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Drivers and Barriers to the Circular Economy Transition: the Case of Recycled Plastics in the Automotive Sector in the European Union

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Abstract

The circular economy aims to decouple growth from environmental impacts by optimizing resource use, minimizing waste and pollution. The European Union (EU) has the ambition to lead a circular economy transition on a global level. Realizing the transition is complex, because it requires substantial and interconnected changes in the current system. Previous literature has identified the main drivers and barriers to a circular economy, categorizing them as technical, economic, regulatory and cultural. Despite its relevance, this literature has a broad focus, not taking into account the characteristics of specific industry sectors. More granular insight is essential to overcome barriers, while leveraging drivers. To this end, research focusing on these drivers and barriers within specific sectors is emerging. However, to date, this research is recent and limited, leaving a large and critical knowledge gap still to be addressed. In this study, we focus on the EU automotive sector. Specifically, in the context of the on-going review of the end-of-life vehicles (ELV) directive, we are carrying out an investigation into the barriers and drivers for increasing the uptake of recycled plastics embedded in new vehicles put on the EU market. Through the analysis of literature and in-depth interviews with key stakeholders (including vehicle manufacturers, suppliers, recyclers, experts and industry associations) we outline the value chain of plastics in the sector, while identifying and explaining specific drivers and barriers to recycling. In this paper we present some initial results of this ongoing effort. From a practice perspective, these results contribute to a better understanding on how to advance circularity in the EU automotive sector. From a theory perspective, the results illustrate how circularity barriers and drivers may be identified at a sectoral level. This may provide future studies with a methodological blueprint to replicate this work in other sectors, as a way to continue addressing the aforementioned knowledge gap.

Keywords: Circular Economy, Plastic, Recycling, Automotive, Sector, Sustainable Innovation

1. Research background and objective

The current economic system is based on a linear model: natural resources are extracted, transformed into products and distributed on the market before becoming waste. This system cannot be sustained by the Earth [1]. The circular economy represents an alternative model, aiming to decouple economic growth from environmental impacts by optimizing resource consumption, minimizing waste and pollution [2,3].

The EU is developing policies to achieve this goal. In particular, the Circular Economy Action Plan focuses on

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"closing resource loops" through several strategies such as remanufacturing and recycling [4]. Implementing the strategies is complex because it requires substantial and interconnected changes in the current system, transforming products, services, people's behaviors and the business models of organizations collaborating across industry sectors [5,6].

Present academic literature has identified the main high-level barriers and drivers characterizing the transition from a linear to a circular economy, categorizing them as cultural, regulatory, economic and technical [7,8]. An example of cultural driver is people's awareness about environmental issues. An example of regulatory barrier is divergent views across governments and organizations on how to decouple resource consumption and other negative impacts from economic growth. An example of economic barrier is the difference in price of virgin and secondary materials. An example of technical driver is a new process for recovering waste and using it to create new products.

The aforementioned literature provides high-level insights, but it does not capture specific drivers and barriers occurring within specific industry sectors [9,10]. Granular insight at this deeper level is essential to better understand, and eventually overcome barriers, while leveraging drivers [9–12]. Research is moving in this direction. For example, a group of researchers conducted a review on drivers and barriers to circularity in the building sector [13], while others focused on drivers and barriers to the implementation of 3D printing in the London metropolitan area [14]. These efforts are relevant. However, to date, they are still limited and a broad knowledge gap remains.

The objective of this study is targeting a small fraction of this gap, focusing on the circular economy transition for plastics within the EU automotive sector. Specifically, we investigate the barriers and drivers for increasing the amount of recycled plastic embedded into new vehicles put on the EU market. The investigation takes place in the context of the on-going review of the end-of-life vehicles (ELV) directive of the EU [15].

Our contribution is twofold. From a practice perspective, we provide insight on how to advance plastic circularity in the EU automotive sector. From a theory perspective, we illustrate how circularity barriers and drivers may be identified at a sector level. This is relevant to provide future studies with a methodological blueprint for replicating this work in other sectors, as a way to continue addressing the knowledge gap.

2. Method

This study is part of a broader investigation of the Joint Research Centre (JRC) of the European Commission aiming to inform the revision of the ELV Directive of the EU [15]. It addresses the knowledge gap on drivers and barriers to plastic circularity in the automotive sector. It puts forward two main outcomes: a visual outline of the plastic value chain in the EU automotive sector; and a selection of barriers and drivers for plastic circularity. The method to derive these outcomes was based on three steps.

First, we performed literature research to gather secondary data on the material flows (i.e. mass, polymer types) and structure of the value chain (i.e. stakeholders, processes). Data was retrieved from academic sources and several technical reports produced by the Ellen MacArthur Foundation, Deloitte Sustainability, the United Nations Environment Programme, the European Commission, The Plastic Industry Trade Association, Plastics Europe, the EU Circular Plastics Alliance (CPA).

Second, we integrated primary data collected through interviews with industry associations, frontrunners in the value chain (i.e., vehicle manufacturers (OEMs), component manufacturers, recyclers), and independent experts. We developed an interview-guide including a list of questions (on the features of the value chain and its material flows, drivers and barriers), and a preliminary sketch of the value chain based on literature. We then conducted the interviews, discussing with stakeholders while taking written notes and gradually validating the value chain sketch. Table 1 contains the list of stakeholders that we interviewed to gather primary data.

Table 1. Primary data sources (stakeholder interviews)

Stakeholder	Type	Respondents
ACEA	European Automotive Manufacturers' Association	20 respondents (environmental policy manager; representative panel of members)
CLEPA	European Association of Automotive suppliers	10 respondents (circular economy manager; representative panel of members)
Plastics Europe	Industry association	2 respondents (public affairs manager; technical expert)
Plastics Recyclers Europe	Industry association	1 respondent (regulatory and public affairs manager)
Frontrunner vehicle manufacturer 1	OEM	4 respondents (circular economy manager; public affairs manager; technical experts on materials and recycling)
Frontrunner vehicle manufacturer 2	OEM	5 respondents (sustainability expert; technical experts on materials and recycling, CSR manager; public affairs manager)
Frontrunner component manufacturer	Tier 1 supplier	2 respondents (technical experts on materials and recycling)
Frontrunner plastic recycler 1	Tier 3 supplier	3 respondents (technical experts; environmental affairs manager)
Frontrunner plastic recycler 2	Tier 3 supplier	1 respondent (general manager)
Frontrunner plastic recycler 3	Tier 3 supplier	1 respondent (general manager)
Independent expert 1	-	-
Independent expert 2	-	-

Third, we analyzed primary and secondary data, condensing them into our results. In line with qualitative data analysis techniques [16], we inductively condensed our notes and preliminary sketches into a final visualization, including value chain steps, stakeholders, and material flows of virgin and recycled plastics. This is shown in Figure 1 and further explained in section 3.1. In parallel, we used a coding procedure (i.e., thematic clustering of qualitative data) [17] to inductively derive from the notes of stakeholder interviews a clean list of four barriers and four drivers (cultural, regulatory, economic and technical) for plastic circularity. We then mapped drivers and barriers on the value chain visualization. This is shown in Figure 1 and further explained in section 3.2.

3. Results

3.1. Outlining the value chain of plastic in the EU automotive sector

Figure 1 shows the transformation steps of virgin and recycled plastic embedded in new vehicles. Virgin plastic is visualized with orange arrows, recycled plastic with blue arrows. The thickness of the arrows does not represent the actual volumes, but provides a good visual indication of where the largest plastic material flows lie. This plastic may be exported or imported in the EU at different stages of the value chain, in the form of virgin and recycled pellets, components products and waste. This is shown in the top-left corner of the figure.

Upstream in the value chain, tier 3 suppliers process raw material (i.e., crude oil and natural gas) into polymers. Polymers are mixed with different fillers and additives in a compounding process, resulting into plastic pellets with different specifications. Tier 2 suppliers (i.e., supplying across sectors) and tier 1 suppliers (i.e., supplying only the automotive sector) mold pellets into different components for new vehicles. Plastics components can be categorized according to four main types of applications: exterior (e.g., bumpers), interior (e.g., dashboard), under the hood (e.g., engine cover), decorations (e.g., wheel covers). Altogether, they add up to 15-18% of the total mass of a vehicle (inputs from stakeholders) [18–20]. The main polymer types used in passenger car applications are PP (37%), PUR (15%), PA (12%), PE (8%), PVC (7%), ABS (7%), PET (5%) and others including PC, PMMA, PBT, POM (9%) [21,22].

At the center of the value chain there are car manufacturers, also defined as original equipment manufacturers (OEMs). The OEMs in the automotive sector are accountable for a plastic demand of 4.4 Mt/year, which is roughly 10% of the aggregated demand from all sectors (3rd sector after packaging and construction sectors) [23]. They source plastic components from suppliers, certify suitability for automotive application, and assemble them into the final product. The vehicle is then put on the EU market, where it is used for approximately 17.5 years (inputs from stakeholders). In this period of time, the plastic embedded is considered as material "stock" within the sector.

Downstream in the value chain, at the end of the use phase, the vehicle is collected in authorised treatment facilities where it is depolluted, dismantled and shredded. After shredding, metals are recovered first. Plastic shreds are considered less valuable and include a mix of different polymers (inputs from stakeholders). In most cases, plastic shreds from vehicles are also merged with additional plastic shreds or waste from other sectors. The total amount of post-consumer plastic that is collected from all sectors in the EU amounts to 24.6 Mt/year [23]. After collection, it either recycled, incinerated for energy recovery or disposed into landfill. Regarding post-consumer plastics from vehicles: 19% is recycled, 41% is used for energy recovery and 40% is disposed into landfill (inputs from stakeholders).

The amount of recycled plastic used in new products in the EU amounts to 4.0 Mt/year [23]. In the automotive sector, the demand of recycled plastic comes from OEMs, mainly driven by a cost-saving rationale, and by the need of responding to market trends such as increased consumer awareness to sustainability issues. Accordingly, tier 1 and tier 2 suppliers source recycled material from recyclers (tier 3 suppliers specialized in the production of plastic pellets from waste). They perform a mechanical recycling process based on several steps: collecting plastic waste; separating polymer types (when possible); shredding (if not already shredded); separating shreds to reach an output as homogeneous as possible (commonly based on wet density sorting techniques); compounding the output (by melting it in combination with fillers and additives); extruding recycled pellets. In most cases, these steps are not performed by a single business. The total mass of the recycled plastic in a vehicle (considering both pre-consumer and post-consumer plastic waste), ranges from 5% to 15%, depending on model and brand. In some cases, it can reach 20% (inputs from stakeholders).

Virtually all recycled plastic embedded in a new vehicle is obtained through mechanical recycling. About 80% comes from pre-consumer waste (i.e., waste generated during disparate industrial production process in different sectors), which is more homogenous and easier to recycle. On the other hand, post-consumer plastic, although representing the majority of waste, it is recycled to a very limited extent. Only 109 kt of post-consumer recycled plastic is entering the automotive sector annually in the EU [23–25]. Relatedly, 20% of recycled plastic embedded in a vehicle currently comes post-consumer sources (i.e., waste from used products e.g., packaging). Precise estimates are difficult to get. These percentages provide a rough indication (based on inputs from stakeholders). Making a more accurate estimate is challenging because before being integrated into a new vehicle, pre-consumer and post-consumer plastic waste is sometimes mixed together in the collection step and sometimes blended with virgin material in the compounding step of mechanical recycling.

Chemical recycling represents an alternative to overcome the limitations of the mechanical process, turning post-consumer waste back into new polymers (purification) or even into raw material (feedstock recycling). However, chemical recycling can have very high environmental impacts, and may only be interesting for specific waste streams. It still requires significant R&D before it can be implemented on the market at full scale [18]. For this reason, the flow of chemically recycled plastic is visualized in Figure 1 with a discontinuous, dashed, blue arrow.

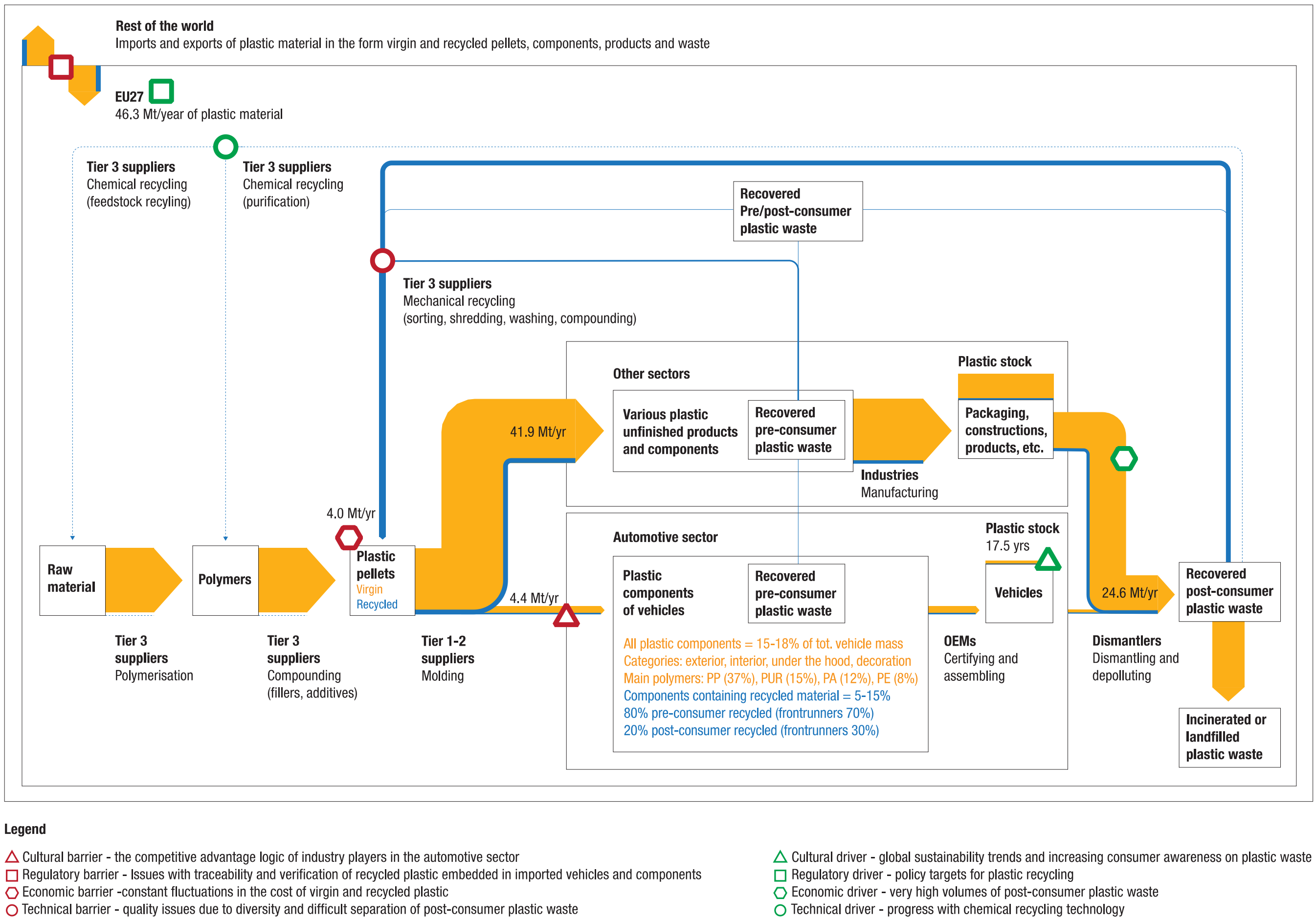

Fig. 1. Value chain of virgin and recycled plastic in the EU automotive sector. Based on literature and stakeholder inputs.

3.2. Identifying the drivers and barriers for increasing the uptake of recycled plastic in the value chain within the EU automotive sector

Figure 1 shows a selection of four barriers and four drivers (identified through the ongoing research and contacts with key stakeholders) for increasing the amount of recycled plastic. These drivers and barriers are mapped on the location of the value chain where they occur, using different colours and shapes, as explained in the legend of the figure.

"Global sustainability trends and increasing consumer awareness on plastic waste" is a cultural driver. The main rationale for vehicle manufacturers to implement a sustainability strategy, including using recycled plastic, is consumer awareness. This affects their brand value (ACEA, Frontrunner vehicle manufacturer 2) even though return on investment is difficult to quantify (Vehicle manufacturer 1, Frontrunner plastic recycler 3).

"Policy targets for plastic recycling" is a regulatory driver. Policies on recycled plastic will fuel progress with recycling technologies (Independent expert 2), support recycling firms to grow and shape the market (Frontrunner plastic recycler 3), and ultimately foster more constant quality of recycled plastic material for the automotive sector. This is happening in particular for PP, with a proposition of standardization for different PP grades (ACEA).

"Very high volumes of post-consumer plastic waste" is an economic driver. There is a huge plastic waste stock embedded in end-of-life vehicles but also in other sectors, such as packaging and electronic equipment (Frontrunner plastic recycler 3). This will induce a big market opportunity for inter-sectorial exchange with the automotive sector, which could source it and use it to manufacture recycled components (Frontrunner vehicle manufacturer 2, Independent expert 1). For example, PET fibres from the 60% of plastic bottles that are currently not recycled in the EU could be used to produce textiles for car seats, instead of importing virgin PET from third countries (ACEA, Frontrunner vehicle manufacturer 1, Frontrunner vehicle manufacturer 2).

"Progress with chemical recycling technology" is a technical driver. Chemical recycling is a promising complementary option next to mechanical recycling, focusing mainly on aged post-consumer plastic waste, and allowing high quality applications (e.g., safety components) (Frontrunner vehicle manufacturer 1, Frontrunner plastic recycler 3). However, chemical recycling maturity is still low and 10 years of R&D might still be needed to demonstrate its technical and economic feasibility, as well as its environmental footprint (Frontrunner plastic recycler 3). Chemical recycling for PET and PUR polymers might be closest to market readiness (Frontrunner vehicle manufacturer 1) but it is becoming clear that chemical recycling still requires waste separation and appears well suited only for very targeted applications (CLEPA).

"The competitive advantage logic of industry players in the automotive sector" is a cultural barrier. This logic hinders

knowledge transfer across tier 1 and 2 suppliers, OEMs and recyclers regarding available options of recycled material. For example, compounding recipes and simulation software represent sources of competitive advantage for recycling firms, not to be shared with competitors and clients (Plastic recycler 2, Component manufacturer). Manufacturers are also concerned with confidentiality of the material used in their components (ACEA, Frontrunner vehicle manufacturer 1, Frontrunner component manufacturer).

"Issues with traceability and verification of recycled plastic embedded in imported vehicles and components" is a regulatory barrier. Vehicle and components manufacturers are concerned that mandatory targets on the incorporation of plastic recycling may affect their ability to compete with non-EU manufacturers (ACEA, CLEPA), especially if the latter are not forced to comply with such targets (Independent expert 1). In order to make sure that this will be the case, it essential to create traceability and verification schemes on imported vehicles and components, which may be quite difficult to implement (ACEA, Plastics Europe).

"Constant fluctuations in the cost of virgin and recycled plastic" is an economic barrier. The cost of virgin plastic changes with the market prices of oil and gas (Frontrunner vehicle manufacturer 1, Frontrunner plastic recycler 2, Frontrunner plastic recycler 3) while the price of recycled plastics changes due to many factors such as availability, sourcing channels, separation methods, and safety testing (Frontrunner plastic recycler 2, Frontrunner plastic recycler 3, CLEPA). This makes it difficult for OEMs to define a clear business case for using recycled material (ACEA, Frontrunner vehicle manufacturer 2).

"Quality issues due to diversity and difficult separation of post-consumer plastic waste" is a technical barrier. Post-consumer plastic waste is largely available, but it is often contaminated (i.e., impurities, hazardous substances, volatile organic compounds) overly aged, and characterized by uncertain composition (CLEPA). This makes it difficult to separate it and recycle it into high quality pellets and polymer grades for automotive applications (Plastic Recyclers Europe).

4. Discussion and conclusion

In this study, we focus on the drivers and barriers to the circular economy transition by conducting research in the context of the on-going review of the end-of-life vehicles directive (ELV) of the EU. Our results outline the value chain of plastics in the EU automotive sector, and identify four drivers and for barriers to increase uptake of recycled plastic embedded in new vehicles.

From a practical standpoint, our results contribute to a better understanding on how to advance circularity in the European automotive sector. In particular, our value chain visualization of recycled plastic in the automotive sector, and the initial identification of specific drivers and barriers within, is an essential first step to develop future scenarios and set actionable targets in the creation of an EU market for recycled plastic, in the automotive sector, and eventually beyond that. In turn, this is relevant to support the high-level objectives of the current Circular Economy Action Plan [2], which prescribe a major focus on transforming the most resource intensive and impactful economic activities, including the production of vehicles and the management of plastic waste.

From a theoretical perspective, our results make an important contribution by showing how to go beyond current research focusing on cultural, regulatory, economic and technical drivers and barriers at the high-level of the entire economic system [7,8]. We focused on a specific sector (i.e., automotive), mapped a specific value chain (i.e., recycled plastic), identified key stakeholders (i.e., industry associations and frontrunning companies), and entered with them into the nitty-gritty of specific drivers and barriers. This degree of specificity is essential to start addressing the broad knowledge gap on circular economy drivers and barriers emerging in different sectors of the economy [9,10,13,14]. To this end, our approach may be replicated in other contexts. For example, future studies may focus on circularity barriers and drivers for critical raw materials embedded in vehicles (i.e., electric batteries, engines), which are still recycled to a limited extent despite their crucial importance for Europe's strategic autonomy [26,27].

We conclude stressing that our investigation is work in progress. Our identification of drivers and barriers to plastic recycling in the automotive sector is still under development and will build on the further exchange and consultation with stakeholders. A follow up work will capture a complete picture of drivers and barriers of incorporating recycled plastics in new vehicles, including quantitative assessment of environmental and economic impacts that could be associated to mandatory EU targets of recycled plastics content in new vehicles.

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Disclaimer

The views expressed in the article are personal and do not necessarily reflect an official position of the European Commission.

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