Driving change: A circular economy for automotive plastic

September 2021

Report produced as part of the ECOBULK project

OAKDENE HOLLINS

Contents

About Oakdene Hollins

Founded in 1994, Oakdene Hollins is a research consultancy that supports private and public organisations and policymakers transitioning to a circular economy. Within this transition, there are technical, commercial, organisational, and societal challenges. Our work identifies the barriers to and levers of change and brings deep technical and science-based research to support decision-making.

Oakdene Hollins works with a mix of clients including governments, the private sector and trade associations to lead on environmental sustainability topics. Our specialist areas include developing evidence to help decision-making including filling knowledge gaps, prioritisation of techno-economic risks and opportunities, and communication of complex topics to a range of audiences.

Acknowledgements

Lead authors: Olivia Bertham, Rachel Waugh, Katerina Michailidou

We would like to acknowledge input from our ECOBULK partners including in particular from CRF and Bellver, although all opinions within the document are attributable to Oakdene Hollins.

About ECOBULK

ECOBULK is a large-scale European initiative which will demonstrate that re-using, upgrading, refurbishing, and recycling composite products is possible, profitable, sustainable, and appealing.

We have selected composite products in the furniture, automotive and building sectors as demonstrators to prove our new circular model.

For more information, see the project website www.ecobulk.eu

Executive summary

Plastic is a major component in modern cars. When it comes to the disposal of end-of-life vehicles (ELVs), capturing plastic for reuse or recycling poses a clear challenge for the automotive industry.

The ELV Directive is designed to promote materials reuse and recycling, but it uses weight-based recovery targets which have so far not required a focus on plastics for compliance. The study notes that the overall mass of plastic used per new vehicle is increasing – with predictions of up to 17% more plastic per vehicle by 2030.

Many automotive companies are experimenting with how to increase recycled plastic content in new vehicles, with some automotive corporates having targets for recycled plastic content. However, the properties of many post-consumer recycled plastics make this challenging. In volume terms, reaching a target of 30% of a vehicle's plastic to come from recycled content would require a substantial increase in the supply of recycled plastic from a current estimate of about 2.5% of total plastic used in the automotive sector. This raises questions as to how the exponential growth supply of the right quality secondary plastics across Europe would be met.

The supply challenge of plastic recyclate is coupled with low levels of recycling for automotive plastics from end-of-life vehicles (ELVs), with most currently landfilled. The poor rates of automotive plastic recovery come from the economic unviability of removing and recovering most plastics from current end of life vehicles, exacerbated by limited infrastructure to recycle the plastics and poor market demand for the resulting secondary raw materials.

There is therefore a case for change which is outlined in this report. Interventions to support the expansion of automotive recycling into opportunities for utilizing automotive plastics for ELVs either within the sector, or elsewhere could be made through developments in infrastructure and investment in new technologies.

The analysis provides an in-depth review of vehicle plastic use and plastic waste, and a comprehensive assessment of end markets for automotive plastic recyclates. It focuses on the three major polymers used in vehicles: Polypropylene (PP), Polyurethane (PU), and Polyvinyl Chloride (PVC).

Aspirations of both increasing recycled plastic content within vehicles, and in finding adequate markets to stimulate automotive plastic recovery have technical, economic, and regulatory challenges. To support the development of a more circular economy for automotive plastics, this study concludes with the following recommendations:

- *Ensure there is clarity around the automotive industries position on the recycling automotive plastics - or not*. Clear signals will support the industry in moving collectively to both increasing recycled content within vehicles and increasing plastics recycling and will challenge the reliance on landfill and incineration for ELV plastics
- *Enhance the current policy framework to support plastic recovery and recycling for automotive*. This would provide the stimuli needed for engagement at scale by OEMs, and also provide confidence

for the SMEs and their investors working in ELV vehicle businesses to invest in the R&D and infrastructure needed to reach both recycled content and recycling targets.

- *Establish stakeholder driven organisation(s) to focus and drive increased automotive plastic recycling* as focused and collective action can improve success when dealing with challenging waste
- *Innovate to improve sorting and segregation to enable appropriate feedstocks for recycling*. Disassembly enables cleaner streams of plastic to be recovered but is currently not economic, whilst recovery of plastic from ASR is technically complex.

The case for change

Plastic is a vital material in today's society, bringing benefits such as light weighting and cost savings compared to alternative materials. Unfortunately, alongside the positives, plastic brings negative environmental consequences such as sourcing from fossil fuels, the carbon impacts of plastic production, and the challenges of waste generation. At the current and growing scale of use, alternatives to virgin raw materials and increasing reuse and recycling have significant potential to reduce the environmental impacts of plastic.

All sectors that utilize and benefit from plastics must tackle these plastic-related challenges, finding solutions that are technically feasible and economically viable. Market forces and the traditional dynamics of a linear "take-make-dispose" economy have proven to be insufficient to drive significant change. However, the context within which companies are operating in is changing. Societal concern regarding the environmental impacts of plastic, especially single use plastic products, is high. Policy makers are beginning to establish legal and fiscal frameworks to encourage improved plastic circularity performance, i.e., improved rates of plastics recycling and reuse.

At current plastic consumption growth rates, greenhouse gas emissions from plastics will reach 15% of the global carbon budget by 2050[1].

Over 350 million tonnes of plastic waste arise from the transport sector each year.

The challenges of making plastics circular varies between sectors, geographies, and plastic polymers. Whilst packaging dominates both demand and waste streams for plastic (and is rightly a key focus of public concern, industry action, and regulatory/fiscal action) the impacts of plastic in the automotive sector are also significant:

- *Contribution to climate change*: Global GHG emissions of conventional plastics were 1.7 Gt of CO_{2e} (carbon dioxide equivalent) in 2015, predicted to grow to 6.5 $GtCO_2e$ by 2050 under the current trajectory[1]. The automotive sector accounts for nearly 10% of the 50 million tonnes of annual plastic demand by the EU in 2019[2].

- *Generation of plastic waste:* Globally over six billion tonnes of plastic waste[3] is produced annually with nearly 6% of plastic waste arising from the transport sector[4]. Most End-of-Life Vehicle (ELV) plastic waste currently ends up in landfill or incineration.

[1] Based on LCA that included resin production, conversion, and end of life options - Zheng, J. & Suh, S., *Strategies to reduce the global carbon footprint of plastics.* Nature Climate Change 9, 374-378 (2019)
[2] Plastics- the facts 2020. Plastics Europe, 2020
[3] Statista website, accessed January 2021
[4] Global plastic waste generation by sector, 2018. Statistica

Figure 1 sets out some of the key challenges for the automotive sector in shifting towards the circular economy for plastics.

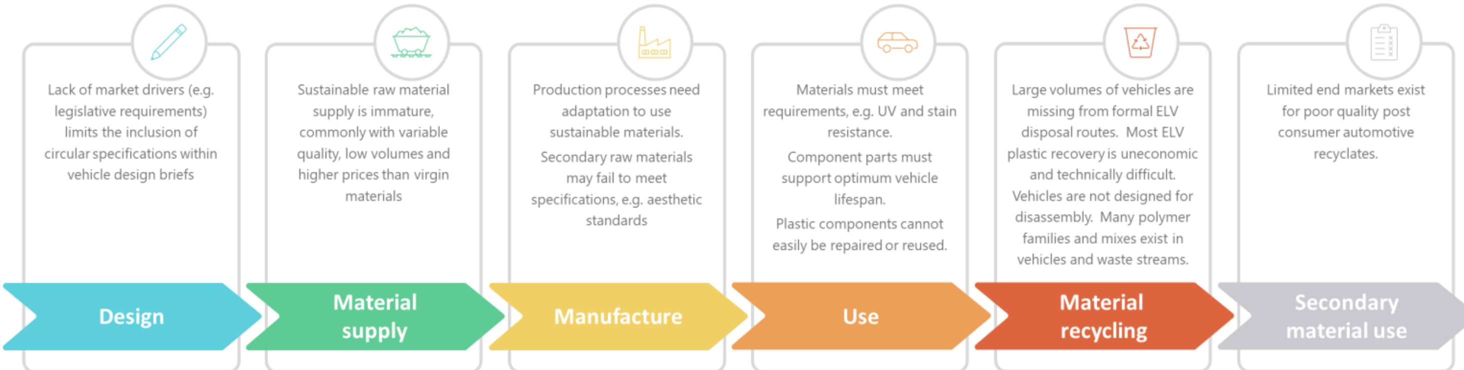


Figure 1: Key circular economy challenges for automotive plastic

The climate and waste management challenges from plastics in the automotive sector require action with significant potential to reduce negative impacts. Recycled plastics, for example, typically have lower carbon emissions than from oil-based virgin plastics. This can be up to 89% lower for acrylonitrile butadiene styrene (ABS) and 73% lower for polypropylene (PP), two plastics common in the automotive sector[5].

EU policy on plastic is clear for plastic packaging:

- A commitment to the use of ten million tonnes of recycled plastics in new products by 2025, signed by more than one hundred public and private partners[6].
- Plastic packaging recycling target of 50% by 2025 and of 55% by 2030[7].
- Introduction of a plastic tax through EU Green Deal in January 2021 of €0.80 per kilogram levied on non-recycled plastic packaging waste and paid by companies in EU member states[8].

There is currently no such clarity for the automotive sector. The ELV Directive is under review with an evaluation[9] noting that:

- it currently does not cover 25% of vehicles, such as trucks over 3.5 tonnes, motorcycles and 'missing' vehicles not registered through official disposal routes;
- a significant share of plastic is directed to energy recovery or landfill; and
- its mass-based material targets are not well adapted to the increased use of plastics in vehicles.

The outcome of the ELV Directive review will be finalized in 2022 but could include material specific reuse and recycling targets or even the inclusion of design for circularity requirements or minimum recycled

[5] Carbon footprint review shows large savings Axions recycled polymers (2017), Axion website, accessed January 2021
[6] European Commission Circular Plastics Alliance: 100+ signatories commit to use 10 million tons of recycled plastic in new products by 2025. 20 September 2019
[7] European Commission Questions & Answers: A European strategy for plastics. 16 January 2018
[8] EU approves tax on nonrecycled plastic (recycling today) 1st Jan 2021
[9] End of life vehicles, revision of EU rules, 2020

plastic content[10]. This would create a clear motive for action along the European value chain to radically improve the circularity of automotive plastic.

The circular plastics context

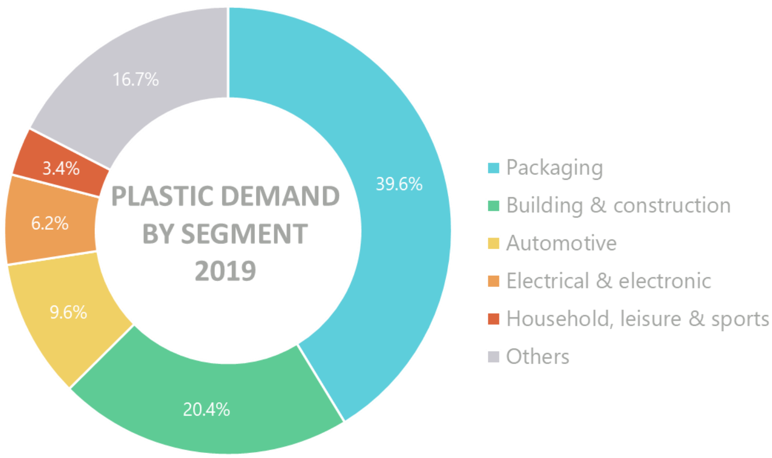


Figure 2: Plastic market demand 2019[11]

Plastic packaging makes up 40% of plastic demand in the EU and much of the plastic waste streams. Plastic packaging is also a significant component of waste plastic in the ocean which has led to intense consumer scrutiny, particularly for big brands. As such this sector has been the focus of policy attention to date. Increasing the circularity of plastic packaging has different challenges to automotive plastics – collection being significant due to the dispersed nature of some of the waste streams (such as post-consumer plastic packaging), the need for kerbside collection and the technical challenges of recycling some polymers such as LDPE and PP films.

The overall trends to collect and recycle more packaging plastic could drive significant change for plastics in the automotive sector by, for example:

- creating a supply of some lower quality plastic recyclates that could be used within the automotive sector;
- creating demand for plastic recyclates of the right quality and polymer;
- speeding up developments in chemical recycling that could open recycling opportunities for mixed and contaminated plastics streams that are currently for difficult to recycle mechanically.

[10] From a presentation given at AFT conference

Plastics: the current situation in the automotive sector

Vehicle plastic use and plastic waste

The automotive sector in the EU uses an estimated 4.8 million tonnes of plastic annually[11]. Based on current trends per vehicle, overall vehicle mass is decreasing whilst overall mass of plastic per vehicle is increasing[12]. Increasing use of plastics has supported the objectives of vehicle light weighting and has therefore improved fuel efficiency.

In addition to increasing amounts of plastic within vehicles, vehicle numbers within Europe have been increasing. In 2019 there were 278 million vehicles in the EU[13] and new car registrations in the EU had increased by 1.2%, the sixth consecutive year of growth, reaching more than 15.3 million units[14]. Whether the trend in increasing total number of vehicles on the roads in Europe will continue is debatable. Trends in increased utilization (such as a rise in shared vehicle usage business models) may lead to fewer vehicles needed and total inventory dropping by 2030[15]. This will lead to changing trends in total annual volumes of ELVs and of volumes of waste plastic arising.

shows the breakdown of different plastic types used within a vehicle. The most common polymer types are polypropylene (PP) (21.1%), polyurethane (PU) (19.6%), and polyvinyl chloride (PVC) (12.2%). Thermoset composites account for about 10% of plastics used.

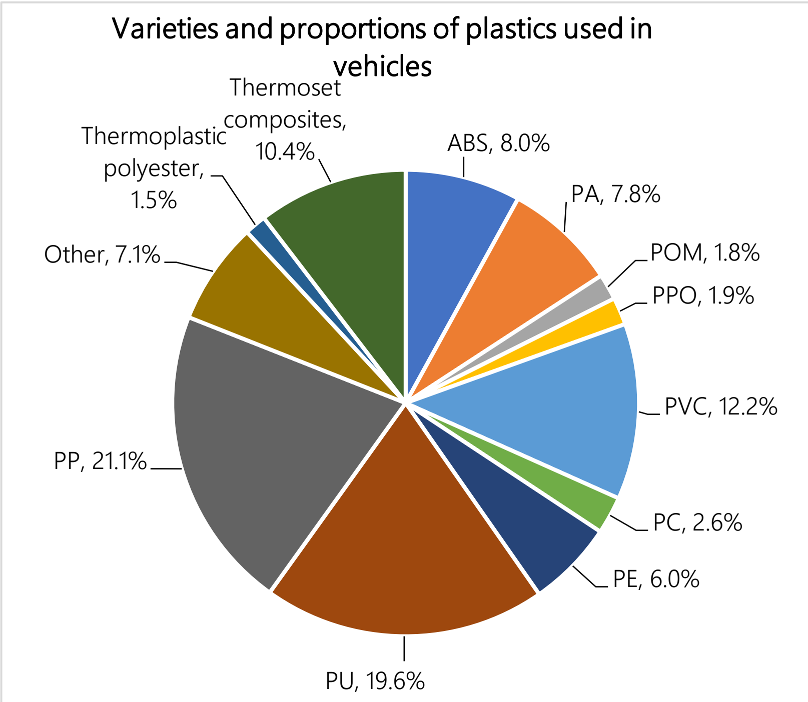


Figure 3: Plastic types in cars. Source: Zhang 2014[1]

[11] Plastic Facts 2020 Plastics Europe
[12] Toni Gallone and Agathe Zeni-Guido, Closed-loop polypropylene, an opportunity for the automotive sector, The Journal of Fields Actions. March 2019
[13] European Automobile Manufacturers Association
[14] Economic and Market Report full year 2019, European Automobile manufacturers Association
[15] Five trends transforming the automotive industry, PwC (2018)

Choice of polymer type depends on the required component function, manufacturing specifications, desired aesthetics, and price. Examples of the typical uses of the three most commonly used polymers in cars are shown in Table 1.

	Example automotive part
PP	Dashboards, wheel covers, engine parts, bumpers, seat panels, safety subsystems, doors, and seat assemblies.
PU	Seats, foam seating, insulation panels, suspension bushings, cushions, electrical compounds, bumpers.
PVC	Electrical cables, pipes, doors, panels of instruments.

Table 1: Polymer type and examples of use within automotive

Currently plastics make up about 50% of a vehicle's volume but only 10% of its mass[16]. Figure 4 and Figure 5 show Renault's prediction for plastic to raise from 12% of a vehicle's mass to just under 16% by 2030.

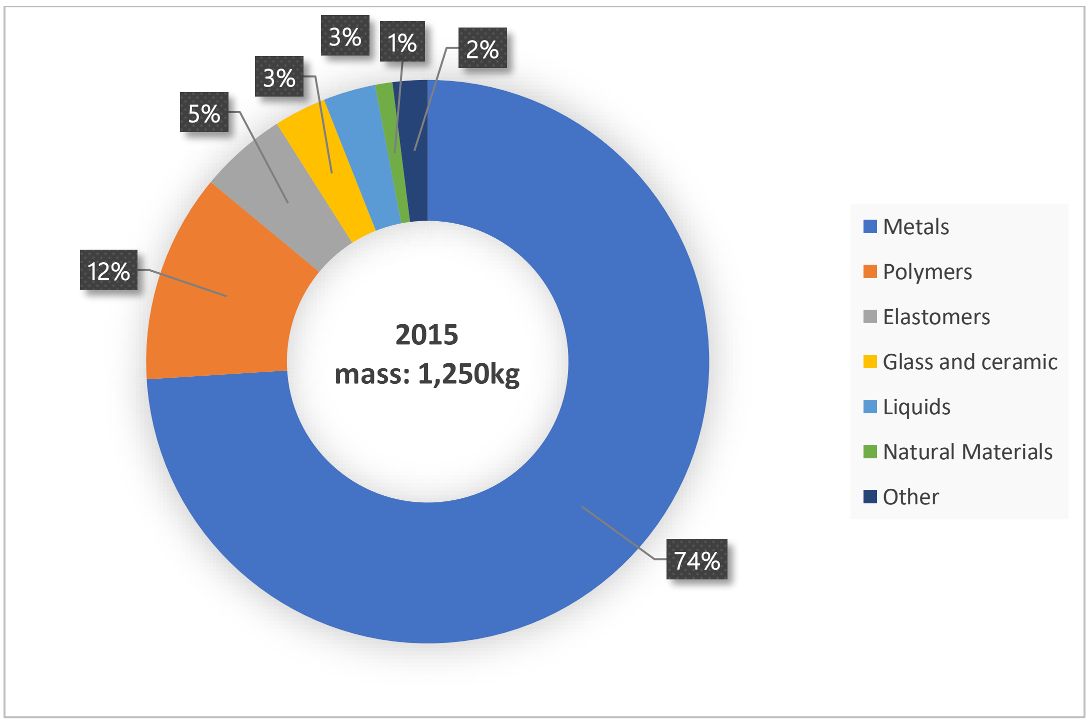


Figure 4: Estimated composition by mass of EoL vehicles in 2015. Source: Renault[17]. m stands for mass.

[16] Plastics Market Watch: Automotive Recycling Devalued is now Revalued, 2016

[17] Toni Gallone and Agathe Zeni-Guido, Closed-loop polypropylene, an opportunity for the automotive sector, The Journal of Fields Actions. March 2019

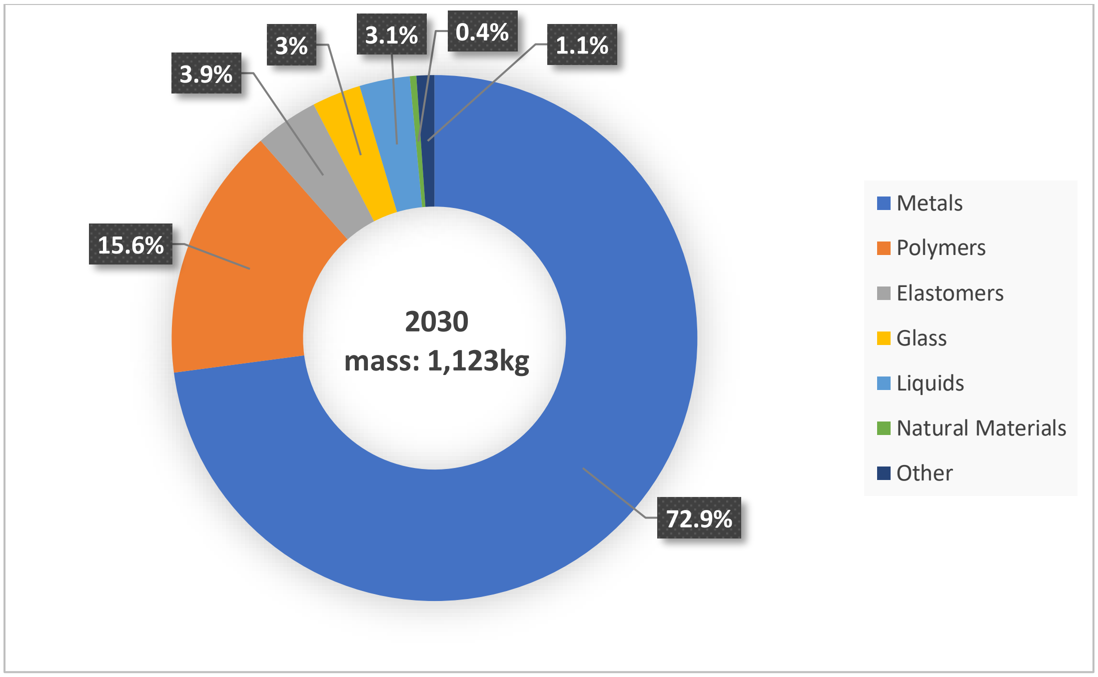


Figure 5: Estimated composition by mass of EoL vehicles in 2030. Source: Renault. m stands for mass.

Renault estimates the average mass of vehicles will decrease from 1,250kg in 2015 to 1,123kg in 2030, however the mass of key polymers used in vehicles will increase during this time by around 17% as shown in Table 2.

	Estimated polymer volumes per vehicle in 2015 (kg)	Estimated polymer volumes per vehicle in 2030 (kg)
All plastics	150	175
PP	32	37
PU	29	34
PVC	18	21

Table 2 Estimates of key polymers per vehicle in 2015 and 2030. Source: Estimates base on Renault figures[18] and Zshang polymer split[19]

[18] Toni Gallone and Agathe Zeni-Guido, Closed-loop polypropylene, an opportunity for the automotive sector, The Journal of Fields Actions. March 2019
[19]Zhang, H., Current recycling regulations and technologies for the typical plastic components of end of life passenger vehicles: A meaningful lesson for China, Journal of Material Cycles and Waste Management. April 2014

ELV Directive

6.1 million vehicles were scrapped in the EU in 2018[20], containing somewhere between 0.9 and 1.2 million tonnes of ELV plastics[21], most of which was landfilled. As the use of plastics in automotive grows, so will the volumes of ELV plastics and the opportunities within the circular economy to recover, reuse and recycle plastics from EoL vehicles could fulfil a proportion of this demand.

The ELV Directive 2000/53/EC aims to promote reuse and recycling. It does this through establishing mass-based targets: a minimum of 95% of the total vehicle mass should be reused or recovered and at least 85% reused or recycled. As of 2017, 15 Member States had met the reuse and recovery target of 95% with an EU average of 94%. 20 Member States had met the reuse and recycling target of 85% with an EU average of 89%[22]. Much of this target is achieved through metal recovery which accounts for approximately 75% of a vehicle's mass and can be easily recycled[23].

The ELV Directive[24] calls for large plastic components such as the bumper and fluid containers to be removed during the dismantling stage for recycling. It specifies that the design of vehicles should facilitate reuse and integrate an increasing number of recycled materials[25], but without setting specific recycled-content targets. The ELV Directive specifies labelling of vehicle plastic components having a mass of more than 100 grams, and of vehicle elastomer components and materials having a mass of more than 200 grams[26].

The ELV Directive is currently being reviewed. In a recent Inception Impact Assessment completed as part of ELV Directive revision[27], the Commission proposed setting up a requirement for the mandatory use of recycled plastics in new cars, either from automotive or other sources. This would increase the demand for recycled plastics within the automotive sector and could support the recovery of plastics from ELVs to generate the recyclates needed. The Commission adoption in the second quarter of 2022 will verify the final proposal.

[20] Europa website - End-of-life vehicle statistics
[21] Assuming 150 - 200kg of plastic per vehicle
[22] EU Report on the implementation of Directive 2000/53/EC on end-of-life vehicles , 30.01.20
[23] Driving with Polyurethanes ISOPA report
[24] ELV Directive Annex 1
[25] EV Directive Article 4 (1)
[26] International Material Data System Fact Sheet
[27] End-of-life vehicles – revision of EU rules , 2020

Industry commitments and innovation

The automotive sector and those involved in the value chain for end-of-life vehicles are initiating change. The European Confederation of Recyclers (EURIC) has called for "gradual and fully achievable recycled content targets" for post-consumer thermoplastics in new cars[28].

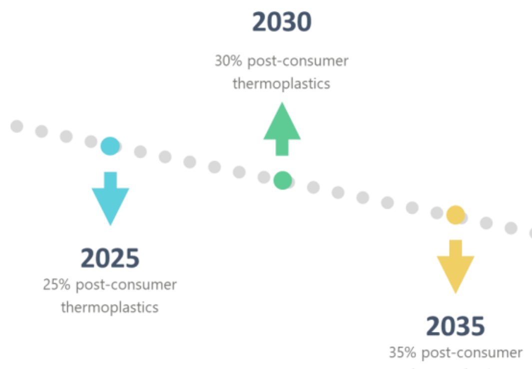


Figure 6: EURIC recycled content targets

Currently around 18-20% of plastics within a vehicle could come from recycled sources[29] based on the functional requirements of components. Moving towards a target for 30% recycled plastic content will be a challenge due to the performance of recycled plastics such as aesthetics within vehicles and the ability to withstand high temperatures near the engine. However some automotive companies have made commitments to increase recycled plastic content in vehicles:

	Commitment on using recycled plastic
Volvo	At least 25% of all plastics in cars launched after 2025 to be made from recycled materials[30].
Groupe Renault	To increase its use of recycled plastic by 50% by 2022 compared to 2013[31]. Plan to incorporate up to 20% recycled plastics in the cars manufactured in Europe[32] and 85% of ELVs are recyclable[33].
Nissan	Long-term vision to reduce dependency on new materials by 70% by 2050[34]. No public targets specifically for plastics.
Toyota	Environmental Action Plan[35] - 2025 recycling targets include: • Develop technologies to utilize recycled materials (especially plastics) in accordance with the conditions in each region • Promote utilization by technological development to optimally exploit recycled materials in Europe and to increase the supply of recycled materials in Japan • Implement initiatives to reduce and recycle plastics used in packaging • Further promote plastic recycling, expanded use of recycled plastic first in Europe, where the recycled plastic market is large

[28] EuRIC call for Recycled Plastic Content in Cars, 2020
[29] Estimate from conversations with automotive plastic experts
[30] Volvo Cars aims for 25% recycled plastics in cars from 2025
[31] Group Renault Circular Economy: Moving Up a gear 31.01.20
[32] EuRIC call for Recycled Plastic Content in Cars, 2020
[33] EMCF short loop recycling of plastics in vehicle manufacturing
[34] Nissan website, 2021
[35] Toyota 2020 Sustainability Report

Fiat	Has internal standards for the use of rPP within vehicle. rPP is primarily used in bumpers, but also in dashboards and body panels[36].

Table 3 Automotive companies – recycled plastics usage commitments

There are no clear public targets from corporates for the recovery of EoL automotive plastics, nor for the recycled plastic content to come from automotive sources, although there are examples of EoL automotive plastic reuse from several companies. OEMs and specialist plastics recyclers have developing processes and products to increase plastics recovery and recycling in vehicles, for example:

- Toyota has developed a recyclable plastic used in most of their cars; Toyota Super Olefin Polymer (TSOP) can be used to make car bumpers and other parts and can then be recycled repeatedly[37].
- Renault uses 52,000 tons of recycled plastic every year and has created a closed-loop system of recycling PP plastics, by transforming car bumpers and wheel arch liners into directly reusable material reused in new car parts.
- Nissan's electric vehicle Nissan LEAF uses recycled plastic bottles for the fabric of its seats and armrests, recycled bumpers for its bumpers, and fabrics from recycled plastics for its floor insulation layers. [38]. The Renault-Nissan ECO2 vehicle range must contain over 7% of recycled plastics[39].
- Volvos XC60 model has several components made from recycled plastics[40].

ELV plastics: current outcomes

Extracting materials from EoL vehicles has 3 main objectives:

- to depollute vehicles (including removal of petrol, oil, batteries, and airbags);
- to meet the requirements of the ELV Directive; and
- to recover components and materials that may have value.

Disassembly information for vehicles is contained in the International Dismantling System (IDIS), which provides dismantling information (mainly airbags and other hazardous automotive components and materials) for each type of vehicle within six months of being placed on the market[41]. In September 2020, TATA Motors announced its Tata Nexon: a compact Sport Utility Vehicle (SUV), would be the first Indian car to be published in the IDIS platform[42]. The company will provide all relevant information on vehicle dismantling, which will act as an enabler of the Indian Authorised Vehicle Scrapping Facilities (AVSF) to carry out dismantling practices in a safe and sustainable manner. To capture additional volumes and

[36] Taken from project communications
[37] Toyota and the Environment, 2009
[38] Zero Waste Europe: Nissan LEAF zero waste, 17.02.11
[39] JRC Best Environmental Management Practice for the Car Manufacturing Sector 2017
[40] Group Volvo Celebration time: Volvo Cars' recycled plastics ambition recognized April 11, 2019
[41] European Commission Assessment of the Implementation of Directive 2000/53/EU on end-of-life vehicles. 2018.
[42] Tata Nexon becomes the first Indian car to be published on the IDIS, HT Auto, September 18th, 2020

increase their capacity to source parts in short loops, Renault is creating a dismantling line-in its "Re-Factory" in Flins, France, which is the first circular economy factory in Europe dedicated to mobility[43].

Clearly there is a cost to the dismantling process which determines the extent to which component removal before shredding is viable. Many plastic components are time consuming to extract and have little value in secondary markets. However, certain parts can be retrieved from ELVs and following quality control and safety checks, they can potentially be reused during vehicle repair. This system is supported by a Reclaimed Original Equipment (ROE) vehicle insurance policy, under which the insurance product offers the consumer the option to use reclaimed parts from ELVs in the event of a claim, which will be directly reused in the vehicle repair process[44]. This offers a more cost-effective solution to the consumer for repair. Ford has invested in an ROE program which captures and redistributes slightly flawed Ford collision parts that are eligible to be reused in the repair of vehicles[45]. Following stakeholder correspondence, it has been noted that non safety critical parts that can be directly reinvested in another vehicle could amongst others include the bumper bar reinforcement, absorber, and cover.

However, a lack of transferability of plastic components between different vehicle models, discoloration, and a lack of design for dis- and re-assembly currently make the reuse of plastic component parts, in their original form, impossible at scale.

Bulky, external components such as bumpers which are predominately made from PP, can be directly removed, and recycled, and plastic components removed as part of the depolluting phase of ELV treatment are air bags and the fuel tank.

In Europe, France has been a pioneer in large plastic parts recycling from EoL vehicles. In 2018, France recycled over 7,000 tonnes of EoL large plastic parts and over 11,400 tonnes were reused (see Figure 7), significantly more than any other country.

[43] Re-Factory: The Flins site enters the circle of the circular economy - Groupe Renault, 25 November 2020
[44] Co-Existence – How Vehicle Manufacturers and Auto Recyclers MUST Work Together - Auto Recycling World, May 1, 2020
[45] Ford's Roe pilot program expands, On Target, Winter 2006-2007

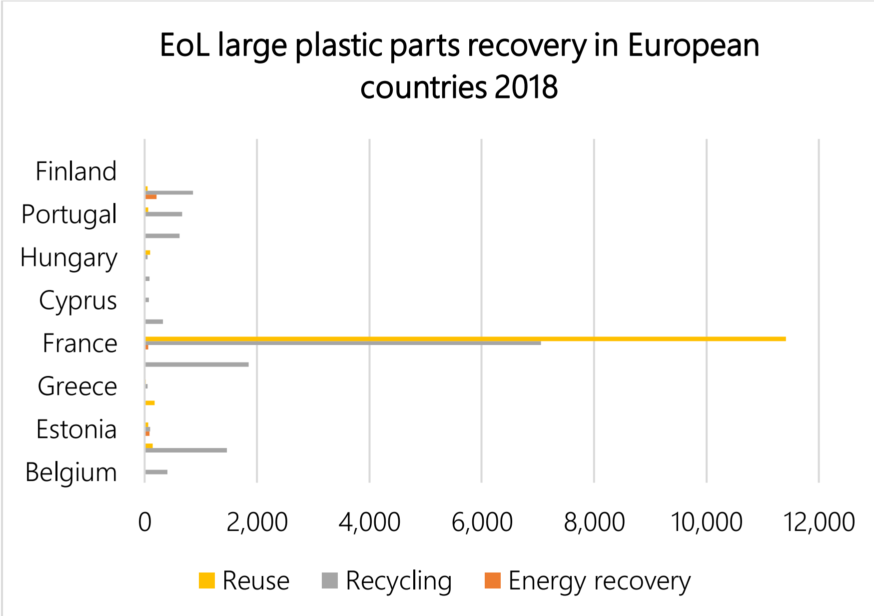


Figure 7 EoL large plastic automotive parts recovery in European countries 2018. Source: Eurostat

However, most plastic is not separated but is shredded as part of the ELV downsizing process. Following shredding, separation technologies (including magnetic and air separation) are used primarily to extract metals. The residual mixed material is known as automated shredder residue (ASR) and includes different types of thermoplastics, thermosets, rubbers, as well as a mix of felt, fibre, glass, wood, water, and other contaminants. ASR constitutes between 15-20% of the ELV mass[46], is classed as hazardous waste in Europe and is mostly disposed of to landfill[47]. ASR has been used as a fuel supplement in cement kilns[48], but this is not common practice.

Recovery of plastics from ASR

ASR can contain large amounts of contaminants including hydrocarbons, polychlorinated biphenyl, and heavy metals. Characteristics of ASR differ depending on the composition of vehicles and previous techniques used prior to shredding. For technical and economic reasons, the removal of plastics from ASR is not undertaken at commercial scale.

At small scale, various approaches to extracting plastics from ASR have been tested including:

- The density measurement method[49] in tanks of liquid that allow some materials to float and some to sink based on their density compared to water. This results in a "light fraction" (mostly PP and PE) and

[46] Ala Khodier, Karl Williams, Neil Dallison, Challenges around automotive shredder residue production and disposal Waste Management Volume 73, March 2018
[47] Plastics Industry Association End-of-Life Vehicle (ELV) Recycling, January 2018
[48] California Department of Toxic Substances Control (DTSC)
[49] Plastics Market Watch: Automotive Recycling Devalued is now Revalued 2016

Audi is considering the challenge of achieving closed loop mechanical recycling for composite plastic automotive parts by exploring chemical recycling. The company has been working on a joint project with Karlsruhe Institute for Technology (KIT), to test the feasibility of chemical recycling for automotive plastics to produce oil, from which new polymers can be created.

in a "heavy fraction" mainly of PVC and PET. These plastics contain different fillers, pigments and reinforcing agents, or even natural fibres or glass, which modify their densities, and affect the way they separate[50]. The efficiency of recovery is low as more than 15% of PP plastics can end up flowing into the dirty water tank, which is removed from the recycling process, while approximately one quarter of the material fed into the density measurement tanks is discarded[51];

- Near-infrared (NIR) optical sorting separating the residue by polymer type;
- Zigzag/ Densiometric tables separating polymers of different densities; and
- Pneumatic separation using a high-pressure air injection system.

Advanced or chemical recycling in the automotive sector

Chemical or advanced recycling uses technologies that change the chemical structure of the infeed materials, producing virgin like polymers or other value-added materials (unlike mechanical recycling that does not change the chemical structures of the infeed materials). Pressures on packaging plastic recycling, the demand for food grade recycled content and the demand for lower carbon fuels have supported recent investment and exploration into chemical recycling of plastics. Pilot plants and early-stage commercial operations are just beginning in the EU. Significant benefits of advanced recycling are that it:

- can take mixed plastic feedstocks with some contamination levels, unlike mechanical recycling; and
- the outputs can be used as feedstock for the production of virgin-like plastic polymers.

Technologies are new and developing with several automotive companies evaluating the chemically recycled plastics. However, there are some barriers still to be overcome. Some technologies have high greenhouse gas footprints, the economics does not yet support large scale commercial uptake and the chemical recycling infrastructure (and financing for it) does not currently exist at the scale needed to make advanced recycling a viable input into large-scale industrial polymer chemical plants. Alternative waste plastic disposal options, such as cheaper landfill and incineration, make scaling of these newer options even more challenging. In addition, some contaminates will make advanced recycling difficult. Lastly, outputs from some advanced recycling plants are fuels and therefore not considered as recycling but rather energy recovery.

[50] O.T.Forton, M.K.Harder, N.R.Moles Value from shredder waste: Ongoing limitations in the UK Resources, Conservation and Recycling Volume 46, Issue 1, January. 2006

[51] Toni Gallone and Agathe Zeni-Guido Closed-loop polypropylene, an opportunity for the automotive sector, The Journal of Field Actions. 2019

Despite these barriers, we may be witnessing the dawn of these new technologies which, alongside developments in mechanical recycling may play a pivotal role in the circular economy of plastic recycling. Mechanical and chemical recycling options can complement each other. Where mechanical recycling is feasible it if often cheaper and has a lower environmental footprint. Where mechanical recycling is not possible, chemical recycling could play a role.

Current barriers to a circular economy for automotive plastic

There are significant barriers to overcome in both finding end markets for ELV plastics (both back onto the automotive sector and into other sectors), as well as increasing the uptake of recycled plastics within the sector.

Economic barriers

Prices of recycled plastic vary considerably depending on quality: The processes needed for the recovery, sorting, cleaning, and processing of some plastics can be higher than the costs of sourcing virgin plastic. In 2020, the market price of quality rPET for example was almost twice the price of virgin PET[52] for example. There was demand for recycled content at this price from packaging companies, created by both delivery of public corporate commitments and due to the introduction new taxes on products without recycled content. This scenario may currently be unique to the rPET and food grade packaging but demonstrates both the costs of providing exceptionally high-quality secondary plastic resin, but also the lack of supply of such materials with demand currently outstripping supply for high quality secondary plastics as the technologies and capacity ramp up.

In the automotive sector, prices of recycled plastic can be 8-10% cheaper than virgin[53]. However the challenge of pushing beyond current recycled content of 20% in vehicle may require investment in high quality resins to meet the functional and aesthetic requirements of components not currently made from recycled plastics. As there is no current recycling and market for post-consumer automotive plastics there is no indication as to what the price differentials might be for key automotive plastics from recycled sources. Cost differences between the chemical recycling of plastic packaging waste and virgin costs are noted as in the region of €400/tonne more expensive than virgin production[54] given current economies of scale and stage of technology development. This might give an indication of the possible virgin/recycled price

[52] A Reuters special report - The plastics pandemic 2020
[53] Information from stakeholder interviews
[54] From comments by CEO of APChem during webinar, Planet Tracker

differences for automotive plastic waste streams were quality issues needing to be overcome to increase recycled content in vehicles.

Cheaper alternative disposal routes: Alternative end of life options for ASR make the economics of recycling less justifiable. In particular, the use of ASR as a feedstock into EfW makes the costs of removing, storing, and selling second-hand car parts, or of any further processing generally higher than EfW or landfill gate fees[55].

Technical barriers

There are significantly different challenges between the reuse of post-industrial (process) waste and end of life vehicle waste. The former is much more easily reused, typically with 90% of the mechanical properties expected from virgin resins[56] allowing them to be substituted for virgin without mould modifications. In this document we are considering post-consumer recycling, for which technical challenges occur in the collection, sorting, recycling, and reuse phases of automotive plastics – and it is clear how costs can mount for recycled plastics from the automotive sector.

Vehicles are not designed for dismantling: Dismantling is expensive, particularly as vehicles are not designed for dismantling. However, when components are removed prior to shredding, sorting is less complex and contamination levels are lower.

Plastic separation from ASR is difficult, but theoretically possible: Research, including within the ECOBULK project, has been undertaken into ASR material separation techniques, although research is not near commercial exploitation. Appropriate techniques need to be developed and refined to identify the most cost-efficient methods to recover sufficient volumes of plastic content from ASR.

Polymer families need to be separated: In addition to the extraction of plastic from vehicles, plastic polymers must be separated from each other. Mixed polymer recyclate would have limited and low value uses[57]. To find useful secondary markets of value, plastic types need to be separated by chemical group, e.g., polyolefin, polyamides and styrenics. Additives used in the manufacture of automotive plastics might make even plastics of the same family different enough to limit potential secondary uses.

Removing contaminates: Any embedded metal components and surface finishes would need to be removed. A cleaning process may be needed to remove odours for some applications. Deodourising

[55] Eunomia Report on the Implementation of Directive 2000/53/EC on End-of-Life Vehicles for the Period 2014-2017. 2019
[56] From conversation with industry experts
[57] JRC Best Environmental Management Practice for the Car Manufacturing Sector 2017

technologies exist, e.g., Starlinger Group offers odour reduction technologies for materials that suffer from strong smell, such as recyclate from car tanks[58].

Analysis of recyclate properties: Thermoplastic properties degrade during use and during the recycling processes. The properties of recycles would therefore have to be analysed for use in higher value component parts. Recycling might be limited to 3-5 cycles, although further recycling cycles could be possible following chemical analysis with the addition of virgin materials and additives.

Design adaptations for the use of recycled polymers: The differences in recyclate properties compared to virgin could require changes in component design e.g., thickness, and the manufacturing processes e.g., different moulds. Depending on plastic type, the use of recycled polymers could also influence whether paint would be needed to improve aesthetics or other performance characteristics.

Following stakeholder correspondence, it was confirmed that there are discussions inside Circular Plastics Alliance about the source of recycled plastic to be used in the new vehicles: only EoL or post-industrial too. OEMs are asking post-industrial too because it produces better quality of recycled plastics. It was also suggested that 18-20% of plastic in EoL vehicles can be recycled, but not for aesthetical components, for which very few recycled plastics can be chosen. For example, recycled plastics cannot be used for the car engine in new vehicles but could be used under the hood.

Regulatory barriers

Lack of regulatory pressure: There are no current regulatory drivers to support plastic recycling in the automotive sector. The mass based ELV Directive requirements are currently met through metals recycling. There is therefore very little pressure for ambitious plans for automotive plastics recovery and recycling without changes to the current EU legislative context. Examples from other countries outside the EU could be followed. In Japan, the Recycling of End-of-Life Vehicles law requires manufacturers to collect and recycle shredder residue from passenger cars and commercial vehicles[59].

Cross border transport of waste plastic: regulations limiting the transboundary transport of waste make the international trade in plastics for recycling difficult. The extension of this is that supplies of recycled plastics need to come from within the country in which vehicle component are being manufactured. Challenges to the market fluidity in these materials make for more complex supply chain challenges than would be found with virgin plastics.

[58] Passing the sniff test: Odor reduction opens new possibilities, Recycling Today, May 2017
[59] M. Walls - EPR Policies and Product Design, 28 Feb. 2006

End markets for automotive plastic recyclates

Demand for recycled plastics exists from many industrial sectors and is likely to increase given the EU commitments for 2025 and 2030 to increase recycling and to increase the recycled plastic content of products. Projects like ECOBULK demonstrate the interest and activities now associated with using recycled plastics. rPP has been one of the most commonly used recycled plastics in the automotive sector, however a much wider spectrum of resins is not being assessed. Fiat[60], for example are evaluating 170 different recycled materials including not just rPP, but Polycarbonate/acrylonitrile butadiene styrene (PC+ ABS) and polyamide families. Recycled plastic supply and plastic recycling infrastructure does not yet exist to service these requirements.

Demand for recycled plastic of the right quality is clearly growing in the automotive sector. Secondary plastic might be sourced from both post-production (from automotive and other sectors) and post-consumer channels. Post-consumer plastic supply to the automotive sector could come from packaging and electronics waste, as well as less obvious sources such as ocean waste[61]. ASR could also become a source of plastic recyclate.

ELV plastic recyclates do currently find end markets back into the automotive sector, but also into other sectors such as construction, as shown in estimates by the UKs Waste Resource Action Programme (WRAP) in Figure 8.

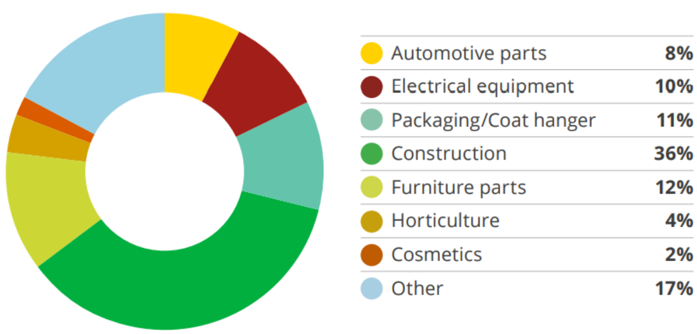


Figure 8: End markets for WEEE and ELV plastics. Source: WRAP estimates[62]

Establishing end markets is critical to successful recovery and recycling of automotive plastics. Without viable demand for the outputs of the recycling process, there will be little motivation to increase recycling.

[60] From correspondence
[61] Jaguar Land Rover will use ocean and landfill plastic waste in floor mats and trims in sustainable luxury interiors, Jaguar Land Rover website, accessed January 2021
[62] Plastics market situation report (2019). WRAP

If legislation were to demand increased plastic recovery paid for by the automotive sector (for example in the form of producer responsibility payments), end markets are still a vital part of the system. Without commercial end markets to use the outputs, there is a risk that recycling systems are established to meet legal obligations but that the outputs are either not saleable, or income raised could never sufficiently cover processing costs.

Examples of the recovery and recycling of bumpers demonstrate the market development for automotive plastics recovery and recycling back into vehicle components. There is a market, in particular, for bumpers and fascia plastics (predominately large components) to be made from rPP with limited impurities[63], with examples of this rPP being sourced from within the automotive sector.

It has been estimated that the majority of polymers used in cars are PP, PU and PVC[64] These plastics will be the focus of the following section to consider where recovered plastics could be utilized – both within and outside the automotive sector.

Table 4 sets out the current demand for each of these three polymers. We assume that the share of recycled polymers will follow the general spit between automotive polymer use to provide a rough idea of current baseline levels of recycled content which amounts to approximately 2.5% of current plastic demand.

	Total plastic (Mt)	PP (Mt)	PU (Mt)	PVC (Mt)
Total EU plastic demand (2019)	50.7	9.8	4.1	5.1
Automotive sector demand	4.9	1	0.96	0.6
Estimated volume of recycled plastic used in the automotive sector (2018)	0.12	0.03	0.02	0.01

Table 4: Summary: current total and recycled plastic use in the automotive sector. Source: Total plastic figures from Plastics Europe[65]. Polymer split based on Zhang [66].

Given the difficulties of recycling some plastics such as PVC and looking at current practice, it is likely that significantly more PP will be recycled, although no figures on this split are available. However, based on this assessment of share, this could amount to over 300k tonnes of rPP needed from a current baseline of 3k used in 2018.

[63] JRC Best Environmental Management Practice for the Car Manufacturing Sector (2017)
[64] Plastic Markets Watch (2016). SPI, US plastics industry trade association.
[65] Plastics Europe - Plastics the Facts 2020
[66]Zhang, H., Current recycling regulations and technologies for the typical plastic components of end of life passenger vehicles: A meaningful lesson for China, Journal of Material Cycles and Waste Management. April 2014

Based on current plastic demand and the proposed recycled content targets suggested by EURIC, Figure 9 sets out the significant increase in recyclate that would be needed if commitments to increase recycled content were to be applied across the automotive sector (assuming an uptake of recyclate replicates current polymer distribution within the sector and based on Oakdene Hollins estimates of polymer share).

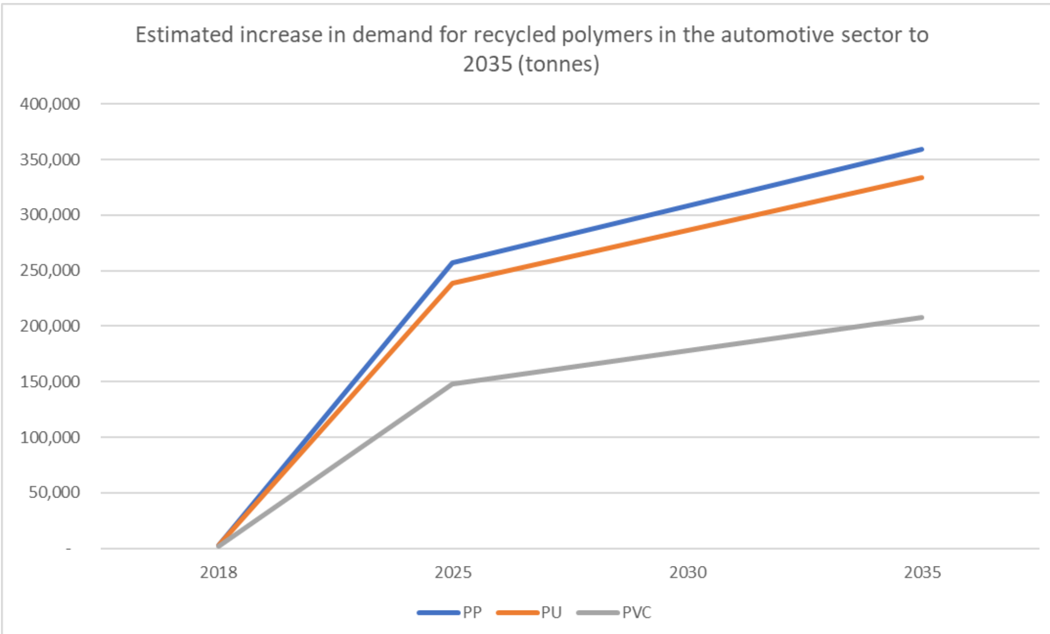


Figure 9: Estimated increases in plastic recyclate demand to 3035

The picture of plastic recycling in the automotive sector is therefore one of supply – where will recycled plastic come from, and of demand – where will recycled automotive plastic be used. The following sections explore this further for the 3 key polymers.

PP

Current demand for PP from the EU28 plus Norway and Switzerland is just under 10 million tonnes and is the most used plastic type in the EU (19% of all plastic resin types)[67]. It is a versatile polymer and has challenged the market share of several other materials in a wide variety of applications including packaging, mouldings, fibres, tape, film (orientated PP) and foam. It is one of the cheapest plastics. Three types of PP are currently available – homopolymers, block copolymers (incorporating 5-15% ethylene) and random co-polymers (incorporating 1-7% ethylene). There are many commercial grades of PP depending on the application and chosen processing method.

1

Supply of rPP from outside the automotive sector

PP is primarily used in packaging. The packaging sector is under pressure from its stakeholders, as part of meeting EU targets and through new plastic taxes to increase collection and recycling of its plastics.

The packaging sector (and its post-consumer value chain) may look to explore opportunities with the automotive sector to make use of the collected post-consumer PP packaging.

An existing example of this is Nissan where recycled plastic bottle caps are used for different components on their model LEAF.

2

Use of automotive rPP within the automotive sector

The automotive sector is the second biggest user of PP after packaging. Based on the need for food grade PP for the packaging sector, reuse of PP within the automotive sector would potentially offer the greatest opportunities.

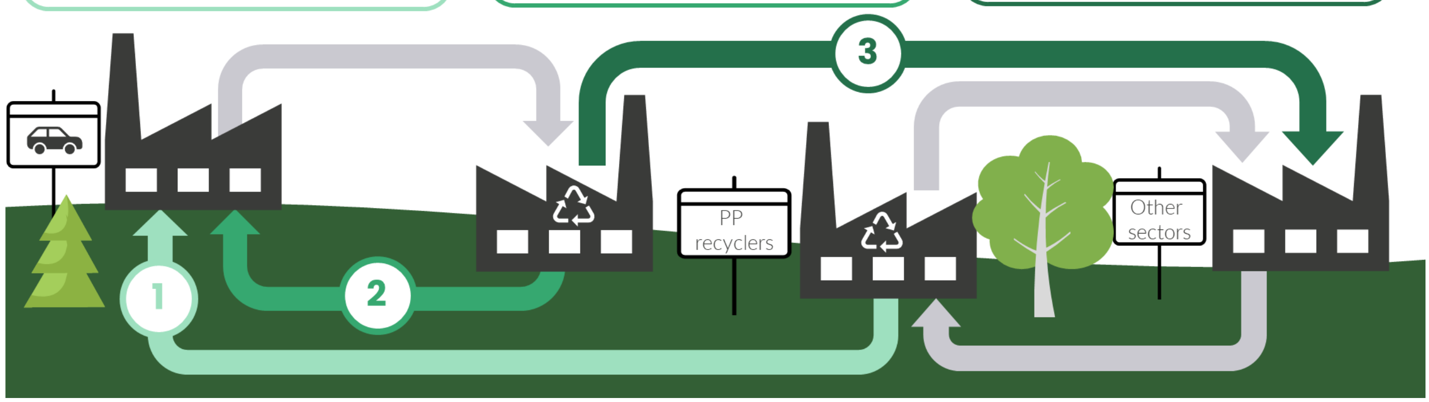
There are already good examples of the use of rPP, particularly from bumpers, back into other vehicle parts, for example wheel arch liners, bumpers, engine bottom protection plates, under the bonnet parts or secondary mud flaps.

3

Use of rPP from the automotive sector for non-automotive applications

It is unlikely that mechanically recycled PP from the automotive sector will have significant use in packaging given the quality requirements and the more likely exploitation of post-consumer packaging PP to fulfil commitments.

Other sectors that use PP include construction, electrical and electronics, agriculture, household, leisure and sport. rPP from ASR has been trialled in moulded products such as storage box lids, paint cans or trays (blends with virgin or regrind PP), dust bin lids and flowerpots, pallets or crates, pipe fittings and DVD cases. Low value products within these sectors could offer end markets for the right quality of automotive rPP.



[67] Plastics Europe - Plastics the Facts 2020

Examples of PP recycling in the automotive sector

Galloo Plastics has developed a post-shredding recycling technology. Their process involves separating PP, PS, ABS and HDPE from ASR. The polymers mechanical properties are adapted to meet automotive specifications. The recycled plastics can be used again in automotive products. Recycled PP granules can be reused in the injection moulding for: wheel arch liners, bumpers, engine bottom protection plates, and under the bonnet parts.

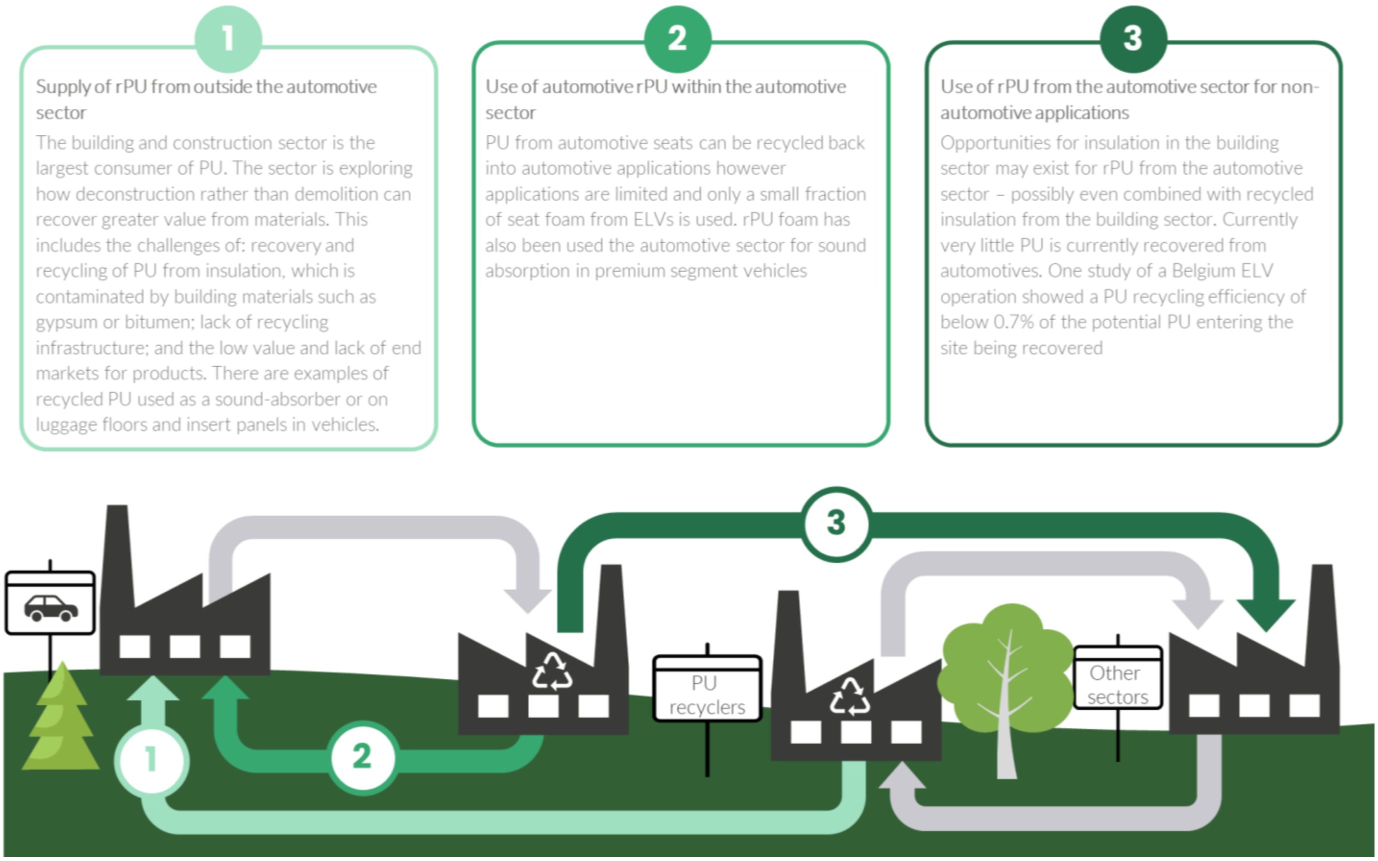
Synova produces 20,000 tonnes per year of PP that meets the highest quality standards of original equipment manufacturers and automakers from recycled plastics.

Geo-Tech recycles TPO bumpers by shredding, removal of non TPO components, cleaning using a patented technology and pelletisation. The paint-stripped TPO pellets were tested for use back within the automotive sector to be used a secondary mud flap for a small-volume vehicle.

Bumper scrap generated at Nissan plants in Japan are sent for removal of paint film and recycling. In addition, there is a bumper return program from dealerships in Japan with materials use for other automotive components.

PU

PU represents nearly 8% of the plastics resin market in the EU28. PU can either be used as foam or in rigid form. The construction sector is a large consumer of PU with its main use being building insulation. Other key uses of PU include pillows and mattresses and insulating foam for fridges.



Examples of PU recycling in the automotive sector

Rebond, a moulded PU product manufactured from pieces of shredded flexible PU foam that are held together with a binder. A company specializing in this technology is Greiner-Multifoam, making a composite foam from post-industrial waste, using cutting residues derived from PU foam processing that can be used in luggage floors and insert panels. The products can be used in the automotive sector.

PVC

PVC represents about 10% of plastic resin demand in the EU of which a very significant proportion is used in the construction and building sector. Within automotives PVC is used for trim, dashboards, and panels. PVC has typically been challenging to recycle, not least because of the unknown risks of legacy chemicals in PVC products, some of which are now banned in the EU. Progress has been made to increase PVC recycling through initiatives such as VinylPlus[68] which have supported increased recycling rates of PVC. Recycling of PVC window frames has been particularly successful, with cables also being a significant proportion of currently recycled PVC. Recovinyl was set up to monitor and verify the recycling of PVC waste to ensure the VinylPlus target of 900,000 tonnes of PVC recycling is achieved by 2025. There have been significant steps in the development of PVC recycling technologies to manage the challenges from a range of PVC products from window frames to vinyl flooring and cables.

1

Supply of rPVC from outside the automotive sector

By far the biggest user of PVC is the building and construction sector where it is used for windows, floor and wall coverings, pipes and cables. PVC is also used for home products such as garden hoses and inflatable swimming pools. There is no evidence of rPVC being used in automotive components from non-automotive sectors.

2

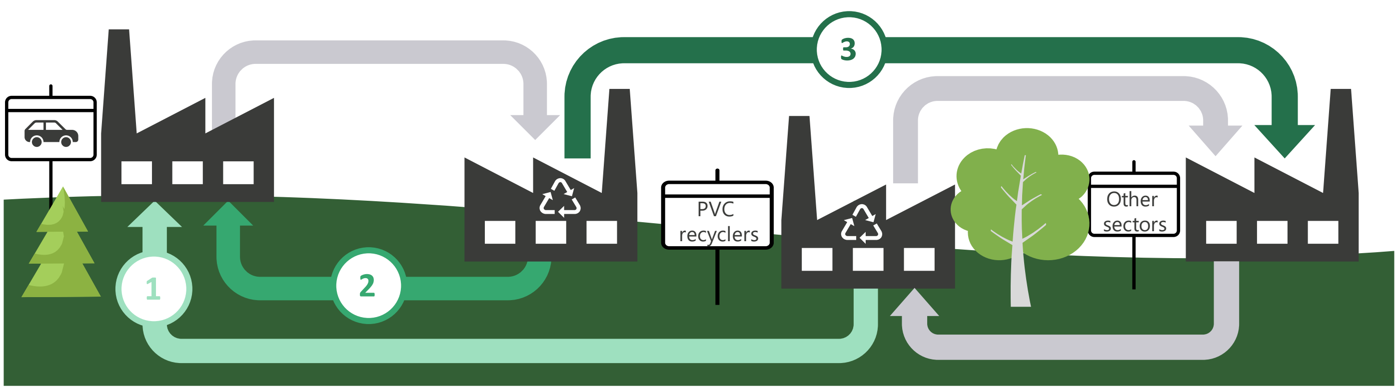
Use of automotive rPVC within the automotive sector

There is no evidence of recycling of ELV PVC back into the automotive sector. Challenges would have to be overcome (such as analysing the chemical composition of mixed PVC streams) to ensure the quality of products made from recycled PVC.

3

Use of rPVC from the automotive sector for non-automotive applications

There is no evidence of ELV PVC being recycled into non-automotive components.



[68] VinylPlus

Other plastics used in the automotive sector

Other plastics used in significant quantities in the automotive sector include high density polyethylene (HDPE), Acrylonitrile Butadiene Styrene (ABS) and polyamide (PA).

Supply of 'other plastics' from outside the automotive sector

Post-consumer plastics from outside the automotive sector have been used in automotive applications including interior lining, carpets and bumpers, or protective covers for as shown in Table 5.

	Recycled Polymer	Automotive part for re-used	Applied technology by
Post-consumer PET	PET	Electrical components, front-end modules, wiper tubes	Petra®
Used carpets	Nylon	Cylinder head covers – used on some Ford engines	EcoLon®

Table 5 Open loop automotive reycling [69]

There are examples in other sectors of ABS recycling[70], including into electronics casings, but no evidence that these materials have been used in the automotive sector.

Use of other automotive recycled plastics within the automotive sector

Airbags, made from PA, must be removed due to the gas used for inflation, as part of the safe disposal of vehicles. As a result, there is a separated and sorted stream of airbags. Two thirds of the airbag is covered with silicon which affects the mechanical recycling processes. Solvay[71] recycled airbag production scraps and developed a process to remove the silicon and recover the PA. Post-consumer airbags are additionally contaminated with exhaust fumes from the gas removal process, however Radici[72], an Italian company, has worked on cleaning fumes and silicon from the polyamide so that it can be recycled.

	Recycled polymer	Automotive part for re-used	Applied technology by
Airbags	High-quality polyamide PA 6.6	Door and tailgate handles, exterior mirrors, front-end grilles, fuel caps and lids, wheel covers and trim where PA 6.6 is used	Solvay

Use of recycled 'other plastics' from the automotive sector in non-automotive applications

There is no evidence of any commercial applications.

---

[69] Volvo takes recycled plastics for automotive up a gear June 2018
[70] Ineos styrolution website
[71] Solvay was acquired by DOMO Chemicals in 2020: DOMO Chemicals - Extension of European distribution partnership with Ultrapolymers
72 Radici 2019 Sustainability Report

Recommendations

The recovery and reuse of ELV plastics is challenging. Some polymer types, such as PP, are more advanced, whilst others such as automotive PVC are more challenging in terms of recovery and recycling. This might indicate where recovery and recycling could be scaled more successfully in the short term.

The following recommendations would support the development a more circular economy for automotive plastics:

Ensure there is clarity around the automotive industries position on the recycling automotive plastics - or not

Whilst there are public commitments by some OEMs to increasing recycled plastic content, there are no public commitments for recovering and recycling automotive plastics. Current legal requirements are met without considering plastics recovery. Enabling commitments for recovering and recycling automotive plastics requires step changes, such as:

- consideration of plastic recycling at the design and materials stage by OEMs such as design for disassembly and simplifying plastic polymer families used; and
- investment in innovation and infrastructure at end of life – whether that is disassembly or recovery of plastics from ASR.

Clear signals that the industry wants to move in this direction, rather than relying on landfill and incineration for ELV plastics is needed.

Enhance the current policy framework to increase plastic recovery and recycling capacity

OEMs currently fulfil the legal obligations of the ELV Directive without recovering plastic and there is currently a clear lack of capacity to provide high quality secondary resins for the automotive sector. Legal requirements (such as landfill bans or requirements to recover and recycle plastics) or fiscal incentives (such as taxing non recycled plastics) would provide the stimuli needed for engagement at scale by OEMs and provide confidence for the SMEs and their investors working in ELV vehicle businesses to invest in R&D and infrastructure.

Establish stakeholder driven organisation(s) to focus and drive increased automotive plastic recycling

Collaboration can improve success when dealing with common and complex challenges. This could be at the sector level (as in the packaging sector, developing design requirements for circular packaging[73]) and/or plastic types (such as VinylPlus for PVC). Such an organisation could encourage and enable long term engagement with stakeholders to:

[73] For example, CEFLEX

- support awareness raising and training within the sector to change perceptions from associating recycled materials with cheap, low quality components;
- develop a roadmap to progress recovery and recycling;
- be a conduit for funding;
- coordinate oversight of significant changes that will impact automotive plastic recycling such as the increasing uptake of electric vehicles and development of advanced (chemical) recycling technologies; and
- develop baseline data and reporting on the use of recycled plastic within the automotive sector and of the recycling of EoL automotive plastic to monitor progress.

Innovate to improve sorting and segregation to enable appropriate feedstocks for recycling

Disassembly enables cleaner streams of plastic to be recovered but is not economic. Recovery of plastic from ASR is technically complex. Significant work (including within ECOBULK) is being undertaken to test technical solutions. Clear market drivers would support the speeding up of this process. Examples of what would support this trend include:

- Defining actions needed to make disassembly, sorting, and recycling economically rewarding[74] and to promote value from automotive plastics recycling; and
- Learning from developments in plastic sorting and recycling from other sectors and testing applicability to the automotive sector, such as the Holy Grail project which is testing digital watermarks to support automated separation technologies for packaging recycling[75].

Automotive plastics recycling is challenging but there are movements from industry and in policy making to push the sector further. Technology breakthroughs are clearly needed, both to enable the use of recycled materials and to solve recycling challenges. This process is currently piecemeal and happening in pockets within the sector. To achieve anything like the targets considered for the next decade needs a step change at all points within the lifecycle of automotive plastic.

[74] Other work within ECOBULK is looking at recommendations as to how to technically and through design enable increased recoverability of plastics from automotives, and for the component parts to test the technical potential for recyclability. These aspects are not covered here in further detail.
[75] HolyGrail: tagging packaging for accurate sorting and high-quality recycling

Annex 1: About ECOBULK

ECOBULK is a Horizon 2020 funded project to rethink the design of bulky composite products from the furniture, automotive, and construction industries to make products more circular. ECOBULK works throughout the lifecycle of a product including design, manufacturing, use and end of first life. It includes considerations of logistics, customer behaviour and new business models along the entire value chain, evaluating social, environmental, and economic benefits.

In the automotive industry, ECOBULK focuses on new designs and sustainable raw materials for composite materials. The demonstrator components are internal car parts, which will be demonstrated in actual and simulated environments by Microcab, a start-up for hydrogen fuel cell vehicles, CRF (Fiat) and MAIER, a major plastic component parts supplier in the automotive sector.

The sustainable raw materials being tested within ECOBULK components include recycled and biobased plastics. One aspect of the automotive demonstrators within ECOBULK, and the focus of this report, is the end of life (EoL) recovery of component parts. In moving towards a circular economy, all sectors need to ensure that materials placed on the market can be recovered for reuse or recycling (or to biological nutrient recovery) – both technically and economically – for ongoing use within the economy. This is not currently the case for much of the plastic used within the automotive sector.

Within the automotive sector, ECOBULK is undertaking investigations in three aspects of EoL component and material recovery:

1. Evaluating the recyclability of composite components made from sustainable materials in ECOBULKs demonstrator automotive products.
2. Testing the recovery of plastics from automotive shredded residue (ASR) from automotive recycling for use in other products.
3. Initiating a CEN (European Committee for Standardization) Workshop Agreement (CWA) for standards development relating to the design requirements to make automotive sector components and materials more circular.