focussing on quality criteria and test methods for recycled plastics. Standards could set protocols for best recycling and trading practices, and enable recyclers to demonstrate compliance with specific treatment operations. Standards could also facilitate the fulfilment of the requirements of the specific waste directives and compliance with quality requisites. The standards link to supporting specifications, which provide technical details, such as sampling protocols, analysis methodologies, etc. The diversity of plastic monomers and products makes this task both essential and challenging. The Technical Committee TC 249 of European Committee for Standardization (CEN), for example, comprises 13 different working groups, covering different aspects of plastic recycling. The use of standards is voluntary but laws and regulations in Member States may refer to standards.

The European Certification of Plastic Recyclers (EUCertPlast) standard focusses on traceability of plastic materials throughout the entire recycling process and supply chain, and on the quality of recycled content in the end product. The purpose is to increase the transparency of the European plastics industry, and to merge a variety of auditing schemes into one. This standard is setting a basis for best recycling and trading practices. The final goal is to create a transparent, efficient and harmonised recycling plastics industry. The certification scheme itself works according to the European Standard EN 15343:2007. EUCertPlast is one of the approved auditing schemes/systems to ensure compliance with the CPA auditing framework. Other approved audit schemes/systems are Recyclass, BQA-CE-CER, the Institute for the Promotion of Recycled Plastics (IPPR) Plastica Seconda Vita, Recovinyl and the Spanish Association for Standardization and Certification (AENOR) (GROW.I.3, 2022).

4 Key sectors for non-packaging plastic consumption

This section presents some key consumers of non-packaging plastics n the EU, namely the automotive, building and construction, agriculture, household, leisure and sports and 'other' categories. The description of each includes a discussion of their characteristics, their material flows for new products, waste generation and recycling volumes, and the relevant legislation, directives and targets.

A common denominator for many of the product categories is that they are not designed to optimise recycling at the end of their products' lives. They very often include a combination of different types of plastics or combinations of plastics and other materials such as textiles, paper and metals, as well as different additives, some of which are hazardous. This aspect hinders the recycling process and makes it very difficult to obtain a recycled plastic material which is desirable, since producers of high-value products demand plastic recyclate which include mono-polymers and is free of contaminants and hazardous substances. This means that impure recyclate, potentially including different additives, is used in applications which present no potential risk to the end-consumer such as equipment needed for traffic control and management.

This also contributes to the fact that the separate collection of plastic waste arising from these sectors is very limited. Since there is little demand for these plastic waste fractions from the recycling market, there are no incentives to collect them separately.

4.1 Automotive

Plastic represented around 15 % of total weight of cars in 2015 (Frost & Sullivan, 2021; David Schönmayr, 2017). As, however, the automotive sector is striving to develop lighter weight vehicles with reduced fuel consumption and emissions, the use of plastics is increasing (Cardamone et al., 2022; Frost & Sullivan, 2021). The share of plastic by weight in vehicles is predicted to rise to 20 % by 2030 (Frost & Sullivan, 2021). Cars produced today are, nonetheless, heavier than current ELVs. With rising ELV weights and escalating plastic contents, future ELV plastic streams are bound to increase.

On average, approximately 105 kg of a wide range of different polymers are used in a car. The use of plastics in vehicles are divided between exterior 21 %, under the bonnet 14.5 %, interior 52.5 % and electric/light 12 % (Plastics Europe, 2013). Plastics in automotive applications are mostly very heterogeneous, strong connected to other plastics and materials, and often contain hazardous additives, such as flame retardants, chlorinated hydrocarbons, polychlorinated biphenyl (PCB) and phthalates. The complexity and heterogeneity of the plastic waste stream makes the recycling of ELVs challenging.

A typical ELV is a car that was manufactured 15–20 years ago, when the polymer share used was different from new cars manufactured today. It is the different polymers used back then that need to be collected, sorted and treated today (Circular Plastics Alliance, 2020a).

4.1.1 Material flows

Production and consumption

Plastics Europe (2021) estimates the total plastics consumption of the automotive sector in 2021 was 4.34 Mt, excluding recycled raw materials, for EU27 plus Norway, Switzerland and the United Kingdom (Table 4.1).

Table 3.1 Converters' polymer demand from the automotive sector, EU27+3, kilotonnes and per cent (Plastics Europe, 2021)

Polymer	[kt]	%
LDPE and LLDPE	170	4 %
HDPE and MDPE	330	8 %
PP	940	22 %
PS	60	1 %
PS-E	10	<1 %
PVC	150	3 %
PET	0	0 %
ABS, SAN	260	6 %
PMMA	50	1 %
PA (PA6 and PA66)	260	6 %
PC	190	4 %
Other thermoplastics	1 000	23 %
PUR	610	14 %
Other plastics	310	7 %
Total	**4 340**	**100%**

Note: percentages may not sum due to rounding

Waste generation and management

Every year ELVs generate 5–7 Mt of waste in the EU27 – in 2019 the volume was 6.9 Mt. Since plastic represented 15 % of total weight of cars in 2015 (Frost & Sullivan, 2021; David Schönmayr, 2017) and is likely to reach 20 % by 2030 (Frost & Sullivan, 2021), plastic waste generation from ELVs in EU27 can be estimated to exceed 1 Mt in 2019. The CPA estimates that plastics waste collected from the automotive sector amount to 1.5 Mt annually (Circular Plastics Alliance, 2020a).

Due to the complexity and heterogenous characteristics of automotive plastics, they are difficult to recycle. Also, the presence of legacy substances often leads to downcycling as the only economically viable course of action. During depollution of an ELV, some car components, such as bumpers and fuel tanks, are dismantled prior to the demolition process, and therefore become available for reuse or recycling. Today, 15 % of ELV plastics are recycled (Circular Plastics Alliance, 2020a). Cardamone et al. (2022) estimate that 42 % of the ELV plastics can be sorted out from the post shredder residues (PSR) as PP and PE and sent to recycling. This share may well contain hazardous substances and must be treated accordingly.

In recycling ELVs, the main emphasis is on the recovery of ferrous and non-ferrous metals. The adjacent plastics are mainly used as fuel in the energy-intensive metal recovery processes. Plastic recovery by manual dismantling remains marginal because, although it allows the segregation of specific plastics, its productivity is strictly limited, its cost elevated, and its automation hampered by the diversity and composite structures of car components. (Buekens and Zhou, 2014).

Cardamone et al. (2022) estimates that 1.3 % of the ELV plastics is dismantled and recycled today, mainly bumpers, whereas 1.2 % that has been dismantled from the ELV is reused as spare parts. The CPA (2020a) estimates the dismantled plastic as 5–10 kg per car, mainly from bumpers although bumper dismantling from ELVs is an exception, not a general practice. Most used large automotive plastics parts that are reprocessed are derived from crash repair streams (Circular Plastics Alliance, 2020a).

In the Netherlands, the plastic volume separated for recycling in the dismantling process is 21 % (Leslie et al., 2013) as local demand for the recyclates has created an economic incentive for plastic separation (Circular Plastics Alliance, 2020a).

4.1.2 Legislation

The ELV Directive (2000/53/EC) ([11]) aims to make dismantling and recycling ELVs more environmentally friendly. It also sets quantified targets for reuse, recycling and recovery of ELVs and their components. As of 2015, the recycling and recovery targets specified in the Directive are 85 % recycling and 95 % recovery by average weight per vehicle and year. The Directive also sets a requirement for the collection of all ELVs at authorised treatment facilities.

In the EU, EPR schemes is mandatory under the ELV Directive, which puts the responsibility for the financing of collection, recycling and end-of-life disposal of vehicles on the producers. The EPR obligates the produces to arrange for collection and treatment of the ELVs, but it also allows for the producer to, for example, join a collective system to take back ELVs. The collection system needs to have adequate coverage and should be at no cost to the last owner.

The ELV Directive covers also the production of vehicles, including their components and materials, to encourage producers to manufacture new vehicles without hazardous substances, thus promoting the reuse, recyclability and recovery of ELVs. Furthermore, it also promotes the integration of an increasing quantity of recycled material in vehicles and other products, to develop the markets for secondary materials.

4.2 Electronics

The main material components in electronics are metals and plastics, and their material composition in general can be characterised as complex. The plastics fraction is a heterogeneous mix of different polymers, and may contain hazardous substances and heavy metals, such as cadmium, chromium (VI), lead, phthalates and brominated flame retardants. (Stenmarck et al., 2017)

The converters demand can be indicative of the polymer distribution in the sectors, as illustrated in Table 4.2. The total demand for virgin polymers by European converters to manufacture plastic products and plastic-containing products for the electronics sector is 3 030 kt ((Table 4.2) (Plastics Europe, 2022).

Table 4.2 Converters' polymer demand from the electronics sector, EU27+3, kilotonnes and per cent (Plastics Europe, 2021)

Polymer	[kt]	%
LDPE and LLDPE	280	9 %
HDPE and MDPE	170	6 %
PP	490	16 %
PS	170	6 %
PS-E	0	0 %
PVC	130	4 %
PET	10	0 %
ABS, SAN	230	8 %
PMMA	10	0 %
PA (PA6 and PA66)	220	7 %
PC	190	6 %
Other thermoplastics	610	20 %
PUR	320	11 %
Other plastics	200	7 %
Total	**3 030**	**100 %**

[11] The ELV Directive is currently under revision

In 2018, 3 993 687 tonnes of WEEE were collected through formal channels in the EU27, of which 81 % was recycled; however, only 39 % of the EEE put on market was collected through official waste collection (Eurostat, 2022c).

The share of plastics vary by WEEE category; averages are given by given by New InnoNet of 22 % by weight (New InnoNet, 2016), supported by Slijkhuis giving an average plastic content of 10-30 % across the six WEEE categories ([12]) (Slijkhuis, C, 2015) and Cardamone giving an average of 20 % plastics in the total WEEE stream (Cardamone et al., 2021).
In 2016, 3 405 582 tonnes of WEEE were collected by the formal channels and treated in Europe; 717 000 tonnes of plastics flakes were obtained from this WEEE treatment and 560 000 tonnes of recycled plastics were produced from these flakes (Circular Plastics Alliance, 2020b)

4.2.1 Legislation

The RoHS Directive 2011/65/EU restricts the use of hazardous substances in EEE. The Directive requires the substitution of safer alternatives to certain hazardous substances as the WEEE has environmental and health risks if mismanaged at end of life.

The WEEE Directive (2012/19/EU) sets the basic concepts and definitions related to management of WEEE such as end-of-life computers, television sets, fridges and cell phones. The Directive aims to increase the recycling and reuse of WEEE and also to protect the environment and human health by preventing or reducing the generation of WEEE.

The recycling and recovery targets specified in the Directive are 55–80 % recycling and 75–85 % recovery ([13]). The Directive also sets quantitative requirements for the collection of WEEE, i.e., of 65 % collection of the average weight of EEE placed on the market in the three preceding years or, alternatively, 85 % of WEEE generated in that same year.

The Directive also promotes the creation of collection schemes through which consumers an return their WEEE free of charge, to increase the recycling and reuse. An EPR scheme is mandatory for EEE with the producer able to choose to fulfil this obligation either individually or by joining a collective scheme. An EPR scheme puts the responsibility for the financing of collection, recycling, and end-of-life disposal on the producers.

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[12] The six WEEE categories according to the European WEEE Registers Network are (i) temperature exchange equipment (TEE); (ii) screens, monitors and equipment containing screens having a surface greater than 100 cm; (iii) lamps; (iv) large equipment (any external dimension of more than 50 cm); (v) small equipment (no external dimension of more than 50 cm); and (vi) small information technology (IT) and telecommunication equipment (no external dimension of more than 50 cm).
Source: https://www.weee.nl/sites/all/files/media/ewrn_definition_6_categories_fin-3.pdf

[13] Minimum annual targets for recycling of the six categories in Annex III of the WEEE Directive are:

WEEE Category 1 (TEE) and Category 4 (Large equipment)
- 85 % recovery
- 80 % recycling and preparation for re-use

WEEE Category 2 (Monitors and equipment with large screens)
- 80 % recovery
- 70 % recycling and preparation for re-use

WEEE Category 3 (Lamps)
- 80 % recycling

WEEE Category 5 (Small equipment) and Category 6 (Small IT/computer/communications equipment)
- 75 % recovery
- 55 % recycling and preparation for re-use

4.3 Buildings and construction

The use of plastic materials and products in buildings and construction has increased in recent years. This is because plastic is a cheap and durable material which is light weight, impermeable and has hight heat insulation properties.

Many plastic products used in buildings and construction have a life span of 50 years or more. Plastics are used:

- as a part of the structure of a building, in roofing and as insulation, in piping and wiring, and windows;
- within a home, plastics are embedded in wallpapering, flooring as well as furniture.

The major plastic types used in this sector are:

- PVC – used in products such as window frames, pipes, flooring and wall coverings, roofing, cables, and swimming-pools;
- PE – also used in pipes and cable insulation, as well as building foil;
  PS – used extensively as wall insulation, as well as insulation foams in the bathrooms and kitchens. (Plastics Europe, 2012).

There is little information on how much plastic is in stock in the building sector in Europe and how much additional plastic is being embedded in buildings every year. The Swedish real estate company Vasacronan has mapped how much plastic has been used during the construction of one of their buildings called The Hub in Uppsala Science Park. The mapping indicates that 16 kg of plastic were used per square meter of the building's total gross area (Vasakronan, 2018).

4.3.1 Material flows

In total, around 10 Mt of virgin polymers were used by the European converters for the construction and building sector in 2021 (Plastics Europe, 2021) (Table 4.3).

Table 4.3 Converters' polymer demand from the building and construction sector, EU27+3, kilotonnes and per cent (Plastics Europe, 2021)

Polymer	[kt]	%
LDPE and LLDPE	460	5 %
HDPE and MDPE	1 390	14 %
PP	810	8 %
PS	250	2 %
PS-E	1 260	13 %
PVC	3 420	34 %
PET	0	0 %
ABS, SAN	120	1 %
PMMA	80	<1 %
PA (PA6 and PA66)	50	>0 %
PC	160	2 %
Other thermoplastics	330	3 %
PUR	1 000	10 %
Other plastics	700	7 %
Total	**10 030**	**100 %**

Note: percentages may not sum due to rounding

Plastics Europe estimates that there were around 1.76 Mt of post-consumer plastic construction waste arising in 2018. Of this, around 26 %, or 0.45 Mt, was sorted for recycling and 47.5 % or about 0.84 Mt were sent to energy recycling. About 0.46 Mt were sent to landfilling (Plastics Europe, 2018).

There are some inconsistencies in reporting from the Member States. A Deloitte report (BIO by Deloitte, 2017) commissioned by the European Commission found that there is a large variation in the methods applied in data reporting at the Member State level, which means that it is difficult to carry out a quantitative assessment of plastic construction waste arising per Member State based solely on this data. (Circular Plastics Alliance, 2020d).

4.3.2 Legislation

The Waste Framework Directive (2008/98/EC) sets the basic concepts and definitions related to management of construction and demolition waste. The WFD promotes selective demolition and site sorting to enable removal and safe handling of hazardous substances and facilitate re-use and high-quality recycling. Selective demolition facilitates the selective removal of materials, and the establishment of sorting systems for construction and demolition waste. The WFD sets a target of recycling 70 % by weight of non-hazardous construction and demolition waste. The European Commission will consider material specific targets for key streams by 2024. There is no EPR scheme for the construction sector.

4.4 Agriculture

Agricultural film is the key plastic demand for non-packaging plastics from the agricultural sector – it accounts for 74 % of all non-packaging plastic in the sector (FAO, 2021). Other non-packaging applications are nets for round bales and protectives nets, twines for horticulture and bales, and irrigation pipes (Circular Plastics Alliance, 2020c).

4.4.1 Material flows

The converters demand can be indicative of the polymer distribution in the sectors, as illustrated in Table 7. The total demand of virgin polymers by European converters to manufacture plastic products and plastic-containing products for the agricultural sector is 1 570 kt Table 4.4 (Plastics Europe, 2022).

Table 4.4 Converters' polymer demand from the agricultural sector, EU27+3, kilotonnes and per cent (Plastics Europe, 2021)

Polymer	[kt]	%
LDPE and LLDPE	530	34 %
HDPE and MDPE	40	3 %
PP	530	34 %
PS	20	1 %
PS-E	0	0 %
PVC	140	9 %
PET	10	<1 %
ABS, SAN	0	0 %
PMMA	0	0 %
PA (PA6 and PA66)	0	0 %
PC	10	<1 %
Other thermoplastics	100	6 %
PUR	0	0 %
Other plastics	190	12 %
Total	**1 570**	**100 %**

Note: percentages may not sum due to rounding

Agricultural plastic waste is generated in significantly higher volumes than the plastic put on market. The CPA estimates that annually 722 kt of agri-plastics are put on market, but that waste generation is 1 175 kt.

The difference relates to the soil and dirt that is attached to the waste, increasing the waste volumes (Hann et al., 2021). Recycling levels for agri-plastics are quite low, at 24 %; the low recycling rate is related to the dirt in the waste, as well as poor markets for secondary plastics from the agricultural sector (Hann et al., 2021).

4.4.2 Legislation

Agricultural waste is steered by the waste hierarchy of the WFD (2008/98/EC), which contains a non-binding requirement for separate collection and recycling in Article 11 (1). In addition, some European countries have an EPR scheme for agricultural plastics, including France, Germany, Ireland and Sweden (Hann et al., 2021).

4.5 Households, leisure and sports, and 'other'

Non-packaging plastics in the households, leisure and sports and 'other' categories are non-packaging, small and large plastic items, such as furniture, toys and sports equipment etc. (Fråne et al., 2014).

4.5.1 Material flows

The converters demand can be indicative of the polymer distribution in the sectors, as illustrated in Table 8. The total demand for virgin polymers by European converters to manufacture plastic products and plastic-containing products for the household, leisure and sports category is 2 100 kt, and for the 'others' category 8 180 kt (Figure 4.5) (Plastics Europe, 2022)

Table 4.5 Converters' polymer demand from the households, leisure and sports, and 'other' sectors, EU27+3, kilotonnes and per cent (Plastics Europe, 2021)

	Households, leisure and sport		Other	
Polymer	**[kt]**	**%**	**[kt]**	**%**
LDPE and LLDPE	60	3 %	1 160	14 %
HDPE and MDPE	250	12 %	560	7 %
PP	780	37 %	1 480	18 %
PS	150	7 %	200	2 %
PS-E	10	>0 %	0	0 %
PVC	190	9 %	270	3 %
PET	10	>0 %	10	>0 %
ABS, SAN	120	6 %	80	1 %
PMMA	20	1 %	90	1 %
PA (PA6 and PA66)	20	1 %	240	3 %
PC	30	1 %	140	2 %
Other thermoplastics	90	4 %	430	5 %
PUR	40	2 %	1 790	22 %
Other plastics	330	16 %	1 730	21 %
Total	**2 100**	**100 %**	**8 180**	**100 %**

Note: percentages may not sum due to rounding

The waste from the households, leisure and sports, and 'other' categories mainly end up in residual MSW. Today, 10–15 % of the residual MSW is plastics (zu Castell-Rüdenhausen et al., 2018) of which approximately 70 % is packaging, the remaining 30 % being non-packaging plastics, mainly from the households, leisure and sports, and 'other' categories (Fråne et al., 2014).

4.5.2 Legislation

The waste from the households, leisure and sports, and 'other' categories is collected as residual MSW, which falls under the WFD (2008/98/EC). The WFD sets binding targets for the recycling of MSW – 55 % by weight by 2025, 60 % by 2030 and 65 % by 2035; there are no material-specific targets for the non-packaging fractions of MSW.

5 Discussion and conclusion

This section presents five key messages from this analysis and the main conclusions.

Key message 1: Plastics play an essential role in modern society, but their inefficient use leads to significant impacts on the environment and climate.

Plastics are remarkable materials, which play an essential role in modern society. Their material characteristics are difficult to compete with and they contribute to increasing efficiency in many sectors. They contribute, for example, to increasing energy efficiency in the transport sector by enabling the development of lighter cars and planes. They are used in very simple applications such as kitchen utensils as well as in advanced applications such as protheses or 3D printing.

The majority of plastics are produced from fossil feedstock and their unsustainable production, consumption and end-of-life management have led to significant impacts on the environment and climate. It is estimated that every tonne of fossil virgin plastic produced and incinerated at the end of life produces 5 tonnes of carbon dioxide equivalent (CO_2-eq) (Material Economics, 2019)(Material Economics, 2019). Plastic is also leaking from the economy into environment and accumulates in terrestrial and marine ecosystems causing harm to their fauna and flora. In addition, micro- and nano-plastic can be found in many living organisms and researchers do not have a proper understating of the potential long-term effects of this pollution on human health or the natural environment.

Key message 2: Non-packaging applications represent the majority of European plastic consumption (up to 75% by recent estimates), but there are few policies or initiatives directly targeting plastic in non-packaging applications.

According to recent estimates at a European level, as much as 75 % of the total plastic consumed in Europe in one year is used in non-packaging applications (Hsu et al., 2021). Similarly, studies at a national level in some EU Member States indicate that non-packaging applications vary between 62–74 % of the total plastic consumption.

There are, however, relatively few policies and initiatives directly targeting plastic in non-packaging sectors, which has resulted in a lack of data on this plastic flow. In comparison, plastic packaging put on market in the EU is fairly well documented through EPR systems in several Member States due to reporting obligations for follow-up on achieving the recycling targets of the PPWD. Aggregated EU-level data on plastic packaging put on market and plastic packaging waste are published by Eurostat (Eurostat, 2022b).

There are no reporting obligations for plastic used in non-packaging applications. The automotive and electronics sectors have mandatory EPR systems initiated by the ELV Directive and the WEEE Directive. These directives do not, however, lay down material specific recycling targets (European Commission., 2018c; European Commission, 2000). It can, therefore, be concluded that the difference in data availability between packaging and non-packaging applications, such as electronics and automotive uses, is related to regulation and reporting obligations. Most probably, however, the manufacturers in, for example, the automotive, electronics and construction sectors have good insights into plastic volumes for each product category, which would be beneficial for policy making if made public available.

Key message 3: Recycling of non-packaging plastics presents additional challenges, due to factors such as mixed materials within complex products and the potential presence of hazardous additives.

Products which include a combination of plastics and different materials such as textiles, paper or metals are difficult to recycle. It is also difficult to recycle products which include different types of plastic. In addition, some plastic products also contain hazardous or toxic additives, such as flame retardants in electric and electronic equipment. These factors contribute to a very limited recycling rate of plastics from

non-packaging applications in Europe. Furthermore, non-packaging plastics include small quantities of several engineering plastics, for which, due to their small volumes spread across large volumes of other waste, there are no recycling systems in place although they are technically recyclable.

Most of the plastic recyclate on the market today comes from the recycling of plastic packaging waste. It is known that there is potential for increasing the recycling of plastic packaging waste but to reach the targets of the EU's Plastic Strategy, non-packaging recycling will need to increase. To achieve higher recycling rates, there is a need for stronger policy measures which set clear targets for design for recyclability of non-packaging applications, quotas for recycled content, separate collection of plastic waste and recycling.

Key message 4: Data on non-packaging plastic flows is limited at both national and EU levels. Some data are available on Europe's plastic industry, but the amount of plastic imported from outside EU27 as part of manufactured products is not known.

Data from the plastics industry provide some insights into demand volumes of virgin polymers by European converters to manufacture plastic products and plastic-containing products. There is, however, little information of the total consumption of plastic products by end users, which includes both goods produced in and imported to Europe.

There are major data gaps regarding the total volume of plastics embedded in products put on market in Europe. Even less is known about plastic in stocks, since data of the past plastics put on the market and removed from stocks in waste streams are even less documented. Some recent estimates indicate that there could be as much as 550 Mt of plastics in use at the moment out of the total of around 2 billion tonnes of plastics used in Europe since the 1950s.

Key message 5: Improved data could support better management of these materials by informing new policies to target non-packaging plastics, which in turn would help achieve Europe's circular plastic ambitions and reduce environmental impacts.

Plastic consumption is increasing in all sectors, but there is little information on current material streams. Plastic resources are being lost in the form of plastic waste which cannot be recycled back into the economy. Data availability facilitates forming an overview of current situation, follow-up on changes, and decision-making. To prepare for increasing volumes of plastics in the future, control of this material stream and building a more circular plastic economy, there is a need for more information on the current system and mass flows. Poor data provides a weak foundation for policy making to target this significant material stream and so support the transition to a circular plastics economy.

To support increasing circularity in the plastics sector, there is a need for improvements in the management system. With the significant data gaps of today, however, it is difficult to identifying improvement measures or assign responsibilities. So far, activities are mainly voluntary through industry pledges. These, however, build upon the current operational environment, whereas policy measures to encourage rapid change require a strong knowledge base.

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Appendix 2 Data at national level

Denmark
The study by the Danish Ministry of Environment is based on material flow analysis methodology. Its aim was to provide initial quantitative estimates of plastic flows in Denmark and is based exclusively on existing national data. No interviews with experts or any additional data collection were undertaken (The Danish Environmental Protection Agency, 2019).

The study is based on data for imports and exports of plastic; domestic production of primary plastic and plastic in products; consumption of plastic, imports and exports of waste plastics, generation of packaging, non-packaging, mixed and combustible waste; imports and exports of waste plastics for recycling as well as treatment of plastics waste and plastics-containing waste. The study mentions that data about potentially important flows were either of insufficient quality or lacking.

The study shows that in 2016, the reference year, Denmark imported 3.1 Mt of plastic and exported 2.5 Mt. This includes primary plastic, plastic products, plastic-containing products and waste plastics. The increase in plastic stock was 610 000 tonnes. The figures show a per person consumption of plastic of about 105 kg per year.

The total plastic waste flow generated in Denmark in 2016 was estimated to be 440 000 tonnes. Most of the plastic waste, some 330 000 tonnes, was collected as residual waste. Of source-separated plastic waste, around 48 000 tonnes were plastic packaging waste and 62 000 tonnes were non-packaging.

In total, 420 000 tonnes of plastics waste were incinerated in Denmark in 2016. Of the separately collected plastics waste, 59 000 tonnes were exported out of which 47 000 tonnes were exported for recycling. The fate of the remaining 12 000 tonnes is unknown. About 54 000 tonnes of waste plastics were managed in Denmark and an additional 38 000 tonnes of sorted plastics were imported, of which 13 000 tonnes were ecycled while the fate of the remaining 25 000 tonnes is unknown (Danish Environmental Protection Agency, 2019).

Sweden
In Sweden, the mapping of plastic flows was commissioned by the Swedish Environmental Protection Agency. The study is based on available import and export, national production and waste management statistics as well as interviews with representatives from the plastics, recycling and waste management industries.

The study shows that in 2019 almost 1.3 Mt of plastics were placed on the Swedish market and contributed to an increase in the stock of plastic. The figures show a per person consumption of plastic of 120 kg per year (Swedish Environmental Protection Agency, 2022).

The total amount of plastic placed on the Swedish market in 2019 is distributed per product category as follows:

- 220 000 tonnes in packaging, excluding PET bottles;
- 170 000 tonnes in construction products;
- 140 000 tonnes in vehicles and tyres;
- 39 000 tonnes in electrical equipment;
- 30 000 tonnes in hardened composite plastic wind turbine blades;
- 28 000 tonnes of redeemable PET bottles;
- 22 000 tonnes of agricultural plastics;
- 7 000 tonnes in toys and sports equipment;
- 5.000 tonnes in furniture and décor;
- 4.000 tonnes in healthcare products from regional healthcare;

- 100 tonnes in fishing equipment.

The study presents plastics waste generated in Sweden in 2020. The distribution is as follows:

- 320 000 tonnes of plastic packaging waste excluding redeemable PET bottles;
- 120 000 tonnes of plastics waste from the construction sector;
- 94 000 tonnes of plastics waste from vehicles and tyres;
- 25 000 tonnes of plastics waste from electrical equipment;
- 24 000 tonnes of redeemable PET bottles;
- 14 000 tonnes of agricultural plastics waste;
- 12 000 tonnes of plastics waste from healthcare products from regional healthcare;
- 40 tonnes of waste including plastic from hardened composite plastic wind turbine blades.

In addition, the study also shows that plastic waste is generated as part of other mixed waste flows:

- 600 000 tonnes of plastics waste in mixed commercial and post-sorting waste;
- 300 000 tonnes of plastics waste from imports and exports of waste for energy recovery;
- 241 000 tonnes of sorted plastics waste from the manufacturing industry;
- 126 000 tonnes of exports of green-listed plastics waste;
- 115 000 tonnes of imports of green-listed plastics waste;
- 83 000 tonnes in municipal mixed waste, excluding packaging;
- 76 000 tonnes of waste from the cement industry, including plastics;
- 73 000 tonnes plastic waste from recycling stations.

When it comes to the waste management of these different plastic waste streams, the study shows that incineration with energy recovery was the most common waste management practice in 2020. More than 1.1 Mt of plastics waste were incinerated and some 76 000 tonnes used as combustion fuel in cement kilns. In total, the plastics waste that was incinerated with energy recovery represents around 87 % of plastics placed on the Swedish market.

Recycling of plastics waste represented about 10 percent of the total plastic which entered the market in 2020, or approximately 120 000 tonnes. The majority of plastic which was materially recycled came from packaging, PET bottles, tyres, electrical equipment and agricultural plastics (The Swedish Environmental Protection Agency, 2022).

Germany

Plastic flows in Germany were mapped in a study commissioned by BKV, an organisation representing the plastic industry in Germany, in cooperation with several companies from the plastic industry and Plastics Europe. The reference year for the study was 2019. The study builds on a survey in which plastic producers and plastic processing companies participated, as well as discussions with experts and available statistics, including production, import and export statistics, and microdata (Conversio, 2020).

The study indicates that in total approximately 12.1 Mt of plastic was used by private and commercial consumers in Germany in 2019 and entered the stock of plastics. This represents around 145 kg of plastic per person per year.

The distribution per type of application of the total amount of plastic used in Germany in 2019 was as follows:

- 3.22 Mt in packaging;
- 2.94 Mt in building and construction;
- 1.10 Mt in the vehicles;
- 0.94 Mt in electronics;
- 3 93 Mt in other applications.

In same year a total of 6.28 Mt plastics waste was collected in Germany, out of which 5.35 Mt was post-consumer waste. Material recycling and incineration with energy recovery were the main waste treatment methods.

A total of 2.93 Mt of plastics waste, made up of both post-industrial and post-consumer waste, was sent to material recycling and resulted in a total output of recycled material of 2.04 Mt, of which 1.03 Mt came from recycling of post-consumer plastics waste. Out of the 1.03 Mt, around 0.43 Mt of recycled plastics were used to replace virgin plastic material, with the remaining 0.58 Mt used as a substitute for other materials and 0.01 Mt used as a reducing agent in the steel-making process (Conversio, 2020).

The Netherlands

The mapping of plastic use and plastic waste flows in the Netherlands was undertaken by consultancy company CE Delft on behalf of Greenpeace Netherlands (CE Delft, 2021). The study is based on estimates due to the lack of data on the amount of plastic in each product category. The study shows that in 2017, approximately 1.9 Mt of plastic were placed on the market in the Netherlands. This represents approximately 112 kg per person per year.

Compared to the other countries presented here as case studies, the Netherlands identifies small and large utensils as the category in which most of the plastic put on the market is found. Small utensils refers to multi-use products such as toys, food containers and hair accessories, while big utensils refer to products such as garden furniture, storage boxes and mattresses.

The distribution plastics used in the Netherlands in 2017 was as follows:

- 747 000 tonnes in small and large utensils, 40 % of the total – the study also notes that the lifespan of these products is approximately 1–50 years;
- 530 000 tonnes in packaging, 28 % of the total, with a lifespan of less than 6 months;
- 290 000 tonnes in building materials, 15 % of the total, with a lifespan of around 50 years;
- 208 000 tonnes in clothing and textiles, 11 % of the total, with a lifespan of approximately 5 years.
- 53 000 tonnes in EEE, 3 % of the total, with a lifespan of 1–20 years;
- 48 000 tonnes in cars, 3 % of the total, with a life span of around 18 years.

Around 1.6 Mt plastic waste was generated in the Netherlands in 2017. It is estimated that of this:

- 512.000 tonnes were plastic packaging waste, from packaging made of 100 % plastic, of which 47.5 % was sent to material recycling;
- 154 000 tonnes were plastic waste from small utensils which was collected as a part of residual household waste; 23 % were sent to material recycling;
- 152 900 tonnes were plastic waste from clothing and textiles of which 31 % was sent to material recycling;
- 68 000 tones were plastic waste from the building sector of which 25 % was sent to material recycling;
- 40 000 tonnes were plastic waste from large utensils which was collected as a bulky waste; 59 % was sent to material recycling;
- 27 000 tonnes were plastic waste from vehicles of which 40 % was sent to material recycling;
- 26 900 tonnes were plastic waste from EEE of which 71 % was sent to material recycling;
- 18 000 tonnes were plastic waste from packaging not entirely made of plastic of which none was sent to recycling;
- 645 000 tonnes were plastics waste from other sources – it is not known how much of this fraction, if any, was sent to recycling (CE Delft, 2019).

Switzerland

The Swiss Federal Institute of Technology in Zürich published a material flow analysis of plastic used and plastic waste generated in Switzerland in 2017 (Klotz and Haupt, 2022). The study builds on a compilation of data from official statistics and databases, literature, websites and personal communication with different stakeholders. The study includes seven main applications for plastic which are then divided into 54 product categories. This study is the only one identified with this level of detail.

The total amount of plastic used in Switzerland within the seven main application categories in 2017 was 1 019 073 tonnes. This indicates a per person use of around 118 kg per year.

The distribution by main application and product category was as follows:

- Packaging: 353 324 tonnes
- Household items, furniture, leisure and others: 225 877 tonnes
- Building and construction: 225 329 tonnes
- Textiles: 88 050 tonnes
- Automotive: 63 691 tonnes
- EEE: 53 354 tonnes
- Agriculture: 9 447 tonnes

Overview of national level mapping of plastic flows

Table A2.1 provides some overview information from these studies and confirms that a high share of plastic is used for non-packaging functions. The data also illustrate the local context and variance in different countries where sectors (such as construction or automotive) account for differing percentages of the overall plastic flow.

Table A2.1: National level mapping of plastic flows

Sector	Germany	Netherlands	Sweden	Switzerland
Packaging	27%	28%	33%	35%
Construction	24%	15%	26%	22%
Automotive	9%	3%	21%	6%
Electronics	8%	3%	6%	5%
Agriculture			3%	1%
Household		40%([a])		22%
Textile		11%		9%
Others	32%		11%	

* categorisation also includes the remaining amount of plastic compared to the total market.

List of abbreviations

Abbreviation	Name	Reference
EEA	European Environment Agency	www.eea.europa.eu
ABS	acrylonitrile butadiene styrene	
AENOR	Spanish Association for Standardization and Certification	
Aramid	aromatic polyamide	
CD	compact disc	
C&DW	construction and demolition waste	
CE	circular economy	
CEAP	Circular Economy Action Plan	
CEN	European Committee for Standardization	
CO_2-eq	carbon dioxide equivalent	
CPA	Circular Plastics Alliance	
EEA	European Environment Agency	
EEE	electrical and electronic equipment	
ELV	end-of-life vehicle	
EPR	extended producer responsibility	
EPS	expanded polystyrene	
EUCertPlast	European Certification of Plastic Recyclers	
HDPE	high-density polyethylene	
HIPS	high-impact polystyrene	
IPPR	Institute for the Promotion of Recycled Plastics	
IT	information technology	
JRC	Joint Research Centre	
kg	kilogram	
kt	kilotonne (1 000 tonnes)	
LDPE	low-density polyethylene	
LLDPE	linear low-density polyethylene	
MDPE	medium-density polyethylene	
MSW	municipal solid waste	
Mt	million tonnes (10^6 tonnes)	
OECD	Organisation for Economic Co-operation and Development	
P4P	Process4Planet	
PA	polyamide	
PA6	polycaprolactam	
PA66	polyamide 66	
PC	polycarbonate	
PCB	polychlorinated biphenyl	
PE	polyethylene	
PEMRG	Plastics Europe's Market Research and Statistics Group	
PET	polyethylene terephthalate	
PMMA	polymethyl methacrylate	
POP	persistent organic pollutant	
PP	polypropylene	

PPWD	Packaging and Packaging Waste Directive
PS	polystyrene
PS-E	expandable polystyrene
PSR	post shredder residues
PVC	polyvinyl chloride
PUL	polyurethane laminate
PUR	polyurethane
RoHS	restriction of hazardous substances
SAN	styrene acrylonitrile resin
SUP	single-use plastic
TEE	temperature exchange equipment
UNEP	United Nations Environment Programme
WEEE	waste electrical and electronic equipment
WFD	Waste Framework Directive
XPS	extruded polystyrene

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