eunomia

HDPE & PP MARKET IN EUROPE

STATE OF PLAY

PRODUCTION, COLLECTION AND RECYCLING DATA

PLASTICS RECYCLERS EUROPE

GLOSSARY OF TERMS

AI	Artificial Intelligence
C&I	Commercial and Industrial (waste stream)
C&D	Construction and Demolition (waste stream)
CITEO	French EPR (Extenden Producer Responsibility) Organisation
COMPOSITE POLYMER PLASTIC	A plastic material composed of two or more polymer types
CONAI	Consorzio Nazionale Imballaggi (Italian EPR)
CONVERSIO	Conversio Market & Strategy GmbH
CONVERTER	Manufacturers of plastic products
EEE	Electrical and Electronic Equipment
EFSA	European Food Standards Agency
ELV	End-of-Life Vehicles
EPR	Extended Producer Responsibility
EU28	European Union as of 2019
EU28+2	European Union + Norway and Switzerland
EU28+EFTA	European Union + European Free Trade Association (Iceland, Liechtenstein, Norway and Switzerland)
EU27	European Union after Brexit
EUROSTAT	European Statistical Office
FLEXIBLE FILMS	Term encompassing films, bags/sacks and flexible packaging
FOOD PACKAGING	Packaging exclusively used for the containment, protection, handling, delivery and presentation of foods, from raw materials to processed foods, from the producer to the user or the consumer.
FLEXIBLE PACKAGING	All packaging made of any flexible materials to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer.
HDPE	High density polyethylene
Kt	Kilotonnes

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MDPE	Medium density polyethylene
Mt	Million tonnes
MULTILAYER	Comprised of multiple (often co-extruded) layers
NIR	Near Infra-Red
PCEP	The Polyolefin Circular Economy Platform
PET	Polyethylene terephthalate
POLYMER	The type of plastic when in product form (large molecular structure formed from resins)
POLYOLEFIN (PO)	Polymer group, predominantly PE or PP
PP	Polypropylene
PPWD	Packaging and Packaging Waste Directive
PRE	Plastics Recyclers Europe
PTT	Pots, tubs and trays
RECYCLATES	Raw material output (e.g. flake, pellet) from recycling operations
RECYCLER(S)	Entity that transforms plastic waste into plastic products (agglomerates, flakes, pellets or finished products)
RESIN	Solid or highly viscous substance convertible into polymers (i.e input to polymer product manufacturing)
REGRANULATE	Granulated form of recyclate
RIGID PACKAGING	All packaging made of any rigid materials to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer.
RIGID POLYOLEFINS	Collective term for rigid HDPE and PP
rHDPE	Recycled high density polyethylene
rPM	Recycled plastic materials
VIRGIN	Resin produced from extracted oil as opposed to recycled resins.
WEEE	Waste Electrical and Electronic Equipment

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ABOUT PLASTICS RECYCLERS EUROPE

Plastics Recyclers Europe (PRE) is an organization representing the voice of the European plastics recyclers who reprocess plastic waste into high-quality material destined for the production of new articles.

Recyclers are important facilitators of the circularity of plastics and the transition towards the circular economy.

Plastics recycling in Europe is a rapidly growing sector representing €3 billion in turnover, 8.5 million tonnes of installed recyclability capacity, 600 companies and over 20.000 employees.

INTRODUCTION

This report, delivered by PRE, provides the latest data and trends regarding:

- The current state of the HDPE & PP market in Europe;
- Key changes impacting the market and the challenges faced by the supply chain; and
- What the future HDPE & PP recycling chain might look like.

PRE intends to update and re-publish this 'State of the Market' report every second year.

This report uses best available data sources to present data estimates, alongside results from a survey of market experts from the industry of HDPE and PP recyclers. PRE has also launched an internal survey of its members to check and improve on data estimates with figures collected directly from facilities, but in this case statistical representativeness will only be achieved in future updates to the report.

The first year's data presented here will provide a benchmark from which to analyse future developments and trends, including outlining remaining gaps in data to support full supply chain analysis.

All data sources references in this report are listed in the Annex.

2. CURRENT STATE OF THE MARKET

Figure 1 illustrates the supply chain of HDPE & PP in the context of the circular economy. The key elements are covered in our analysis of the HDPE & PP market within this section.

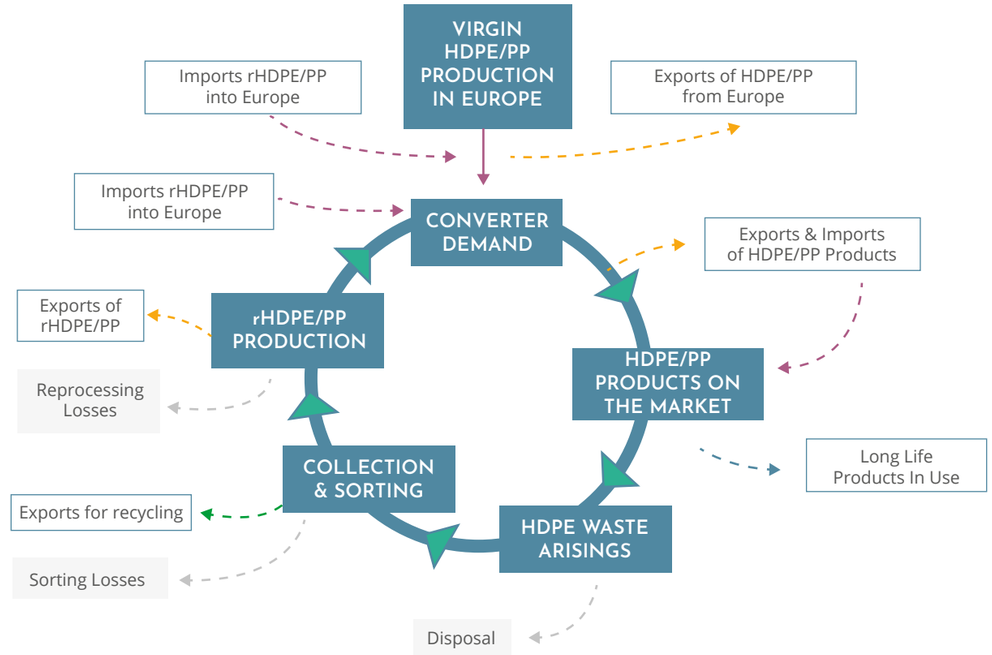


FIGURE 1: HDPE & PP Lifecycle in the Circular Economy

The data provided in this section is used in Section 3 to identify the key challenges facing the recycling market based on the HDPE & PP mass balance across the EU28+2.

PRODUCTION AND CONSUMPTION

Net demand for HDPE was reported by Eurostat at 6.2 Mt, and net demand for PP at 10.5 Mt.[1] Together, HDPE and PP account for almost a third of all converter demand in the EU28 for polymer resins.[2]

Europe produces almost enough to meet internal demand – 92% of net EU28 demand for HDPE can be met by EU28 production and supply; for PP, the figure is 98%. Recyclate from post-consumer rigid product applications within the EU28 meets approximately 8% of demand for HDPE and 3% of demand for PP (12% of demand for HDPE and 5% of demand for PP when pre-consumer recyclate is included).

	HDPE	PP
Virgin Production	5.0	9.8
Recyclate production in EU28	0.7	0.5
Net Imports	0.5	0.2
Total Demand	6.2	10.5

TABLE 1: Production and Consumption of Primary Form HDPE and PP From Virgin and Recycled Sources, EU28, Mt (sources Eurostat, PRE)

Figure 2 shows that the demand for HDPE has remained relatively stable, with net demand in 2018 at the same level as in 2009.

In comparison, Figure 3 shows that production and demand for PP has grown through the period 2011 to 2017. This followed a period of reduced and then static growth in demand, possibly influenced by the recession following the 2008 banking crisis. The production capacity and resin value for both polymer types have increased over the years and are expected to continue to grow.[3]

Not all of this demand is for rigid applications (the focus of this report). An estimated 2–2.5 Mt of PP is used in flexible films (including flexible packaging) and 0.7 Kt of HDPE across construction and packaging films.[4] Additionally, textiles manufacture accounts for in the region of 2 Mt of PP and 200 Kt of HDPE.[5]

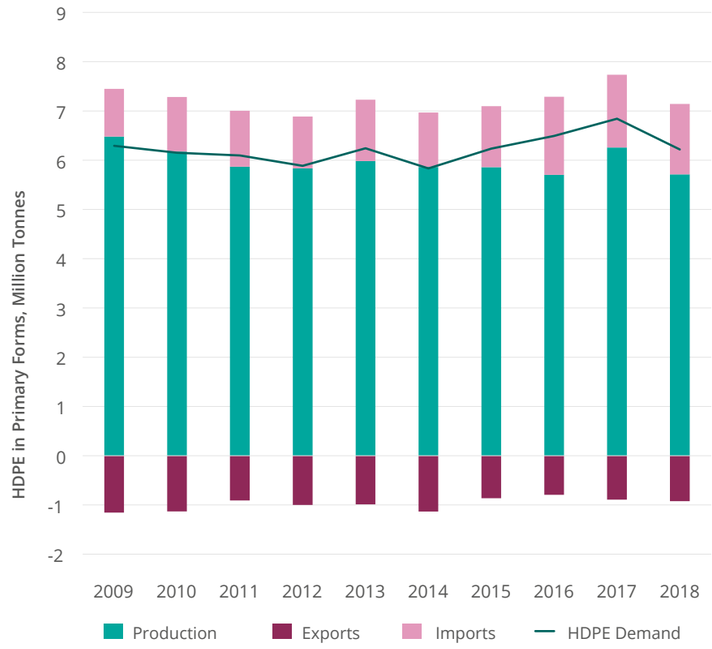


FIGURE 2: HDPE (Sold) Production and Demand, EU28 (source: Eurostat)

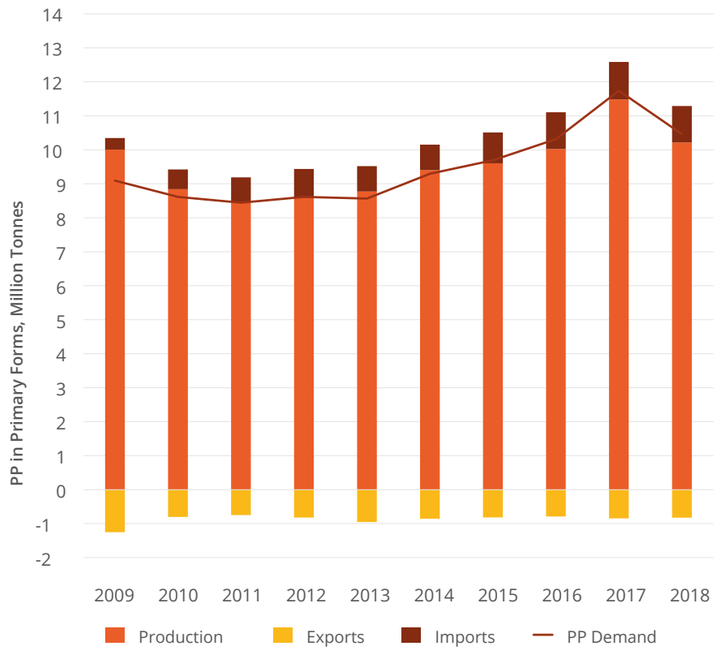


FIGURE 3: PP (Sold) Production and Demand, EU28 (source: Eurostat)

IMPORT AND EXPORT

THE EU28 IS:

- **A SLIGHT NET IMPORTER OF PRIMARY FORMS OF HDPE AND PP (THE VALUE OF IMPORTS IS 25% HIGHER THAN EXPORTS FOR HDPE AND 12% HIGHER FOR PP).**
- **A NET EXPORTER OF PE AND PP RIGID PIPES (THE VALUE OF HDPE EXPORTS IS 3 TIMES THAT OF THE IMPORT VALUE, WHILE THE VALUE OF PP EXPORTS IS 3.5 TIMES THAT OF THE IMPORT VALUE).**
- **A NET EXPORTER OF PP SHEET >0.125mm (THE VALUE OF IMPORTS IS 1.7 TIMES HIGHER THAN EXPORTS).**

Eurostat reports export and import data on primary forms of HDPE and PP, on rigid PE and PP pipes, and on HDPE and PP sheet >0.125mm.

In 2018, consumption of both HDPE and PP in primary forms was 750 Kt higher than production, with a combined negative trade balance of €340m. Imports of HDPE and PP have both grown significantly over the last decade (the EU28 was a net exporter of both HDPE and PP in 2009).[6]

The EU28's biggest trading partner for HDPE and PP in primary forms is Saudi Arabia, which accounts for 42% of HDPE and PP imports combined. Over the last decade, the Republic of Korea has emerged as a major source of both resins, and in 2018 it was the second largest source of imports of PP to the EU28.[7] The largest export destination is Turkey, which accounts for 40% of PP exports.[8]

Within the EU28, Belgium is by far the biggest net exporter of HDPE and PP, with a positive trade balance of €1.4bn. Italy is the largest net importer, with a negative trade balance of €1bn. The UK is the largest net importer of HDPE.

The other main rigid HDPE and PP product categories are not clearly identified in Eurostat data.

MARKET SECTORS (APPLICATIONS)

- **ROUGHLY 62% OF RIGID HDPE AND 37% OF RIGID PP ARE USED FOR PACKAGING APPLICATIONS.**
- **CONSTRUCTION (HDPE FOR PIPES) AND AUTOMOTIVE (PP FOR CAR BODYWORK) ARE ALSO MAJOR USES OF RIGID HDPE AND PP.**
- **THERE IS GREATER USE OF PP IN NON-PACKAGING SECTORS THAN HDPE, INCLUDING THE AUTOMOTIVE, HOUSEHOLD PRODUCT AND EEE SECTORS.**

HDPE and PP are both strong and lightweight plastics, with good resistance to solvents and corrosion. The main differences between the two are density, mouldability and visual properties:

- **HDPE is less brittle than PP** and can be moulded into virtually any shape, while maintaining its lightweight nature.
- **HDPE is naturally translucent but not clear,** while PP can be processed so as to have transparent properties, and so can be used for transparent cups and food packaging.
- **PP has the lowest density** of all the main plastic polymers, while maintaining good barrier properties, and resistance to high temperatures and corrosion.

HDPE and PP have a wide variety of rigid product uses. In addition to packaging applications – primarily HDPE bottles and PP pots, tubs and trays (PTTs), as well as caps and closures – other major applications include construction products, such as pipes, for HDPE and automotive and household products for PP.

Data on quantities of rigid HDPE and PP packaging and products on the market is not readily available. For this report, estimates have been drawn together from different studies covering different sectors.[9] There remains considerable uncertainty in some of the tonnage estimates detailed in the sector-specific paragraphs below.[10]

Figure 4 and Figure 5 show an approximate breakdown of HDPE and PP applications, based on Eurostat production data for different applications for which the main materials used are HDPE and/or PP, combined with Deloitte estimates of quantities of key packaging products and other studies for automotive, furniture and EEE sectors. However, it should be noted that whereas this gives a figure of 1,540 Kt for HDPE used in household packaging, an estimate from one of PRE's market experts puts this figure lower at 1,100 Kt (based on all household HDPE packaging within extended producer responsibility (EPR) systems).

FIGURE 4: HDPE applications, derived from Eurostat data and other studies, Kt

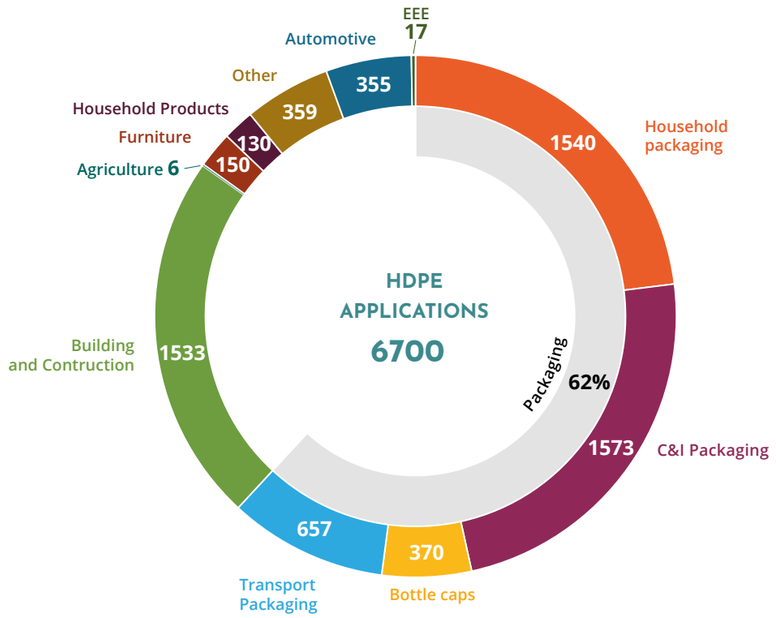
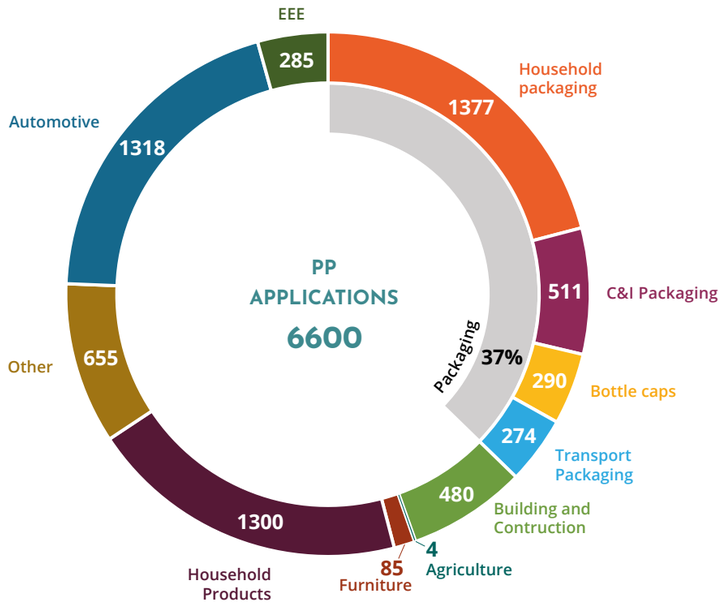


FIGURE 5: PP applications, derived from Eurostat data and other studies, Kt



PACKAGING

The packaging sector has the largest share of HDPE and PP use, accounting for an estimated 62% of rigid HDPE products by weight and 37% of rigid PP products by weight. Figure 6 shows a further breakdown of rigid HDPE and PP use in packaging products.

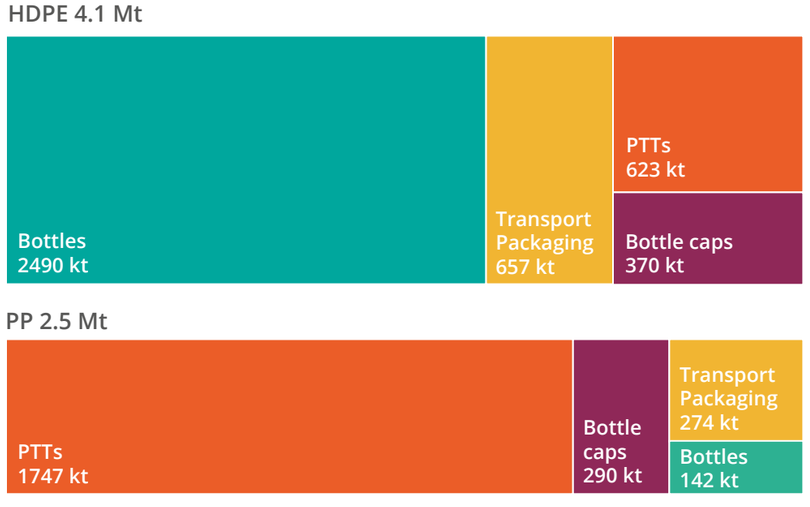


FIGURE 6: HDPE and PP Rigid Packaging Applications, derived from Eurostat data and Deloitte studies

The main rigid packaging uses are:

- **Bottles/Containers (2.49 Mt HDPE, 0.14 Mt PP)[11]:** HDPE is widely used for blow-moulding bottles. Natural HDPE is used in some countries for juice packaging, and in a small number of countries (e.g. the UK) most HDPE milk packaging utilises natural HDPE. Coloured HDPE is used primarily for bottles for household products and chemicals, due to its good resistance to solvents, corrosion, and fracturing. HDPE is also widely used for larger containers in the commercial sector as it has the highest strength-to-weight ratio of common polymers, is less brittle than PP and maintains its lightweight nature in moulding, making it ideal for larger sized containers such as plastic cannisters.[12]
- **Pots, Tubs and Trays (0.62 Mt HDPE, 1.75 Mt PP)[13]:** PP is widely used for rigid food packaging such as margarine tubs, yogurt containers, and trays (as well as flexible food packaging such as packets and wrappers outside the scope of this report). It is lower density, more lightweight and more durable than PET, yet can be similarly manufactured to be transparent (unlike HDPE), and has a wide temperature tolerance allowing it to be hot-filled and also put in the microwave, dishwasher or freezer. HDPE is also used for trays, particularly in the commercial sector.
- **Bottle caps (circa 0.7 Mt)[14]:** 55% of plastics caps and closures are made from HDPE, while 45% are made from PP.[15] HDPE is more commonly used for standard plastic caps, whereas customised and hinged caps are more commonly made from PP due to its high stress-tolerance.
- **Other packaging, including boxes and crates (at least 0.66 Mt HDPE, 0.27 Mt PP)[16]:** Since both polymers are strong and lightweight, they are used to manufacture boxes and crates, pallets, drums/kegs and bulk containers for transporting goods.

A primary use of PP in particular is for food packaging: in the region of 55% of PP rigid packaging (1 Mt) is food-contact, equivalent to around 10% of total PP demand.[17] Additionally, a proportion of crates and boxes are used for food packaging (for instance groceries).

BUILDING AND CONSTRUCTION

The second biggest sector for HDPE is building and construction applications. For 2018, Eurostat reports consumption of rigid PE and PP pipes and pipe fittings of 2 Mt, of which 1.2 Mt is rigid PE pipes (which are primarily HDPE) and 0.4 Mt PP pipes.[18]

AUTOMOTIVE

The automotive sector is the second largest user of PP, using in the region of 1.3 Mt in 2018 alongside 350 Kt of HDPE.[19] PP (and to a lesser extent HDPE) is used in the manufacture of car bumpers, wheel arch liners, and internal vehicle components such as dashboards. Car bumpers, for instance, are almost exclusively made from polyolefins.[20] The use of plastics in bodywork, especially PP, is increasing in the automotive sector, partially driven by efforts to improve fuel economy through lightweighting.[21]

HOUSEHOLD PRODUCTS AND FURNITURE

PP (and smaller quantities of HDPE) is used in the production of a wide variety of household plastic products. A 2018 report shows that the household products sector accounts for an estimated 1.3 Mt of PP use alongside under 130 Kt HDPE,[22] while the furniture sector accounts for 150 Kt of HDPE and 85 Kt of PP use.[23]

EEE

Based on recent compositional analyses, an estimated 285 Kt of PP and minor quantities of HDPE were used in electrical and electronic equipment sold in 2018.[24]

COLLECTION AND SORTING

- MOST HDPE & PP IN WASTE IS PACKAGING, HOWEVER, SOURCES OF COLLECTED HDPE AND PP SPAN A VARIETY OF SECTORS, INCLUDING AUTOMOTIVE, CONSTRUCTION AND WEEE.
- THERE IS A LACK OF RELIABLE DATA ON THE QUANTITY OF END-OF-LIFE RIGID HDPE AND PP PACKAGING AND PRODUCTS COLLECTED FOR RECYCLING.
- HDPE & PP COLLECTION FOR RECYCLING RATES ARE CURRENTLY BELOW THE 2025 EUROPEAN TARGETS FOR PLASTICS PACKAGING RECYCLING. COLLECTION FOR RECYCLING RATES ARE HIGHER FOR RIGID HDPE THAN FOR RIGID PP.

Plastic products have varying lifespans, from single-use packaging that can become waste within minutes of consumption, to pipes that enter the built environment for 50+ years. For materials with longer lifetimes, the amounts of material reaching end-of-life reflect historic consumptions levels of products and usage rates of different materials within those products. Therefore, the amount of HDPE and PP end-of-life packaging and products is different from the amount put on the market.

TABLE 2: Comparison of tonnages put on the market and waste arisings for two applications (sources provided in footnotes)

Sector	Put on the market	Arising in waste streams
Pipes	1.2 Mt Consumption of rigid pipes [25]	0.12 Mt (10% of quantity put on the market) Est. total HDPE building and construction waste [26]
Automotive	1.32 Mt Approx 85kg of PP used per new car [27]	0.90 Mt (68% of quantity put on the market) Reflects lower plastics use per car in early 2000s – the average age of vehicles delivered to ELV centres was 17.5 years in 2014.[28]

This section of the report covers collections of rigid plastics suitable to be reprocessed by non-specialist reprocessing operations. Therefore, it excludes end-of-life EEE and plastics in automotive shredder residue (ASR).

A maximum of 5.0 Mt of end-of-life rigid HDPE and 4.8 Mt of end-of-life rigid PP arose as waste in 2018, adjusting for just the rigid plastics to be within scope.

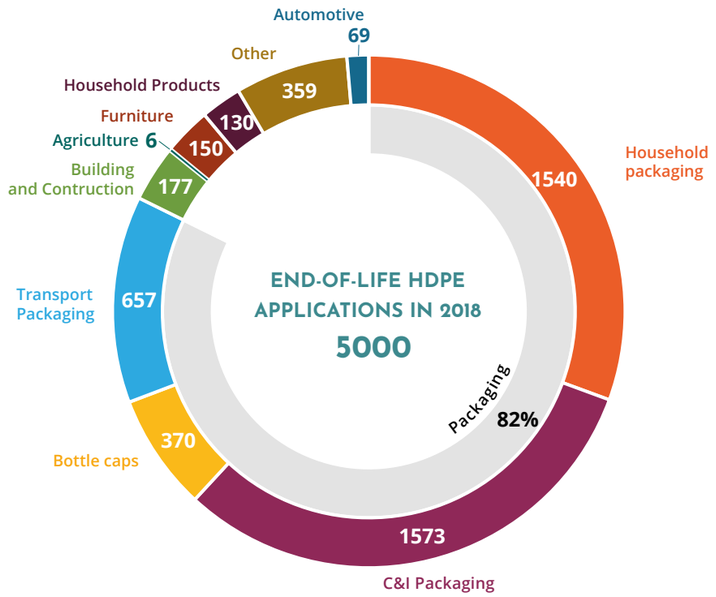


FIGURE 7: End-of-life HDPE Applications in 2018, derived from Eurostat data and other studies, Kt

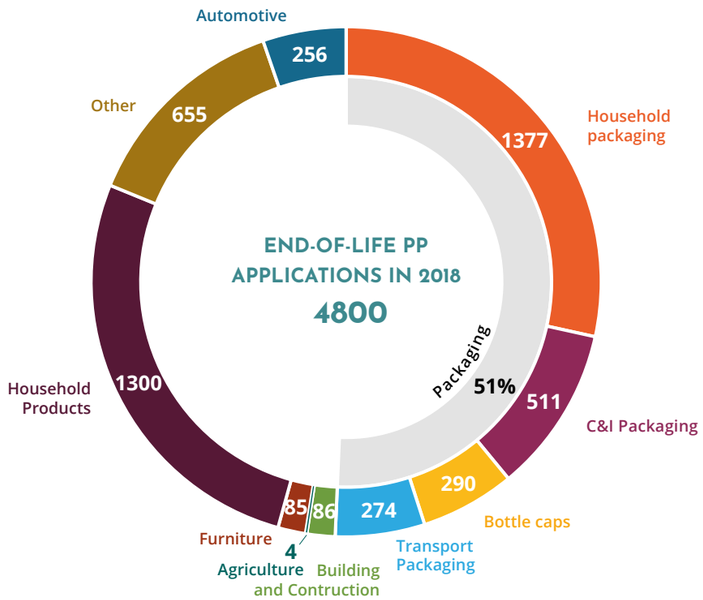


FIGURE 8: End-of-life PP Applications in 2018, derived from Eurostat data and other studies, Kt

As shown in Figure 7 and Figure 8, the majority of rigid polyolefin waste arising in the EU28 was packaging waste – 82% for HDPE and 51% for PP[29]. Most of this was from single-use packaging applications: primarily HDPE bottles and containers for liquid household and commercial applications and PP PTTs, caps and closures. The data suggests there were also substantial tonnage arisings, particularly of PP, from a diverse range of household and commercial rigid applications.

There were less waste arisings than amounts placed on the market for both HDPE & PP from the 'building and construction' and 'automotive' sectors in 2018. The 'household products' and 'other' sectors may be an overestimate, as it is possible that certain plastic products, which may otherwise be classed under a different sector, accumulate and reach end-of-life within private households.

There is a lack of available and well-identified data for total tonnages of end-of-life HDPE and PP collected and sorted for recycling. Despite this, the collection and sorting rate estimates by collection stream outlined in the respective paragraphs below and summarised in Table 3 result in tonnage estimates of material collected and sorted for recycling of up to 2.1 Mt of HDPE and 1.2 Mt of PP in 2018. These estimates appear high in the context of European reprocessing capacity (see section 'Recycling'), suggesting the underlying research on quantities available for collection and collected/sorted may be overestimated. As noted above (see section 'Market Sectors (Applications)'), PRE market intelligence suggests a lower figure for HDPE household packaging placed on the market, by some 440 Kt; this would have the impact of lowering the amount of HDPE estimated to be collected and sorted by up to 300 Kt. This highlights the need for improved data collection.

Across Europe, reported recycling rates for plastic packaging overall range from 19% to 74%. Though data is not reported specific to different plastic polymers, this range is indicative of the variation in collection system performance for rigid polyolefins.

The collected HDPE and PP was sourced from a diverse range of collection and sorting schemes used to target different HDPE and PP product types and sources, with variation in collection systems also seen between countries.

The main waste streams in which HDPE and PP arise, the key products within these waste streams, and the collection systems used are shown in Table 3, alongside estimated sorting for recycling performance of these collection systems. The rate of material sorted into distinct HDPE and PP grades will be lower than shown in the figures in Table 3, particularly for packaging collection systems, since a portion of collected HDPE and PP packaging is sorted into a mixed PO grade.

Collection and sorting systems of flexible films for recycling in Europe target the main sources of end-of-life HDPE & PP: packaging (household, commercial and transport), building and construction, and automotive.

Waste Stream	Key Products	Typical Collection System	Estimated Sorting for Recycling Performance
WASTE STREAMS COLLECTED PRIMARILY IN MUNICIPAL COLLECTION SYSTEMS			
Household Packaging	HDPE bottles, PP (pots, tubs and trays) PTTs, HDPE bottle caps	Door-to-door or bring-site based separate collections, often provided by extended producer responsibility (EPR) schemes for packaging waste or by municipalities. Commonly collected alongside other light plastic and metal packaging.	HDPE 56% PP 36%[30] packaging overall: HDPE 42% PP 41%
Household Bulky/ Hard Plastics	Consumer goods, furniture, flowerpots	Primarily drop-off locations for mixed plastics stream of bulky non-packaging products. Some door-to-door collections of bulky waste.	Unknown. Furniture collection estimated in the region of 10%[31]
WASTE STREAMS COLLECTED PRIMARILY IN COMMERCIAL COLLECTION SYSTEMS			
Commercial Packaging	HDPE bottles, HDPE and PP containers	Mixed plastic packaging collection from smaller businesses is sometimes included in municipal collection systems, and sometimes collected by the commercial sector. Homogenous streams of packaging waste products from larger waste producers tend to be collected by the commercial sector.	HDPE 29% PP 52%[32]
Transport Packaging	Crates, drums, bulk container rates,	Privately organised collection homogenous waste streams, often bulked up. Sometimes collection is coordinated by the companies providing the transport packaging.	Estimated in the region of 80%[33]
Commercial rigid HDPE/PP products	Spools, recycling bins, other miscellaneous	Monomaterial rigid products arising in larger quantities are collected by the commercial sector. Other products likely not to be collected, though drop-off collections may be available.	Unknown
OTHER WASTE STREAMS			
Building and Construction	Pipes	Some waste sorting by site contractors, often mixed C&D waste sorted at facilities.	20%[34]
Automotive	Automotive parts – e.g. bumpers, bodywork, dashboards	Collected at facilities that treat ELVs, some small quantities of producer take-back.	Unknown

TABLE 3: Sources of HDPE & PP Waste Arisings (sources given in footnotes)

HOUSEHOLD AND COMMERCIAL PACKAGING WASTE

The main collection methods for HDPE & PP packaging waste from households are separate recycling collections, either door-to-door or from bring sites. Some HDPE and PP packaging waste is also sorted from mixed waste collections.

Commercial packaging waste is sometimes covered by EPR schemes but often privately arranged. Sector specific packaging types are sometimes targeted by EPR schemes; for example, France, Germany and Belgium have EPR schemes covering agricultural plastics that target pesticide, fertilizer, seed and plant packaging.[35]

Annual and reliable data on amounts collected is not reported. Deloitte assessed collection for recycling rates of plastic packaging waste streams in five countries (Germany, Italy, the UK, France and Spain), showing collection for recycling rates of below 50% for polyolefin rigid packaging.[36] Collection rates for rigid HDPE and PP packaging are shown in Table 4. Due to losses in sorting, amounts sorted for recycling will be lower and amounts sorted into distinct HDPE and PP grades lower still (perhaps in the region of 10–15%). The overall EU28 plastic packaging recycling rate reported in Eurostat is shown for comparison.

		HDPE	PP
Deloitte[37]	All rigid packaging, collected for recycling (i.e. average of household and commercial packaging)	49%	47%
	Household rigid packaging	64%	42%
	Commercial rigid packaging	34%	60%
Eurostat	Plastic packaging recycling rate[38]	41.9%	

TABLE 4: HDPE/PP Packaging Collection and Recycling Rates in EU28 (sources: Deloitte and Eurostat)

Across household and commercial streams:

- Collection rates for HDPE packaging were 2 percentage points higher than for PP packaging (see Table 4); and
- Collection rates for rigid polyolefin bottles were 56%, and collection rates for rigid polyolefin PTTs were 46%.

Household PP packaging had the lowest collection rate, as well as the highest ratio of PTTs to bottles. PP pots and trays are more likely than HDPE bottles to end up in mixed PO fractions. Not all countries target PP in sorting operations (85% according to a recent CPA survey).[39]

HOUSEHOLD COLLECTION SYSTEMS

Table 5 shows, for each country in the EU28+EFTA, the type of collection scheme in place and the waste fraction with which HDPE & PP are collected.

Some countries have made recent changes to their collection systems, at least in part in response to legislated recycling rate targets for municipal and packaging wastes, and the requirement within the Waste Framework Directive to separately collect waste. For example, Belgium, through the producer responsibility organisation (PRO) FostPlus, expanded the scope of its plastics collection in 2019 from just bottles to include pots, tubs and trays. The plastics packaging collection in almost all Member States includes pots, tubs and trays, but sorting systems (especially those at a smaller scale) prioritise PET and HDPE bottles, which have higher value, and a significant fraction of collected PP waste is likely to up in "mixed plastic" outputs from sorting plants.

26 of the 28 EU Member States have some form of EPR in place for packaging waste, as recommended by the Packaging and Packaging Waste Directive (Directive 94/62/EC). EPR is an important driver developing collection systems.

Country	Predominant Collection System	
	Main Household Collection System	Collected In
Austria	Door-to-Door	Light packaging (Light plastic & metal packaging, often including cartons)
Belgium	Door-to-Door	Light packaging
Bulgaria	Bring	Light packaging and glass
Croatia	Bring	Light packaging
Cyprus	Door-to-Door	Light packaging
Czech Republic	Bring	Plastic packaging
Denmark	Door-to-Door	Light packaging, in some regions glass
Estonia	Door-to-Door	Light packaging
Finland	Bring	n/a
France	Door-to-door	Light packaging, and in some regions paper/card
Germany	Door-to-door	Light packaging
Greece	Door-to-Door	Co-mingled material: Metals, glass, paper
Hungary	Door-to-door	Light packaging
Iceland	Bring	Light packaging and glass
Ireland	Door-to-door	Light packaging
Italy	Door-to-door / Bring	Light packaging
Latvia	Door-to-door / Bring	Plastic packaging
Lithuania	Bring, some door-to-door	Light packaging, in some regions glass
Luxembourg	Door-to-door	Light packaging
Malta	Door-to-door	n/a
Netherlands	Door-to-door / Bring	Plastic packaging
Norway	Door-to-door / Bring	Varies by region
Poland	Door-to-door	Co-mingled material: Metals, glass, paper
Portugal	Bring, some door-to-door	Packaging
Romania	Bring	Paper, glass, plastic, metal (additional fraction: wood)
Slovakia	Bring	Plastic packaging
Slovenia	Door-to-door	Light packaging and paper/card
Spain	Bring / Door-to-door	Light packaging
Sweden	Door-to-door / Bring	Light packaging and paper/card
United Kingdom	Door-to-door	Mixture, often co-mingled (Paper & cardboard, plastic, glass, metal)

SOURCES: BIPRO/CRI (2015), Assessment of separate collection schemes in the 28 capitals of the EU, Final report; Eunomia (2018), Early Warning Mechanism

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TRANSPORT PACKAGING WASTE

Transport packaging waste (e.g. boxes and crates for transporting goods) tends to arise in large, homogenous quantities and is therefore cost-effective to recycle. Collection rates for this application are likely therefore to be high. Additionally, take-back schemes such as Sweden's 'Svenska Retursystem' for grocery crates can help ensure high levels of reuse and, when packaging is unsuitable for reuse, recycling.[40] In Spain, the HDPE agricultural crates used to transport fresh fruit and vegetables are being replaced by PP agricultural crates – these crates are non-reusable, but their collection and recycling rates are very high.

BUILDING AND CONSTRUCTION

Stripping out a building during deconstruction takes significant time and logistical planning, and requires specialist skills, as well as large storage spaces for the duration of the process. Plastic pipes are lightweight but bulky, and so can be costly to transport. Many plastic construction materials are part of composite structures, and plastic waste arising from renovation and demolition projects can contain now banned substances, such as cadmium and lead, which limit the potential for recycling.

Plastics Europe has reported in the region of 20% collection for recycling of HDPE and PP from building and construction.[41]

AUTOMOTIVE ELVs

Directive 2000/53/EC on End-of-Life Vehicles (the 'ELV Directive') mandated the establishment of EPR systems for ELVs and set a 2017 target for the reuse and recycling of ELVs equating to 85% of the average weight of the vehicle.[42] In 2016, most member states had met this target, with those that didn't (Portugal, Italy, and Finland) only missing it by a small margin.

The scrap value in ELVs covers the cost of processing, so in many Member States the focus of implementation of the Directive has been on ensuring sufficient coverage of ELV collection points.[43] Whereas composite polymer plastics and those contained in automotive shredder residue (ASR) need more specialist treatment and do not tend to be economical to recycle, large body parts such as PP bumpers are mono-material and can be processed by standard rigid polyolefin reprocessing operations.[44] The quantity of monomaterial PP in front and rear bumpers, as well as vehicle arches, is in the region of 16 kg per vehicle currently.[45] However, the scrap metal content of the car is more valuable, and therefore more consistently recycled, than plastic material. There is no specific legislation regarding recycling rates for plastic automotive waste separate from the overall reuse and recycling target for ELVs, and overall collection and recycling rates for specific materials are not tracked. However, the European Commission is set to revise the ELV Directive.

OTHER HOUSEHOLD HDPE & PP PRODUCTS

Some Member States have introduced EPR schemes covering other waste streams; for example, Finland has an EPR scheme for bulky plastics.[46] Otherwise, collection is left to municipalities and businesses to organise, and the economics of collection suggest that lower value or difficult-to-collect portions of plastic waste streams are overlooked.

RECYCLING

- **IN 2018, THE EU28+2 HAD THE PROCESSING CAPACITY TO RECYCLE 1.7 Mt OF RIGID HDPE AND PP, OF WHICH 1.2 Mt WAS FOR POST-CONSUMER MATERIAL. COMBINED rHDPE AND rPP PRODUCTION IN THE EU28+2 IN 2018 WAS ESTIMATED AT 0.8 Mt FROM POST-CONSUMER MATERIAL, WITH THIS FIGURE RISING TO 1.2 Mt WHEN PRE-CONSUMER RECYCLATE IS INCLUDED.[47]**
- **EU28+2 RECYCLING CAPACITY HAS INCREASED RECENTLY AND IS EXPECTED TO CONTINUE TO GROW WITH ADDITIONAL INVESTMENT.**

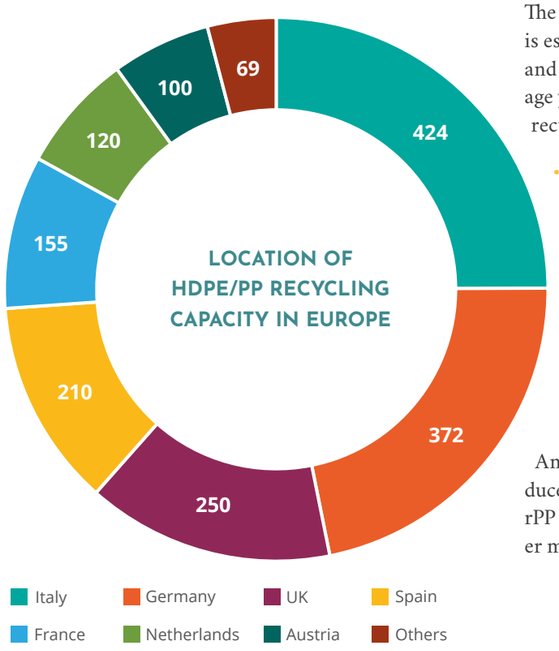

FIGURE 9: Location of HDPE/PP Recycling Capacity in Europe, Kt Total Capacity in 2018 (source: PRE)

Since the reprocessing steps for HDPE & PP rigid applications are the same, the same capacity can process both HDPE & PP (in batches), and the total capacity is tracked together.

In 2018, Europe had approximately 1.2 Mt of recycling capacity for post-consumer rigid polyolefins alongside 0.5 Mt capacity for pre-consumer material.[48] This capacity is growing with investment. 83% of reprocessing capacity is concentrated in 5 countries: Italy, Germany, UK, Spain, and France. The capacity data tracks recycling capacity for separately sorted HDPE and PP, so excludes a small additional amount of mixed rigid polyolefin recycling.

The 1.2 Mt capacity for post-consumer rigid polyolefins is estimated to produce in the region of 0.8 Mt of rHDPE and rPP, based on assumed utilisation at 86% and an average yield assumption of 80%.[49] Typical output yields from recyclers vary depending on the material:

- Household packaging is diverse and has high levels of moisture, organics and non-target material. Yields are between 70% and 90% depending on the quality of the input material and the standard of sorting at sorting plants for household recycling.
- Conversely, yields from bulk containers and other rigid applications, where levels of non-target material and organic contamination is lower, tend to be 90% or higher.

An additional estimated 0.4 Mt of recyclate was produced from pre-consumer material. The total rHDPE & rPP produced from both pre-consumer and post consumer material was therefore 1.2 Mt.

EXPORTS

Eurostat does not report export data for HDPE waste separately from export data for other PE waste. Export data for PP is reported separately, but exports of only 0.1 Mt of PP sorted for recycling are reported, and there will be additional PP (and HDPE) within mixed plastics exported for recycling.

An estimate of total exported HDPE & PP therefore currently comes from comparing estimates of quantities of HDPE & PP collected with estimates of inputs to European recycling capacity, as the difference between these two figures should be the amount exported. This would result in up to 2.4 Mt of exports, though this is higher than believed by PRE market experts. This implies that the collected tonnage is an overestimate.

The Eurostat data shows a significant decline in extra-EU exports, with a 30% drop in PP exports, and a 47% drop in PE exports, since 2016. This reflects the restriction on exports to China and, subsequently, other export markets, as well as the growth in European recycling capacity discussed above. Growing recycling capacity within Europe helps to ensure that end-of-life plastic is managed to the highest environmental standards.

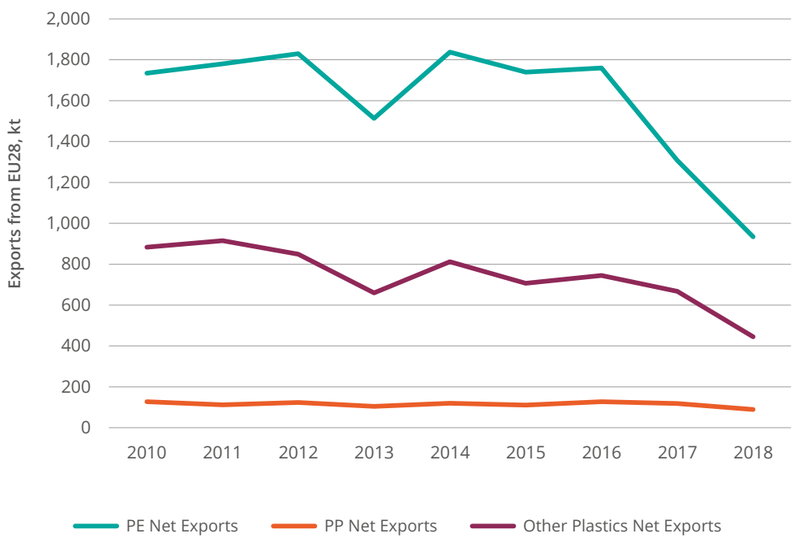

FIGURE 10: PE, PP and Other Plastics Exports (Kt) from the EU28 (source: Eurostat)

END MARKETS (RECYCLED HDPE & PP)

- **THE LARGEST END MARKETS FOR rHDPE (ACROSS POST-CONSUMER AND PRE-CONSUMER SOURCES) ARE PIPES AND TUBES.[50] HOWEVER, DEMAND IS INCREASING PARTICULARLY FOR WHITE/NATURAL rHDPE IN PACKAGING APPLICATIONS.**
- **THE LARGEST END MARKETS FOR rPP ARE FOR INJECTION MOULDING IN THE AUTOMOTIVE INDUSTRY, AND IN PACKAGING AND CONSTRUCTION.[51]**

Table 6 shows the end markets for HDPE & PP recyclate from different end-of-life sorted application streams.

	End Markets
HDPE bottles	Blow-moulding, pipes and tubes, injection-moulding and sheet production.
Other HDPE consumer packaging	Some recycled with bottles to the same destinations as bottle grades, some recycled with mixed PO for injection-moulding.
PP packaging	Primarily to injection moulded applications, some to PP sheet and to blow-moulding. PP bottles do not tend to be sorted out for separate recycling.
Caps and closures	Injection-moulding.
Larger/ bulk containers	Pipes and tubes
Transport packaging (e.g. crates)	Injection-moulding, with some circular applications and some back into food-contact (where collected and recycled in a closed-loop collection scheme).
Pipes	Primarily pipes and tubes
Furniture, other	Primarily injection-moulding

TABLE 6: End markets for HDPE and PP recyclate from different end-of-life sorted application streams (source: PRE expert group)

There are some fully circular uses of rigid polyolefin recyclate (in which product types are recycled into the same product types). Some rHDPE from bottles is used in bottle production, and some HDPE and PP crates can be recycled back into crates (especially if collected in a fully closed-loop collection scheme). However, the majority of rHDPE and rPP outputs are currently destined for pipes or injection-moulded applications, where colour and odour are less important.

Table 7 and Table 8 compare estimates of uptake of rHDPE and rPP (both pre-consumer and post-consumer material) in different sectors, based on a sector usage split derived from a 2017 Deloitte study[52] (total demand for HDPE and PP for key applications in those sectors is the same as that summarised in the earlier section 'Market Sectors (Applications)').

Demand is growing for rHDPE in the packaging sector, and for rPP in the automotive and packaging sectors. As the sector split is based on 2017 data, the market shares for those sectors in Table 7 and Table 8 may therefore be underestimates for 2018. The initial set of responses to PRE's survey of recyclers shows a similar split in rHDPE usage as presented in Table 7, and with a greater level of recycler participation, the survey would provide an opportunity to better track and report on developments in recyclate use over time.

	rHDPE to Product Application 2018 (Est), Kt	Consumption, 2018, Kt	Implied rHDPE Usage Rate
Packaging	188	3,880	5%
Construction (pipe or sheet)	421	1,533	27%
Other	140	1,672	8%

TABLE 7: Use of rHDPE compared to European production, key sector applications (sources: PRE, Deloitte, Eurostat)

HDPE packaging can be recycled for use in packaging applications, particularly if separated into a natural and/or white grade. A portion of rHDPE is used for blow-moulding again back into bottles. However, the largest part of rHDPE output is mixed colour flake and is used for construction of pipes.

The automotive sector is a major user of rPP. In packaging applications, rPP can be used in non-food film packaging applications, and injection-moulded reusable transport packaging products such as crates and boxes.

A proportion of PP and HDPE packaging is recycled into mixed polyoefin recyclate, often in compound form for use in injection-moulded applications (i.e. buckets, flowerpots). Additives are used to enhance structural characteristics for specific product categories. Data is not available on these specific product output streams (i.e. on which specific compounds supply which kinds of applications), and no study has yet been undertaken of the the various compounds available on the market and their suitability for different applications.

	rPP to Product Application 2018 (Est), Kt	Consumption, 2018, Kt	Implied rPP Usage Rate
Packaging	87	2,493	4%
Automotive	158	1,318	12%
Construction (pipe or sheet)	80	586	17%
EEE	67	285	23%
Other	96	5,782	2%

TABLE 8: Use of rPP compared to European production, key sector applications (sources: PRE, Deloitte, Eurostat)

3. KEY CHALLENGES FACING THE RECYCLING MARKET

- **THERE IS A NEED TO RAISE COLLECTION RATES FOR HDPE & PP PACKAGING, SO THAT HDPE & PP RECYCLING CAN MAKE A GREATER CONTRIBUTION TO PLASTIC PACKAGING RECYCLING TARGETS.**
- **IN ORDER TO ENSURE END MARKETS FOR rHDPE & rPP, IT IS NECESSARY TO RAISE DEMAND FOR RECYCLED RIGID POLYOLEFINS ACROSS DIFFERENT APPLICATIONS AND SECTORS, SUPPORTED THROUGH PUBLIC PROCUREMENT.**
- **IT IS IMPORTANT TO ENSURE THAT THE QUALITY OF HDPE & PP RECYCLATE CAN IMPROVE IN A COST EFFECTIVE WAY TO MEET THE SPECIFICATION DEMANDS OF DIFFERENT APPLICATIONS.**

This section explores the key challenges facing the HDPE & PP recycling market in Europe. It takes the data from the previous section and looks at the mass balance across the supply chain, the recyclability of products and the resultant impacts on the sorting and recycling reprocessing industry.

The extent to which sorted and reprocessed streams are suitable for different kinds of product applications are not captured in most definitions of recyclability, including PRE's definition (see section 'Quality: Recyclability of HDPE and PP Packaging Products'). The range of potential uses of recycled material relates to the mechanical properties of the recyclate, the visual (colour and consistency) properties and odour.

Polymers degrade over time and during the recycling process, but product design features, product uses, and co-collected contamination can all add to the challenges of maintaining quality of recycling output in a cost-effective way.

QUANTITY: HDPE & PP MASS BALANCE

MASS BALANCE

Figure 12 shows the current mass balance of HDPE and PP across the EU28. The stages are shown across the horizontal axis, with the coloured blocks indicating the flows in or out at each stage. Though there are losses in sorting and in reprocessing, the major source of leakage of plastic out of the recycling chain is low rates of collection and sorting.

The estimate of HDPE and PP within products has a significant margin of error due to a lack of reliable reported data on HDPE and PP in packaging and products imported into Europe. Based on market intelligence from PRE market experts, the data on quantities of HDPE and PP collected, sorted and exported are believed to be overestimates, demonstrating the need for considerably improved data reporting if performance within individual plastics streams is to be reliably assessed.

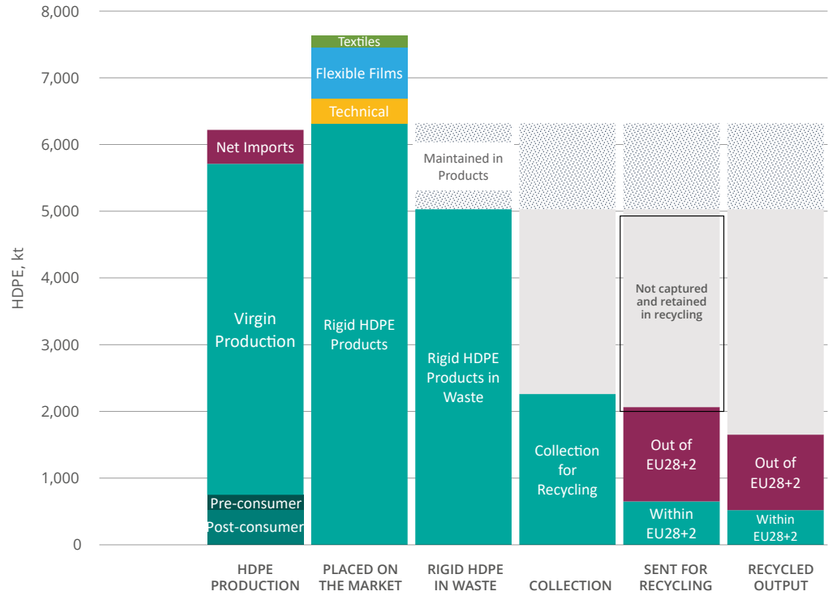

FIGURE 12: HDPE Mass Balance from Production to Output Recycling (source: PRE/Eunomia, summarised data from this report)

Based on the data analysis presented throughout this report for 2018, an estimated 80% of rigid HDPE sold onto the market arises as waste and, of this, up to 41% is sorted and sent for recycling.[53] However, the EU28+2 reprocesses in the region of 13% of end-of-life rigid HDPE.[54] Post-consumer rHDPE output in Europe in 2018 is estimated to be able to supply 8% of total European converter demand for HDPE resin.[55,56]

FIGURE 13: PP Mass Balance from Production to Recycling (source: PRE/Eunomia, summarised data from this report)

Based on the data analysis presented throughout this report, an estimated 92% of rigid PP sold onto the market arises as waste (excluding automotive and WEEE applications), and an estimated 19% of technical plastics put on the market arise as waste suitable for non-specialist reprocessing.[57,58]

Of this combined figure arising as waste, up to 28% is sorted and sent for reprocessing. However, European recycling capacity is estimated to reprocess 8% of rigid PP products arising in waste.[59] Post-consumer rPP output in Europe in 2018 is estimated to be able to supply 3% of total European converter demand for PP resin.[60]

Export restrictions have been the main driver of increased European reprocessing since 2016, as they have made it challenging for sorting plants to secure both offtake routes outside of Europe and cost-competitive offtake routes within Europe. However, they have also led to a greater quantity of waste being sorted to the standards required by European recyclers.[61] In Germany, for example, where sorting plants are required to meet recycling targets, recyclers can now charge a significant gate fee for mixed plastic waste that might previously have been exported at lower cost.[62]

PRODUCT DESIGN

Where products are not designed for recyclability, not only are the products less likely to be recycled themselves, but they have knock on impacts on the rest of the sorted waste streams, increasing losses (and therefore disposal costs), and/or increasing reprocessing costs.

There are established design guidelines for recyclability but little current data as to how much of the HDPE and PP waste stream meets these guidelines[63]. However, there are now heightened levels of communication across the industry, for instance with the RecyClass initiative showing considerable success in engaging producers with practical, recyclability assessments for specific products.[64]

COLLECTION

If products arising in waste streams are not recycled and sorted for recycling, they cannot be reprocessed. Only in the region of 33% of rigid polyolefins were sent for reprocessing in 2018 (see section 'Collection and Sorting').[65]

QUALITY: RECYCLABILITY OF HDPE & PP PACKAGING AND PRODUCTS

Ensuring a product is readily recyclable requires more than simply manufacturing the main product body from a technically recyclable polymer. Other features of product design (adhesives, labels, pigments) can hinder recyclability, and increase the costs of producing and/or reduce the value of secondary material. The technical and economic practicability of arranging the collection and onward sorting and management of the material must also be considered. The RecyClass initiative aims to help the plastics value chain find the correct way to approach and evaluate the design of packaging products with recyclability in mind, with the goal of improving their recyclability.[66]

According to the definition released by PRE in association with the Association of Plastics Recyclers (APR) in the USA, plastics must meet four conditions for a product to be considered recyclable:

1. The product must be made with a plastic that is **collected for recycling,** has **market value** and/or is supported by a legislatively **mandated program.**

2. The product **must be sorted and aggregated** into defined streams for recycling processes.

3. The product **can be processed** and reclaimed/recycled with commercial recycling processes.

4. The recycled plastic **becomes a raw material** that is used in the production of new products.

The definition references the economic viability of collection (in condition 1, with the concept of market value or legislative support) and of recycling processes (condition 3, with the reference to commercial recycling processes).

Table 9 examines each main HDPE & PP product group against all four conditions. The table highlights the challenges faced in particular in the recycling of food contact PTTs, PP pipes, bulky rigid household products, and especially other household and C&I products.

TABLE 9: Recyclability Assessment of HDPE and PP Rigid Product Groups

	Consumer packaging				Transport Packaging (HDPE/ PP)	Pipes		Automotive	Bulky rigid products (e.g. furniture)		Other household and C&I products	
Assessed HDPE and PP Product Groups for Recyclability	**HDPE**			**PP**		**HDPE**	**PP**	**PP**	**C&I sources (mono-material)**	**Household and mixed sources**	**C&I sources**	**Household sources**
Recyclability Criteria	**Natural / white bottles**	**Colour bottles**	**Other packaging**	**PTTs and bottles**								
OVERALL												
Collection	Included in EPR collections, and targetted by commercial recycling collections.			Included in EPR collections and targeted by commercial recycling collections in only a few Member States.	Economic to collect, as arising at end-of-life in bulk quantities and often managed by a specialist packaging company.	Most pipes are collected in mixed construction waste. Greater potential for separate collection where arising in bulk.	PP pipes used more in domestic plumbing, and arise in waste stream in bulk quantities less commonly than HDPE pipe.	Collection networks for ELVs well established and mandated by EPR legislation	Collection networks for ELVs well established and mandated by EPR legislation. Where end-of-life arisings in bulk quantities of uniform products, collection is viable. Otherwise, present in mixed bulky plastics streams.	Collection often relies on residents paying for collection or separating material correctly at container parks.	Some coverage of non-packaging products by some EPR household collections, but dense plastic products not targeted.	
Sorting	At sufficient scale, economic to sort separately from other colours.	Widely viable to sort, usually to mixed colour grade.	Acceptable in limited quantities in bottle bales, but also sortable into mixed polyolefin grades.	A smaller portion of the intput stream to sorters than HDPE. A significant fraction of PP packaging is recycled together with PE packaging in a mixed polyolefin stream. PP bottles tend to be too minor a portion of the input stream to be economic to sort separately.	Homogenous product stream, often requires no further sorting.	Sortable at C&D recycling sites, but not commonly separated.	Smaller quantity present in waste steam so less commonly separately sorted.	Disassembly can be costly due to design complexity, so many plastics end up in automotive shredder residue. However, large parts (e.g. bumpers) can be separated and recycled.		Variable mix of dense plastic products not desired in packaging streams and with no separate recycling markets.	Variable mix of dense plastic products not desired in packaging streams and with no separate recycling markets.	

	Consumer packaging				Transport Packaging (HDPE/ PP)	Pipes		Automotive	Bulky rigid products (e.g. furniture)		Other household and C&I products	
Assessed HDPE and PP Product Groups for Recyclability	**HDPE**			**PP**		**HDPE**	**PP**	**PP**	**C&I sources (mono-material)**	**Household and mixed sources**	**C&I sources**	**Household sources**
Recyclability Criteria	**Natural / white bottles**	**Colour bottles**	**Other packaging**	**PTTs and bottles**								
Recycling	Viable	Viable	Viable, though greater challenges in cleaning and consistency of recyclate output due to copolymers and contamination.		Viable	Dirt, soil and chemicals cause challenges in recycling.		Recycling of monomaterial large parts can be viable but the abundance and diversity of mineral fillers reduce yields	Reprocessing of bulk, uniform, monomaterial rigid products is viable with high yields.	In more diverse household or commercial bulky streams, collected streams can be contaminated with other materials (e.g. steel components of furniture).	Dense and hard plastics (e.g. toys) not recyclable with packaging materials, and no separate recycling markets due to variability of product stream, contamination with other materials from other products and product components.	
End-Market	Increasing demand in packaging applications.	wide demand for recyclate though limited to darker coloured applications	Limited to injection-moulded applications.	Tend to be limited to injection-moulded products.	Large potential for circular applications, including some use back into food-grade crates .	Potentially suitable for use in new pipes/ tubes.		Primarily injection moulded products. Some circular use through producer-organised collection networks.	Primarily injection moulded products.	Primarily injection moulded products.	No current end use	

BALE CONTAMINATION

The major source of HDPE and PP available for recycling is post-consumer packaging: over 80% of rigid HDPE waste and over 50% rigid PP waste is packaging (see section 'Collection and Sorting)'. Contamination within bales such as paper fibres, textiles and glass shards causes issues such as:

- Additional costs of sorting and disposal;
- A reduction in production efficiency; and
- The loss of a portion of wanted polymers.

RECYCLING

In addition to the quality issues caused by contamination within the household packaging bales, the use and complexity of consumer HDPE and PP packaging causes futher issues:

- Chemicals and odour causing compounds that have migrated into the polymers from organic waste and household products affect the odour of the material;
- The range of colourforms affects the colour of the output; and
- The mix of co-polymers, additives and different polymer grades within the variety of consumer packaging affects the resulting mechanical properties of the output.[67]

USE OF rHDPE AND rPP IN FOOD CONTACT PACKAGING

A key criteria determining suitability for use with food contact applications is the safety of the recycled resin. Processes for producing food-contact recyclate are required to have a safety assessment from the European Food Safety Authority (EFSA) and, following EFSA's published opinion, final authorisation from the European Commission and Member States. EFSA's opinions are published on its website, and a search shows only three opinions published regarding the production of food-contact recycled polyolefin resins: one covering two processes in the UK reprocessing HDPE natural milk bottles for the production of bottles and fruit and vegetable trays, and two processes for the recycling back into crates of HDPE/PP crates from closed-loop collection systems. EFSA has produced a document clarifying its assessment approach and evaluation criteria for food-contact PET processes, and no corresponding criteria for HDPE or PP have been published. Additionally, during that time the European Commission has not authorised any of the processes, leaving legal uncertainty over their use.

4. WHAT IS CHANGING?

- LEGISLATION WILL PLAY A VITAL ROLE IN CHANGING THE COLLECTION AND SORTING OF PLASTIC RECYCLING IN THE EU27, SUPPORTED BY CIRCULAR ECONOMY AND EPR PACKAGES.
- THERE ARE POLICY GAPS REGARDING INTEGRATION OF RECYCLED CONTENT IN PRODUCTS TO SUPPORT DEMAND, AND IN MEASURES TO SUPPORT THE QUALITY OF MATERIAL SORTED AND COLLECTED.
- R&D IS NEEDED TO PROVIDE CONTINUAL IMPROVEMENT IN PROCESSES, TO SOLVE PARTICULAR PROBLEMS IN RECYCLABILITY, AND TO OPEN UP THE POTENTIAL FOR STEP CHANGES IN HOW COLLECTION, SORTING AND RECYCLING IS OPTIMISED FOR A CIRCULAR ECONOMY.

GOVERNMENT PRESSURE VIA LEGISLATION

- Revision to Packaging and Packaging Waste Directive (PPWD) in 2018
- Article 8(a) of the amended Waste Framework Directive (WFD)
- (VOLUNTARY only) Strategy for Plastics in a Circular Economy - vision statement includes fourfold increase in sorting and recycling capacity for plastics from 2015 to 2030

MARKET PRESSURE

Brands positioning ahead of governement position with regards to pledges on recycled content of plastics products

RESEARCH AND DEVELOPMENT

PRODUCT DESIGN	• Tackling specific recyclability issues • Mono-material replacements for multi-material packaging
COLLECTION	• Considering Expansion of Deposit-Return and Take-Back Schemes for other Packaging • Focus on improving engagement and participation in collection services
SORTING	• Continuing to develop the speed and accuracy of automated sorting equipment (e.g. NIR), its ability to detect levels of legacy and organic additives, and the development of AI algorithms to replicate or support the decisions of manual pickers • An approach to programming materials for smarter sorting (e.g. through digital watermarking) would enable a step - change in sorters ability to produce high - quality outputs
RECYCLING	**Mechanical** • Further improving cleaning, odour reduction and filtration processes to improve quality of recyclate • Investigating approaches to improve the separation of polymers with similar densities, ink removal processes and filtration processes **Chemical** • Still largely at the pre-commercial stage, however significant investment decisions and commercial capacity commitments have been announced in relation to chemical recycling processes over the past 18 months

LEGISLATION AND INDUSTRY COMMITMENTS

The following legislation will result in changes to both the collection and sorting of plastic for recycling within the EU27:

- The revision to the Packaging and Packaging Waste Directive (PPWD) in 2018 established in European law a 50% target for the recycling of plastic packaging by 2025 which rises to 55% by 2030.
- The revised calculation method for reporting against these targets applies stricter and more accurate approaches to the measurement of recycling rates of municipal and packaging waste.
- The PPWD references the amended Waste Framework Directive (WFD), which requires, in Article 8a, that producer responsibility schemes cover the full net costs of the separate collection of packaging (including for the clean-up of litter), and that the fees charged to producers are modulated according to one or more of a range of criteria, including recyclability.
- Member States and EPR schemes will need to continue improving the quantity of plastics collected and sorted for recycling. EPR schemes should transfer the end-of-life costs of products to producers, and so create an incentive for eco-design (where this reduces end-of-life management costs).

Most of this legislation is focused on providing for collection and increasing the quantity of material collected for recycling (and in turn increasing the quantity recycled). However, there are policy gaps regarding integration of recycled content in products to support demand, and in measures to support the quality of material collected and sorted and of the recyclate produced.

In 2018, the European Commission published its 'Strategy for Plastics in a Circular Economy', announcing within its vision statement a fourfold increase in sorting and recycling capacity for plastics from 2015 to 2030, inviting voluntary commitments and pledges from industry groups across the supply chain.[68] The European Commission has also launched the Circular Plastics Alliance.[69] The signatory organisations to the alliance (which include over 175 organisations representing industry, academia and public authorities) 'take action to boost the EU market for recycled plastics to 10 million tonnes by 2025'. A separate initiative, the European Plastic Pact (EURPP) was created to bring together government and industry across the whole value chain, to work together to address challenges of design, responsible use, recycling capacity and use of recycled content for packaging and single-use plastics.[70]

TECHNOLOGY RESEARCH & DEVELOPMENT

Research and development (R&D) is needed to provide continual improvement in processes, to solve particular problems in recyclability, and to open up the potential for step changes in how collection, sorting and recycling is optimised for a circular economy.

DESIGN FOR RECYCLABILITY

Design determines whether packaging can be recycled. RecyClass, an initiative and toolkit for checking and certifying the recyclability of packaging, has published design for recycling guidelines for PP containers, and protocols for evaluating the recyclability of both HDPE containers and PP containers.[71]

Research and development (R&D) in this area focuses on innovative packaging design that meets brand objectives, while continuing to tackle specific recyclability issues, such as reducing the use of multilayer trays.

The innovations in design that have most potential for radical impact on the sector are those that integrate additional information in the packaging material to facilitate, among wider industry benefits, increased potential for more intelligent and nuanced sorting. One key project is the 'Holy Grail' project, which has demonstrated the potential of digital watermark technology to integrate 'invisible codes' with printed materials and directly into a mould. Each product can then be individually read by a camera, allowing product-specific sorting and, for instance, information about the product use of the packaging as well as the polymer type to be used by Near Infra-Red (NIR) and other optical sorters. This would allow, for instance, food-contact packaging to be separately sorted, or to separate out packaging likely to contain problematic odours or chemical contaminants.

COLLECTION

Today, state-of-the-art collection systems use effective communications to engage residents in the correct use of recycling services, often utilising social media and phone applications alongside traditional communications.

Looking to the future, R&D efforts focus on continuing to improve understanding of how to maximise engagement and incentivise people to participate in the services that are provided. Innovation in deposit-refund scheme technologies and systems could open up further opportunities to collect other packaging waste streams aside from beverage bottles.

BEST PRACTICE CASE STUDY
EXPANDING PLASTICS COLLECTION AND SORTING: FOSTPLUS, BELGIUM

Fostplus, the packaging EPR scheme in Belgium, rolled out in 2019 expanded collection of plastics to include pots, tubs and trays, covering the majority of PP packaging waste. It has also introduced new sorting guidelines for sorting plants mandating a set of sorted output streams, ensuring consistency at a national level of sorted packaging waste streams. HDPE or PP have been published.

SORTING

Near Infra-Red (NIR) technologies are widely used in sorting plants to sort specific polymers from each other and to remove contaminants. Ongoing development of NIR sorting technology has already provided the ability to sort smaller items with increasing accuracy, including sorting material post flaking operations. PRE has produced a set of guidance documents (known as Recycling Input Characterisation Guiding Requirements) that provide definitions and requirements for a range of different polymer types, for use by both sorting centres and recyclers.[72]

Looking to the future, R&D continues to develop the capacity for fully-automated sorting systems, especially in countries with high labour costs, including R&D into the use of artificial intelligence (AI) and robotics in the sector. However, sorting plant outputs are primarily determined by the output quality standards the plants work to, and by economic cost and revenue drivers. Moreover, most problems in sorting can be dealt with by current technologies supplemented by manual operatives, provided there is a sufficient economic benefit. Digital watermarking of products would enable a step change in the ability of sorters to produce high quality outputs, allowing specific problematic products to be removed, or desirable products to be selected, in a highly targeted way.

RECYCLING

Hot-washing of plastic flake, often with added caustic soda or other detergents, reduces the levels of inks, adhesives, organic contamination, odours and microorganisms, improving the suitability of flake for a wider set of outputs. Fine filtration during extrusion further removes physical contamination, while decontamination through vacuum-based degassing, whether applied to material in flake form or during extrusion, provides a final step in removing volatile compounds and gases. NIR can also be employed to colour-separate flake and remove contaminating polymers.

Existing technologies are sufficient to create high quality outputs from high quality sorted waste streams, where the demand is there. However, the odour and variability in mixed household pots, tubs, and trays present a particular challenge.

R&D is ongoing in further improving odour reduction and filtration of recyclate to improve quality. Particularly for the less homogeneous household PP stream, the measurement of composition needs to improve and the impact of the use of additives and stabilisers on subsequent recyclate quality to be better understood.

Approaches to odour reduction being developed include adding counter odour (such as citrus or vanilla) into the extrusion of secondary material. Other solutions being researched include microporous additives, neutralizing agents (for reducing the volatility of odorous compounds), and stripping agents (for removing volatile compounds by degassing during extrusion).[73]

Development is also ongoing in improving filtration technologies (which remove lumps, fine particles and other polymer contamination).[74]

Looking to the future, converters are working with machinery manufacturers to develop additional technologies to incorporate more rPM into final products. Recyclers are also innovating with compound materials (produced particularly from mixed polyolefin outputs) to enhance the recycled output characteristics for suitability in a broader range of product applications. [75]

CHEMICAL RECYCLING

Chemical recycling of plastics generally refers to a range of different processes that can break down or depolymerise polymers into their original monomers or other chemical feedstocks to then create new polymers. These processes are still largely at the pre-commercial stage; however, they are generating interest as a replacement for unsustainable feedstock sources.

The main processes applicable to HDPE & PP are as follows:

- Solvent-based purification – dissolving the polymer in a specific solvent, removing additives and impurities through filtration or phase extraction, and precipating the polymer using an appropriate anti-solvent. This kind of process may not remove all impurities and does not restore the chain-length of polymers. Thus the output is more comparable to that from mechanical recycling.[76]
- Pyrolysis – using heat (without oxygen) to break down polymers into smaller hydrocarbon molecules, resulting in a hydrocarbon mix resembling the composition of oil. The output can be used as fuel or refined using conventional refining processes to produce value-added chemicals including building blocks for polymers. [77]

Solvent-based purification processes for HDPE & PP are still largely at the pre-commercial stage. Industry-scale pyrolysis has failed in the past, but new pilots are emerging. According to Suschem's recent research report, high costs of utilities, low yields, and low-quality of the final product need to be addressed in order to make these processes more financially, industrially and environmentally attractive.[78] However, with increased focus on circular industrial processes, considerable scale-up effort is underway by a number of chemical industry players, including major resin producers such as BASF, Dow, Sabic and Eastman.

Development of chemical recycling capacity at scale may be necessary in the longer term to tackle more contaminated HDPE & PP streams. However, it is doubtful whether chemical recycling will scale up quickly enough to make a meaningful contribution to EU packaging recycling targets for 2025 and 2030.

5. WHERE NEXT ?

This section draws together our analysis of the current state of the HDPE & PP market and the key challenges facing recyclers in order to reflect on the future state of the market. This is set into the context of recent legislative changes and industry developments, and where/how the supply chain should focus its efforts going forward, in order to provide a robust view on the market as it continues to develop.

- WITHIN THE EU, THERE IS SCOPE TO FURTHER GROW EUROPEAN RECYLING CAPACITY, IN ORDER TO RECYCLE THE EXTRA QUANTITIES OF HDPE & PP THAT WILL BE COLLECTED AS MEMBER STATES MOVE TOWARDS PLASTIC PACKAGING RECYCLING TARGETS.
- ONLY 5% OF EU28 DEMAND FOR HDPE & PP IS CURRENTLY MET BY POST-CONSUMER rHDPE & rPP (7% INCLUDING PRE-CONSUMER RECYCLATE), LEAVING MUCH POTENTIAL TO FURTHER INCREASE THE USE OF RECYCLED CONTENT ACROSS A RANGE OF SECTORS AND APPLICATIONS.
- THERE ARE POLICY AND R&D GAPS WHICH THE INDUSTRY NEEDS TO WORK ON, TOGETHER WITH POLICY MAKERS, TO ENSURE THAT INCREASED QUANTITIES OF COLLECTED RIGID POLYOLEFINS CAN BE PROCESSED INTO RECYCLING OUTPUT SUITABLE FOR USE IN A GREATER RANGE OF HDPE & PP APPLICATIONS.

FUTURE STATE OF THE MARKET

DEMAND FOR HDPE & PP IN PRODUCTS

Demand for HDPE & PP packaging is likely to continue to grow with demand for plastic packaging and increasing use of technical plastics in place of metals, for instance in the automotive sector.

A clear definition of design for recyclability, alongside a common framework for product-level assessments and financial incentives, should:

- Continue to decrease the use of opaque colours in products with high virgin content, ensuring more recycled polymer is suitable for colour-sensitive product applications (e.g. packaging); and
- Reduce contamination from other polymers, adhesives, and fibre, reducing losses in sorting and processing, and improving the visual and mechanical properties of outputs.

INCREASING COLLECTION RATES

With the right support and frameworks in place, the amount and quality of collected and sorted rigid polyolefins is expected to increase substantially over the next decade.

An increase in collection and sorting of post-consumer plastic packaging

EU plastic packaging recycling targets of 50% by 2025 and 55% by 2030 will drive an increase in collected waste volumes, as Member States and EPR schemes improve rates of collection and sorting.

In order to meet higher recycling targets for packaging waste in particular, Member States and EPR schemes will need to continue improving the quantity of plastics collected and sorted for recycling. Given that, alongside PET bottles, rigid HDPE and PP are more readily collected and sorted for recycling than other plastic packaging items (particularly multi-layer trays and PVC packaging), it is likely that the rigid polyolefin recycling rate would have to surpass these recycling targets to ensure the targets are generally met for all plastic packaging. The Polyolefin Circular Economy Platform (PCEP) has announced an industry-wide 2030 commitment to create a roadmap to reach 60% recycling and reuse of collected polyolefin packaging.[79]

The PCEP 2030 target of 60% recycling and reuse of polyolefin packaging would require sorting for recycling rates closer to 75% (taking into account losses in reprocessing), resulting in up to 4.9 Mt input to recycling compared with 1 Mt input to European recyclers in 2018.[80]

Potential for EPR-driven increase in collected HDPE and PP waste in other sectors

Further actions to improve the coverage and effectiveness of EPR schemes in these areas are likely to be needed to improve collection and sorting rates. EPR potentially has a role to play in targeting currently challenging HDPE & PP product streams, for example agri-plastics, and products from the construction and automotive sectors.

RECYCLING CAPACITY AND RECYCLATE PRODUCTION

The quantity of recycling capacity available for reprocessing is set to grow substantially by 2030 in response to legislative targets for plastic packaging waste and industry ambitions around the recycling of polyolefin packaging. The EU has set a plastic packaging recycling targets of 50% by 2025 and 55% by 2035, while PCEP (the polyolefin Circular Economy Platform) has committed to 60% reuse or recycling of collected polyolefin packaging.

Polyolefin packaging was estimated at 6.6 Mt in total for 2018 (see section 'Market Sectors (Applications)'), whereas European capacity is at 1.2 Mt, implying a current capacity to treat only 18% of rigid HDPE and PP packaging (lower when taking into account non-target material in inputs and reprocessing losses). Though there is uncertainty over the total market figure, it is clear that European reprocessing has room to scale up significantly to meet increased collected and sorted tonnages.

The major source of HDPE and PP collected for recycling is post-consumer packaging. Improving the recycling material from these sources means addressing the key challenges (discussed in section 3.b. 'Quality: Recyclability of HDPE & PP Packaging and Products') that are currently encountered, such as:

- High levels of bale contamination from polymers, fibres and glass, reducing production efficiency, increasing costs and causing production issues; and
- High levels of chemicals and odour causing compounds that have migrated into the polymers from organic waste and household products.

THE MARKET – rHDPE & rPP

As noted the End Markets section, demand for rHDPE and rPP is largely for non-packaging applications, with the construction and automotive sectors as the main outlets. Drivers for change in output markets include aspirations to increase recycled content within the automotive and packaging sectors, and continued growth in demand for rPP in particular for film, pipe and non-food packaging applications.[81] The European Commission strategy for plastics notes specific potential for further uptake of recycled content in certain applications in the construction and automotive sectors (e.g. insulation materials, pipes, outdoor furniture or dashboards).[82]

The main opportunities to increase demand for rHDPE & rPP in products include:

- If a market is developed for food-contact rPP, this could unlock a further demand in the packaging sector. Consumption of PP for rigid food grade products is estimated at around 1 Mt (see section 'Market Sectors (Applications)'), and PP is also used for flexible food packaging.
- Greater use of recycled material in the automotive sector.
- Greater potential for producing food-grade packaging by specifically targeting more defined collection streams (e.g. food crates and bottle caps)

There are opportunities to increase the supply of rHDPE and rPP into non-food packaging applications, but also room to significantly increase supply into the automotive and construction sectors. Currently, there is no food grade packaging production using post-consumer rPP and coloured rHDPE. The complexity of PP polymers, additives and contamination within the post-consumer stream creates significant complexity and cost to meeting demanding product specifications from mixed PP and HDPE consumer packaging, particularly to the safety standards necessary for food contact material. Moreover, unlike for PET, EFSA has not clarified its assessment criteria or evaluation approach to processes producing food-grade rPP.[83]

There is significant scope to increase the use of rHDPE and rPP into more product applications, most notably within the automotive sector and non-food packaging applications.

However, the increase in tonnage will largely be from additional household HDPE and PP packaging waste, the stream which faces the most quality challenges in recycling. Continued progress and innovation is needed to tackle quality challenges within this stream and to enable recycled output from household waste streams to meet more demanding product specifications.

New opportunities to reprocess specific fractions of the household packaging stream (i.e. food-contact material) could be opened up by widespread adoption of a system for making packaging 'readable' by sorting machines (e.g. digital watermarking).

The SUP Directive sets a target for 30% average recycled content in beverage bottles of three litres and under, covering HDPE bottles used for juices and dairy products. Though to date beverage bottles are the only product category to have a European target for recycled content,[84] producers and brands of other rigid polyolefin products have made a range of commitments and goals.

MARKET SUPPORT

Various pieces of legislation have come into force to support the recycling of plastics. However, there remain a number of policy and R&D gaps to increasing the quantity of material collected that can also feed high-quality recycling output into more mature markets. This requires collaboration between industry and European policy makers.

A COMMON APPROACH TO ASSESSING RECYCLABILITY

CITEO in France, and to a lesser degree CONAI in Italy, use eco-modulation of fees to provide specific cost incentives for producers to ensure products meet recyclability criteria. Eco-modulated fees should be used across all EPR schemes as a key way of helping meet increased targets for the recycling of plastic packaging.

For calculation of eco-modulated fees, and to provide additional clarity to brands that are aiming to increase the recyclability of their packaging, a common framework is needed. Recyclability should be assessed in the same way across the industry, underpinned by a clear definition, and with claims of recyclability tested against reliable protocols. This framework needs to be based upon:

- Technical data and current/latest processes; and
- Capacities of recyclers to recycle products without prohibitive cost.

In addition, such a framework should be:

- Updateable in response to developments in technology and processes; and,
- Able to assess recyclability at the level of individual products.

The RecyClass initiative could provide the basis for such a framework, with protocols already in place for the assessment of HDPE & PP. PRE has also already released a definition of recyclability in cooperation with APR in the US, taking into account the viability of collection and recycling(further refered to in section 3.b. 'Quality: Recyclability of HDPE & PP Packaging and Products').

CONSIDERING EXPANSION OF DEPOSIT-RETURN AND TAKE-BACK SCHEMES FOR OTHER PACKAGING

Deposit-return schemes for consumer packaging and take-back schemes for transport packaging have proven successful both in increasing capture of plastics and in ensuring low levels of contamination of non-targeted materials in collected waste streams. Deposit schemes for PET beverage containers have created high return rates and played an important role in expanding closed-loop, bottle to bottle recycling. While early reverse-vending machines (RVMs) were restricted to round beverage containers, modern technology has the ability to register and refund deposits on a far wider range of container shapes. However, the costs and benefits of expanding these schemes to consumer packaging beyond beverage bottles, and the knock on impacts to the other portions of the sorted waste streams, need further assessment.

FULLER EPR COVERAGE IN NON-PACKAGING WASTE STREAMS, INCORPORATING PLASTICS-SPECIFIC TARGETS

Recycling targets for EPR schemes covering ELVs are not specific to plastic materials, and while collection rates for ELVs are high (owing to both EU legislation and the high value of ELVs) this does not necessarily translate into high separate collection rates for automotive plastics. At present, much automotive plastic is recovered as a component of the mixed-material residue generated in the shredding of ELVs. EPR could provide a way of driving the separate collection and recycling of the HDPE & PP present in ELVs.

In addition, further roll-out of EPR schemes covering pesticide and fertiliser containers (as in France) could be expected to increase collection rates for recycling of agricultural rigid plastics.

SORTED PACKAGING BALE QUALITY STANDARDS

Processing bales with higher levels of contamination increases the cost and complexity of reprocessing operations and of achieving a high quality of rHDPE/rPP flake or regranulate. Where PROs are involved in contracting sorting plants, such as CITEO in France, Green Dot in Germany, or Fost Plus in Belgium, there is a greater opportunity to mandate a certain quality of outputs. Common European quality standards for sorted packaging waste bales could be agreed upon and implemented across the Industry, which would place the onus on collectors and sorters to reduce problematic contamination within sorted bales.

If bale standards cannot be achieved by better quality sorting of plastics collected with other materials (fibre and glass), then the industry should consider collection of plastics recycling separately from papers and glass.

FOOD-CONTACT AUTHORISATION FRAMEWORK FOR HDPE AND PP RECYCLING

Producing food-contact quality rPP from mixed consumer packaging waste is challenging and expensive, and the market opportunity is limited, as food contact PP consumer packaging only amounts to an estimated 11% of PP use (see section 'Market Sectors (Applications)'). While there is sufficient demand growth for rPP in other markets (automotive, construction and packaging films, secondary packaging), there may not be a sufficient economic or environmental case to develop the food-grade rPP market until recycling rates have significantly increased. Additionally, there could be limits on recycled content within food grade applications (for structural or safety reasons) that could further limit the size of the potential market.

However, drivers to create and authorise food-grade rHDPE and rPP processes may come from producers and brands keen to develop and integrate recycled content within food packaging, and these processes may be enabled by sorting innovations that allow highly targeted separation of, for instance, transparent PP food packaging. The technical feasibility of creating thermoformed and blow-moulded food contact rPP trays from PP food contact packaging that satisfy safety assessments has been demonstrated at a small scale.

In the European Plastics Strategy, the European Commission notes it will:

"assess whether safe use [for food contact materials] of other recycled plastic materials [i.e. aside from PET] could be envisaged, for instance through better characterisation of contaminants". [85]

The evaluation criteria and legislation need further development at European level to enable positive assessments of such processes.

CERTIFICATION PROCESS FOR RECYCLED MATERIAL

Responding to consumer awareness, brands are making commitments to integrate recycled content into their products. There is a need for EU-wide quality certification to verify the claims made by brands and producers to guarantee the quality of the recycled material they are incorporating.

RecyClass has developed the Recycled Content Traceability Certification Audit Scheme to evaluate and calculate the recycled content in plastics applications.[86] This is based on two main principles:

- Traceability of materials and products through the supply chain; and,
- Chain of Custody, allowing for an unbroken chain of organisations legally owning the material and the transfer of information throughout the supply chain, from the certified recycler output to the final product.

This allows brands and producers to meet internal targets or legislative requirements regarding recycled content with confidence in the traceability of the material. It can also be used to ensure that commitments to incorporate recycled content will create equivalent demand for certified recycled output from recyclers.

Another existing quality certification scheme covering recycling processes and waste traceability is EUCertPlast, created by PRE, EPRO, EuPC and Recovinyl, and based on the European Standard EN 15343:2007. It is recognised by German and Italian authorities and could also form the basis for an EU-wide certification.[87,88]

FURTHER R&D

To achieve a step-change in the technological potential of current sorting machinery, producers and brands should align behind an information solution for product packaging, such as digital watermarking, that opens up new opportunities for targeted sorting of specific HDPE & PP streams.

The Circular Plastics Alliance (CPA, an initiative under the European Strategy for Plastics) has published a report setting out a short term agenda for the R&D projects needed to achieve the Alliance's goal of boosting the EU market for recycled plastics to 10 million tonnes by 2025.[89] The agenda, which has been set through discussion between CPA signatories in market oriented working groups, presents R&D needs across what the CPA has identified as the five main plastics-using sectors: packaging, automotive, construction, agriculture and electronic and electrical equipment (EEE).

The agenda includes R&D needs specific to each sector, as well as broader strategic needs applying to at least three sectors. The strategic needs identified concern:

- Chemical and physical recycling;
- Quality control and consistency of recyclate;
- Methods for traceability;
- Improved recycled material properties;
- Better separation of polymer types; and
- Detecting and separating hazardous substances.

ROBUST DATA SOURCES

While this report goes some way to examining the state of the HDPE & PP market, it has also identified a number of data gaps regarding the total HDPE & PP supply chain and how it is changing over time. There is a need to improve the quality of data across the board, including data on tonnages of HDPE & PP placed on the market, collected and sorted, reprocessed domestically and exported. This data is needed to ensure that the EU continues to develop appropriate capacity and technology to meet the demands of the changing world of packaging.

To improve the data and enable better tracking of progress towards higher recycling rates for HDPE & PP, there is a need for EPR schemes to publish information on tonnages of rigid HDPE & PP product applications placed on the market, ideally by polymer, colour, and product type, as these are relevant to different recycling streams.

To understand the evolving market for HDPE & PP recyclate there is a need for tracking and reporting quantities of different HDPE, PP and PO grades sorted and sent for recycling, along with reporting on the amounts of non-HDPE & non-PP in sorted bales. This could be achieved by:

- Member States and EPR schemes improving the ways in which they track and report amounts of HDPE & PP collected and sorted, and providing greater data resolution on plastic exports; and
- Contribution of recyclers to data gathering efforts, both through increased participation in PRE surveys, and through Circular Plastics Alliance (CPA) initiatives, such as its proposed monitoring system to trace the collection, sorting and recycling of plastic waste, as well as the use of recycled plastics.[90]

To understand the recycling routes and destinations of smaller HDPE and PP products, better data is needed on the amounts and types of polyolefins in mixed plastic and reject streams from MRFs.

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A FINAL NOTE

In order to support the further development of markets for recycled rigid polyolefins within EU28, there is a need for the industry to work together with European policy makers to:

INCREASE THE QUALITY AND QUANTITY OF COLLECTED AND SORTED WASTE STREAMS, BY:

- adopting a common approach and framework for product-level recyclability assessments, with an agreed definition of recyclability; and
- developing and implementing agreed bale quality standards (of the kind provided in PRE's Recycling Input Characterisation Guiding Requirements[91]).

IMPROVE MARKETS FOR RECYCLED MATERIAL, BY:

- developing a certification process for the quality of recycled polymer resins and compounds (of the kind provided by RecyClass's Recycled Content Traceability Certification Audit Scheme[92]), and the use of certified material within product applications; and
- continuing to develop understanding of the potential for rHDPE and rPP material to contribute to different product applications.

Additionally, to achieve a step-change in the technological potential of current sorting machinery, producers and brands should align behind an information solution for product packaging (such a digital watermarking) that opens up new opportunities for targeted sorting of high-quality output streams.

A clear definition of design for recyclability, alongside a common framework for product-level assessments and financial incentives, should:

- Continue to decrease the use of opaques colours, ensuring more recycled polymer is suitable for colour-sensitive product applications (e.g. packaging); and
- Reduce contamination from other polymers, adhesives, and fibre, reducing losses in processing and improving the visual and mechanical properties of outputs.

ANNEX

1. *Eurostat PRODCOM: Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data (DS-066341), last accessed: 19/06/2019, (https://ec.europa.eu/eurostat/web/prodcom/data/database)*
2. *The Eurostat 'Primary Forms' product codes by definition cover both virgin and recycled resins. Plastics Europe (2018), Plastics – the Facts 2018, https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics_the_facts_2018_AF_web.pdf*
3. *Plastics Insight, HDPE (High-Density Polyethylene): Production, Market, Price and its Properties, last accessed: 19/06/2019, https://www.plasticsinsight.com/resin-intelligence/resin-prices/hdpe/*
4. *Eunomia (2020), 'Flexible Films Market in Europe: State of Play', report for PRE; HDPE films estimate from combined studies (Deloitte (2017), Kawecki et. al (2018))*
5. *Kawecki et. al (2018), '"Probabilistic Material Flow Analysis of Seven Commodity Plastics in Europe"*
6. *Eurostat PRODCOM: Statistics on the production of manufactured goods, Sold production, exports and imports (DS-056120), last accessed: 19/06/2019 (https://ec.europa.eu/eurostat/web/prodcom/data/database)*
7. *UN Comtrade Database, last accessed: 19/06/2019 (https://comtrade.un.org/data/)*
8. *Eurostat PRODCOM: Statistics on the production of manufactured goods, Sold production, exports and imports (DS-056120), last accessed: 19/06/2019 (https://ec.europa.eu/eurostat/web/prodcom/data/database)*
9. *Studies specific to each sector are detailed in the below sections, and include: Deloitte & PRE (2017) for packaging; Eurostat (2018) for pipes and fittings, and bottle caps; Transparency Market International for transport packaging; Plastics Europe (2018) for automotive sector; EEB (2017) and Kawecki (2018) for furniture; Kawecki (2018) for agriculture and other household products; and Eurostat (2018) and CECED (2017) for EEE*
10. *The total amount of HDPE in product applications on the market estimated from studies also exceeds the amount of HDPE consumed as reported by Eurostat. This difference is unlikely to be fully explained by imports of HDPE products into the EU28+2, suggesting the study-derived data is overestimated*
11. *Deloitte & PRE (2017), Blueprint for plastics packaging waste: Quality sorting & recycling. Data relates to 2014 flows for five countries extrapolated to the EU28. An annual growth rate of 2.9% is applied corresponding to the growth in plastic packaging generation reported to Eurostat from 2014 to 2018*
12. *While best efforts have been made to give accurate estimates based on the official Eurostat data and other available data sources, it is important to note that, based on market intelligence, PRE market experts believe that figures for HDPE household packaging placed on the market may be overestimated, in particular with regard to bottles/containers – and so may overrepresent this sector of the market*
13. *As above*
14. *Total EU28 consumption of caps and closures was 2.2 Mt in 2018, but many of these are for HDPE and PP products (bottle, tubs etc) which appear elsewhere in these reported figures. The 0.7 Mt tonnage included accounts for an estimated portion of bottle caps in other plastics streams (notably from PET bottles)*
15. *Borealis (2007), Polyolefins Moulding Caps and Closures*
16. *Transparency Market International data shared with Eunomia. This figure does not include an estimate for HDPE and PP used for crates.*
17. *A UK composition study on the PP consumer waste stream from household and commercial sources found that 90% of household PP PTTs were food contact packaging; and 20% of commercial rigid PP packaging waste was food contact packaging (WRAP (2018), UK Market Composition of Polypropylene Packaging)*
18. *Eurostat PRODCOM: Statistics on the production of manufactured goods, Sold production, exports and imports (DS-056120), last accessed: 19/06/2019 (https://ec.europa.eu/eurostat/web/prodcom/data/database)*
19. *Plastics Europe, Annual Review 2017-2018 (2018); https://www.plasticseurope.org/en/resources/publications/498-plasticseurope-annual-review-2017-2018*
20. *Toni Gallone and Agathe Zeni-Guido (2019) Closed-loop polypropylene, an opportunity for the automotive sector, Field Actions Science Reports, Special Issue 19*
21. *As above*
22. *Kawecki et. al (2018). This report concerns data for 2014*
23. *EEB (2017), 'Circular Economy Opportunities in the Furniture Sector'; assuming the majority of plastic non-upholstered seats and 'other' plastic furniture are HDPE and PP, and taking the split of HDPE and PP in furniture from Kawecki et al. (2018)*
24. *CECED (2017), 'Material Flows of the Home Appliance Industry'; Eurostat, Waste electrical and electronic equipment (WEEE) by waste management operations (env_waslee), last accessed: 19/06/2020, https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waslee&lang=en*
25. *Eurostat PRODCOM: Statistics on the production of manufactured goods, Sold production, exports and imports (DS-056120), last accessed: 19/06/2019 (https://ec.europa.eu/eurostat/web/prodcom/data/database)*
26. *PlasticsEurope (2017), Overview Plastic Waste from Building and Construction by Polymer and by Recycling, Energy Recovery and Disposal, 2014*
27. *https://www.plastics.gl/automotive/benchmarking-polypropylene-in-automotive/, accessed July 2020. Note, this 2018 data*
28. *Toni Gallone and Agathe Zeni-Guido (2019) Closed-loop polypropylene, an opportunity for the automotive sector, Field Actions Science Reports, Special Issue 19*
29. *The 5,000 Kt total for HDPE shown in Figure 7 is rounded down from a total of 5,032 Kt.*
30. *Deloitte & PRE (2017), Blueprint for plastics packaging waste: Quality sorting & recycling. Incorporates 13% loss in sorting.*
31. *Based on estimated recycling rate for furniture cited in Eunomia (2017), 'Circular Economy Opportunities in the Furniture Sector', report for EEB*
32. *Deloitte & PRE (2017)*
33. *Market expert estimate*
34. *PlasticsEurope (2017), Overview Plastic Waste from Building and Construction by Polymer and by Recycling, Energy Recovery and Disposal, 2014*
35. *IEEP (2017), EPR in the EU Plastics Strategy and the Circular Economy: A focus on plastic packaging*
36. *Deloitte & PRE (2017), Blueprint for plastics packaging waste: Quality sorting & recycling. Note, data is for 2014*
37. *Deloitte & PRE (2017) Note, data is for 2014*
38. *Eurostat: Packaging waste by waste management operations and waste flow (env_waspac), 2017 data, last accessed: 12/11/2020 (https://ec.europa.eu/eurostat/web/products-datasets/-/ENV_WASPAC)*
39. *Circular Plastics Alliance (2020), State of Play on Collection and Sorting, available at https://ec.europa.eu/docsroom/documents/43694*
40. *https://www.retursystem.se/sv/*
41. *PlasticsEurope (2017), Overview Plastic Waste from Building and Construction by Polymer and by Recycling, Energy Recovery and Disposal, 2014. Note, data is for 2014*
42. *Article 7(2) of Directive 2000/53/EC (https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0053:20050701:EN:PDF)*
43. *EC COM/2020/33 Final; Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Implementation of Directive 2000/53/ec on end-of-life vehicles for the period 2014-2017 (https://ec.europa.eu/environment/waste/elv/implementation_en.htm)*
44. *Communication with PRE expert steering group*
45. *Toni Gallone and Agathe Zeni-Guido (2019)*

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46. *IEEP (2017)*
47. *PRE Data Mapping*
48. *Ibid*
49. *PRE expertise*
50. *Deloitte & PRE (2017), Blueprint for plastics packaging waste: Quality sorting & recycling*
51. *Ibid*
52. *Ibid*
53. *6.32 Mt rigid HDPE products placed on the market (column 2 in figure 12), of which 5.03 Mt (80%) arising as waste (column 4 in figure 12); of which up to 2.06 Mt (41%) sorted for recycling (column 4 in figure 12) rigid HDPE products*
54. *Estimated 650 Kt input to recyclers in EU28+2 out of an estimated 5 Mt arising in waste*
55. *Estimated 520 Kt post-consumer rHDPE output compared to 6.2 Mt total demand (total of column 1 in figure 12)*
56. *The total amount of HDPE in product applications on the market estimated from studies also exceeds the amount of HDPE consumed as reported by Eurostat by 1.4 Mt. This difference is unlikely to be fully explained by imports of HDPE products into the EU28+2, suggesting the study-derived data is overestimated*
57. *Total 4.86 in column 3 of figure 13 = 4.58 Mt non-technical rigid PP (92% of 4.98 Mt non-technical rigid PP placed on the market) plus 256 Kt estimated PP bumpers (19% of total 1.6 Mt technical PP)*
58. *The difference between the amount put on the market and the amount collected and in scope of non-specialist reprocessing is due to both the higher quantity of PP in cars placed on the market today compared to the average end-of-life vehicle, and the proportion of PP in collected ELVs that is sorted into large parts compared to ending up in shredder residue*
59. *Estimated 384 Kt input to recyclers in EU28+2, out of an estimated 4.8 Mt arising in waste*
60. *Estimated 307 Kt post-consumer rPP output compared to 10.5 Mt total demand (total of column 1 in figure 13)*
61. *Communication with PRE Steering Group*
62. *Communication with HDPE/PP recycler, Germany*
63. *Guidelines for HDPE and PP packaging available from https://recyclass.eu/recyclass/design-for-recycling-guidelines/*
64. *RecyClass, last accessed: 19/09/2019; (https://recyclass.eu/)*
65. *Combined sorted estimate of up to 3.3 Mt compared to up to 9.9 Mt rigid HDPE and PP in waste.*
66. *More information available at https://recyclass.eu/*
67. *FIACE (2017), Mapping Flexible Packaging in a Circular Economy*
68. *EC COM (2018) A European Strategy for Plastics in a Circular Economy, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN*
69. *For more information see https://ec.europa.eu/growth/industry/policy/circular-plastics-alliance_en*
70. *For more information see https://europeanplasticspact.org/*
71. *Available from https://recyclass.eu*
72. *Available from https://www.plasticsrecyclers.eu/waste-characterisation*

73. *Available from https://recyclass.eu*
74. *Ibid*
75. *EUPC (2018), The Useage of rPM by Plastics Converters in Europe*
76. *Crippa, M., De Wilde, B., Koopmans, R., Leyssens, J., Muncke, J., Ritschkoff A-C., Van Doorsselaer, K., Velis, C. & Wagner, M. (2019) A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions (M. De Smet & M. Linder, Eds.). European Commission, Brussels, Belgium*
77. *Ibid*
78. *Suschem (2018) Plastics Strategic Research and Innovation Agenda in a Circular Economy*
79. *Plastics Europe website, accessed 16/10/2019, (https://www.plasticseurope.org/en/newsroom/press-releases/archive-press-releases-2018/enhancing-circularity-polyolefin-based-packaging)*
80. *60% of 6.6 Mt packaging waste on the market is 4.0 Mt (see section 'Market sectors (Applications)'). At an average yield of 80%, 4.9 Mt of input material would be required to produce 4.0 Mt of recyclate*
81. *See PRE's Flexible Films Market in Europe, State of Play, Production, Collection and Recycling Data for a full discussion of the plastic flexible films market. Available at https://www.plasticsrecyclers.eu/plastics-recyclers-publications*
82. *EC COM(2018) 2, A European Strategy for Plastics in a Circular Economy, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN#footnote33*
83. *EFSA website, last accessed: 16/10/2019, (https://www.efsa.europa.eu/en/topics/topic/plastics-and-plastic-recycling)*
84. *RecyClass, https://recyclass.eu/*
85. *EC COM(2018) 2, A European Strategy for Plastics in a Circular Economy, (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN#footnote33)*
86. *Full scheme details available at https://recyclass.eu/recycled-content/*
87. *Full scheme details available at https://www.eucertplast.eu/downloads-links. EuCertPlast certification of PE Film recycling capacity rose from 27% to 36% of EU28+2 installed capacity between 2018 and 2019.*
88. *Bund/Länder-Arbeitsgemeinschaft Abfall (LAGA, https://www.laga-online.de/) and Consorzio nazionale per la raccolta, il riciclaggio e il recupero degli imballaggi in plastica (COREPLA, http://www.corepla.it/).*
89. *Circular Plastics Alliance (2020), Research & Development Agenda (2020), available at https://ec.europa.eu/docsroom/documents/43693*
90. *Circular Plastics Alliance (2020), State of Play on Collection and Sorting, available at https://ec.europa.eu/docsroom/documents/43694*
91. *Available at https://www.plasticsrecyclers.eu/waste-characterisation*
92. *Full scheme details available at https://recyclass.eu/recycled-content/*

PLASTICS RECYCLERS EUROPE

Avenue de Broqueville 12,
1150 Brussels - Belgium
+32 2 315 24 60
info@plasticsrecyclers.eu
www.plasticsrecyclers.eu