JRC EXTERNAL STUDY REPORT

Modelling plastic product flows and recycling in the EU

The Plastic Product Mass Flow Model 2.0

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Contents

Abstract

The European Commission is supporting initiatives to increase the use of recycled plastics in Europe to 10 million tonnes (Mt) per year by 2025, but there is still a considerable way to go before achieving this goal. Studies estimate that only an amount between 3.5-5.6 Mt of recyclates is currently directed back into products.

The objective of the present study is to improve the quality of data and the modelling of plastics mass flows in Europe. This report describes a second iteration of a Plastic Product Mass Flow Model which is based on public data sources and inputs from the Circular Plastics Alliance (CPA), for the reference year 2019. The modelled results for 2019 are in the range of values found in other studies, while providing a dynamic tool for industry players to take forward, update, and improve over time.

Acknowledgements

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Executive summary

Policy context

With the publication of the 2018 European Plastics Strategy, the European Commission aimed at improving the economics of plastics recycling and set ambitious targets for recycling. The goal is to reach 10 million tonnes (Mt) of recycled plastic used in the EU27+UK market by 2025[1] (hereafter "the 10 Mt target"), against around 4.5 Mt used to make new products in Europe in 2020 (Plastics Europe, 2021).

Currently, the majority of the plastic waste is still directed to landfill, incineration, or is mismanaged. Signatories of the Circular Plastics Alliance (CPA), an industrial alliance covering the entire plastics value chain, have already endorsed the ambitious 10 Mt target and are working together to increase recycling and the uptake of recycled content in production.

Background

In 2020, the Joint Research Centre (JRC) worked with the Circular Plastics Alliance to develop a first mass flow model of plastic flows across the five CPA sectors (packaging, construction, automotive, electronics, and agriculture) which used data from 2014-2018 (Watkins et al, 2020). This was successful in terms of providing new insights at a granular level of products. This model also showed how far away the EU market for recycled plastics still was from achieving the 10 Mt target, as it estimated that only around 3.8 Mt of recyclates were being directed back into products. Besides, there were some areas in which this model needed further improvement. The first iteration of the model did not include chemical recycling or pre-consumer wastes and these were areas where more insight was desired. Hence, the second iteration of the model, which is presented in this document, is aiming at improving the quality of data and the modelling of plastics mass flows in Europe.

Approach

The "Plastic Product Mass Flow Model 2.0" as elaborated in this study uses existing publicly-available data and data collected from CPA signatories with reference year 2019. The original model 1.0's shortcomings were addressed by expanding the model to include chemical recycling and pre-consumer waste, and research was conducted to identify whether further adaptations would be needed to track policy goals. A country-level model was built for five products to explore how this could be done at a higher level of national granularity and to deliver insights based on the differences between countries.

A key purpose of building a second version of the model was to also ensure that the model could be taken forward and updated over time. The model was built carefully to ensure it could be used by others, updated, and improved (as is described in Annex 2). A large part of the project also focused on building assets such as overviews of key studies and databases that could be used in the future to update the model as well.

The majority of the data collection methodology was focused on building ways to automatically process public datasets like Prodcom production data and Eurostat waste data into the desired format, using a model where background assumptions can be modified over time.[2] This comes with some shortcomings, both as the publicly available data sets are incomplete and/or inconsistent, and because the model outcomes are dependent on assumptions that convert categories used by these national statistics into the granularity of specific priority products that constitute the main focus of the CPA signatories. For example, Eurostat waste data do not provide a complete picture of plastic waste. These limitations and the reasons for any discrepancies with other studies or private market data are described in the report.

[1] The target is approximately 9.2 Mt for the EU27 only (excluding the UK).

[2] Note that Eurostat is not responsible for data modifications made within this project.

In addition, while the scope of the 10 Mt target is the EU27+UK, the scope of the Plastic Product Mass Flow Model v2.0 is the EU27. This scope was selected because 2019 is the last year with Prodcom data available for the EU28. Since the end of 2020, the UK does not report anymore to Eurostat, so no more data will be available in subsequent years.[3] Using EU27 as our target group makes the model updatable moving forward.

For these reasons, the model was set up to allow for updating the assumptions and annual data over time as well as to compare public data sets and estimations with the values provided by CPA signatories or other sources. A data request template was shared with CPA signatories, and the subsequent data or reports provided were added to a second mirrored version of the model that uses point data when available instead of modelled outcomes.

Key conclusions

The modelled results of the current state are in line with other studies. For example, despite some differences in sector, product, or geographic scope, the present Plastic Product Mass Flow Model 2.0 estimates 44.6 Mt of plastics are used (vs 36.9-49 Mt in other studies), 20.2 Mt of plastic waste is generated (vs 20-45 Mt in other studies), and 3.8 Mt of recyclate is generated (vs 3.5-5.6 Mt in other studies). While further adaptations may help to make the model even more consistent with other reliable sources, it does provide a dynamic tool for industry players to take forward, update, or improve over time.

[3] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/WDN-20200201-1

1 Introduction

1.1 Context

With the publication of the 2018 European Plastics Strategy, the European Commission aimed to improve the economics of plastics recycling and set ambitious targets for recycling. In particular, the European Commission is supporting initiatives to help the European market for recycled plastics increase to 10 million tonnes (Mt) per year by 2025 (hereafter "the 10 Mt target"), against around 4.5 million tonnes of recycled plastic used to make new products in Europe in 2020 (Plastics Europe, 2021).

One of the initiatives developed by the European Commission was to establish the Circular Plastics Alliance (CPA), which now has more than 300 signatories. This group aims to work together on achieving the EU target of directing 10 Mt of recycled plastics into products on the European market by 2025. Its main activities include sharing information, identifying key barriers and bottlenecks, and identifying and working on solutions that can enable achieving the target. There are working groups set up to tackle design for recycling, analysis of the untapped potential for more collection and sorting in Europe, and other key issues. In 2022, a major milestone was achieved with the establishment of a first-of-its-kind EU-wide monitoring system to track the quantities of recycled plastics used and produced in Europe.[4]

In 2020, the Joint Research Centre (JRC) worked with the CPA to develop a first mass flow model of plastic flows across the five CPA sectors, which used data from 2014-2018 (Watkins et al, 2020). This was successful in terms of providing new insights at a granular level of products, rather than only sectoral flows. This model also showed how far away the European market still was from achieving the EU's 10 Mt target, as it estimated that only around 3.8 Mt of recycled plastics are reused in products in Europe. However, there were some areas in which this model needed further improvement. For example, the first iteration of the model did not include chemical recycling or pre-consumer wastes, while these were areas where more insight was desired.

However, the biggest challenge was that the model was set up using individual data points collected from CPA signatories and reports from different years. This approach makes it difficult to update the model in future years and also meant that there was some work needed to align and validate the information.

1.2 Objectives

The objective of the present study is to improve the quality of data and the modelling of plastics mass flows in Europe

The "Plastic Product Mass Flow Model 2.0" as elaborated in this study uses existing publicly-available data and data collected from CPA signatories with reference year 2019. The original model 1.0's shortcomings were addressed by expanding the model to include chemical recycling and pre-consumer waste, and research was conducted to identify whether further adaptations would be needed to track policy goals. This was done by reviewing relevant policy documents for goals and framing relevant for the present model's scope. In addition, a country-level model was built for five plastic products to explore how plastic flow modelling could be done at a higher level of national granularity and to deliver insights based on the differences between countries.

A key purpose of building a second version of the model was to also ensure that the model could be taken forward and updated over time. The model was built carefully to ensure it could be used by others, updated, and improved (as is described in Annex 2). A large part of the project also focused on building assets such as overviews of key studies and databases that could be used in the future to update the model.

[4] EU27+ UK, which is also the geographical scope of the 10 Mt target as adopted by the European Commission in 2018

Table 1: Comparison between Plastic Product Mass Flow Model 1.0 and 2.0.

	Model 1.0	**Model 2.0**
Granularity	EU level for priority products (combination of sector, product and polymer) in five CPA sectors	Priority product level (combination of sector, product and polymer - other sectoral mass flows are modelled in a generic "other" category), & Country level (for 5 priority products)
Scope	EU 27+UK	EU 27
Data source	Mechanical recycling, post-consumer waste	Mechanical and chemical recycling Pre and post-consumer waste
Model setup	Individual data points from different sources and years	More consistent data sources from Eurostat, as well as data shared by CPA signatories
Data source	Static, difficult to update and validate the results	Dynamic, easy to update and improve when data points from a specific country, sector, or product become available

2 Modelling plastic flows

This chapter outlines how the Plastic Product Mass Flow Model 2.0 was elaborated and discusses main outcomes from the model, including a comparison with mass flow models developed by other organisations.

2.1 Methodology Summary

Scoping "Priority Products"

The main aspect that sets apart the Plastic Product Mass Flow Model 2.0 from other efforts to model plastic flows in Europe is a more precise level of granularity to which plastic flows are modelled. Most plastic flow models capture flows at the level of either polymers or products, which is already challenging. For the purpose of meeting the 10 Mt target, the CPA has selected 29 priority product categories in its Design-for-recycling Work Plan[5]. These priority products are defined as a combination of a market/sectorial application and a main plastic material. For example, HDPE pipes used for construction and HDPE pipes used in irrigation for agriculture would be considered two different products.

The commitment by the CPA has been to develop design-for-recycling guidelines for each of these priority products in order to ensure their recyclability in the European market. A product-level approach will be necessary to achieve high recycling rates. The CPA has estimated that the priority products listed in its Design-for-Recycling Work Plan account for over 18 Mt of plastic waste generated per year, including over 15 Mt of plastic packaging waste. Hence if all collected and sorted for recycling, these priority products would provide sufficient feedstock to achieve the EU's 10 Mt target (as detailed in the CPA's Untapped Potential analysis).[6]

The Plastic Product Mass Flow Model 2.0 includes all plastic flows for the five CPA sectors: electronics, agriculture, construction, automotive, and packaging. 35 specific priority products were modelled as separate flows with the rest of the plastics for the five sectors captured in an "other" category per sector. The country-level model only covers five priority products. These priority products were selected by the CPA and the JRC in consultation at the beginning of the project.

For further information about the scoping and selection of priority products and to see the full list, please see Annex 1*, section titled "I. Selection of Priority Products".*

Scoping Flows

Figure 1 shows the scope of the EU-level flow model, starting from raw material inputs (primary or secondary) and going through the use of recyclate in sectors (or products, where information is available). Non-recycled waste is only shown as "landfilled, incinerated, or mismanaged" and therefore not further broken down, as the purpose of the model is not to evaluate what happens to non-recycled flows.

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[5] https://ec.europa.eu/docsroom/documents/47334
[6] https://ec.europa.eu/docsroom/documents/46956

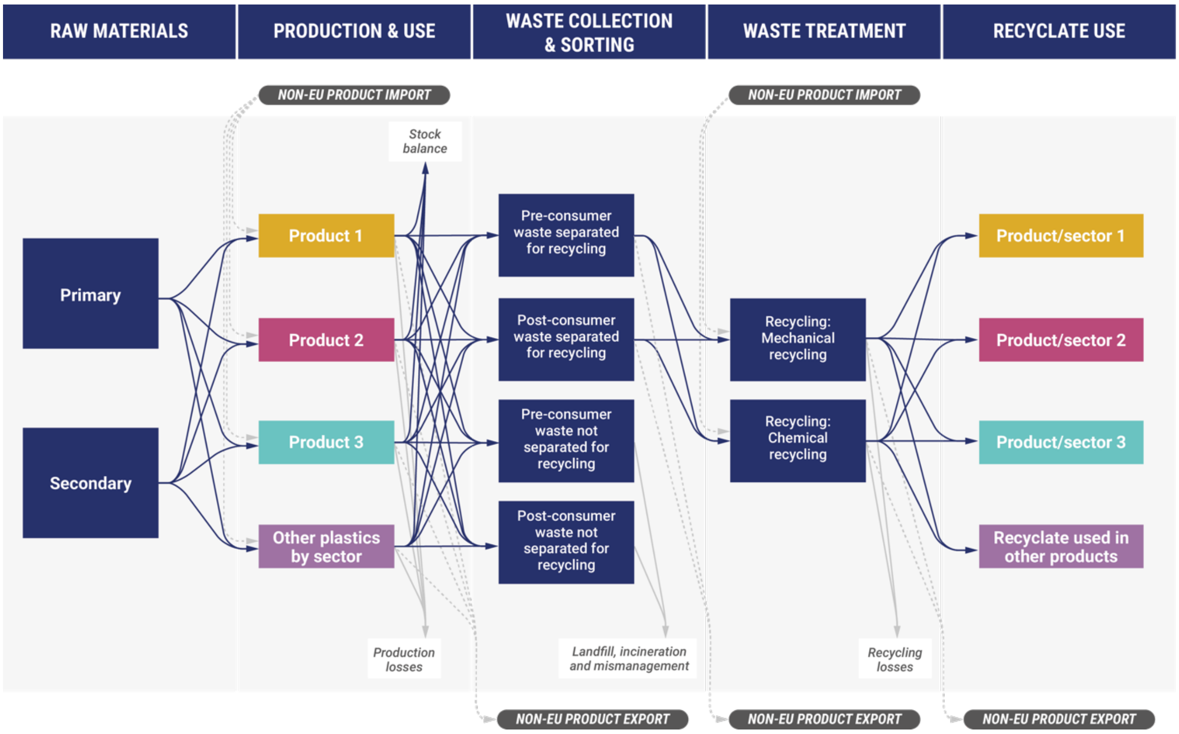


Figure 1: Scope of the Plastic Product Mass Flow Model 2.0 - EU-level Model.

The Country-level Model is scoped in the same way as the EU-level model, but only five products are included (Figure 2).

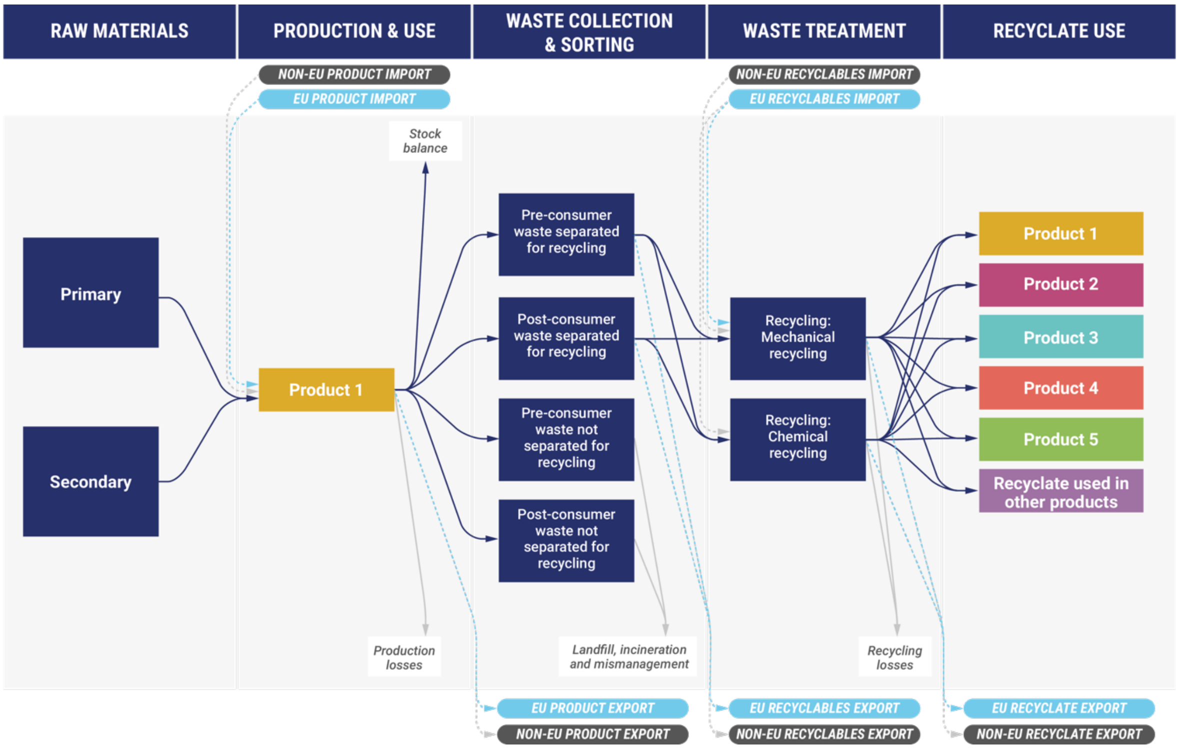


Figure 2: Scope of the Plastic Product Mass Flow Model 2.0 - Country-level Model.

Modelling vs. Measuring

Most efforts to model plastic flows apply an approach that uses data and assumptions to estimate the mass flows. However, the previous JRC plastic product mass flow model applied a different approach, largely filling in the mass flows point-by-point, based on information available in reports or shared by CPA signatories. Both approaches are valuable as the modelling approach can be easily updated with new data in future years and it provides a complete picture of the flows, while the data point approach often presents more accurate data for a specific part of the picture.

One of the goals of developing the Plastic Product Mass Flow Model 2.0 was to include modularity allowing to incorporate data provided by CPA signatories combined with an easily updatable and flexible modelling structure. To capture the benefits of these both approaches, a combined method was applied. Plastic mass flows were modelled on the basis of public production, trade, and waste data as well as a series of assumptions (or transfer coefficients) that capture how plastic waste is expected to be treated downstream. Both the annual public data and the assumptions can be easily updated in the future.

The majority of the data collection methodology was focused on building ways to automatically process the public data sets like Prodcom into the required format. However, an entire methodology was also set up around comparing public data sets and model estimations with the values provided by CPA signatories. The structure of the model is mirrored in a second version (sheets *EU_input* and *country_Input*) that allows to add individual data points shared directly by CPA signatories or found in reports that they have suggested to incorporate.

Data Collection from CPA Signatories

To gather data that improves the quality of understanding mass flows for the priority products, a data request template[7] was made to gather data from CPA signatories for the model. This data request was reviewed by the project team and revised. Based on input from the project team, this data request was shared with a selection of CPA signatories. During the modelling process, the project team held many alignment calls with CPA signatories to explain the data that is needed and how it will be used. Many CPA signatories were unable to share much data with only a few months' notice and most of what was received was existing reports that needed to be checked for relevant data. However, the model is set up in a way where this data can be added and refined over time. The data and reports that the project team did receive were documented in a spreadsheet to keep an overview of what was received and where it could be helpful. A final version of the model takes the individual data points provided by the CPA where available, or it otherwise uses the model outcomes for that part of the product flow.

Data and assumptions

Data availability is a major barrier for understanding plastic flows. During the course of the project, the project team held several meetings with other stakeholder groups to discuss data availability and challenges. This included discussions with other JRC Plastic Product Mass Flow Modelling teams, other plastic flow modellers outside of the JRC, including Eurostat, the Circular Plastics Alliance Monitoring Group, and the European Plastics Pact. From these discussions, it became clear that mainly data from Eurostat (including Prodcom) is typically used as a basis for analysis due to a low availability of public market data.

While the scope for the 10 Mt target is the EU27+UK, the scope of the Plastic Product Mass Flow Model 2.0 is the EU27. This scope was selected because 2019 is the last year with Prodcom data available for the EU28. From the end of 2020, the UK does no longer provide data to Eurostat, so no more data will be available in subsequent years. Using *EU27_2020* as the target group makes the model updatable moving forward. Annex 1 details all of the data sources and assumptions that went into the model, but a few key points are highlighted here in brief. Annex 4 contains the full bibliography used to gather the data and

[7] Link to data request template:
https://docs.google.com/spreadsheets/d/1OOPerzHcKmlAID6jHW7n87IWqaCtkNbG/edit#gid=277404429

information that formed the basis of the complete modelling exercise. In addition, Figure 3 provides a visual overview of key data sources used in the model.

Eurostat's Prodcom data from 2019 is used to estimate production, imports, and exports of products. Product flows are converted into mass flows of plastics by building further on an approach developed by Amadei et al. (2022): in order to make this conversion, assumptions are used regarding the share of plastics of a specific polymer type in different product categories. An example of the process going from Prodcom data to priority product mass is explained in Annex 1 under the section "Production and trade data, processing, and assumptions", with links to the relevant parts of the model. We note that Eurostat is not responsible for data modifications made within this project.

Eurostat's waste data is used to estimate total waste generated and some treatment. Much of this data is unavailable for 2019 and was extrapolated from previous years. Additionally, some of the waste flows (e.g. electronics, automotive) required conversion from total mass to plastic flows for specific polymers. This was done in the same way as the Prodcom data was converted by using assumptions on the share of plastics by polymer type.

The pre-consumer waste includes packaging and retail loss[8] based on the definition from Cimpan et al. (2021). The generation of pre-consumer waste and how waste is treated downstream is modelled on the basis of transfer coefficients, which measure the percentage of production volumes that ended up in the waste stream. These values were derived from literature research, which was only available for packaging flows. After the point of waste generation or collection, the flows are calculated by the model by multiplying the total waste by the share going to different types of treatment or use (e.g. chemical recycling/mechanical recycling, recyclate uptake in different sectors or products). All of these key assumptions are captured in one sheet of the model for review and can be easily updated.

CPA signatories shared data for only two products: PVC window profiles and doors and agricultural gardening films. However, a number of reports and studies were also shared. Information shared by the CPA signatories, whether data or information pulled from reports, was added to the "Input" sheet and taken as the correct value for specific data points. However, as this information was spotty, the model outcomes are used where this "primary data" is unavailable. In the version that incorporated point data from the CPA signatories (*EU_final* tab), a colour flag has been added in the cell whenever point data differs substantially (>50%) from the modelled results. This will allow for users of the model to note discrepancies more clearly.

[8] Retail loss or shrinkage refers to any unknown or unaccounted for loss of inventory.

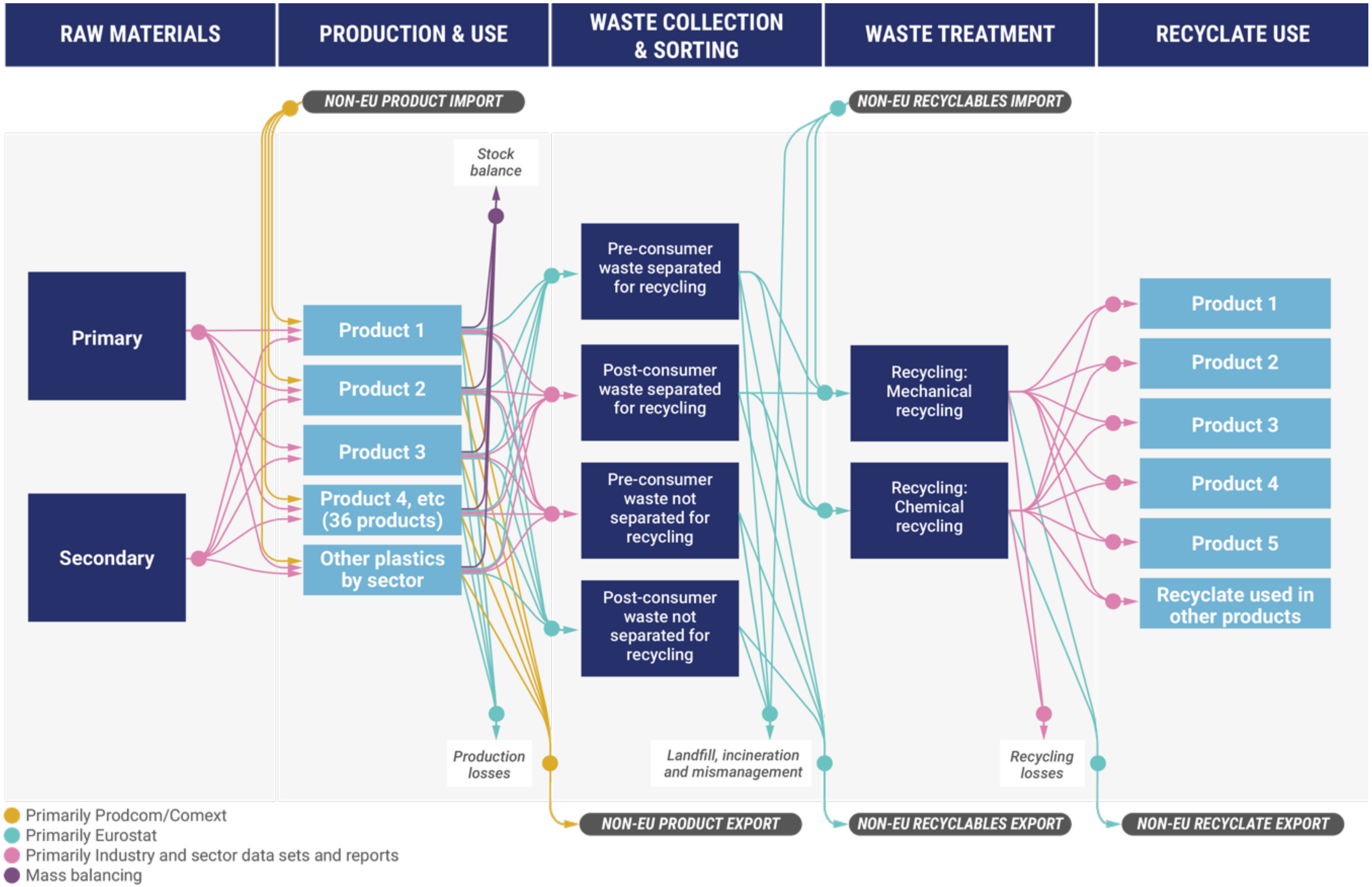


Figure 3: Overview of key data sources used in the Plastic Product Mass Flow Model.

Austria exclusion - Country-level model

The raw Prodcom data is included in the model itself, which means Eurostat's copyright notice needs to be followed. In the copyright text[9], one relevant point can be found regarding the data that can be reissued with commercial purposes:

> *"4.e Trade data originating from Austria (as a declaring country) for a level of detail of the Combined Nomenclature of 8 digits; again, it is not allowed to sell export/import declared by Austria (concerning the above named commodity classifications), but it is allowed to sell Austrian export/import data declared by another EU Member State."*

This project uses and publishes raw Prodcom data on a country level, at a level of detail of 8 digits. As part of the work done in this project was based on a contractual agreement with a commercial third party (Metabolic BV), Austria's data has not been included in the country-level model. However, the European-level model includes data from Austria, since it is aggregated with the data from all other member countries.

Data sources quality and uncertainty

It was important to capture uncertainty in a quantitative way in the Plastic Product Mass Flow Model, and several approaches were explored for doing so. In the end, a relatively simplistic approach was selected to facilitate updates in the future. In this approach, a qualitative assessment was applied for data sources that feed into the model, using the framework developed by Laner et al. (2016). Data sources are given a score of 1 (high) to 4 (low) across five dimensions: reliability, completeness, temporal correlation, geographic correlation, and other correlation. The average of these five dimensions is taken for the overall score. Scores are converted into percentage uncertainty ranges, which for the scores 1-4 are 5%, 20%, 40%, and 90%, respectively. This means that for a data source with a score of 3, an uncertainty range of 40% of the value will be applied. When multiple data sources are used to estimate a column in the mass flow model, the average uncertainty values for the data sources are applied.

[9] https://ec.europa.eu/eurostat/about/policies/copyright

Table 2: Evaluation of data sources used in the model.

Data source	Reference	Score					
		Reliability	Completeness	Temporal correlation	Geographical Correlation	Other correlation	Total Score
Production, trade	*Prodcom*	1	1	1	1	1	1.0
Waste generation, some waste treatment	*Eurostat waste data*	1	4	2	1	2	2.0
Plastic product breakdown assumptions	*Various, and assumptions*	3	1	1	1	3	1.8
Primary vs secondary material input	*Cimpan et al. (2021)* *GIZ (2021)*	1	2	2	1	2	1.6
Pre-consumer waste generation and treatment	*Lindner et al. (2020)* *Cimpan et al. (2021)* *Hsu et al. (2021)*	1	3	2	1	2	1.8
Mechanical vs chemical recycling value	*Plastics Europe. (2019)* *Plastics Europe. (2020)*	3	4	2	1	3	2.6
Chemical and mechanical recycling losses	*Jeswani et al. (2021)*	1	2	2	1	3	1.8

Recyclate exports	*Plastics Europe (2019)* *Material Economics (2022)*	3	3	2	1	2	2.2
Post-consumer waste treatment	*Plastics Europe (2019)*	3	3	2	1	2	2.2
Sector (and estimated product) allocation of plastics	*Plasctics Europe (2021)*	3	3	2	1	2	2.2
Recyclate in products	*JRC Plastic Product Mass Flow Model 1.0*	2	2	2	1	2	1.8

Table 3: Uncertainty scores based on evaluation framework by Laner et al. (2016)

Uncertainty score	**Percentage +/- uncertainty range**
1	5%
2	20%
3	40%
4	90%

Table 4: Evaluation framework by Laner et al. (2016). (GDP= Gross Domestic Product)

Indicator	Definition	Score: 1	Score: 2	Score: 3	Score: 4
Reliability	Focus on the data source: documentation of data generation, e.g., assessment of sampling method, verification methods, reviewing processes.	Methodology of data generation well documented and consistent, peer-reviewed data.	Methodology of data generation is described, but not fully transparent; no verification.	Methodology not comprehensively described, but principle of data generation is clear; no verification.	Methodology of data generation unknown, no documentation available.
Completeness	Composition of the data of all relevant mass flows. Possible over- or underestimation is assessed.	Value includes all relevant processes/flows in question.	Value includes quantitatively main processes/flows in question.	Value includes partial important processes/flows, certainty of data gaps.	Only fragmented data available; important processes/mass flows are missing.
Temporal correlation	Congruence of the available data and the ideal data with respect to time reference.	Value relates to the right time period.	Deviation of value 1 to 5 years.	Deviation of value 5 to 10 years.	Deviation more than 10 years.
Geographical correlation	Congruence of the available data and the ideal data with respect to geographical reference.	Value relates to the studied region.	Value relates to similar socioeconomical region (GDP, consumption pattern).	Socioeconomically slightly different region.	Socioeconomically very different region.
Other correlation	Congruence of the available data and the ideal data with respect to technology, product, etc.	Value relates to the same product, the same technology, etc.	Values relate to similar technology, product, etc.	Values deviate from technology/product of interest, but rough correlations can be established based on experience or data.	Values deviate strongly from technology/ product of interest, with correlations being vague and speculative.

2.2 Outcomes

EU-Level Model

The mass flow model is available as a supplementary excel file that can be downloaded together with this report, and can also be accessed online via this link.[10] See the table in the "*EU model*" tab in the supplementary excel file for the full overview of calculated mass flows, which is the basis for the mass values and Sankey diagrams used throughout the report.

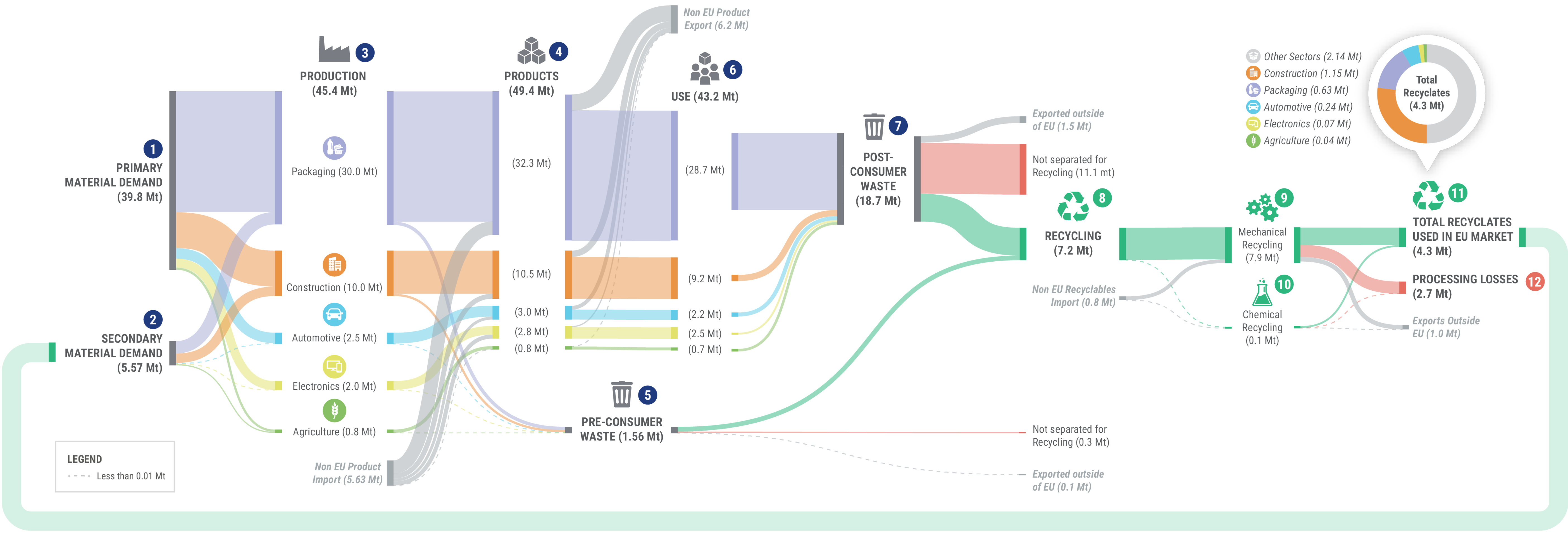
[10] Plastic Flows Model v2.0 https://docs.google.com/spreadsheets/d/1qw4UNm03PQUpYRTmhLBE6x50aV1XON3fNdLkiTUZZj4/edit?usp=sharing

The Sankey diagram in Figure 4 visualises the plastic flows estimated by the model. The data used in these diagrams is based on the "*EU_Model*" tab, which is primarily based on Prodcom production and Eurostat waste data, which does not include the point data provided by CPA signatories. The packaging, construction, and automotive sectors are visualised in Figure 5 , Figure 6 and Figure 7. To see a breakdown by polymer type, see Figure 8.

See Annex 3**Error! Reference source not found.** for Sankey diagrams of the remaining sectors.

The Sankey diagrams visualise the flow of plastics through the entire product life cycle, from production, use, and end-of-life. The discrepancy in mass between use and post-consumer waste is due to a combination of factors, including products that are still in use (i.e. "stocks") and differences in Prodcom production and Eurostat waste data. See Section 2.3 for a more detailed discussion and a cross-comparison of results from similar studies.

Plastic Flows MFA - EU27 (2019)



1. **Primary material demand** is the demand for virgin, non-recycled plastics for products produced in Europe
2. **Secondary material demand** is the demand for secondary, recycled plastics for products produced in Europe
3. **Production** is an aggregate of all plastics ending up in products produced in Europe for the five priority sectors, essentially summarizing inputs for European plastics converters
4. **Products** is an aggregate of plastics in Europe, taking into account production, imports, and exports
5. **Pre-consumer waste** is the waste generated in product manufacturing processes or commercial activities, before that material becomes a finished product
6. **Use aggregates** only plastics consumed in Europe, after accounting for trade flows
7. **Post-consumer** waste is the waste generated after use of the material as a finished product
8. **Recycling** is the material ultimately separated for recycling processes, whether that is source separated or not
9. **Mechanical recycling** is the material recycled through conventional, mechanical recycling processes
10. **Chemical recycling** is the material recycled through chemical recycling processes
11. **Total recyclates used in EU market** is the amount of recyclate that ends up in products made in the EU, as opposed to being exported for use in another country
12. **Processing losses** are the recycling losses from the recycling process. This includes both losses to the environment and losses due to process inefficiencies

Figure 4: Plastic flows for the EU-level model (2019) split by sector.

Description*: Material flow analysis showing plastic flows for five priority sectors in EU27 (2019). All results shown in the Sankey diagrams in this report are pulling from the "EU_Model" tab of the Plastic Flows 2.0 model, which does not account for individual point data from CPA signatories. The production and end-of-life stages described at the bottom of the graphic apply across all Sankey diagrams used in the report.*

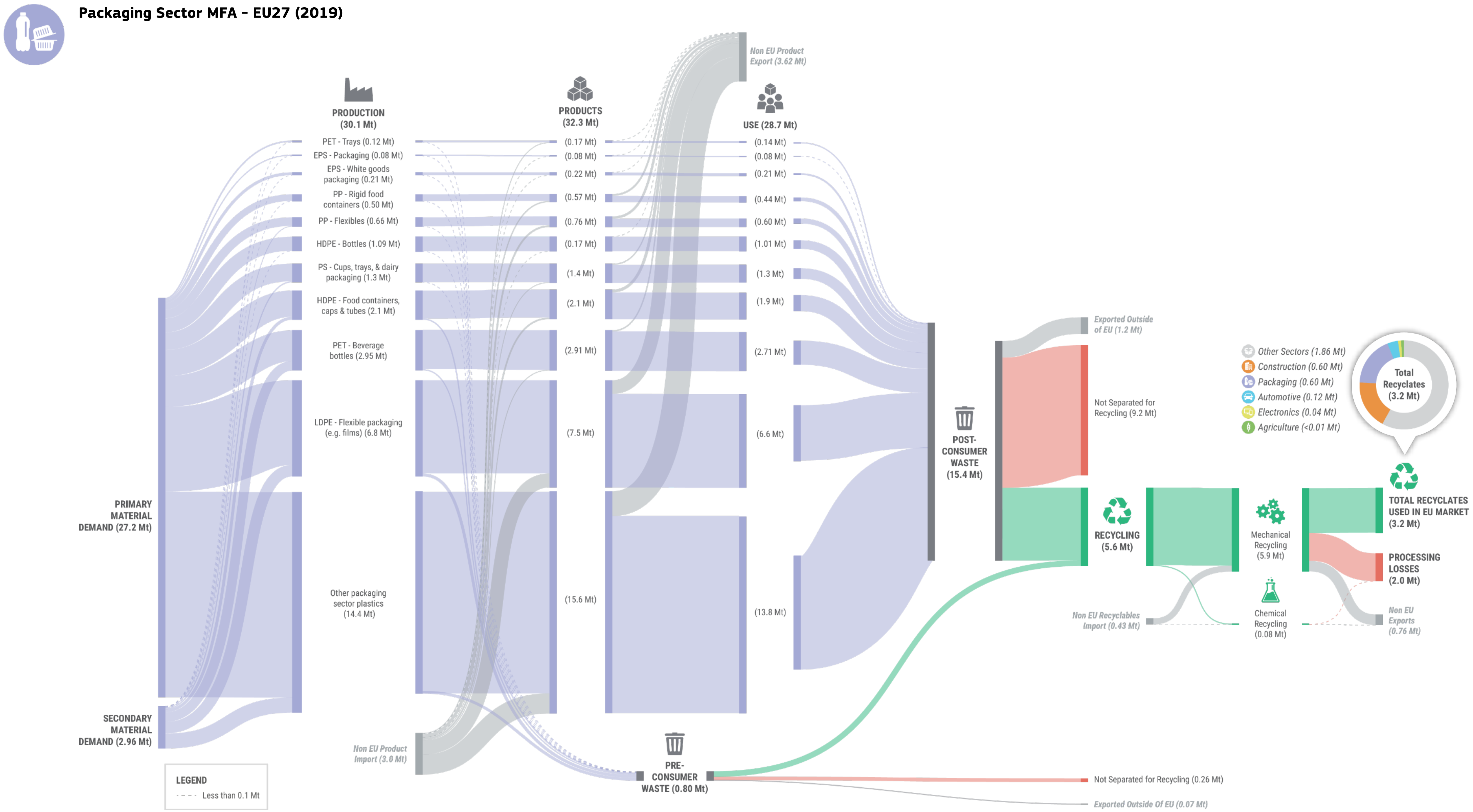


Figure 5: Material Flow Analysis (MFA) diagram of plastic flows in the EU packaging sector (2019) split by priority product.

Description: *Material flow analysis zooming in on the packaging sector for priority products across EU27 (2019). The modelled results are pulling from the "EU_Model" tab in the supplamentary excel file, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. The total polymer production mass is based on Prodcom data linked to priority products summarised in the "Data: Prodcom Classification" tab. These linked categories, as well as the conversion rates for the product mass, plastic share per product, sector share, and priority product share, all contribute to the total mass of polymers produced for each priority product. The modelled results show that 3.2 Mt of recyclate from the packaging sector are reintegrated back into the EU market in 2019.*

Construction Sector MFA - EU27 (2019)

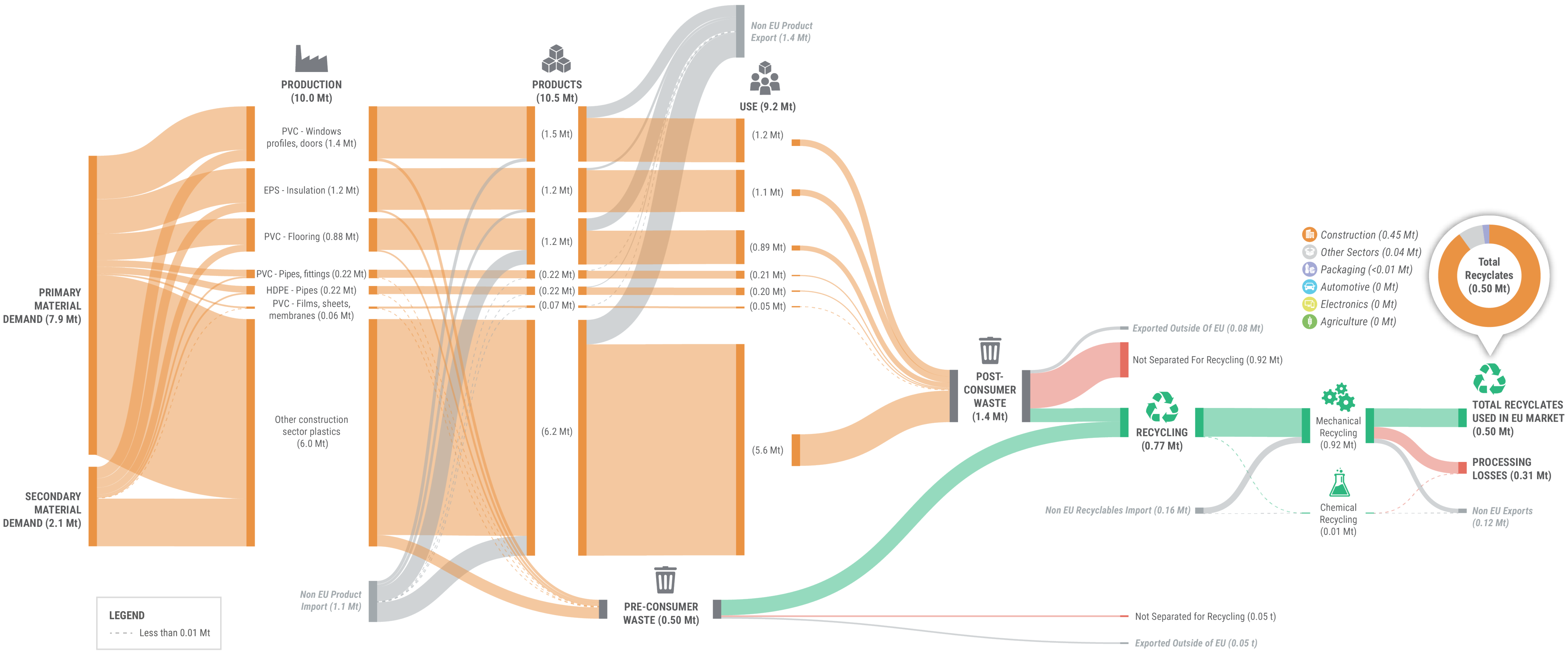


Figure 6: Material Flow Analysis (MFA) diagram of plastic flows in the EU construction sector (2019).

Description: *Material flow analysis of the construction sector for priority products across EU27 (2019). The modelled results are pulling from the "EU_Model" tab in the supplementary excel file, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. The total polymer production mass is based on Prodcom data linked to priority products summarised in the "Data: Prodcom Classification" tab. Differences in the mass of products in use and the mass of post-consumer waste is primarily due to the long lifetime of products used in the construction sector. The modelled results show that 0.5 Mt of recyclate from the construction sector are reintegrated back into the EU market in 2019.*

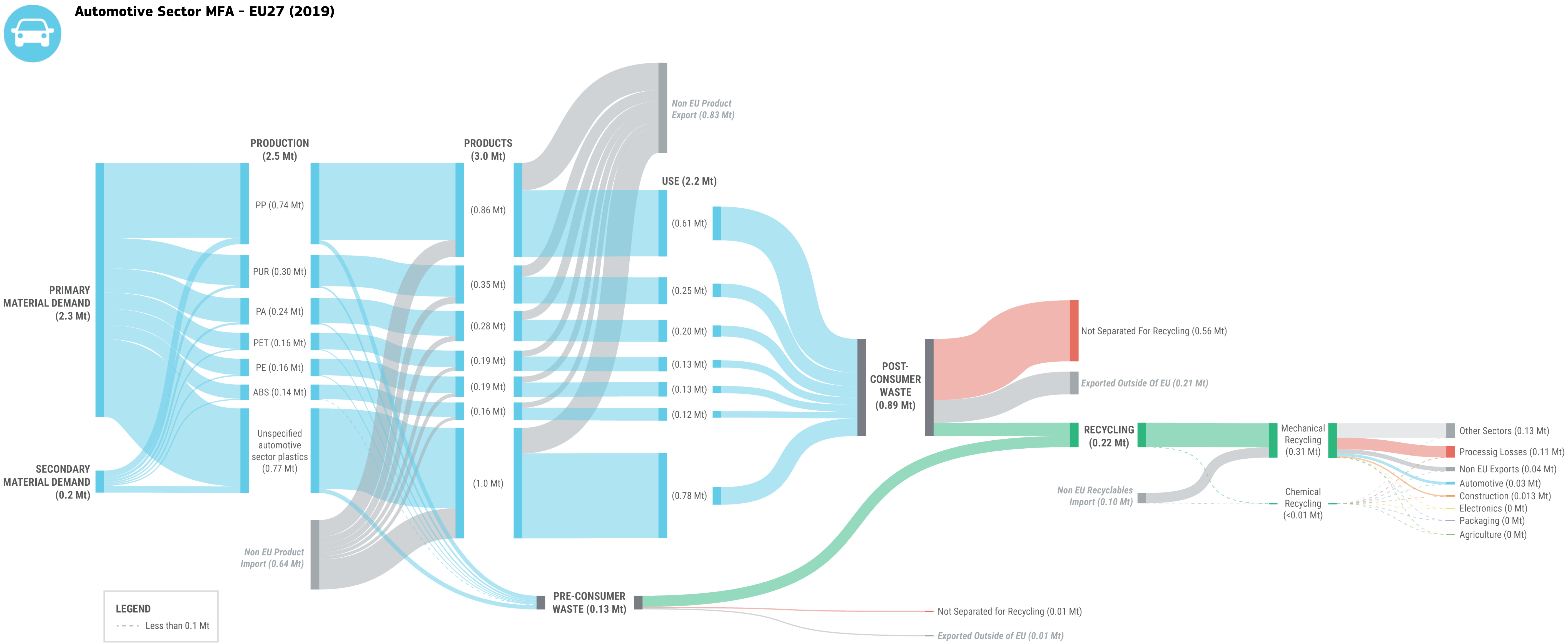


Figure 7: Material Flow Analysis (MFA) diagram of plastic flows in the EU automotive sector (2019)

Description: *Material flow analysis for polymers used in the automotive sector across EU27 (2019). As most automobiles are recycled through shredding rather than broken down into components, simply modelling the polymer flows for this sector was deemed the best approach. The modelled results are pulling from the "EU_Model" tab in the supplementary excel file, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. CPA members from the automotive sector have already provided point data on the "EU_Input" tab (not shown here), and discrepancies between modelled results and point data are summarised on the "EU_Final" tab.*

Plastic Flows MFA – Breakdown by Polymer – EU27 (2019)

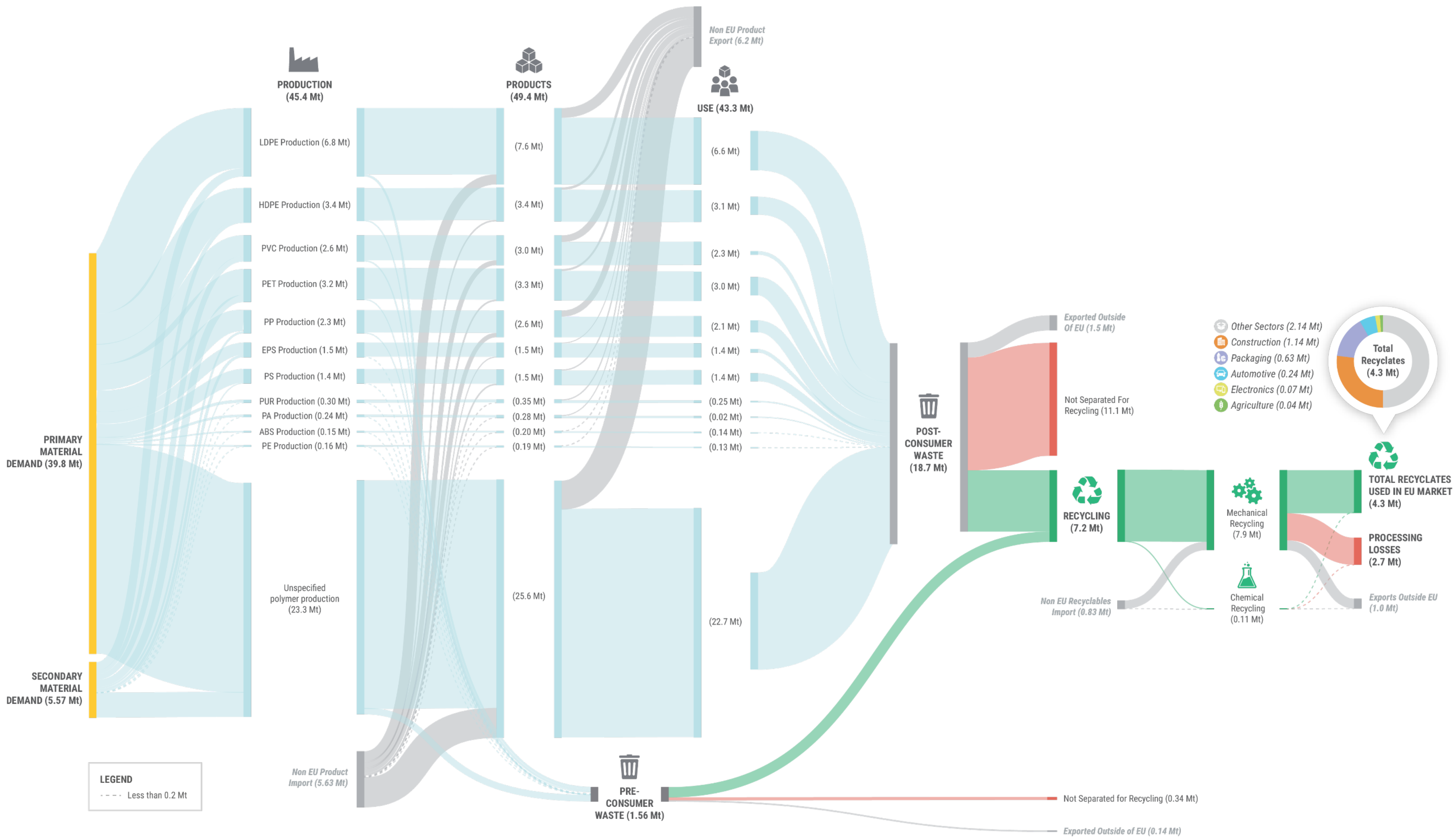


Figure 8: Plastic flows for the EU-level model (2019) split by polymer type.

Description: *Material flow analysis of plastics for priority products across EU27 (2019) with a breakdown by polymer. The modelled results are pulling from the "EU_Model" tab, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. The total polymer production mass is based on Prodcom data linked to priority products summarised in the "Data: Prodcom Classification" tab. These linked categories, as well as the conversion rates for the product mass, plastic share per product, sector share, and priority product share, all contribute to the total mass of polymers produced for each priority product. All products that are listed as "Other plastics" in the sector-specific MFAs are grouped together here under "Unspecified polymer production". The modelled results show the total amount of recyclate used in the EU market is 4.3 Mt.*

While the model can still be improved with additional research and the improvement of assumptions, Table 5 provides an overview of the key metrics or outcomes in the plastic product mass flow model. Section 2.3 compares these results with other key studies and explains why the outcomes from these data sources deviate from market data such as PlasticsEurope / Conversio.

The EU plastic strategy aims to "*ensure that by 2025 ten million tonnes of recycled plastics find their way into new products on the EU market*". The target was set in 2018, based on the geographical scope of the EU at that time, hence the EU27+UK. The European Commission has clarified that it will consider the measurement point for the 10 Mt target to be the inputs to European plastics converting plants, i.e. recyclates made from waste generated in Europe and used by plastics converting plants located in Europe to make new products, excluding imported recyclates made from non-European waste. The CPA has endorsed the target with the same scope.

There are other ways to measure the amount of recyclates, based on production or consumption, and our model allows to see results from all three definitions, as shown in Table 6. The EU plastic strategy and CPA's ambition align with the strictest definition, and also the lowest amount, where 3.8 Mt of recyclate are produced from EU waste and end up in products in the EU. This strict definition should incentivise plastic waste collection, recycling capacity development, and uptake of recyclate within the EU.

The production-focused definition only looks at recyclates produced in the EU, without defining origin, so the input could come from EU waste or plastic waste from other countries. Although a limited share of imported plastic waste may be acceptable or necessary to ensure stability of supply, in the long term, policy makers may want to ensure proper domestic plastic waste collection and sorting to provide enough input for recycling facilities within the EU. The production-focused definition also does not specify the end use, meaning the recyclates could be exported, which would hinder recyclate uptake within the EU.

On the other hand, the consumption-focused definition only accounts for recyclates used in the EU, which could either be produced in the EU or imported. This definition does little to encourage investment in recycling capacity within the EU, especially if recyclates can be cheaply made elsewhere. Under this definition, EU plastic waste could be exported to countries with lower recycling standards and data transparency and there is a higher risk of mismanagement.

Table 5: Overview of key EU-level Model outcomes (Scope: EU-27). All values expressed in Mt/year

	Total	Electronics	Packaging	Construction	Agriculture	Automotive
Total primary material used in production	39.80	1.94	27.18	7.87	0.50	2.32
Total secondary material used in production	5.57	0.06	2.96	2.09	0.26	0.20
Total pre-consumer waste generation	1.56	0.10	0.80	0.50	0.04	0.13
Total post-consumer waste generation	18.69	0.43	15.42	1.37	0.58	0.89
Total pre- and post-consumer waste to recycling	7.18	0.43	5.57	0.77	0.19	0.22
Total pre- and post-consumer waste not recycled	11.44	0.08	9.42	0.97	0.39	0.57
Total pre- and post-consumer waste exported outside of EU	1.63	0.01	1.23	0.13	0.04	0.22
Total Non-EU recyclables import to recycling	0.82	0.13	0.44	0.16	0.00	0.09
Total recyclates produced in EU (production-focused definition)	5.26	0.31	4.00	0.62	0.13	0.21
Total recyclates consumed in EU (consumption-focused definition)	4.26	0.25	3.24	0.50	0.10	0.17
Total recyclates produced from EU waste and used in the EU (strictest definition)	3.80	0.18	2.99	0.41	0.10	0.12
Recyclate to Packaging	0.63	0.00	0.60	0.01	0.02	0.00
Recyclate to Construction	1.14	0.06	0.60	0.45	0.02	0.01
Recyclate to Automotive	0.24	0.10	0.12	0.00	0.00	0.02
Recyclate to EEE	0.07	0.03	0.04	0.00	0.00	0.00
Recyclate to Agriculture	0.04	0.00	0.00	0.00	0.04	0.00
Recyclate to Other	2.14	0.07	1.88	0.04	0.02	0.13
Recyclate to Export	1.00	0.06	0.76	0.12	0.02	0.04

Table 6: Different ways to measure the amount of recyclates.

Definition	Calculation	Mt/yr
Strictest definition: Recyclate produced in EU that ends up in products in the EU	Recyclate generated from EU plastic waste and used in products in 27 European Union member states	3.8
Production-focused definition: All recyclate produced in the EU	Recyclate generated from i) EU plastic waste and ii) imported recyclable plastic waste in 27 European Union member states	5.3
Consumption-focused definition: All recyclate used in the EU	Recyclate used in products in 27 European Union member states (including recyclate made in the EU and imported to the EU)	4.3

Country-Level Model

The mass flow model is available as a supplementary excel file that can be downloaded together with this report, and can also be accessed online via this link.[11] See the table *Country_Model* tab for the full overview of mass flows. See **Error! Reference source not found.**Annex 3 for Sankey diagrams showing results of the country-level model.

2.3 Reflection

Key outcomes of the Plastic Products Mass Flow Model 2.0 are compared with other models developed by the JRC, as well as other studies such as Reshaping Plastics, the Plastics Europe report, the EU's Missing Plastics by Material Economics, and CPA's Untapped Potential report. See Table 7 for an overview of these results.

[11] https://docs.google.com/spreadsheets/d/1qw4UNm03PQUpYRTmhLBE6x50aV1XON3fNdLkiTUZZj4/edit#gid=286767573

Table 7: Comparison of the Plastic Products Mass Flow Model 2.0 with other key studies.

Comparison with other key studies					
Study name	Plastic Products Mass Flow Model 2.0 (present study)	SYSTEMIQ. (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.	Plastics Europe. (2022, April 28). The Circular Economy for Plastics – A European Overview.	Material Economics. (2022). Europe's Missing Plastics.	Roadmap to 10 Mt - Untapped Potential
Geographic coverage	EU 27	EU27+UK	EU 27 + UK, Switzerland, and Norway	EU 27 + UK, Switzerland, and Norway	EU 27+UK
Sector coverage	Packaging, electronics, construction, automotive, agriculture	Packaging, household, construction, automotive	Packaging, construction, electronics, automotive, , household leisure and sport, agriculture, and other	Packaging, building & construction, automotive, electronics, household goods, agriculture, and other	Packaging, electronics, construction, automotive, agriculture
Total plastic production covered in project scope (Mt)	45.4	36.9	47.5	49	45.1
Total plastic waste generated covered in project scope (Mt)	20.2	25	29.5	45	21
Total plastic waste sent to recycling covered in project scope (Mt)	7.2		9.1	8.6	9.2
Total plastic waste sent to landfill, incineration, mismanaged covered in project scope (Mt)	11.4	19	19.4	38	
Total plastic waste exported covered in project scope (Mt)	1.6	2	1	1.1	
Recyclate produced in EU covered in project scope (Mt)	5.26	3.6		5.6	5.3
Recyclate used in EU	4.26		4.6		
Recyclate produced in EU and used in EU covered in project scope (Mt)	3.80				

Comparison with other key studies					
Key data sources	Production, import and export is based on Prodcom, waste generation, treatment is based on Eurostat waste data, point data from CPA.	SYSTEMIQ analysis based on WRAP (2018), Conversio (2020), Plastics Europe (2020), Deloitte et al. (2017) references in the report.	Industry surverys and interviews.	Variety of data sources, with the analysis mainly based on data from Plastics Europe, Plastics Recyclers Europe and Eurostat trade and waste statistics.	Production, import and export is based on Prodcom, waste generation, treatment is based on Eurostat waste data, point data from CPA.

The differences mainly stem from:

1) Geographic coverage. The Plastic Products Mass Flow Model 2.0 covers the EU27, while the other studies have a wider geographic scope.

2) Sector scope. With the exception of SYSTEMIQ's study (4 sectors, with lower production value), PlasticsEurope and Material Economics's report (8 sectors) have more comprehensive sectoral coverage. To help CPA signatories prioritise circular efforts, the Plastic Products Mass Flow Model 2.0 took a deep dive into the five CPA sectors in order to examine the products with high plastic content in more detail.

3) Availability of data sources. For plastic production, imports and exports, waste generation and treatment, the present study relied on Eurostat data (including Prodcom), which are the most comprehensive publicly available data sources. However, these data sources also have drawbacks. Prodcom, for example, contains thousands of different product categories, and the classification of products, carried out by different enterprises, may not always be the most consistent. On the waste side, bottom-up inventory of national waste statistics is likely an underestimation, as has been discussed in both the SYSTEMIQ and Material Economics reports. There has been a consistent gap between demand for plastic and plastic waste generation, which could not be fully explained by the in-use stock. Actual plastic waste is likely significantly higher than reported. This is due to the difficulty to aggregate waste numbers from highly decentralised municipal waste systems, and to quantify the precise share of plastics in mixed waste streams. Other reports also pointed out that the "missing" plastic waste is likely being landfilled or incinerated, leaked through illegal exports, or mismanaged.

The Material Economics and SYSTEMIQ studies both cited PlasticsEurope for production data, which are based on surveys and interviews of industry players. The underlying studies are not published so it's not possible to comment on the methodologies or assumptions used therein.

Finally, there is also uncertainty in the Plastic Products Mass Flow Model 2.0 assumptions, particularly the variables summarised in the "Data: Prodcom Classification" tab of the model. The links between Prodcom and priority products, as well as the conversion rates for the product mass, plastic share per product, sector share, and priority product share, all contribute to the total mass of polymers produced for each priority product. Changing any of these assumptions will have a large impact on the modelled results.

The purpose of this project is to build an easily updatable model that can quickly process common public data sources and be refined with point data from the CPA. However, this requires applying assumptions to transform this data into mass flows that match the priority products of interest to the CPA. For instance, when screening Prodcom data for plastic production, the model used the list of Prodcom codes for major plastic products (Supplementary Material, table SM8) compiled by Amadei et al. (2022). This list is not exhaustive and misses products that have a minor amount of embedded plastics and are relevant to the selected priority products. As an example of this, Table 8 contains Prodcom codes that are not in the aforementioned list and that are relevant for the priority product "Electronics-Small Household Appliances-ABS".

Table 8: Examples of Prodcom codes which are relevant to the Electronics-Small Household Appliances-ABS priority product category, but are not currently included in the Plastic Products Mass Flow Model 2.0.

27511400	Electric blankets
27512313	Electric hair drying hoods
27512315	Electric hair dryers (excluding drying hoods)
27512490	Electro-thermic appliances, for domestic use (excluding hairdressing appliances and hand dryers, space-heating and soil-heating apparatus, water heaters, immersion heaters, smoothing irons, microwave ovens, ovens, cookers, cooking plates, boiling rings, grillers, roasters, coffee makers, tea makers
27512530	Electric instantaneous water heaters
27512550	Electric water heaters (including storage water heaters) (excluding instantaneous)
27512560	Electric water heaters and immersion heaters (excluding instantaneous water heaters)
27512570	Electric immersion heaters (including portable immersion heaters for liquids, usually with a handle or a hook)
27512630	Electric storage heating radiators
27512650	Electric radiators, convection heaters and heaters or fires with built-in fans
27512690	Other electric space heaters
27512810	Domestic electric cookers with at least an oven and a hob (including combined gas-electric appliances)
27512830	Electric cooking plates, boiling rings and hobs for domestic use
27512833	Domestic electric hobs for building-in
27512835	Domestic electric cooking plates, boiling rings and hobs (excluding hobs for building-in)
27512850	Domestic electric grills and roasters
27512870	Domestic electric ovens for building-in
27512890	Domestic electric ovens (excluding those for building-in, microwave ovens)
27513010	Parts for vacuum cleaners
27513030	Parts for electro-mechanical domestic appliances with a self-contained electric motor (excluding parts for vacuum cleaners)
27513050	Parts for shavers and hair clippers with a self-contained electric motor

A list of Prodcom codes used, finished goods or semi-finished goods that fall into the five CPA sectors and that were included in the calculations is provided in the model data sheets[12]. Raw materials that contain plastics but without a clear sector pathway, such as “20162050 - Styrene-acrylonitrile (SAN) copolymers”, are not assigned to any sector and are therefore not included in the calculations. It is possible that some raw materials could later flow to the CPA sectors and be made into packaging or products at the manufacturing site.

For products that fall under the five CPA sectors, only specific combinations of certain polymers and product types (such as PET bottles) are singled out as priority products (the rest falls under a category for “other”). Each Prodcom product had to be researched to assign proportions to each sector, product, and polymer combination. This division may also introduce some errors, but can be reviewed and revised by experts to refine assumptions.

In addition, Prodcom production data values come in a variety of units, which can range from weight to pieces of product. To ensure all mass flows are comparable, each Prodcom product which is not already in kilotonne units is assigned a conversion factor from their original unit to kilotonnes. These conversion factors can greatly influence the outcome of the modelled results. As an example, PET plastic bottles are connected to two Prodcom products: bottles of less than two liters and bottles of more than two liters. In the original Table SM8 from Amadei et al. (2022), both of these Prodcom categories were transformed from items to mass with the same assumed conversion factor regardless of bottle size (0.016 kg/bottle). When using this value along with the other conversion factors including the priority product share, the modelled results showed the total mass of PET bottle production in the EU27 to be 1.4 Mt, which is much lower than the expected market value. When updating the weight assumption to be 0.029 kg for small bottles and 0.111 kg for large bottles, the total market mass of PET bottles nearly doubles to 2.95 Mt. In this case, this conversion plays a direct role in the final mass of the priority product PET bottles. These assumptions can continue to be reviewed and refined by industry experts to improve the model outcomes over time.

A note on country-level Prodcom data: Prodcom data on a country level is very scarce for some categories so that confidential data cannot be extracted from the dataset. Whenever only one or two producers are present for one Prodcom code in a country, the figures are omitted by Eurostat. In the case of Large Household Appliances, for example, we note that many countries have no data available (see Figure 9, where all red cells with ":" as the value mean that the data is not disclosed, which is not the same as a "0"). This means large amounts of production, import, and export data are likely excluded due to this confidentiality issue. This is an important caveat to take into account when looking at the figures of the country-level model, and is the reason some product categories have a large discrepancy between production and waste data. The full EU model is not affected, since the EU publishes full figures on a continent level because no confidential data can be extracted on that scale.

			Production						
PERIOD	PRCCODE_LABEL	PRCCODE	France	Germany	Greece	Hungary	Iceland	Ireland	Italy
2019	Household dishwashing machines	27511200	:	:	:	0	0	0	8
2019	Cloth washing and drying machines, of the household type	27511300	:	:	:	:	0	0	25
2019	Table, floor, wall, window, ceiling or roof fans, with a self-contained el	27511530	57657	3729624	:	0	0	:	:
2019	Ventilating or recycling hoods incorporating a fan, with a maximum h	27511580	:	1064999	:	0	0	:	31
2019	Domestic microwave ovens	27512700	:	:	0	0	0	0	:
2019	Axial fans (excluding table, floor, wall, window, ceiling or roof fans wit	28252030	165831	7393329	0	5249968	0	:	49
2019	Centrifugal fans (excluding table, floor, wall, window, ceiling or roof fa	28252050	62680	:	598	0	0	:	57
2019	Fans (excluding table, floor, wall, ceiling or roof fans with a self-conta	28252070	:	3653298	:	25	0	:	6

Figure 9: Screenshot of the “Data: Prodcom Raw” tab of the model, where cells in red show data that has been excluded on the country level due to data confidentiality issues.

It is acknowledged that discrepancies exist among different data sources such as Eurostat and Plastics Europe, and each of those sources has its limitations. For example, Material Economics has identified that national waste statistics (Eurostat) are usually decentralised and may not account for all the plastics that were sent to waste. Therefore, the Material Economics’ study reported a much higher plastic waste amount and a much lower plastic recycling rate. The new CPA monitoring system being rolled out in 2022 might help fill in the data gap in the coming years. This monitoring framework will be instrumental in improving the state of understanding of European plastic flows. However, one challenge will be reconciling the fact that not all plastics converters and recyclers are part of the CPA or will be making use of this system. Even after rolling out the CPA monitoring framework, a model will be needed to check that the data generated by the system provides a complete picture

[12] “Data: Prodcom Classification” tab in the supplementary excel file

of plastic flows. The JRC's Plastic Products Mass Flow Model 2.0 can serve as a means to cross-compare aggregated outcomes for plastic flows.

The study that is most comparable with the Plastic Products Mass Flow Model 2.0 is the CPA's Untapped Potential report, which has the closest geographic (EU 27+UK vs EU27) and sectoral coverage (both cover five CPA sectors). The results are comparable for most sectors and at an aggregated level (see Table 9).

Table 9: Comparison of outcomes by sector between the present model and CPA's Untapped Potential report.

Plastic Products Mass Flow Model 2.0						
	Total (Mt)	Electronics	Packaging	Construction	Agriculture	Automotive
Total plastic production	45.38	2.00	30.14	9.96	0.76	2.52
Total plastic waste generation	20.24	0.53	16.22	1.87	0.62	1.01
Total plastic waste sorted for recycling	7.18	0.43	5.57	0.77	0.19	0.22
Total recyclate produced in the EU	5.26	0.31	4.00	0.62	0.13	0.21
Reference year	2019	2019	2019	2019	2019	2019
Untapped Potential Report						
	Total (Mt)	Electronics	Packaging	Construction	Agriculture	Automotive
Total plastic production	38.14	1.75	20.43	10.14	0.72	5.10
Total plastic waste generation	20.88	0.75	16.11	1.75	0.76	1.50
Total plastic waste sorted for recycling	9.23	0.72	6.95	0.45	0.76	0.35
Total recyclate produced in the EU	5.28	0.56	3.9	0.34	0.33	0.15
Reference year	2016-2019	2016	2016-2019	2018	2019	2019

When aggregating all sectors, total plastic production in the Plastic Products Mass Flow Model 2.0 is higher than that in the Untapped Potential report. The Untapped Potential report shows total plastic production is 38 Mt for the 5 CPA sectors strictly speaking (e.g. agricultural plastics, excluding any packaging, and EEE, household only). The main differences in the total plastic production in the present model and the Untapped Potential report come from the packaging and automotive sector. The Untapped Potential report combines various data sources from Conversio, PlasticsEurope, and PETCORE surveys, ranging from 2016 to 2019, while the present production data is only from 2019 Prodcom with the associated conversion factor calculations. Furthermore, the PlasticsEurope study (2019) cited by the Untapped Potential report shows that plastic production for all sectors are about 55 Mt in 2018, of which 82% fall under the five CPA sectors, or about 45.1 Mt when scaled accordingly, which is closer to the present modelled outcome of 45.4 Mt.

As for waste sorted for recycling, the difference lies in the point of measurement. The Untapped Potential report estimated that 9.2 Mt of waste was sorted for recycling, of which 7.5 Mt was sent to recyclers located in Europe. The Plastic Products Mass Flow Model 2.0 model value of 7.2 Mt was referring specifically to waste sent to recycling within the EU, so the results are well aligned.

3 Conclusions

3.1 Final Reflections

The Plastic Product Mass Flow Model 2.0 presented here uses a bottom-up approach to map out aggregated plastic mass flow at the EU, member state, and key product level. It builds on Prodcom production data and national waste statistics in particular, while allowing point data entry. The modelled results of the current state are within the same scale of magnitude as in other studies, while providing a dynamic tool for industry players to take forward and update over time. Currently, the majority of the plastic waste still ends up in landfilling or incineration, or it is mismanaged.

The CPA signatories have already endorsed the ambitious EU target - 10 Mt of recyclates used in Europe by 2025 - and are working together to increase recycling and uptake of recycled content. While the 10 Mt target provides an aspirational goal for the plastics value chain, setting an absolute target may have limited impact on curbing virgin material use, if production and consumption continue to grow. Therefore, as part of strengthened ambitions, additional initiatives may be envisaged that focus on reducing resource extraction. This could include, for example, embracing a relative target such as percentage of recyclate uptake compared to total plastic production, for selected priority products, and/or setting an absolute cap on the amount of plastic waste landfilled or incinerated while monitoring closer potential sources of leakage and mismanagement of plastic waste.

Lastly, recycling is only part of the solution towards the transition to a circular and sustainable economy. Although it is out of the scope of this project, the CPA signatories could consider expanding the focus from recyclate uptake to the broader picture. In addition to improving the collection and processing infrastructure for high-quality plastics recycling, the industry could also focus on upstream solutions like circular design, product lifetime extension, or investing in sustainable and regenerative material alternatives to reduce the current reliance on plastic materials and therefore reduce overall plastics production.

3.2 Limitations and possible next steps

The Plastic Product Mass Flow Model 2.0 presented in this study is more granular than in the Version 1.0 model by Watkins et al. (2020), introducing further product categorisation, a pre-consumer waste fraction, and chemical recycling in addition to mechanical recycling. Moreover, EU MS breakdown is possible, visualising plastic material flows at country level. Despite these improvements, there is still room for further developments of some aspects of the modelling, for instance by including further relevant plastic-containing products such as the ones presented in Table 8, and by defining potential existing reuse systems that contribute in product reuse and circulation of plastic material within the system before it becomes waste – at the "production and use" component of the model.

The authors also recognise that mechanical recycling and chemical recycling can be operated in a cascading fashion for some products/polymer types, as opposed to in parallel. For example, chemical recycling usually involves treating the feedstock by sorting, grinding, washing, and drying, which is a basic mechanical recycling process. In many studies, the definition of feedstock for chemical recycling (pre-washed flakes) is not the same as for mechanical recycling (sorted bales). This model takes a simplistic approach that splits chemical recycling and mechanical recycling at the same point, and assumes a certain percentage goes on to be chemically recycled. Therefore, the losses from chemical recycling come from pre-treatment and recycling inefficiencies. Future research could add a separate pre-treatment phase of chemical recycling to get a more granular picture.

The author team suggests that the CPA signatories continue to fill in the data gaps in the model and involve an independent third-party to verify the data to ensure consistency and data quality. As such the evolving model could help generate further insights for CPA signatories and other stakeholders to help close the loop on plastic production and use.

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List of abbreviations and definitions

ABS	Acrylonitrile Butadiene Styrene
CPA	Circular Plastics Alliance
DRS	Deposit Return Systems
EEE	Electrical and Electronic Equipment
ELVs	End-of-Life Vehicles
EoL	End-of Life
EPS	Expanded Polystyrene
EU	European Union
HDPE	High-density Polyethylene
JRC	Joint Research Centre
LDPE	Low-density Polyethylene
MFA	Material Flow Analysis
Mt	Million tonnes
PA	Polyamide
PE	Polyethylene
PET	Polyethylene Terephthalate
rPET	Recycled Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PUR	Polyurethane
PVC	Polyvinyl Chloride
UK	United Kingdom
WEEE	Waste Electrical and Electronic Equipment
WG	Working Group

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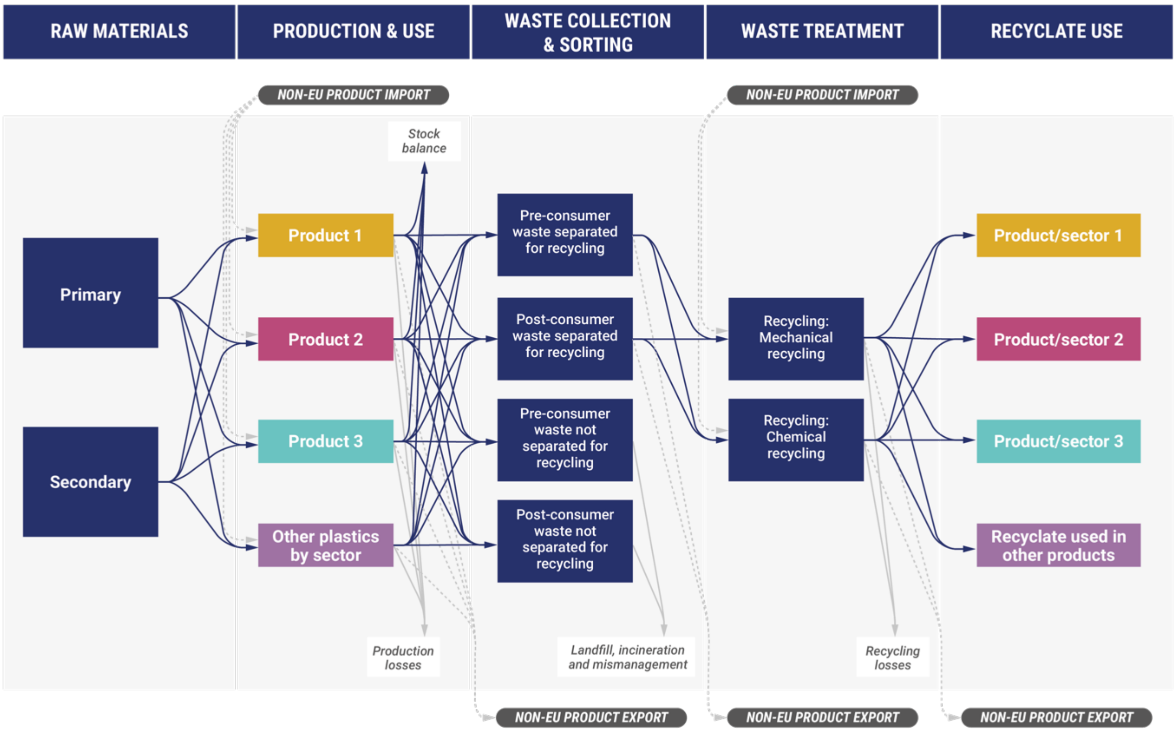
Annexes

Annex 1. Plastic Product Mass Flow Model 2.0 – Detailed Methodology

- **Scoping Flows**

The following diagram shows the scope of the EU-level flow model, starting from raw material inputs (primary or secondary) and going through the use of recyclate in sectors (or products, where information is available).

Figure 10: Scope of the Plastic Product Mass Flow Model 2.0.



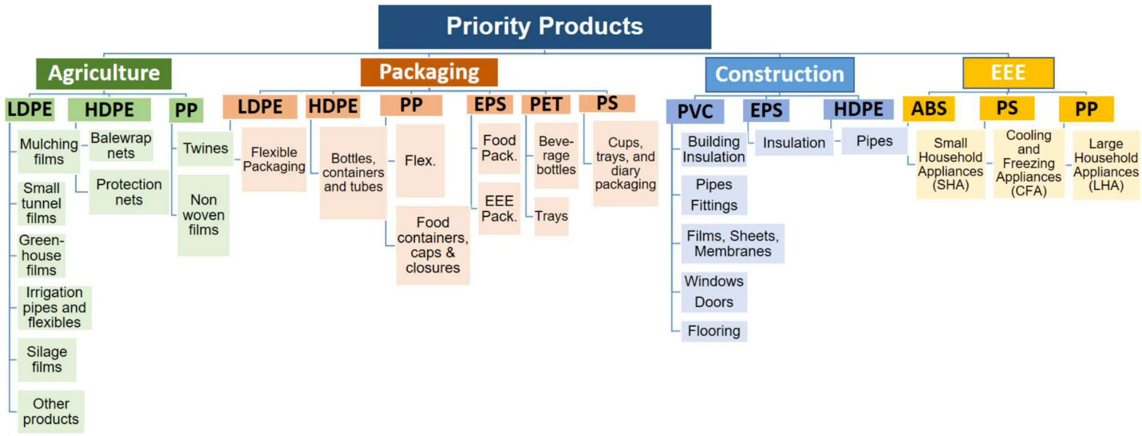
Important considerations include the following:

- Waste that goes unrecycled is only shown as “landfilled, incinerated, or mismanaged”. It is not further broken down as the purpose of the model is not to evaluate what happens to non-recycled flows. This includes materials that do not end up in recycling due to shortcomings in both source and post separation.
- Pre- and post-consumer waste are separated. However, there is only data available on post-consumer waste. The mass flows of pre-consumer waste are estimated based on production volumes.
- Chemical and mechanical recycling are separated. We only found high-level information from Plastics Europe (2019 and 2020) and not a sector-level breakdown.
- In terms of the definition of the recyclate, this can be broken down by product or sector. We start the assessment with the sector-to-sector breakdowns and have made a further subdivision by product where information is available.

- **Selection of Priority Products**

According to CPA’s Design for Recycling Work Plan, the original list of priority products were selected based on factors such as the quantities produced in the EU market, actual and potential quantity collected and sorted for recycling, and end use market applications to absorb the recyclates.

Figure 11: Original list of priority products selected by CPA in the Design-for-Recycling work plan.[13]



Starting from the list of the priority products published in the CPA Design-for-Recycling Work Plan, and following a consultation process with the CPA, 35 priority products to be separately shown in the model were selected. This list is summarised in Table 10. All other product-polymers for the five CPA sectors would be captured in an "other" category per sector. Six products were selected from the longlist (one per sector, though two for packaging) which we would spend extra effort on trying to gather more reliable primary data for. This selection was made on the basis of where we expected data quality would be rather poor.

Additionally, five products were selected for the country-level model (one per sector). These were selected based on the expectation that these products would have large differences between countries. During conversations with CPA, we noted that data confidentiality would be a challenge for the country-level model and because of this, we aggregated three products for gardening films (greenhouse, small tunnel, silage) for the country-level model.

The full list of priority products that were taken into the model are shown in Table 10. The priority products highlighted are those that were shortlisted (either for specific data collection or for inclusion in the country-level model).

[13] CPA Design-for-Recycling Work Plan. Retrieved from https://ec.europa.eu/docsroom/documents/47334

Table 10: Full List of Priority Products. The selected product groups used in the model are highlighted.

Sector	Complete EU-level Model		Country-level Model	
Electronics	PP	Large household appliances	PP	Large household appliance
	ABS	Small household appliances		
	PS	Cooling and freezing appliances		
	Other	Other products		
Packaging	PET	Beverage bottles		
	PS	Cups, trays, and dairy packaging		
	HDPE	Bottles		
	PET	Trays	PET	Trays
	EPS	Packaging (insulation)		
	EPS	White goods packaging (protection)		
	PP	Rigid food containers		
	PP	Flexibles		
	HDPE	Food containers, caps and tubes		
	LDPE	Flexible packaging (e.g. films)		
	Other	Other products		
Construction	HDPE	Pipes		
	PVC	Pipes, fittings		
	PVC	Flooring		
	PVC	Windows profiles, doors	PVC	Windows profiles, doors
	EPS	Insulation		
	PVC	Films, sheets, membranes		
	Other	Other products		

Sector	Complete EU-level Model		Country-level Model	
Agriculture	LDPE	Mulching		
	HDPE	Bale wrap nets		
	LDPE	Greenhouse	LDPE	Films (greenhouse, small tunnel, silage)
	LDPE	Small tunnel		
	LDPE	Silage		
	PP	Twines		
	PP	Nonwoven films		
	HDPE	Protection nets		
	LDPE	Irrigation pipes and flexibles		
	LDPE	Other products		
	Other	Other products		
Automotive	PP	Automobile (shredder fluff)	PP	Automobile (shredder fluff)
	PUR	Automobile (shredder fluff)		
	PA	Automobile (shredder fluff)		
	PE	Automobile (shredder fluff)		
	PET	Automobile (shredder fluff)		
	ABS	Automobile (shredder fluff)		
	Other	Other products/polymers		

- **General Model Setup**

Most efforts to model plastic flows apply an approach where data and assumptions are used to estimate the mass flows. However, the previous JRC Plastic Product Mass Flow Model applied a different approach, largely filling in the mass flows point-by-point based on information available in reports or shared by CPA signatories. Both approaches are valuable as the modelling approach can be easily updated with new data in the future, and it provides a complete picture of the flows, while the data point approach often means more accurate data for part of the picture.

The goals of Plastic Product Mass Flow Model 2.0 included a desire to both incorporate data provided by CPA signatories as well as make an easily updatable and flexible approach, essentially the best of both worlds. To capture the benefits of both approaches, we applied a combined method. Plastic mass flows are modelled on the basis of public production, trade, and waste data as well as a series of assumptions (or transfer coefficients) which capture how plastic waste is expected to be treated downstream. However, we also mirror the structure of this model in a version that allows us to add individual data points shared by CPA signatories directly or in reports they have suggested we incorporate. A final version of the model takes the individual data point where available, or otherwise uses the model outcomes for that part of the product flow.

For this reason, the model sheets are set up in a way to facilitate this.

- *EU_model* & *Country_model* include the estimated model outcomes of all mass flow model points.
- *EU_input* & *Country_input* include the data points provided by CPA signatories or pulled from reports shared by the CPA.
- *EU_final* & *Country_final* contain the data points manually entered where available, and the model estimations when no values are available.

Data Collection from CPA Signatories

To gather data that improves the quality of understanding mass flows for the priority products, we made a data request template to gather data from CPA signatories for the model. This data request was reviewed by the project team and revised. Based on input from the project team, this data request was shared with a selection of CPA signatories. During the modelling process, the project team held many alignment calls with CPA signatories to explain the data that is needed and how it will be used. Many CPA signatories were unable to share much data with only a few months' notice and most of what was received was existing reports that we needed to gather data from manually. However, the model is set up in a way where this data can be added and refined over time. The data and reports that we did receive were documented in a spreadsheet to keep an overview of what was received and where it could be helpful. A final version of the model takes the individual data point provided by the CPA where available, or it otherwise uses the model outcomes for that part of the product flow.

Production and trade data, processing, and assumptions

Data sources

Eurostat's Prodcom data is used for the year 2019.

Data processing

We started with table SM8 in the supplementary material developed in the work of Amadei et al. (2022)[14].

This classifies Prodcom categories by sector and estimates the plastic content and sector share of those products. Additionally, the table provides mass conversions for products that are measured in units rather than mass.

We have altered this table for our purposes, namely:

- Reclassifying "vehicles" as "automotive" — other related categories we kept as "other vehicles"
- Reclassifying some products that were listed as semi-finished as finished, based on the sector under which they were classified, whereas in the study by Amadei et al. (2022) a product was either classified as finished or semi-finished regardless of the sector. For example, we would classify a plastic pipe as a finished product for agriculture or construction sectors, while the same product might be a semi-finished product for the electronics or automotive sectors. This distinction is important as we want to ensure that all plastics are counted, but only counted once. We only consider the share of products that are finished products for the sector of interest.
- Classifying each product as a priority product (e.g. polymer-product combo for a specific sector). Sometimes, multiple priority products would fall under the Prodcom category.

[14] https://www.sciencedirect.com/science/article/pii/S0921344921006947?via%3Dihub#ecom0001

- Adding a column for “priority product share” to account for the split when multiple priority products fall under a single Prodcom category for a single sector. The assumptions that go into these breakdowns are provided on the tab “*Plastic product breakdown assumptions*”. These assumptions can be reviewed and adjusted in this tab and will flow through the rest of the model.

Once we had adapted the table of Amadei et al. (2022) to our own needs, we have multiplied the production, imports, or exports mass by the plastic share, sector share, and product share to arrive at a value for each of the priority products.

Only finished products are accounted for to ensure there is no double-counting of plastic flows which may undergo many steps as raw materials and semi-finished products.

Key assumptions:

There are no EPS products for the packaging sector. Our assumption is that EPS is produced on-site as it becomes a packaging product, so there is no selling of EPS products. This means that we need to account for the raw material of EPS.

Likewise, there are no packaging products like films and flexibles. Prodcom does have a lot of categories that include films, sheets, and foils of plastic. Presumably, these are formed into packaging products as the packaging occurs, meaning there is no separate category for packaging products of these types. For this reason, we count part of these types of categories as finished products for packaging.

Carpets were classified as “textiles” in the original table. We have classified some of the carpets as “construction - other” because wall-to-wall carpeting is considered a construction product. We used a basic assumption on the percentage of these carpet products that are wall-to-wall carpeting.

All changes made to the original Table SM8 from the work of Amadei et al. (2022) have been highlighted in yellow in our data sheets in the model.

To provide an example for how the baseline production values are calculated, we start with the raw Prodcom data in the “Data: Prodcom Raw” tab of the model. If the Prodcom unit is not already in kilotonne units, the data then goes through a series of conversions, the output of which is summarised in the “Data: Prodcom Processed” tab. These conversion assumptions are all outlined in the “Data: Prodcom Classification” tab, including the link between Prodcom and priority product categories in Column F, the unit conversions to kilotonne in Columns I and K, and the estimated share of plastic in Column O. If the Prodcom code is split between multiple priority products, this is noted in Column Q. All of these variables contribute to the overall mass of polymer production for each of the priority products used in our model, and the model is set up in a way that allows each assumption to be modified and updated over time with new data.

Using PET and HDPE bottles as an example, we’ve identified two Prodcom codes that relate to these priority products: “22221450 - Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity <= 2 litres” and “22221470 - Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity > 2 litres”. In Column F, we have classified these Prodcom codes into three categories: “Packaging-HDPE-Bottles”, “Packaging-PET-Beverage bottles”, and “Packaging-Other-Other products”, with an assumed split of 9% HDPE, 79% PET, and 12%, pulling from the “Assumptions: Product Breakdown” tab. As the Prodcom raw data unit for these products is in items rather than weight (p/st), we updated the mass using an average weight per item (Column I, with assumptions described in Column R), and converted to kilotonne using the conversion factor in Column K.

To see which Prodcom codes are matched to each priority product, simply filter by priority product category in Column F of the “Data: Prodcom Classification” tab of the model.

Table 11 provides a summary of the key assumptions that go into the mass calculations for PET beverage bottles and HDPE bottles. The same process was followed for each of the priority products.

Table 11: Overview of key assumptions used in the model that affect the total production mass for two priority products: PET beverage bottles and HDPE bottles.

Sector	Packaging			
Polymer	**PET**		**HDPE**	
Product	**Beverage bottles**		**Bottles**	
Prodcom code – description	22221450 - Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity <= 2 litres	22221470 - Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity > 2 litres	22221450 - Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity <= 2 litres	22221470 - Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity > 2 litres
Model Value [tonnes]	2,951,119		1,088,889	
Model Uncertainty Range [tonnes]	±325,000		±38,000	
How it was calculated	Number of bottles (Prodcom original), multiplied by the average weight of a bottle, multiplied by the priority product share	Number of bottles (Prodcom original), multiplied by the average weight of a bottle, multiplied by the priority product share	Number of bottles (Prodcom original), multiplied by the average weight of a bottle, multiplied by the priority product share	Number of bottles (Prodcom original), multiplied by the average weight of a bottle, multiplied by the priority product share

(Table continues on next page)

Sector	Packaging			
Polymer	**PET**		**HDPE**	
Product	**Beverage bottles**		**Bottles**	
What assumptions go into the calculation	The consumption in ktonne was derived considering the weight of an average PET bottle. Average weight of a bottle (<=2L): 29.2g Estimated from Supplementary Dataset: Becerril-Arreola, R., Bucklin, R.E. Beverage bottle capacity, packaging efficiency, and the potential for plastic waste reduction. Sci Rep 11, 3542 (2021). https://doi.org/10.1038/s41598-021-82983-x	The consumption in ktonne was derived considering the weight of an average PET bottle. Average weight of a bottle (>2L): 110.8g Estimated from Supplementary Dataset: Becerril-Arreola, R., Bucklin, R.E. Beverage bottle capacity, packaging efficiency, and the potential for plastic waste reduction. Sci Rep 11, 3542 (2021). https://doi.org/10.1038/s41598-021-82983-x	The consumption in ktonne was derived considering the weight of a 1.5L HDPE bottle (mass = 100g). Source: https://www.menke-industrieverpackungen.de/en/products/produkt/bottles/chemical-bottles/02-1500-80-01-41-017	The consumption in ktonne was derived considering the weight of a 3L HDPE bottle (mass = 160g). Source: https://www.perfectplastic.com.my/product/73/HDPE-BOTTLE---3-LITRE.html
Conversion from PRODCOM unit to [kg]	0.029 kg/bottle	0.111 kg/bottle	0.100 kg/bottle	0.160 kg/bottle
Conversion from [kg] to [kton]	0.000001	0.000001	0.000001	0.000001
Plastic Share	1	1	1	1
Sector Share	1	1	1	1
Priority Product Share	79%	79%	9%	9%

Waste generation, collection, and sorting data, processing, and assumptions

Note: data sources used or model sheets that contain the assumption references are included in the parenthesis.

Data sources, processing and assumptions for electronics

Pre-consumer waste not separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste not separated for recycling (*Assumptions: By product*)

Pre-consumer waste separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: by product*), multiplied by % pre-consumer waste separated for recycling (*Assumptions: By product)*

Pre-consumer waste exported outside of EU

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste exported outside of the EU (*Assumptions: By product*))

Post-consumer waste not separated for recycling

For PP - large household appliances, ABS - small household appliances, other products (as data was available): The total amount of waste collected per product (*Eurostat*), excluding recycling and preparing for reuse (*Eurostat*), excluding waste treated outside the EU (*Eurostat*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*)

For PS - cooling and freezing appliances: The total amount of waste collected for the sector (*Eurostat*), excluding recycling and preparing for reuse (*Eurostat*), excluding waste treated outside the EU (*Eurostat*), multiplied by the production share of the product within the sector (*Model*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*)

Post-consumer waste separated for recycling

For PP - large household appliances, ABS - small household appliances, other Products (as data was available): The total amount of waste going to recycling and preparing for reuse (*Eurostat*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*)

For PS - cooling and freezing appliances: The total amount of waste going to recycling and preparing for reuse for the sector (*Eurostat*), multiplied by the production share of the product within the sector (*Model*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*)

Post-consumer waste exported outside of EU

For PP - large household appliances, ABS - small household appliances, other products (as data was available): The total amount of waste treated outside of the EU (*Eurostat*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*)

For PS - cooling and freezing appliances: The total amount of waste treated outside of the EU for the sector (*Eurostat*), multiplied by the production share of the product within the sector (*Model*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*)

Data sources, processing and assumptions for packaging

Pre-consumer waste not separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste not separated for recycling (*Assumptions: By product*)

Pre-consumer waste separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste separated for recycling (*Assumptions: By product*)

Pre-consumer waste exported outside of EU

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste exported outside of the EU (*Assumptions: By product*)

Post-consumer waste not separated for recycling

The total amount of waste generated (*Eurostat*), excluding waste going to recycling (*Eurostat*), multiplied by the production share of the product within the sector (*Model*)

Post-consumer waste separated for recycling

The total amount of waste going to recycling (*Eurostat*), multiplied by the production share of the product within the sector (*Model*), multiplied by % post-consumer waste recycled inside the EU (*Assumptions: By product*)

Post-consumer waste exported outside of EU

The total amount of waste going to recycling (*Eurostat*), multiplied by the production share of the product within the sector (*Model*), multiplied by % post-consumer waste recycled outside the EU (*Assumptions: By product*)

Data sources, processing and assumptions for construction

Pre-consumer waste not separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste not separated for recycling (*Assumptions: By product*)

Pre-consumer waste separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste separated for recycling (*Assumptions: By product*)

Pre-consumer waste exported outside of EU

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste exported outside of the EU (*Assumptions: By product*)

Post-consumer waste not separated for recycling

The total amount of post-consumer plastic waste in construction (*PlasticsEurope*), multiplied by the production share of the product within the sector (*Model*), multiplied by % post-consumer waste not separated for recycling (*Assumptions: By product*)

Post-consumer waste separated for recycling

The total amount of post-consumer plastic waste in construction (*PlasticsEurope*), multiplied by the production share of the product within the sector (*Model*), multiplied by % post-consumer waste separated for recycling (*Assumptions: By product*)

Post-consumer waste exported outside of EU

The total amount of post-consumer plastic waste in construction (*PlasticsEurope*), multiplied by the production share of the product within the sector (*Model*), multiplied by % post-consumer waste recycled outside of the EU (*Assumptions: By product*)

Data sources, processing and assumptions for agriculture

Pre-consumer waste not separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste not separated for recycling (*Assumptions: By product*)

Pre-consumer waste separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste (as a share of production) (*Assumptions: By product*), multiplied by % pre-consumer waste separated for recycling (*Assumptions: By product*)

Pre-consumer waste exported outside of EU

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste exported outside of the EU (*Assumptions: By product*)

Post-consumer waste not separated for recycling

The total amount of post-consumer plastic waste in agriculture (*EPI-AGRI*), multiplied by the production share of the product within the sector (*Model*), multiplied by % post-consumer waste not separated for recycling (*Assumptions: By product*)

Post-consumer waste separated for recycling

The total amount of post-consumer plastic waste in agriculture (*EPI-AGRI*), multiplied by the production share of the product within the sector (*Model*), multiplied by % post-consumer waste separated for recycling (*Assumptions: By product*)

Post-consumer waste exported outside of EU

The total amount of post-consumer plastic waste in agriculture (*EPI-AGRI*), multiplied by the production share of the product within the sector (*Model*), multiplied by % post-consumer waste recycled outside of the EU (*Assumptions: By product*)

Data sources, processing and assumptions for automotive Pre-consumer waste not separated for recycling

Pre-consumer waste not separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste (as a share of production) (*Assumptions: By product*), multiplied by % pre-consumer waste not separated for recycling (*Assumptions: By product*)

Pre-consumer waste separated for recycling

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste separated for recycling (*Assumptions: By product*)

Pre-consumer waste exported outside of EU

The total amount of production per product (*Prodcom*) multiplied by % pre-consumer waste as a share of production (*Assumptions: By product*), multiplied by % pre-consumer waste exported outside of the EU (*Assumptions: By product*)

Post-consumer waste not separated for recycling

The total amount of waste arising only from end-of-life vehicles of type passenger cars (*M1*), light commercial vehicles (*N1*), and three-wheeled moped vehicles (*ELV Directive*) (*Eurostat*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*), multiplied by % post-consumer waste not separated for recycling (*Assumptions: By product*)

Post-consumer waste separated for recycling

The total amount of waste arising only from end-of-life vehicles of type passenger cars (*M1*), light commercial vehicles (*N1*), and three-wheeled moped vehicles (*ELV Directive)* (*Eurostat*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*), multiplied by % post-consumer waste separated for recycling (*Assumptions: By product*)

Post-consumer waste exported outside of EU

The total amount of waste arising only from end-of-life vehicles of type passenger cars (*M1*), light commercial vehicles (*N1*), and three-wheeled moped vehicles (*ELV Directive*) (*Eurostat*), multiplied by % share of plastic in product (*Assumptions: Product Breakdown*), multiplied by % of polymer breakdown (*Assumptions: Product Breakdown*), multiplied by % post-consumer waste recycled outside of the EU (*Assumptions: By product*)

General Assumptions

Exported waste data is limited to recycling.

- **Waste Treatment data, processing, and assumptions**

Note: data sources used or modelled sheets that contain the assumption references are included in the parenthesis.

For all sectors (Electronics, Packaging, Construction, Agriculture, Automotive)

Pre-consumer waste to chemical recycling

Pre-consumer waste separated for recycling (*Model*) multiplied by% pre-consumer waste going to chemical recycling (*Assumptions: By product)*

Pre-consumer waste to mechanical recycling

Pre-consumer waste separated for recycling (*Model)* multiplied by % pre-consumer waste going to mechanical recycling (*Assumptions: By product*)

Post-consumer waste to chemical recycling

Post-consumer waste separated for recycling (*Model)* multiplied by % post-consumer waste going to chemical recycling (*Assumptions: By product*)

Post-consumer waste to mechanical recycling

Post-consumer waste separated for recycling (*Model*) multiplied by % post-consumer waste going to mechanical recycling (*Assumptions: By product*)

Non-EU recyclables import to chemical recycling

The total amount of plastic waste imported to the EU (*Eurostat*) multiplied by the import share of the product across all sectors (*Model*), multiplied by % post-consumer waste going to chemical recycling (*Assumptions: By product*)

Non-EU recyclables import to mechanical recycling

The total amount of plastic waste imported to the EU (*Eurostat*) multiplied by the import share of the product across all sectors (*Model*), multiplied by the assumption for % post-consumer waste going to mechanical recycling (*Assumptions: By product*)

Chemical recycling

For chemical recycling data and approaches, the chemical recycling rate was assumed from Plastics Europe 2018.

Table 12: Plastics Europe 2018 data used to calculate the chemical recycling rate.

PLASTICS EUROPE 2018	million tonnes	%
Recycled	**7.48**	**42.0%**
Incinerated	7.03	39.5%
Landfilled	3.29	18.5%
Total	**17.80**	**100%**

Recycled	million tonnes	%
Mechanical	7.38	98.7%
Chemical	0.10	1.3%
Total	**7.48**	**100%**

Chemical and mechanical recycling losses

The definition of chemical recycling is based on the study from Broeren et al. (2022). Chemical recycling is the process in which plastics (sorted into standardised fractions) goes through pre-treatment and then through (chemical) recycling. The recycled plastic is ready for compounding at the end of this process. Hence the loss of chemical recycling is only considered during the process.

Our assumptions are also based on Jeswani et al. (2021), Achilias et al. (2007), Achilias et al. (2012), and Broeren et al. (2022). When information was not available for recycling efficiencies for a specific polymer, generic values of 66.5% (chemical recycling) and 44% (mechanical recycling) were used. These values represent dummy values that were fed in the model in absence of available data. However, this proxy use of dummy values is in the same order of magnitude of other values found in the literature.

Losses are considered to be any materials lost during the recycling process, whether that is a loss to the environment or a loss to incineration through inefficient processing.

Recyclate data and approaches

Recyclate data comes from Plastics Europe (2019).

Recyclate distribution to sectors and products

Calculation of how much recyclates are flowing into different sectors is based on the circularity matrix in the first version of JRC plastic mass flow model. For example, the EEE sector generates 72 tonnes of recyclates, of which 8 tonnes is used in the EEE sector, 23 tonnes flow to construction, and the rest goes to automotives and other industries. At a sector level, the percentage of recyclates from EEE to its own sector is 8/72=11%, and the % recyclates from EEE to construction is 23/72=32%.

Due to the lack of granular data at the product level, we assume that the same sector-level distribution of recyclates applies to the priority products in the same sector. For example, all priority products in the EEE sector, such as large household appliances, small household appliances, cooling and freezing appliances, and other products would have 11% of recyclates circled back into the same products.

Data certainty level is colour-coded in the "*Assumptions: By product*" tab, where green indicates high certainty, yellow indicates the calculation is based on assumptions, and grey indicates there is no recyclate flow for that specific sector/product combination.

Uncertainty

It was important to capture uncertainty in a quantitative way in the Plastic Product Mass Flow Model, and we explored several approaches to doing so. In the end, we selected a relatively simplistic approach to make it easy to update in the future.

The approach works as follows:

We applied a qualitative assessment of data sources that feed into the model, using the framework developed by Laner et al. (2016), explained in Table 13. Data sources are given a score of 1 (high) to 4 (low) for five dimensions: reliability, completeness, temporal correlation, geographic correlation, and other correlation.

The average of these five dimensions is taken for the overall score.

Scores are converted into percentage uncertainty ranges, which for the scores 1-4 are 5%, 20%, 40%, and 90% respectively. This means that for a data source with a score of 3, an uncertainty range of 40% of the value will be applied.

When multiple data sources are used to estimate a column in the mass flow model, the average uncertainty values for the data sources are applied.

The average score for a column is multiplied by the uncertainty range and the estimated mass flows. This provides an absolute value of uncertainty values that can be added or subtracted from the estimated value to provide the range of potential values.

Table 13: Framework to characterize data uncertainty (source: Laner et al., 2016; GDP= Gross Domestic Product).

Indicator	**Definition**	**Score: 1**	**Score: 2**	**Score: 3**	**Score: 4**
Reliability	Focus on the data source: documentation of data generation, e.g., assessment of sampling method, verification methods, reviewing processes.	Methodology of data generation well documented and consistent, peer-reviewed data.	Methodology of data generation is described, but not fully transparent; no verification.	Methodology not comprehensively described, but principle of data generation is clear; no verification.	Methodology of data generation unknown, no documentation available.
Completeness	Composition of the date of all relevant mass flows. Possible over- or underestimation is assessed.	Value includes all relevant processes/flows in question.	Value includes quantitatively main processes/flows in question.	Value includes partial important processes/flows, certainty of data gaps.	Only fragmented data available; important processes/mass flows are missing.
Temporal correlation	Congruence of the available date and the ideal date with respect to time reference.	Value relates to the right time period.	Deviation of value 1 to 5 years.	Deviation of value 5 to 10 years.	Deviation more than 10 years.
Geographical correlation	Congruence of the available date and the ideal date with respect to geographical reference.	Value relates to the studied region.	Value relates to similar socioeconomical region (GDP, consumption pattern).	Socioeconomically slightly different region.	Socioeconomically very different region.
Other correlation	Congruence of the available date and the ideal date with respect to technology, product, etc.	Value relates to the same product, the same technology, etc.	Values relate to similar technology, product, etc.	Values deviate from technology/product of interest, but rough correlations can be established based on experience or data.	Values deviate strongly from technology/ product of interest, with correlations being vague and speculative.

Table 14: Overview of uncertainty level for key data sources and assumptions.

Uncertainty score	Percentage +/- uncertainty range
1	5%
2	20%
3	40%
4	90%

Data source	Reference	Score					
		Reliability	Completeness	Temporal correlation	Geographical Correlation	Other correlation	Total Score
Production, trade	PRODCOM	1	1	1	1	1	1.0
Waste generation, some waste treatment	Eurostat waste data	1	4	2	1	2	2.0
Plastic product breakdown assumptions	Various, and assumptions	3	1	1	1	3	1.8
Primary vs secondary material input	Cimpan, C., Bjelle, E. L., & Strømman, A. H. (2021). Plastic packaging flows in Europe: A hybrid input-output approach. Journal of Industrial Ecology. GIZ. (2021). Recycled content in plastic material with focus on PET, HDPE, LDPE, PP State of play.	1	2	2	1	2	1.6
Preconsumer waste generation and treatment	-GmbH. (2020). Material flow analysis plastics in Germany 2019. -Cimpan, C., Bjelle, E. L., & Strømman, A. H. (2021). Plastic packaging flows in Europe: A hybrid input-output approach. Journal of Industrial Ecology. -Hsu, W.-T., Domenech, T., & McDowall, W. (2021). How circular are plastics in the EU?: MFA of plastics in the EU and pathways to circularity. Cleaner Environmental Systems, 2, 100004.	1	3	2	1	2	1.8

Data source	Reference	Score					
		Reliability	Completeness	Temporal correlation	Geographical Correlation	Other correlation	Total Score
Mechanical vs chemical recycling value	Plastics Europe. (2019). Plastics-the Facts 2019. Plastics Europe. (2020). Plastics-the Facts 2020	3	4	2	1	3	2.6
Chemical and mechanical recycling losses	Jeswani et al.(2021). Life cycle environmental impacts of chemical recycling via pyrolysis of mixed plastic waste in comparison with mechanical recycling and energy recovery. Science of The Total Environment, 769, 144483.	1	2	2	1	3	1.8
Recyclate exports	Plastics Europe. (2019). Plastics-the Facts 2019. Material Economics. (2022). Europe's Missing Plastics.	3	3	2	1	2	2.2
Post-consumer waste treatment	Plastics Europe. (2019). Plastics-the Facts 2019.	3	3	2	1	2	2.2
Sector (and estimated product) allocation of plastics	Plastics Europe. (2021). Plastics-the Facts 2021.	3	3	2	1	2	2.2
Recyclate in products	JRC Plastic Product Mass Flow Model 1.0	2	2	2	1	2	1.8

Annex 2. Plastic Product Mass Flow Model 2.0 – User Guide

We have designed the model to be as easy to understand and as flexible as possible. This chapter details the different parts of the Plastic Product Mass Flow Model 2.0 and how it could be updated or expanded in the future.

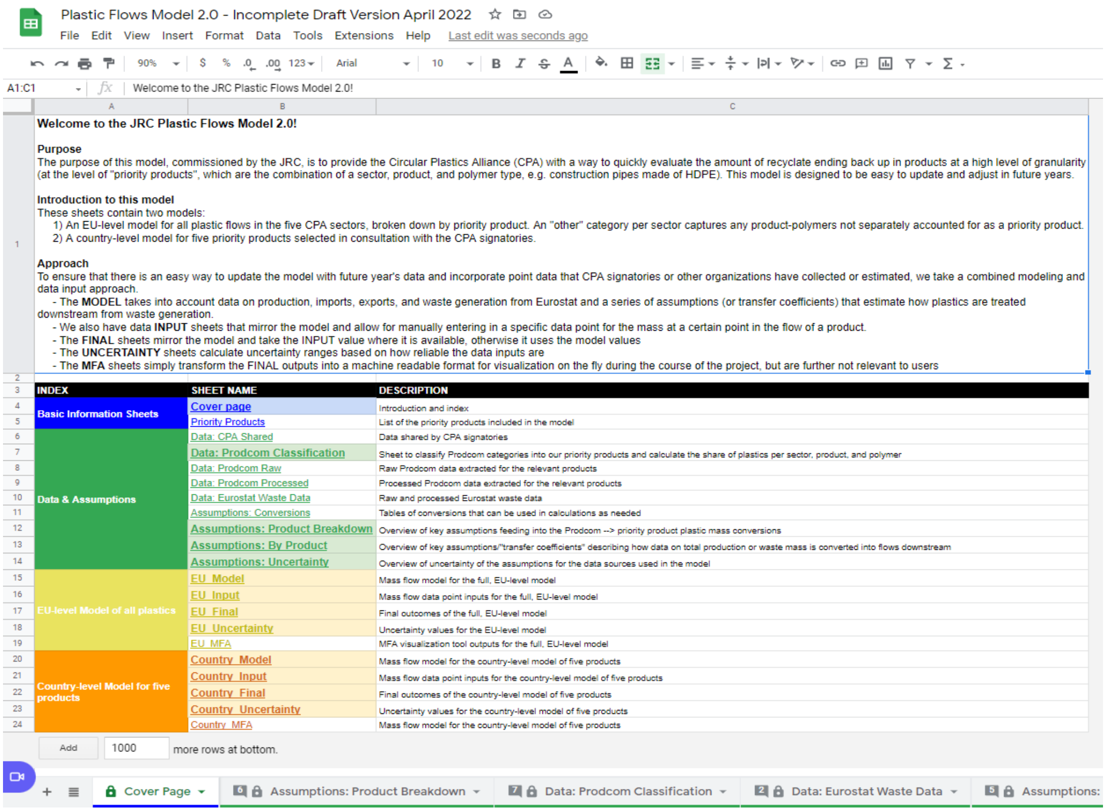
Model Tour

General information

The model is available online in Google Sheets here[15]. At the top left corner of the page, you can click on "File - Download" to download an Excel format version, though some of the nice usability features (such as cell histories and dynamic filters) are lost in this way. A brief video introduction to the model is available via this link[16], which is especially helpful to get started with the model. Note that certain aspects of the model have not been developed further, and are not fully substantiated in the final version of the model which is available as an excel supplementry file together with this report.

Model index and sheets overview

Figure 12 shows what you will see when you enter the model: a brief description of the model and an index that links to the other sheets.


Plastic Flows Model 2.0 - Incomplete Draft Version April 2022

Welcome to the JRC Plastic Flows Model 2.0!

Purpose
The purpose of this model, commissioned by the JRC, is to provide the Circular Plastics Alliance (CPA) with a way to quickly evaluate the amount of recyclate ending back up in products at a high level of granularity (at the level of "priority products", which are the combination of a sector, product, and polymer type, e.g. construction pipes made of HDPE). This model is designed to be easy to update and adjust in future years.

Introduction to this model
These sheets contain two models:
1) An EU-level model for all plastic flows in the five CPA sectors, broken down by priority product. An "other" category per sector captures any product-polymers not separately accounted for as a priority product.
2) A country-level model for five priority products selected in consultation with the CPA signatories.

Approach
To ensure that there is an easy way to update the model with future year's data and incorporate point data that CPA signatories or other organizations have collected or estimated, we take a combined modeling and data input approach.
- The **MODEL** takes into account data on production, imports, exports, and waste generation from Eurostat and a series of assumptions (or transfer coefficients) that estimate how plastics are treated downstream from waste generation.
- We also have data **INPUT** sheets that mirror the model and allow for manually entering in a specific data point for the mass at a certain point in the flow of a product.
- The **FINAL** sheets mirror the model and take the INPUT value where it is available, otherwise it uses the model values
- The **UNCERTAINTY** sheets calculate uncertainty ranges based on how reliable the data inputs are
- The **MFA** sheets simply transform the FINAL outputs into a machine readable format for visualization on the fly during the course of the project, but are further not relevant to users

INDEX	SHEET NAME	DESCRIPTION
Basic Information Sheets	Cover page	Introduction and index
	Priority Products	List of the priority products included in the model
Data & Assumptions	Data: CPA Shared	Data shared by CPA signatories
	Data: Prodcom Classification	Sheet to classify Prodcom categories into our priority products and calculate the share of plastics per sector, product, and polymer
	Data: Prodcom Raw	Raw Prodcom data extracted for the relevant products
	Data: Prodcom Processed	Processed Prodcom data extracted for the relevant products
	Data: Eurostat Waste Data	Raw and processed Eurostat waste data
	Assumptions: Conversions	Tables of conversions that can be used in calculations as needed
	Assumptions: Product Breakdown	Overview of key assumptions feeding into the Prodcom --> priority product plastic mass conversions
	Assumptions: By Product	Overview of key assumptions/"transfer coefficients" describing how data on total production or waste mass is converted into flows downstream
	Assumptions: Uncertainty	Overview of uncertainty of the assumptions for the data sources used in the model
EU-level Model of all plastics	EU_Model	Mass flow model for the full, EU-level model
	EU_Input	Mass flow data point inputs for the full, EU-level model
	EU_Final	Final outcomes of the full, EU-level model
	EU_Uncertainty	Uncertainty values for the EU-level model
	EU_MFA	MFA visualization tool outputs for the full, EU-level model
Country-level Model for five products	Country_Model	Mass flow model for the country-level model of five products
	Country_Input	Mass flow data point inputs for the country-level model of five products
	Country_Final	Final outcomes of the country-level model of five products
	Country_Uncertainty	Uncertainty values for the country-level model of five products
	Country_MFA	Mass flow model for the country-level model of five products

Figure 12: Screenshot of Google Sheets based Plastic Product Mass Flow Model 2.0

In the bottom left corner there is also an icon consisting of four stacked lines which pulls up the index and allows you to easily navigate to other sheets from another point in the model.

[15] https://docs.google.com/spreadsheets/d/1qw4UNm03PQUpYRTmhLBE6x50aV1XON3fNdLkiTUZZj4/edit#gid=286767573

[16] Plastic Flows 2.0 Model Walkthrough video: https://drive.google.com/file/d/1ubgJEs4jlLVHl3ZOPQvV4Wp9Uy3UHP_7/view?usp=sharing

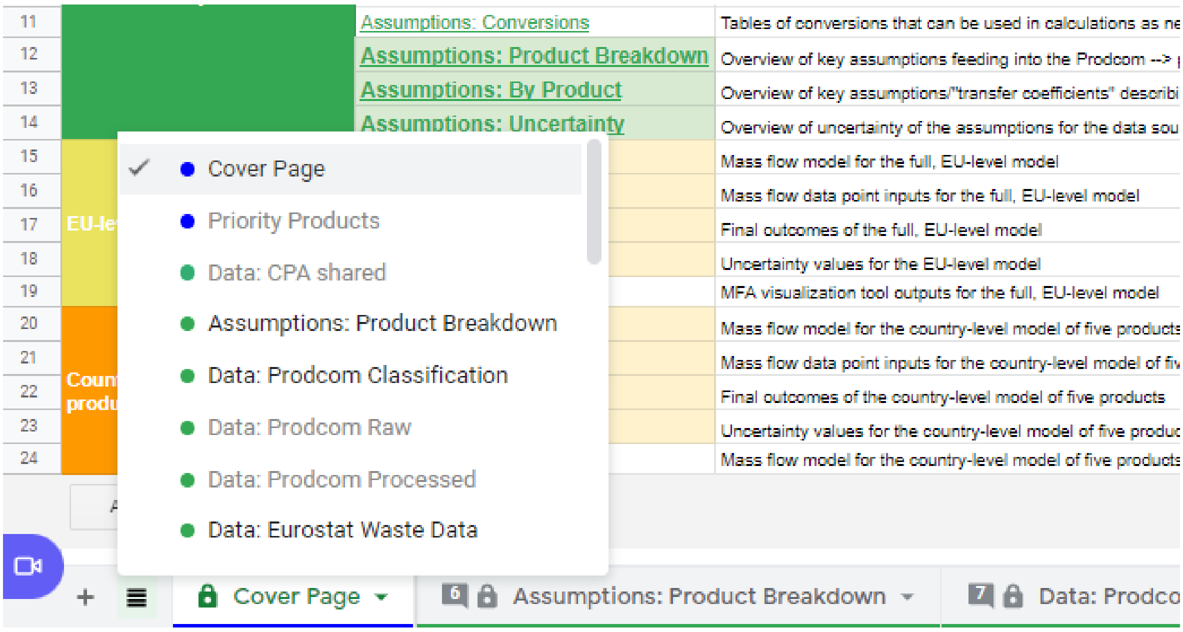


Figure 13: Index for navigation in Google Sheets version of the Plastic Product Mass Flow Model 2.0

The index and the tabs in the sheet are colour-coded. Blue tabs contain basic information about the model scope. Green sheets contain all of the data and assumptions that are used in the model. Yellow sheets contain the outputs of the EU-level model of all plastic flows in Europe. Orange sheets contain the outputs of the country-level model of five plastic flows. The sheets with a background color and are in bold have been highlighted because these sheets are relevant for reviewers and general users to visit. The sheets which are not highlighted will not be relevant for the majority of users and are hidden by default.

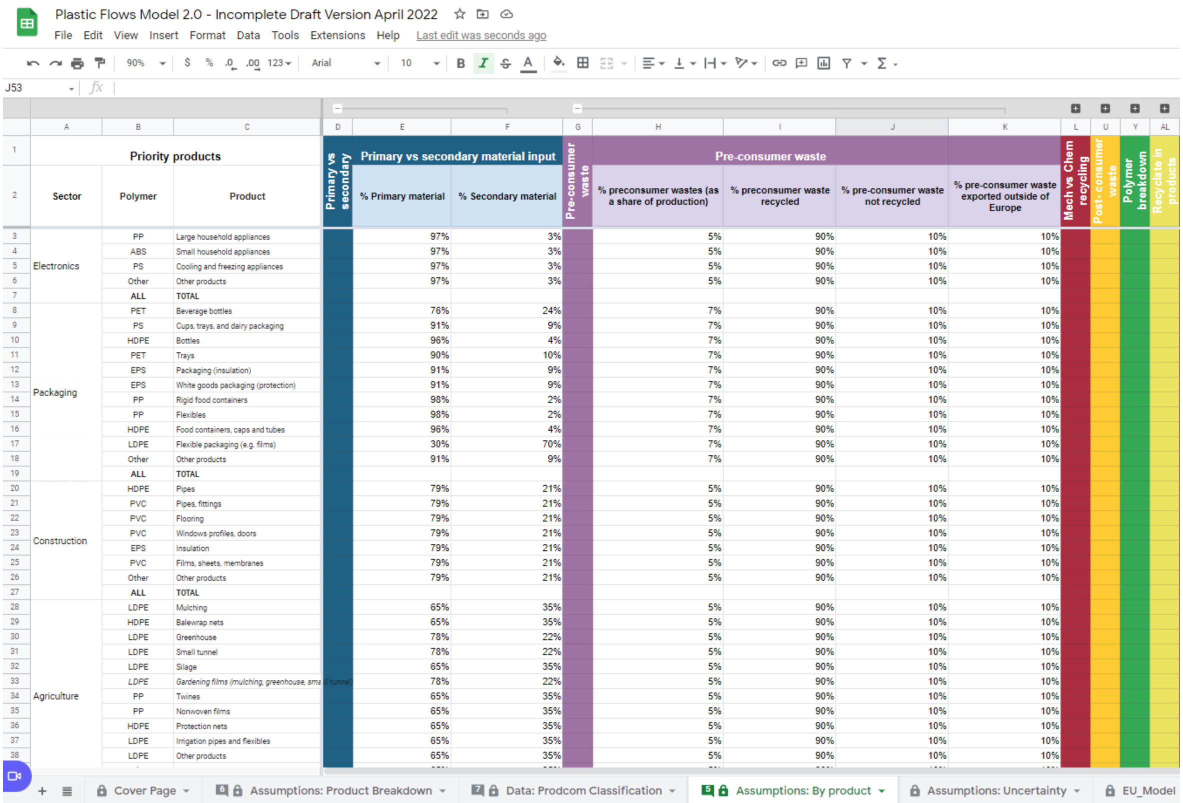
Table 15: Overview of the sheets in the Plastic Product Mass Flow Model 2.0.

Index	Sheet Name	Description
Basic Information Sheets	Cover page	Introduction and index
	Priority Products	List of the priority products included in the model
Data & Assumptions	Data: CPA Shared	Data shared by CPA signatories
	Data: Prodcom Classification	Sheet to classify Prodcom categories into our priority products and calculate the share of plastics per sector, product, and polymer
	Data: Prodcom Raw	Raw Prodcom data extracted for the relevant products
	Data: Prodcom Processed	Processed Prodcom data extracted for the relevant products
	Data: Eurostat Waste Data	Raw and processed Eurostat waste data
	Assumptions: Conversions	Tables of conversions that can be used in calculations as needed
	Assumptions: Product Breakdown	Overview of key assumptions feeding into the Prodcom --> priority product plastic mass conversions
	Assumptions: By Product	Overview of key assumptions/"transfer coefficients" describing how data on total production or waste mass is converted into flows downstream
	Assumption: By Country	Overview of key assumptions/"transfer coefficients" describing how data on total production or waste mass is converted into flows downstream
	Assumptions: Uncertainty	Overview of uncertainty of the assumptions for the data sources used in the model
	EU_Input	Mass flow data point inputs for the full, EU-level model
	Country_Input	Mass flow data point inputs for the country-level model of five products
EU-level Model of all plastics	EU_Model	Mass flow model for the full, EU-level model
	EU_Final	Final outcomes of the full, EU-level model
	EU_Uncertainty	Uncertainty values for the EU-level model
	EU_MFA	MFA visualisation tool outputs for the full, EU-level model - not relevant for users

Index	Sheet Name	Description
Country-level Model for five products	Country_Model	Mass flow model for the country-level model of five products
	Country_Final	Final outcomes of the country-level model of five products
	Country_ Uncertainty	Uncertainty values for the country-level model of five products
	Country_MFA	MFA visualisation tool outputs for the full, EU-level model - not relevant for users
Summary	Comparison with Other Studies	Comparison of key model outcomes with other relevant studies
	Key Outcomes	Compilation of key model outcomes

Data and assumptions sheets

The most important sheet for review by experts is the sheet "*Assumptions: By Product*". This is the sheet containing "transfer coefficients", which estimate how plastics flow in the model. The +/- icon at the top of the sections of the sheet allows the user to collapse and open different sections of the sheet for review.



	Priority products			Primary vs secondary	Primary vs secondary material input		Pre-consumer waste	Pre-consumer waste				Mech vs Chem recycling	Post-consumer waste	Polymer breakdown	Recyclate in products
2	Sector	Polymer	Product		% Primary material	% Secondary material		% preconsumer wastes (as a share of production)	% preconsumer waste recycled	% pre-consumer waste not recycled	% pre-consumer waste exported outside of Europe				
3		PP	Large household appliances		97%	3%		5%	90%	10%	10%				
4		ABS	Small household appliances		97%	3%		5%	90%	10%	10%				
5	Electronics	PS	Cooling and freezing appliances		97%	3%		5%	90%	10%	10%				
6		Other	Other products		97%	3%		5%	90%	10%	10%				
7		ALL	TOTAL												
8		PET	Beverage bottles		76%	24%		7%	90%	10%	10%				
9		PS	Cups, trays, and dairy packaging		91%	9%		7%	90%	10%	10%				
10		HDPE	Bottles		96%	4%		7%	90%	10%	10%				
11		PET	Trays		90%	10%		7%	90%	10%	10%				
12		EPS	Packaging (insulation)		91%	9%		7%	90%	10%	10%				
13	Packaging	EPS	White goods packaging (protection)		91%	9%		7%	90%	10%	10%				
14		PP	Rigid food containers		98%	2%		7%	90%	10%	10%				
15		PP	Flexibles		98%	2%		7%	90%	10%	10%				
16		HDPE	Food containers, caps and tubes		96%	4%		7%	90%	10%	10%				
17		LDPE	Flexible packaging (e.g. films)		30%	70%		7%	90%	10%	10%				
18		Other	Other products		91%	9%		7%	90%	10%	10%				
19		ALL	TOTAL												
20		HDPE	Pipes		79%	21%		5%	90%	10%	10%				
21		PVC	Pipes, fittings		79%	21%		5%	90%	10%	10%				
22		PVC	Flooring		79%	21%		5%	90%	10%	10%				
23		PVC	Windows profiles, doors		79%	21%		5%	90%	10%	10%				
24	Construction	EPS	Insulation		79%	21%		5%	90%	10%	10%				
25		PVC	Films, sheets, membranes		79%	21%		5%	90%	10%	10%				
26		Other	Other products		79%	21%		5%	90%	10%	10%				
27		ALL	TOTAL												
28		LDPE	Mulching		65%	35%		5%	90%	10%	10%				
29		HDPE	Balewrap nets		65%	35%		5%	90%	10%	10%				
30		LDPE	Greenhouse		78%	22%		5%	90%	10%	10%				
31		LDPE	Small tunnel		78%	22%		5%	90%	10%	10%				
32		LDPE	Silage		65%	35%		5%	90%	10%	10%				
33		*LDPE*	*Gardening films (mulching, greenhouse, small tunnel)*		78%	22%		5%	90%	10%	10%				
34	Agriculture	PP	Twines		65%	35%		5%	90%	10%	10%				
35		PP	Nonwoven films		65%	35%		5%	90%	10%	10%				
36		HDPE	Protection nets		65%	35%		5%	90%	10%	10%				
37		LDPE	Irrigation pipes and flexibles		65%	35%		5%	90%	10%	10%				
38		LDPE	Other products		65%	35%		5%	90%	10%	10%				

Figure 14: Sheet "Assumptions: By Product" in Google Sheets version of the Plastic Product Mass Flow Model 2.0

Model sheets

The *EU_model* and *Country_model* sheets draw on the data and the transfer coefficients to build the full picture of mass flows of plastics for the five CPA sectors.

The *EU_input* and *Country_input* sheets mirror the mass flow model, but include space to enter a specific data point when the mass flow is known at just one point. The data sources or person/organisation who provided the data is noted at the bottom of the sheet and in a note on the cells.

The *EU_final* and *Country_final* sheets take the individual data points or the model outcomes if it is not available and compiles the information into one sheet.

How to update

Improving existing data sources or assumptions

Changes can be made to data sources or assumptions directly on the relevant sheets of the model. This includes the following:

Values in the "*Assumptions: Product Breakdown*" sheet, which are all percentages of product types of polymers that form a share of a product in Eurostat.

Values in the "*Data: Prodcom Classification*" sheet. In particular, the percentage of plastic in products (Column O) or the sector share can be updated here directly for specific products.

Values in "*Assumptions: By product*" which contains all of the values for the percentage of waste that ends up separated for recycling, recycled chemically vs mechanically, losses in recycling, exports, etc. This sheet also contains basic assumptions on the percentage of products produced from secondary or primary material and the amount of pre-consumer waste generated in production of products.

In each of these cases, changing the relevant values in these sheets will cascade through the model results.

If these values or data sources are changed, this should be noted as well along with what changes have been made. Additionally, in the sheet "*Assumptions: Uncertainty*", you should evaluate whether you believe that the qualitative assessment of data quality should also be updated. This can be done by changing the value of the scores for the relevant set of data, based on the scoring method provided.

Updating the data to build the model for a new year

There are two sheets where the model's data needs to be updated to build the model for a new year: "*Data: Prodcom Raw*" and "*Data: Eurostat Waste Data*."

Prodcom is a large data set, so to use in Google Sheets, the data should ideally be pre-processed to extract only the rows of product categories that contain plastic (e.g. the ones listed in the "Prodcom Classification" sheet).

The Eurostat waste data includes many tables. New versions of the tables will need to be pasted over the old data table.

Adding new priority products

Adding new priority products is one of the most complex updates that can be done to the model as changes will need to be reflected across most sheets. However, most of the changes are also relatively simple. To break out a new priority product, the following process should be followed:

Create a new row in the "*Priority Products*" sheet for the product and drag the formula for Column G to create a new unique identifier for the priority product.

Go to the "Prodcom classification" sheet and identify which Prodcom categories would count as the new priority product. If a relevant Prodcom category would be fully counted as the new priority product and was previously just counted as "other", then you can simply reclassify it as the new priority product in Column F using the dropdown selection. Otherwise, you will need to create a new row that is a copy of the category. In this case, make sure you change the value in Column Q for the share of the priority product in the total product category. Assumptions on how these product categories are broken down into priority products can be stored in the "*Assumptions: Product Breakdown*" sheet to facilitate review as needed.

Add a new row in the sheets "*Data: Prodcom Processed*" for the new priority product and copy the formula down from one of the other rows.

Add a new row in the sheet "*Assumptions: By product*" and fill in the relevant transfer coefficients data/assumptions.

Add a new row in all of the model sheets, ensuring that it falls in the same place as it fell in the "*Assumptions: By product*" sheet so it is easy to copy formulas. The model sheets include the following:

EU_model

EU_input

EU_final

Country_model

Country_input

Country_final

In the model sheets, Columns O, P, and Q (post-consumer waste) should be evaluated carefully. These connections between Eurostat waste data and assumptions were designed based on the products and will require some manual work and consideration.

To add a new sector, a similar process can be followed for the relevant group of products.

Adding new destinations for recyclate

Destinations for recyclate are sectors and, in a few cases, products. These are broken down in the "*Assumptions: By Product*" sheet. To add new destination products, you can add new columns in this sheet for the new products in the section "Recyclate in products". Add the percentage of recyclate from a specific product ending up in the new product. Make sure this amount is not double counted in the sector percentage allocations by subtracting it from those sector-level values. There is a total for each row to check that the values add up to 100%.

Once the assumptions are in place, the same columns need to be added in the same places on all of the model sheets. The model sheets include the following:

EU_model

EU_input

EU_final

Country_model

Country_input

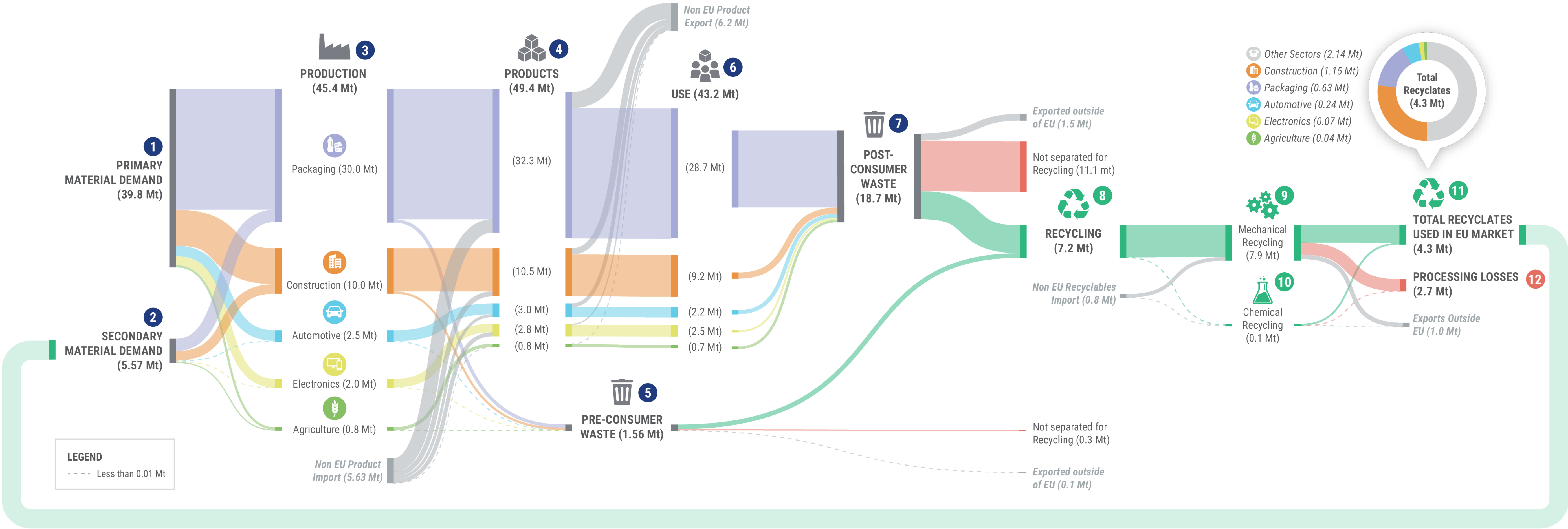
Country_final

Once the columns have been added, new formulas will need to be set up that refer to the new columns.

Annex 3. Sankey Diagrams

EU-Level Sankey Diagrams

Plastic Flows MFA - EU27 (2019)



1. **Primary material demand** is the demand for virgin, non-recycled plastics for products produced in Europe
2. **Secondary material demand** is the demand for secondary, recycled plastics for products produced in Europe
3. **Production** is an aggregate of all plastics ending up in products produced in Europe for the five priority sectors, essentially summarizing inputs for European plastics converters
4. **Products** is an aggregate of plastics in Europe, taking into account production, imports, and exports
5. **Pre-consumer waste** is the waste generated in product manufacturing processes or commercial activities, before that material becomes a finished product
6. **Use aggregates** only plastics consumed in Europe, after accounting for trade flows
7. **Post-consumer** waste is the waste generated after use of the material as a finished product
8. **Recycling** is the material ultimately separated for recycling processes, whether that is source separated or not
9. **Mechanical recycling** is the material recycled through conventional, mechanical recycling processes
10. **Chemical recycling** is the material recycled through chemical recycling processes
11. **Total recyclates used in EU market** is the amount of recyclate that ends up in products made in the EU, as opposed to being exported for use in another country
12. **Processing losses** are the recycling losses from the recycling process. This includes both losses to the environment and losses due to process inefficiencies

Figure 15: Plastic flows for the EU-level model (2019) split by sector.

Description: *Material flow analysis showing plastic flows for five priority sectors in EU27 (2019). All results shown in the Sankey diagrams in this report are pulling from the "EU_Model" tab of the Plastic Flows 2.0 model, which does not account for individual point data from CPA signatories. The production and end-of-life stages described at the bottom of the graphic apply across all Sankey diagrams used in the report.*

Packaging Sector MFA – EU27 (2019)

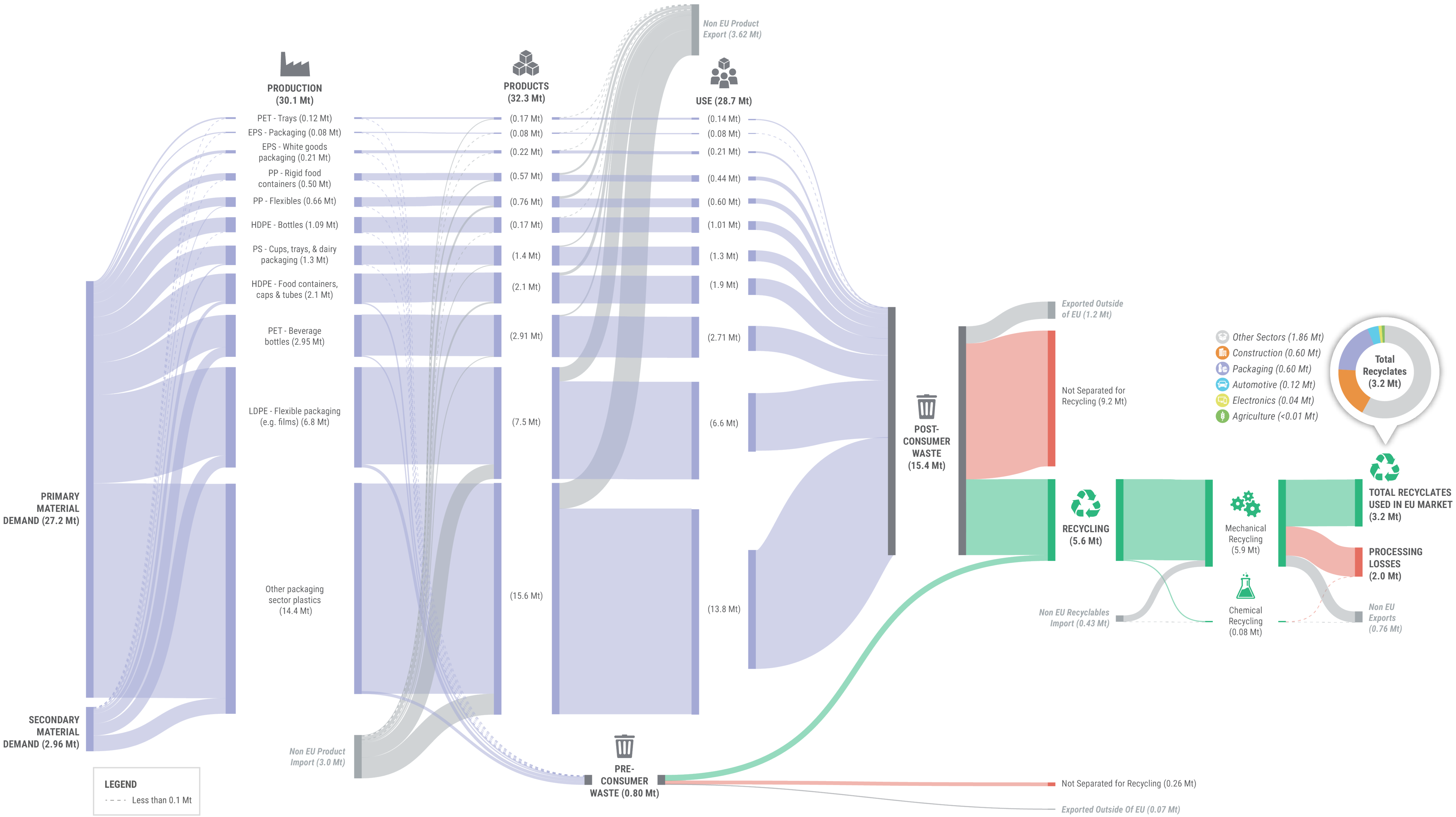


Figure 16: Plastic flows for the EU-level model (2019) - Packaging sector split by polymer/product type

***Description:** Material flow analysis zooming in on the packaging sector for priority products across EU27 (2019). The modelled results are pulling from the "EU_Model" tab, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. The total polymer production mass is based on Prodcom data linked to priority products summarised in the "Data: Prodcom Classification" tab. These linked categories, as well as the conversion rates for the product mass, plastic share per product, sector share, and priority product share, all contribute to the total mass of polymers produced for each priority product. The modelled results show that 3.2 Mt of recyclate from the packaging sector are reintegrated back into the EU market in 2019.*

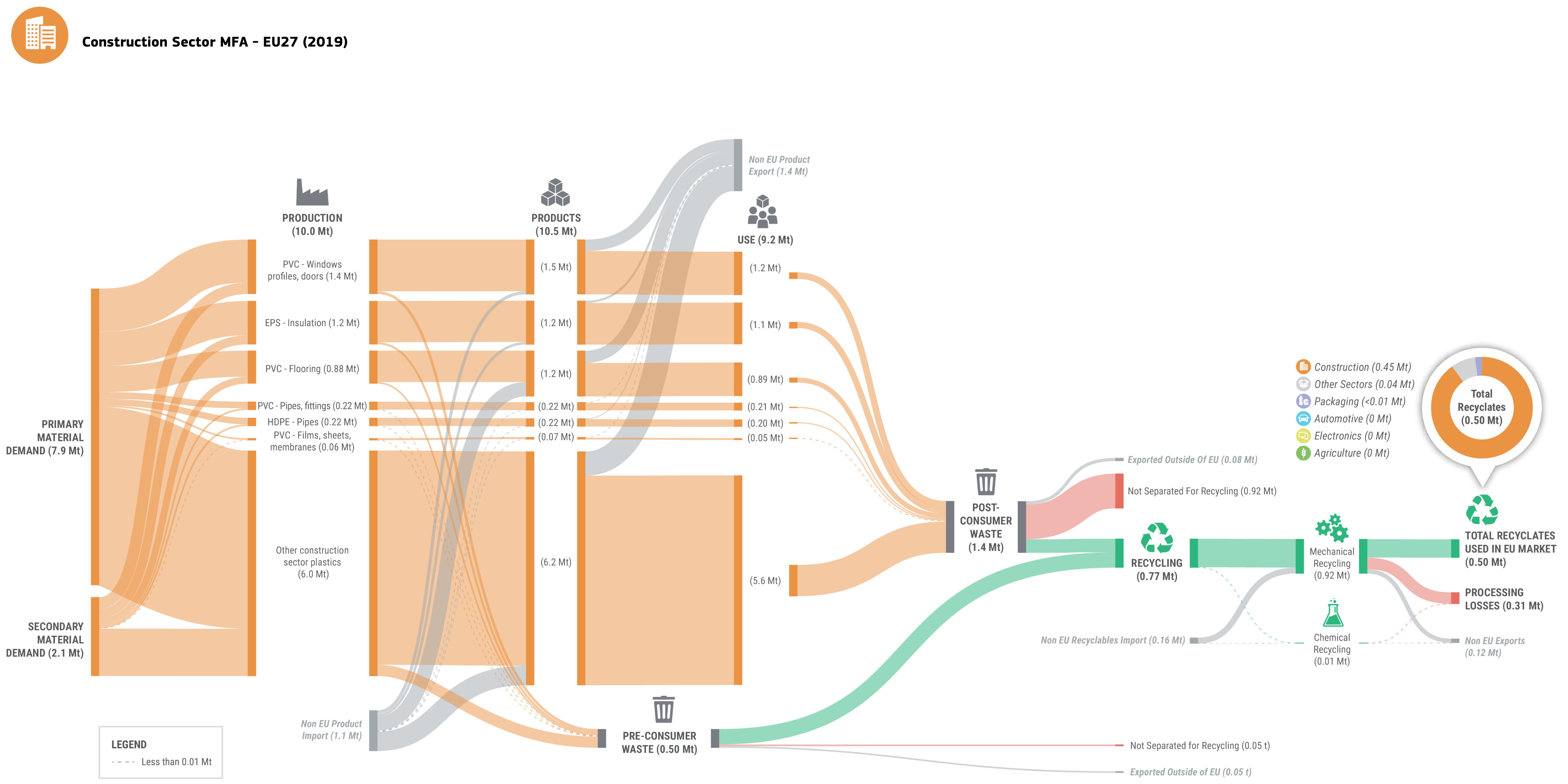


Figure 17: M Plastic flows for the EU-Level model (2019) - Construction sector split by polymer/product type

Description: *Material flow analysis of the construction sector for priority products across EU27 (2019). The modelled results are pulling from the "EU_Model" tab, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. The total polymer production mass is based on Prodcom data linked to priority products summarised in the "Data: Prodcom Classification" tab. Differences in the mass of products in use and the mass of post-consumer waste is primarily due to the long lifetime of products used in the construction sector. The modelled results show that 0.5 Mt of recyclate from the construction sector are reintegrated back into the EU market in 2019.*

Automotive Sector MFA - EU27 (2019)

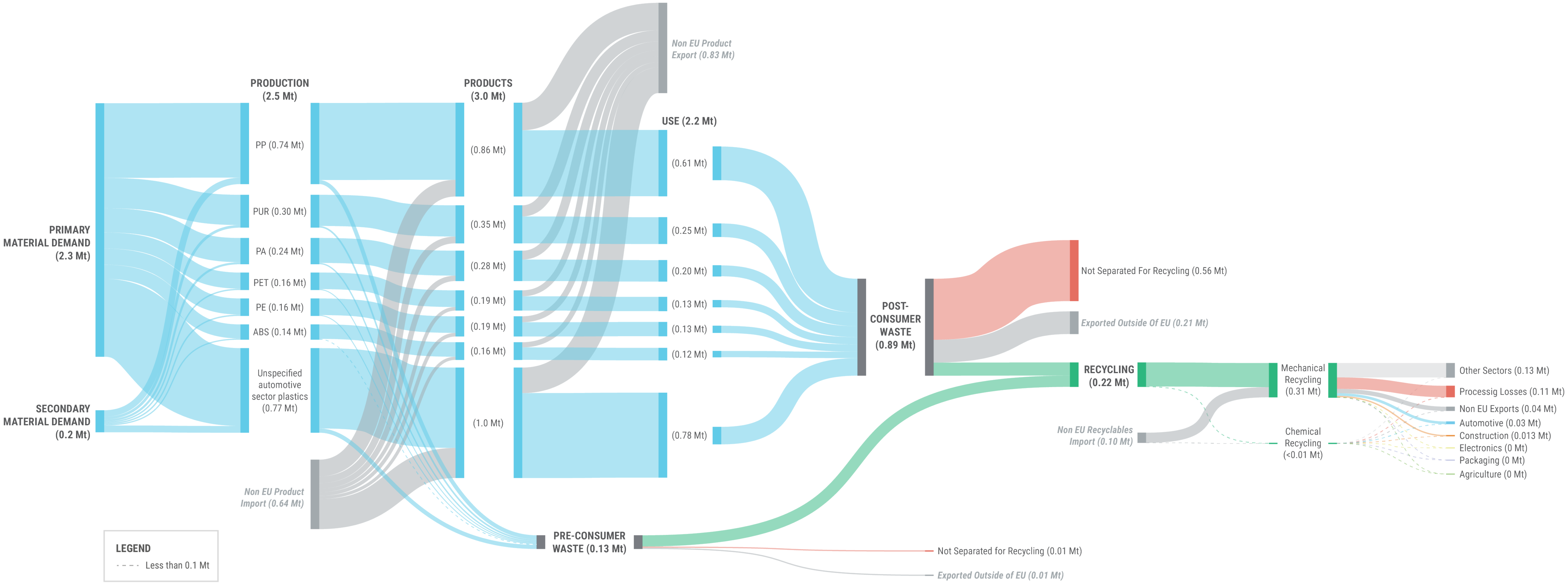


Figure 18: Plastic flows for the EU-level model (2019) - Automotive sector split by polymer type

Description: *Material flow analysis for polymers used in the automotive sector across EU27 (2019). As most automobiles are recycled through shredding rather than broken down into components, simply modelling the polymer flows for this sector was deemed the best approach. The modelled results are pulling from the "EU_Model" tab, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. CPA members from the automotive sector have already provided point data on the "EU_Input" tab (not shown here), and discrepancies between modelled results and point data are summarised on the "EU_Final" tab.*

Electronics Sector MFA - EU27 (2019)

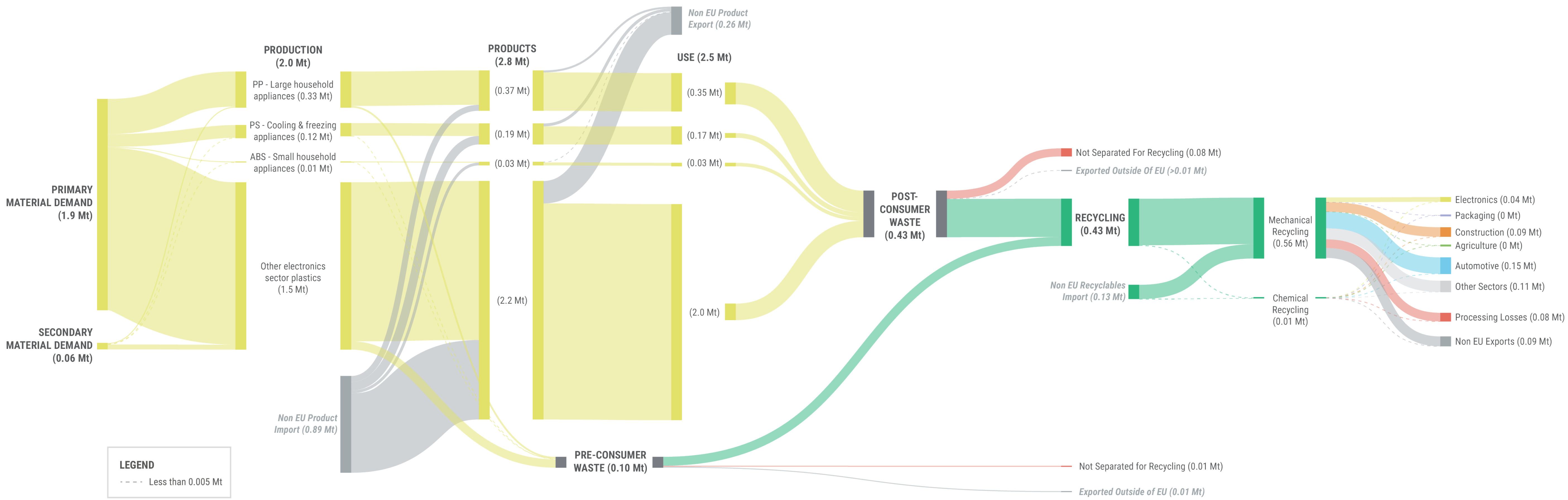


Figure 19: Plastic flows for the EU-level model (2019) - Electronics sector split by polymer/product type

Description: *Material flow analysis of plastics used in the electronics sector for priority products across EU27 (2019). The modelled results are pulling from the "EU_Model" tab, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. The total polymer production mass is based on Prodcom data linked to priority products summarised in the "Data: Prodcom Classification" tab. These linked categories, as well as the conversion rates for the product mass, plastic share per product, sector share, and priority product share, all contribute to the total mass of polymers produced for each priority product. To see which Prodcom codes are linked to "Other electronics sector plastics", filter by Priority Product Category in* Column F *of the "Data: Prodcom Classification" tab.*

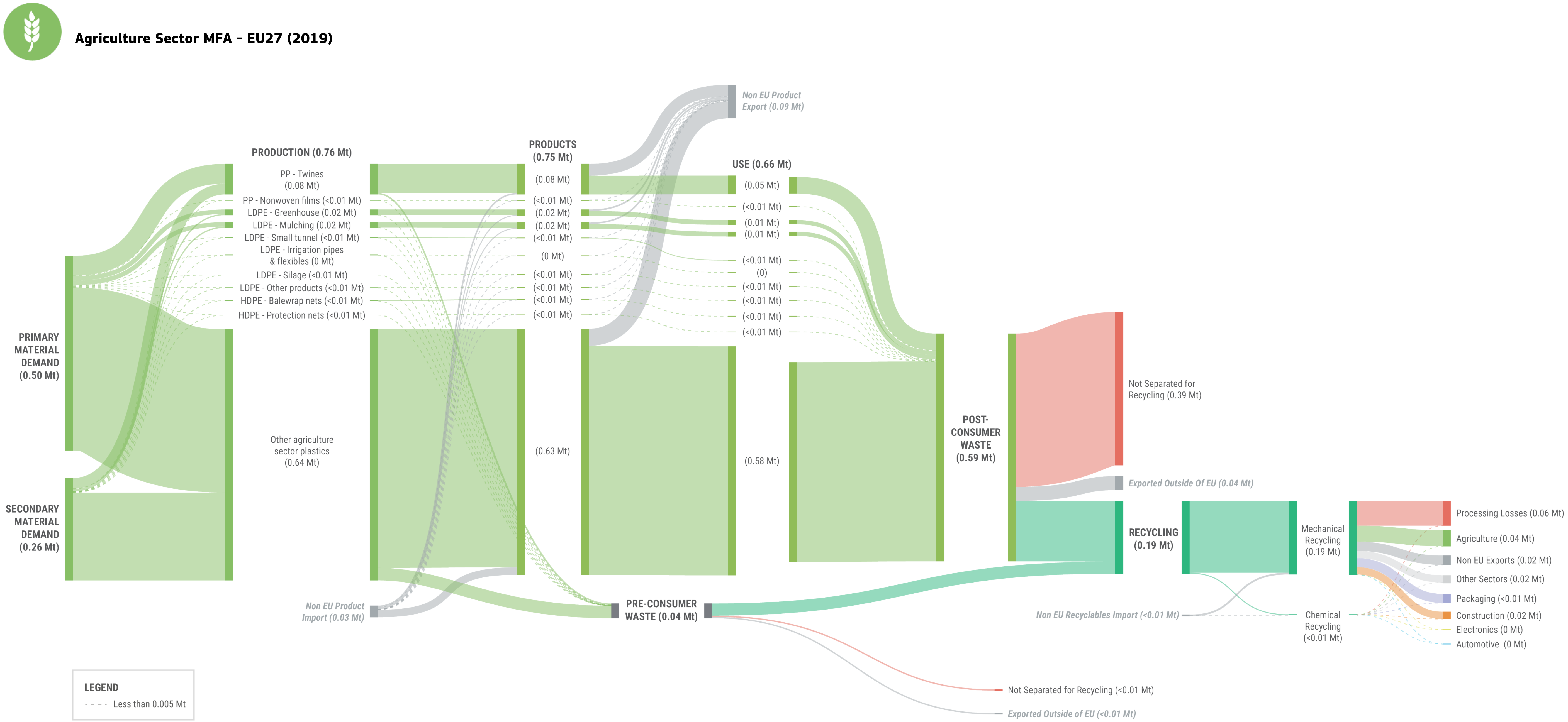


Figure 20: Plastic flows for the EU-level model (2019) - Agriculture sector split by polymer/product type

Description: *Material flow analysis of plastics used in the agriculture sector for priority products across EU27 (2019). The modelled results are pulling from the "EU_Model" tab, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. The total polymer production mass is based on Prodcom data linked to priority products summarised in the "Data: Prodcom Classification" tab. These linked categories, as well as the conversion rates for the product mass, plastic share per product, sector share, and priority product share, all contribute to the total mass of polymers produced for each priority product. To see which Prodcom codes are linked to "Other agriculture sector plastics", filter by Priority Product Category in* Column F *of the "Data: Prodcom Classification" tab.*

Plastic Flows MFA – Breakdown by Polymer – EU27 (2019)

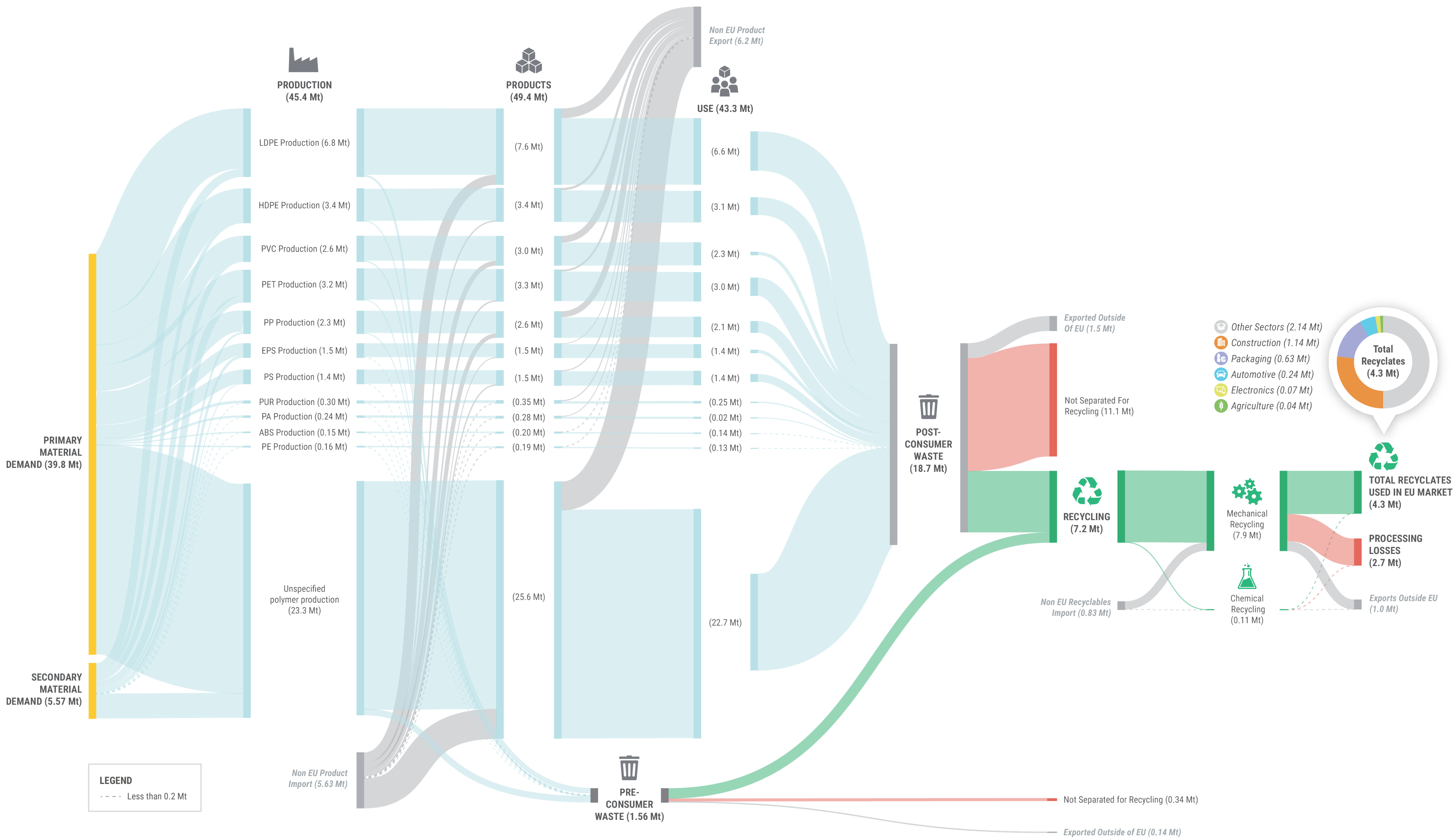


Figure 21: Plastic flows for the EU-level model (2019) split by polymer type

Description: *Material flow analysis of plastics for priority products across EU27 (2019) with a breakdown by polymer. The modelled results are pulling from the "EU_Model" tab, with assumptions for primary and secondary materials summarised per product on the "Assumptions: By Product" tab. The total polymer production mass is based on Prodcom data linked to priority products summarised in the "Data: Prodcom Classification" tab. These linked categories, as well as the conversion rates for the product mass, plastic share per product, sector share, and priority product share, all contribute to the total mass of polymers produced for each priority product. All products that are listed as "Other plastics" in the sector-specific MFAs are grouped together here under "Unspecified polymer production". The modelled results show the total amount of recyclate used in the EU market is 4.3 Mt.*

Country-Level Sankey Diagrams

Austria exclusion - Country-level model

The raw Prodcom data is included in the model itself, which means Eurostat's copyright notice needs to be followed. In the copyright text,[17] one relevant point can be found regarding the data that can be reissued with commercial purposes:

"4.e Trade data originating from Austria (as a declaring country) for a level of detail of the Combined Nomenclature of 8 digits; again, it is not allowed to sell export/import declared by Austria (concerning the above named commodity classifications), but it is allowed to sell Austrian export/import data declared by another EU Member State."

This project uses and publishes raw Prodcom data on a country level, at a level of detail of 8 digits. Therefore, Austria's data has not been included in the country-level model. However, the European-level model includes data from Austria, since it is aggregated with the data from all other member countries.

In addition, Prodcom data on a country level is very scarce for some categories so that confidential data cannot be extracted from the dataset. Whenever only 1 or 2 producers are present for one Prodcom code in a country, the figures are omitted by Eurostat. In the case of Large Household Appliances, for example, we note that many countries have no data available (see Figure 22, where all red cells with ":" as the value mean that the data is not disclosed, which is not the same as a "0"). This means large amounts of production, import and export data are likely excluded due to this confidentiality issue. This is an important caveat to take into account when looking at the figures of the country level model, and is the reason some product categories have a large discrepancy between production and waste data. The full EU model is not affected, since the EU publishes full figures on a continent level because no confidential data can be extracted on that scale.

Figure 22: Screenshot of the "Data: Prodcom Raw" tab of the model, where cells in red show data that has been excluded on the country level due to data confidentiality issues.

			Production						
PERIOD	PRCCODE_LABEL	PRCCODE	France	Germany	Greece	Hungary	Iceland	Ireland	Italy
2019	Household dishwashing machines	27511200	:	:	:	0	0	0	8
2019	Cloth washing and drying machines, of the household type	27511300	:	:	:	:	0	0	25
2019	Table, floor, wall, window, ceiling or roof fans, with a self-contained el	27511530	57657	3729624	:	0	0	:	:
2019	Ventilating or recycling hoods incorporating a fan, with a maximum h	27511580	:	1064999	:	0	0	:	31
2019	Domestic microwave ovens	27512700	:	:	0	0	0	0	:
2019	Axial fans (excluding table, floor, wall, window, ceiling or roof fans wit	28252030	165831	7393329	0	5249968	0	:	49
2019	Centrifugal fans (excluding table, floor, wall, window, ceiling or roof fa	28252050	62680	:	598	0	0	:	57
2019	Fans (excluding table, floor, wall, ceiling or roof fans with a self-conta	28252070	:	3653298	:	25	0	:	6

[17] https://ec.europa.eu/eurostat/about/policies/copyright

Packaging MFA: PET Trays - EU27 (2019)

Country-level breakdown (Excluding Austria)

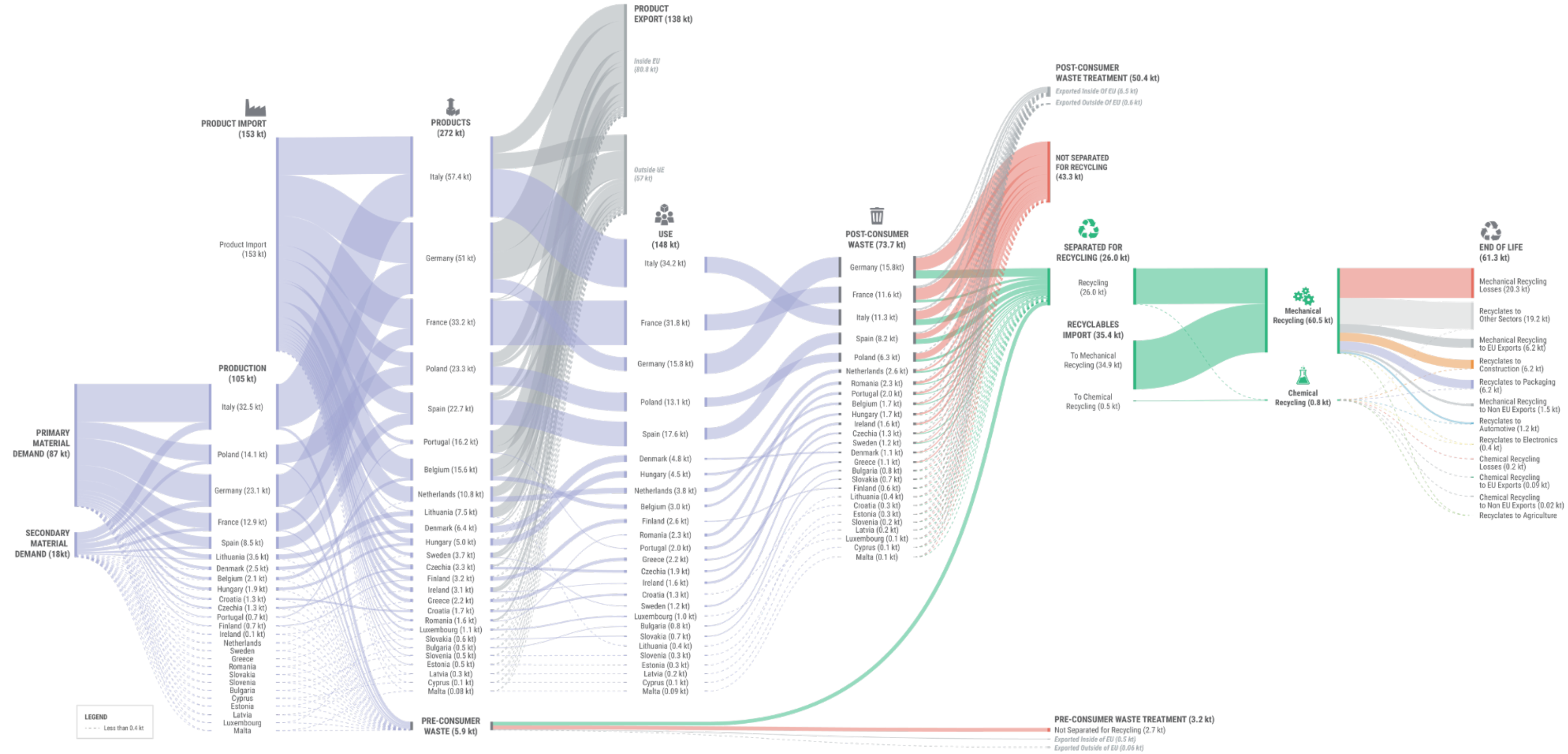


Figure 23: Plastic flows for the country-level model (2019) - Packaging PET trays

Description: *Material flow analysis of one selected priority product in packaging (PET trays) covering EU27, excluding Austria, in 2019. The modelled results are pulling from the "Country_Model" tab, with assumptions for exported products, exported waste, post-consumer waste recycling, and exported recyclates summarised per country on the "Assumptions: By country" tab. The total production, import, and export per country is based on Prodcom data on the "Data: Prodcom processed" tab. The results show that for PET tray waste generated within the EU, less than half are separated for recycling. The current recycling system relies heavily on recyclable imports (35.4 kt imported recyclables versus 26 kt EU waste), and a significant portion is lost (20.3 kt) during recycling. The recyclate outputs are mainly used in other non-priority product sectors (19.2 kt), construction (6.2 kt), and packaging (6.2 kt).*

Construction MFA: PVC Window profiles, Doors - EU27 (2019)

Country-level breakdown (Excluding Austria)

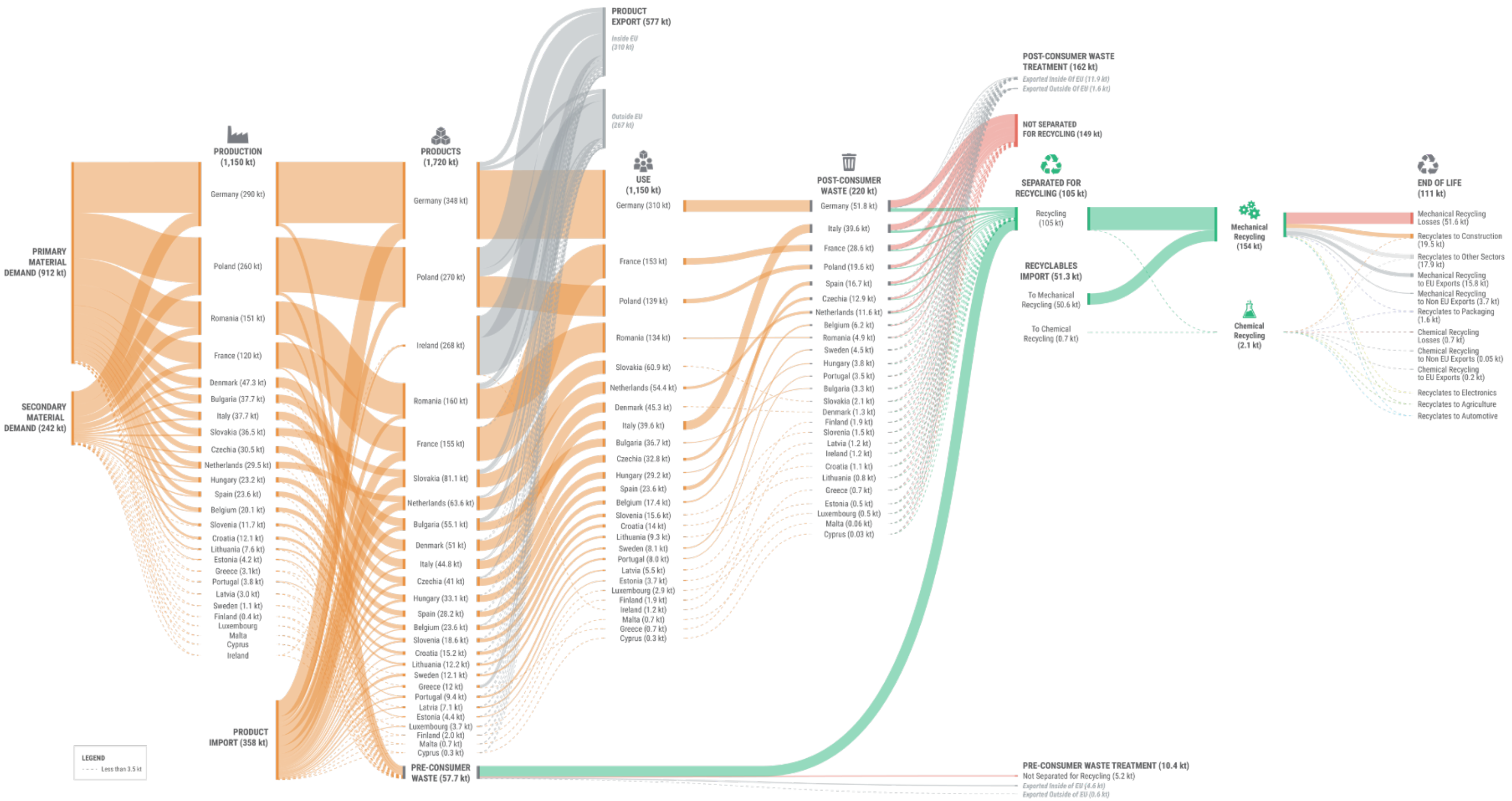


Figure 24: Plastic flows for the country-level model (2019) - Construction PVC window profiles and doors.

Description: *Material flow analysis of one selected priority product in construction (PVC Window profiles, Doors) covering EU27, excluding Austria, in 2019. The modelled results are pulling from the "Country Model" tab, with assumptions for exported products, exported waste, post-consumer waste recycling, and exported recyclates summarised per country on the "Assumptions: By country" tab. The total production, import, and export per country is based on Prodcom data on the "Data: Prodcom processed" tab. A considerable amount of pre-consumer waste (57.7 kt) is separated for recycling (total amount 105 kt). The recyclate outputs are mainly used in construction (19.5 kt) and other non-priority product sectors (17.9 kt).*

Automotive MFA: PP Shredder fluff - EU27 (2019)

Country-level breakdown (Excluding Austria)

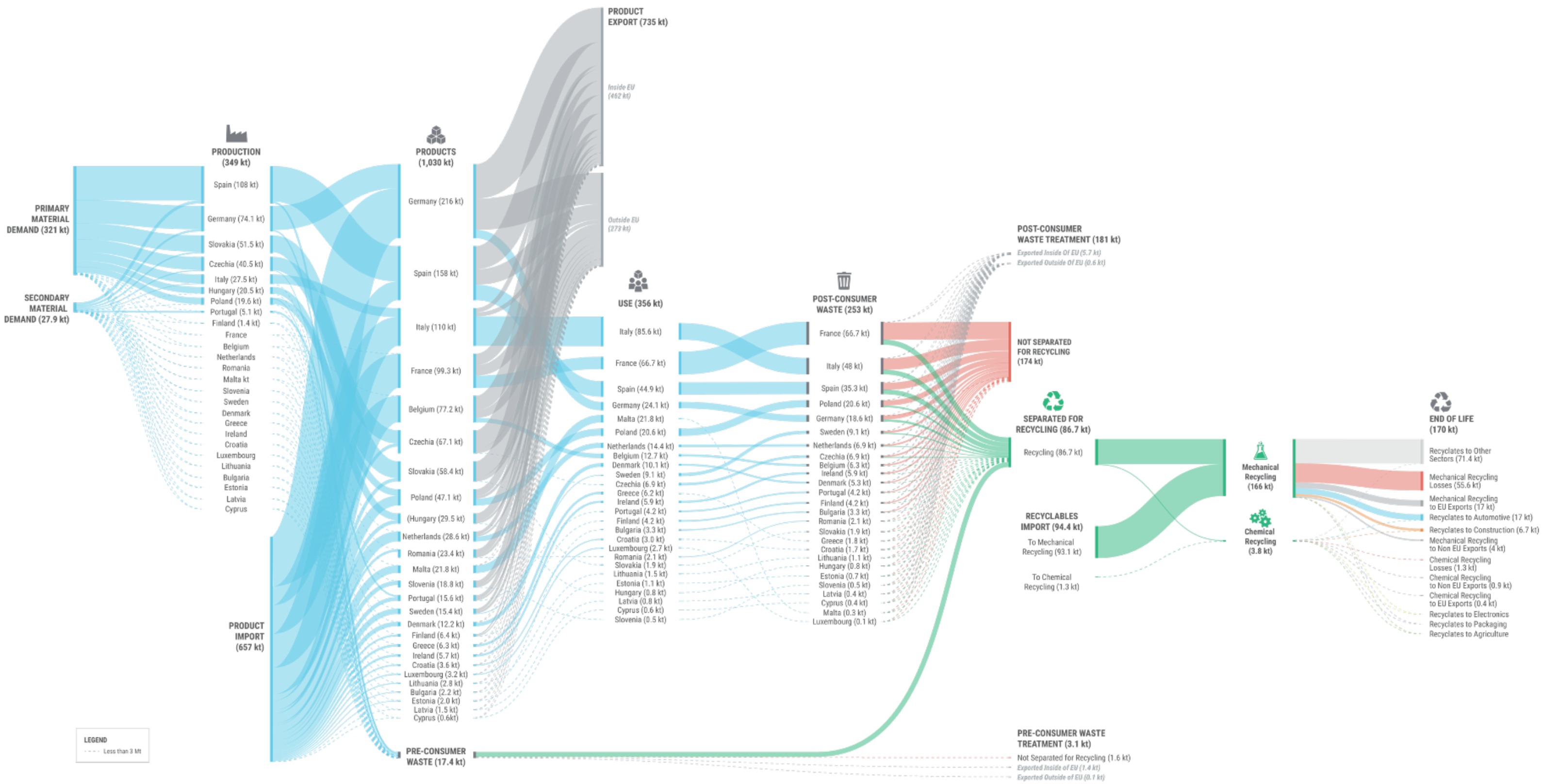


Figure 25: Plastic flows for the country-level model (2019) - Automotive PP, shredder fluff

Description: *Material flow analysis of one selected priority product in automotive (PP Shredder fluff) covering EU27, excluding Austria, in 2019. The modelled results are pulling from the "Country Model" tab, with assumptions for exported products, exported waste, post-consumer waste recycling, and exported recyclates summarised per country on the "Assumptions: By country" tab. The total production, import, and export per country is based on Prodcom data on the "Data: Prodcom processed" tab. The current recycling system relies heavily on recyclable imports (94.4 kt imported recyclables versus 86.7 kt EU waste), and a significant portion is lost (55.6 kt) during recycling. The recyclate outputs are mainly used in other non-priority product sectors (71.4 kt), automotive (17 kt), and construction (6.7 kt).*

Electronics MFA: PP Large household appliances – EU27 (2019)

Country-level breakdown (Excluding Austria)

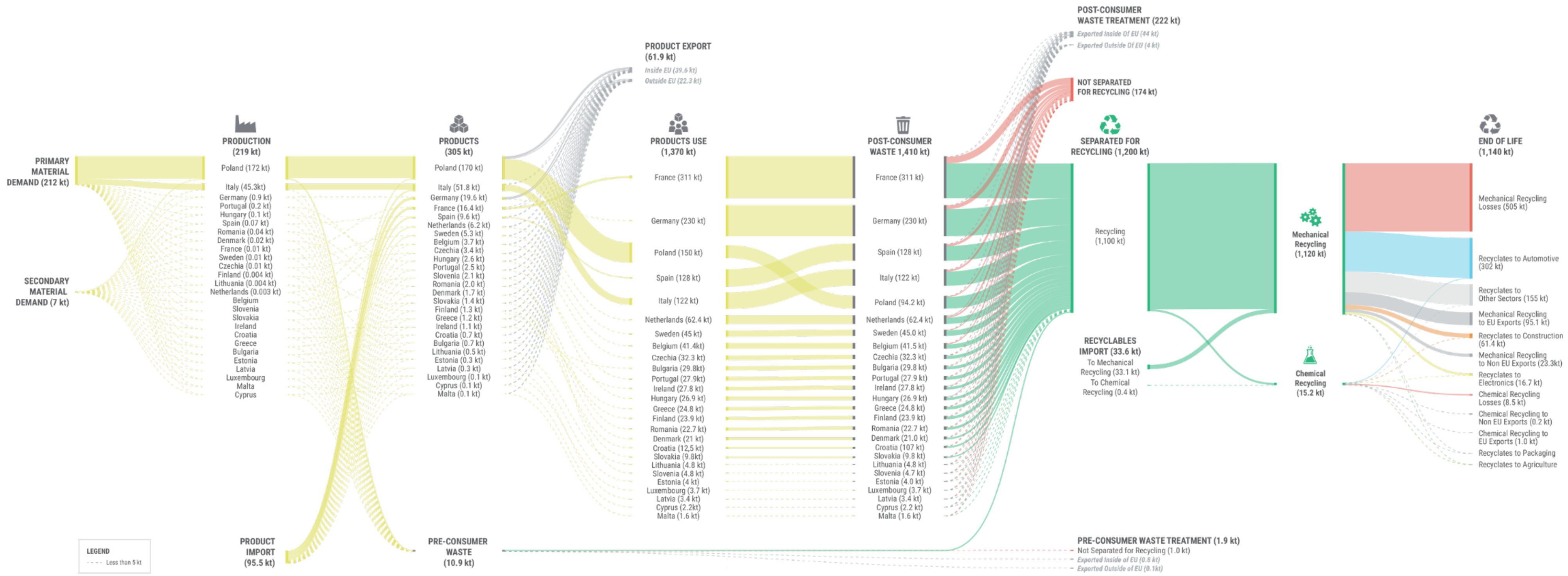


Figure 26: Plastic flows for the country-level model (2019) - Electronics PP in large household appliances

Description: *Material flow analysis of one selected priority product in electronics (PP large household appliances) covering EU27, excluding Austria, in 2019. The modelled results are pulling from the "<u>Country Model</u>" tab, with assumptions for exported products, exported waste, post-consumer waste recycling, and exported recyclates summarised per country on the "<u>Assumptions: By country</u>" tab. The total production, import, and export per country is based on Prodcom data on the "<u>Data: Prodcom processed</u>" tab. A significant amount of waste from large household appliances are separated for recycling (1200 kt separated for recycling out of 1410 kt post-consumer waste). The recyclate outputs are mainly used in automotive (302 kt) or other non-priority product sectors (155 kt).*

Agriculture MFA: LDPE Gardening films - EU27 (2019)

Country-level breakdown (Excluding Austria)

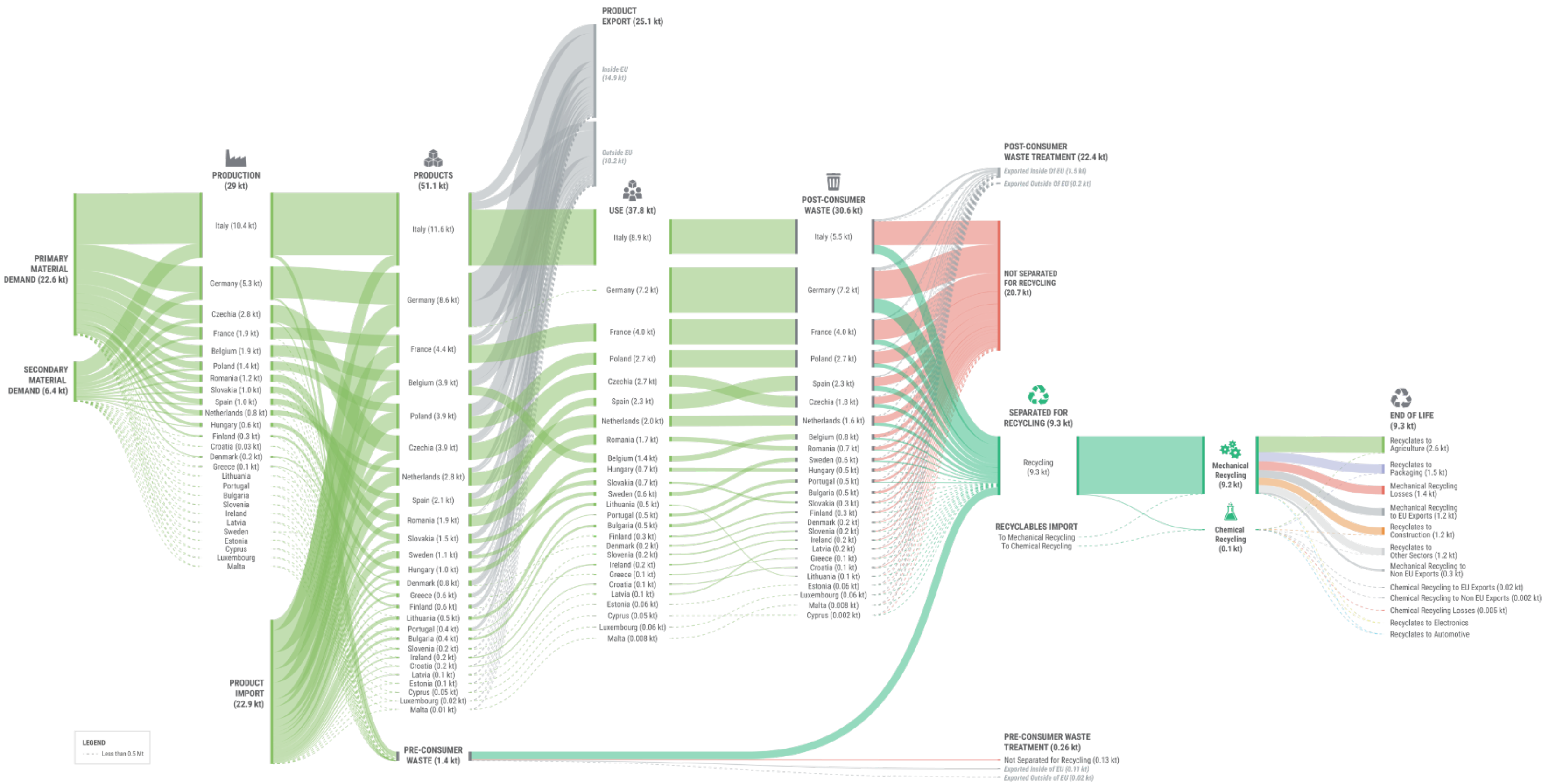


Figure 27: Plastic flows for the country-level model (2019) - Agriculture LDPE in gardening films

***Description**: Material flow analysis of one selected priority product in agriculture (LDPE gardening films) covering EU27, excluding Austria, in 2019. The modelled results are pulling from the "Country_Model" tab, with assumptions for exported products, exported waste, post-consumer waste recycling, and exported recyclates summarised per country on the "Assumptions: By country" tab. The total production, import, and export per country is based on Prodcom data on the "Data: Prodcom processed" tab. The recyclate outputs are mainly used in agriculture (2.6 kt) and packaging (1.5 kt).*

Annex 4. Bibliogrpahy

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