Nordic Council of Ministers

Towards Ending Plastic Pollution by 2040

15 Global Policy Interventions for Systems Change

Technical Annex

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1. Disclaimer objective and scope

The detailed description of the objectives and scope of the report can be found in the document: ***Towards Ending Plastic Pollution by 2040 - 15 Global Policy Interventions for Systems Change.*** This ***Technical Annex*** provides detail on the assumptions, metrics and data used for the model underlining the report.

2. Introduction

This Appendix highlights the methodology and approach to the modelling as well as the scenarios and corresponding key assumptions. The model projects volumetric stocks and flows of plastics in:

- **8 regions**: 1) Europe, 2) USA and Canada, 3) Japan, Republic of Korea, New Zealand and Australia, 4) Central and South America and the Caribbean, 5) China, 6) South Asia, Southeast Asia and Eurasia, 7) India, and 8) Africa and Middle East.
- **9 sub-systems**: 1) packaging and consumer goods, 2) textiles, 3) transportation, 4) construction, 5) electronics, 6) agriculture, 7) fishing gear and aquaculture, 8) sources of microplastics, and 9) others; see section "Sub-systems and plastic categories" for detail.

The model presents two alternative scenarios on how the plastic system can develop by 2040:

- First, the **Business as Usual Scenario** shows the impacts on plastic stock & flows, GHG emissions, costs, and employment from now to 2040 of continuing on the current trajectory of plastic production, consumption, and waste management.
- Second, the **Global Rules Scenario** represents a package of legally-binding policy interventions, implemented across all regions, to minimise mismanaged plastics and microplastic releases to the environment by 2040. The model estimates an environmental, economic, and social opportunity from implementing these policies, calibrating by region and plastic application. The study also identifies gaps in research and innovations that could be required for this scenario to materialise. The Global Rules Scenario is not the only combination of policies that could achieve similar outcomes and does not claim to be the only set of policies to consider. It aims to show an approximate level of reach and diversity of policies needed to meaningfully reduce mismanaged plastics.

3. A note on data, approach, and uncertainty

The objective of this modelling exercise was to size and represent current plastic flows and the end of life fate of its waste. Subsequently the current trajectory until 2040 is projected and used to estimate the impact of a series of policies on the system, resulting in the Global Rules Scenario.

The existing or available data on plastic consumption, GHG emissions, waste management, and overall, all system information is limited and fragmented. In some cases, for geographical regions or plastic categories, the available data simply does not exist, and assumptions needed to be taken. Some areas where data is particularly lacking are agriculture plastics, fishing gear, aquaculture, and microplastics. In general, regions like Europe and USA have better data availability, with other regions being more challenging. In addition, the data or evidence on how policies can be effective, or the impact on plastic flows is also limited and fragmented, being an area that requires further development in the future.

Modelled scenarios were designed using the best available information to inform mass flows and costs, yet the model does not capture all the components and complexity of the global plastic systems. Because data gaps exist on the generation, collection, recycling, disposal, and leakage of plastic waste, the model is unable to accurately measure all feedbacks in the system. As a result, the analyses include inherent assumptions and are unable to determine system sensitivities to important external drivers, such as the price of oil. In addition, a global model has, by definition, limited granularity, and our conclusions need to be applied carefully to local contexts.

This analysis aims to provide directional insight on what some of the critical policies to consider are, the considerations to make them as ambitious as the can be and to show an unconstrained "size of the prize" in terms of reducing plastic consumption, and mismanagement of plastic waste, and mitigating GHG emissions. Given that the timeline of the analysis looks up to 2040, there must be understood there is a high level of uncertainty embedded and that policy levers may be impacted by a multitude of factors that would prevent their effectiveness and that are not considered in the model.

The analytics included in our modelling draw from best available sources. When no data was available, assumptions were made in collaboration with experts in each specific topic. The figures in this analysis reflect directional outputs from the model, not precise estimates. Despite these limitations, the model results are highly informative in demonstrating effective solutions and the general level of ambition that is required to change the plastic system.

4. Geographical region taxonomy

Since the plastic waste metrics vary greatly across geographies, the 8 regions listed below were established as clusters with relatively similar waste properties and waste management systems. Each of these geographies are attributed individual input values and modelled separately. Consequently, every geography receives a separate output of waste flows, costs, jobs, and GHG emissions for both scenarios. These geography outputs are then aggregated to global outputs.

Table 1: Geographical region taxonomy

Code	Regions	Detail (Regions are an aggregation of geographies from OECD's Global Plastic Outlook)
R1	Europe	OECD EU countries, OECD Non-EU countries (Iceland, Israel, Norway, Switzerland, Turkey, United Kingdom), Other EU (Bulgaria, Croatia, Cyprus, Malta, Romania)
R2	USA and Canada	USA and Canada
R3	Japan, Republic of Korea, New Zealand, Australia	Japan, Republic of Korea, New Zealand, Australia
R4	Central, South America and the Caribbean	Chile, Colombia, Costa Rica, Mexico and Non-OECD Latin American and Caribbean countries
R5	China	People's Republic of China, Hong Kong (China)
R6	South/South-East Asia, Eurasia (excl. Japan, Republic of Korea, New Zealand, Australia, China, India)	Other non-OECD Asian and Pacific countries, non-OECD European and Caspian countries, including Russian Federation
R7	India	India
R8	African and Middle Eastern countries	Middle East & North Africa, and Sub-Saharan Africa

5. Subsystems and plastic category taxonomy

The model calculates waste flows for nine chosen sectors that cover the entire plastic waste system (see System map section). These sectors are modelled separately to account for the difference in their respective waste systems. For each sector, a list of baseline inputs pertaining to the sector's system map is established, as well as the impact inputs that a set of policies is expected to have in the system change scenario. The resulting waste flows, costs, jobs, and GHG emissions are then calculated for each scenario of each sector and depicted in a sector-specific dashboard. In a "master" document, the impact of all sector's is combined to establish the "all-sector-total" outputs.

In each sector, waste flow input values are additionally split between different plastic categories to account for different system characteristics within a sector. For example, bottles tend to enjoy higher collection rates than multi-materials in the packaging sector. Considering data scarcity and model complexity – cost, jobs, and GHG data was not split by plastic categories. Note: while microplastics are not a plastic category, they are modelled as their own system.

Table 2: Overview of plastic categories / sectors in model

Main source: Resources, Conservation & Recycling 151, 2019

Sector	Plastic category	Examples of products in included in the plastic category
Packaging & Consumer goods	Bottles	Water bottles, other food-grade bottles
	Other rigids	Non-food-grade bottles, Food service disposables, Pots tubs and trays, B2B packaging, Other rigid mono-material packaging
	Flexibles	Carrier bags, Films, B2B films
	Multi-materials	Sachets and multilayer flexibles, Laminated paper and aluminium
	Consumer goods	Household goods, diapers, and hygiene products
Construction	Construction	Pipe, conduit and fittings (including drainage, irrigation, plumbing fixtures and septic tanks), siding, flooring, insulation materials, panels, doors, windows, skylights, bathroom units, agricultural film, gratings and railings (American Chemistry Council, 2008)
Transportation	Transportation – General	Motor vehicles and parts (including autos, trucks, buses, motorcycles and bicycles), railroad equipment, travel trailers, campers, golf carts, snowmobiles, aircraft, military vehicles, ships, boats and recreational vehicles (American Chemistry Council, 2008)
	Tyres	Plastics related to tyres for vehicles
Textiles	Clothing	Clothing textiles
	Other textiles	All other textiles except for clothing

Electronics	Electronics	Home and industrial appliances (including electrical industrial equipment), wire and cable coverings, communications equipment, resistors, magnetic tape, records and batteries (American Chemistry Council, 2008)
Agriculture	Agriculture	A collective term that is generally used for products made from plastic that are used in the production phases of terrestrial agriculture, primarily crop and livestock production. However, for the purposes of this study, the term also includes products used in forestry and fisheries, and in the downstream phases of the agrifood value chains such as harvesting, storage, processing, and distribution (FAO, 2021).
Fishing gear & Aquaculture	Fishing Gear	Fishing nets, lines, buoys/floaters, ropes
	Aquaculture	Plastic mesh, feeding pipes, walkways, fishing nets, buoys/floaters, ropes
Microplastics	Paint	Microplastics from paint application, wear and tear, removal and unused
	Tyres abrasion	Tyre abrasion from roads and runways
	Textiles	Textile losses from production, handwash, and washing machine
	Pellets	Pellets losses shipping, from production m and from recycling
	Personal care products	PCP from wash-off consumption and stay-on consumption
Others	Others	Other plastic which cannot be assigned to the previous categories (American Chemistry Council, 2008)

Table 3: Global plastic consumption by application

Subsystems	Amount 2019 Million Mt	Amount 2040 Million Mt	Reference
Packaging & Consumer goods	189	317	OECD Global Plastic Outlook, which leverages data from Geyer et al., 2017; Grand View Research, 2017, European Bioplastics, 2017; ETRMA, 2011 "Others" group has been subtracted the volumes estimated for fishing gear, aquaculture, and agriculture plastics below, from the total value in the OECD report.
Construction	77	121	
Transportation	62	115	
Textile sector	44	73	
Electronics	17	29	
Others	44	68	
Agriculture	10	18	FAO. 2021. Assessment of agricultural plastics and their sustainability. A call for action. Rome. https://doi.org/10.4060/cb7856en Page 28
Fisheries and Aquaculture	5.5 (see note)*	5.4 (see note)*	*No direct sources available*, we estimated the volumes with the assumptions and methodology below:* Annual catches from fisheries and aquaculture by region (FAO) CAGR catches per year (OECD-FAO Agricultural Outlook 2021-2030): - Fisheries: <1%/year for every region between 2025-2030; 0% between 2030-2040 - Aquaculture: 2.09%/year for every region to 2030, continuous in the middle- and low-income regions and 1% in high-income regions after 2030 How much plastic gear is used for each tonne of catch? - Fishing gear volume to catch ratio of 4.2% (Kuzcenski et al. 2021) - Aquaculture gear volume to catch ratio 1.3% (Sundt 2020; FAO)
Microplastics Losses – Paint	4.5	7.5	Paint per capita by region Microplastics losses (vs macro plastics losses) Microplastics loss broken down by losses type: application, wear and tear, removal, unused, end of life (Environmental Action 2022) Assumption that application, wear and tear and removal is mainly at the origin of microplastics (compared to unused and end of life at the origin of macroplastic losses)
Microplastics Losses – Tyres abrasion	3.7	7.7	Kilometres driven by car, light vans, motorbike, lorry (Monteith et al. 2015, 2016, 2017) Average microplastic loss rate per vehicle type (Monteith et al. 2015, 2016, 2017) Share driven on urban roads, rural roads, motorways, runways (Monteith et al. 2015, 2016, 2017)
Microplastics Losses – Textiles	0.1	0.2	Wash cycles per households (Pakula et al 2010; Laitala et al 2017) Load per household wash (Pakula et al 2010; Laitala et al 2017) Share of handwashing and washing machine (households / commercial) Share of synthetic clothing (Bouchet, Friot 2017) Microplastics losses by washing methods
Microplastics Losses – Pellets	0.4	0.6	Volume of pellets handled through seaport (Plastics Europe 2018) Volume of pellets handled through recycling (based on our model) Volume of pellets handled by producers, intermediary facilities, processors (Plastics Europe 2018) Pellets loss rate from seaport, from recycling, from pellet handlers (Eunomia 2018) CAGR (OECD Plastic Outlook) Loss rate to drains from pellets holders (Eunomia 2018)

Microplastics Losses–Personal care products	0.1	0.1	Market share of PCP consumption (Ryberg et al 2018) Share of wash-off PCP that contains MP (Sherrington et al 2016) Share of stay-on PCP that contains MP (Sherrington et al 2016) Microplastic concentration in wash-off and stay-on PCP (Sherrington et al 2016)

***Note:** There is no widely agreed volume of plastic losses nor more general volume of plastic gear use in fisheries and aquaculture. Some of the commonly share numbers have been questioned (Richardson, 2021). The lack of data in the field has forced us to make some assumptions and use the latest numbers from reliable sources to complete the analysis on fisheries and aquaculture.

Sources:
- Microplastics: The Pew Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution"
- Microplastics from paint: Paruta et al., "Plastic Paints the Environment" Environmental Action, 2022.
- Microplastics from tyres: Monteith et al. 2015, 2016, 2017
- Microplastics from textiles: Pakula, C. and Stamminger 2010; Laitala, K., Klepp, I.G., Henry, B. "Global laundering practices – Alternatives to machine washing", 2017
- Microplastics from pellets: Hann, S. Sherrington, C. et al "Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products" Eunomia, 2018; PlasticsEurope "Plastics Facts" 2018.
- Microplastics from PCP: Ryberg, M., Laurent, A., & Hauschild, M. Z. "Mapping of global plastic value chain and plastic losses to the environment: with a particular focus on marine environment" United Nations Environment Programme, 2018.
- C. Sherrington, C. Darrah, G. Cole, M. Corbin, S. Hann "Study to support the development of measures to combat a range of marine litter" Report for European Commission DG Environment, Eunomia, 2016.

The packaging sub-system was further split into the following categories: Beverage bottles (a food-grade bottle used for water, beverages, and other drinks applications), Rigid mono-material plastics [an item made from a single plastic polymer that holds its shape such as a non-food bottle or tub], Flexible mono-material plastics [an item made from a single plastic polymer, that is thin such as plastic wraps and bags], Multilayer plastics [an item, made of multiple plastic polymers that cannot be easily and mechanically separated], and multi-materials [an item made of plastic and non-plastic materials - such as thin metal foils or cardboard layers - that cannot be easily and mechanically separated], consumer goods.

Many plastic types are produced, converted, and then spend several years "in use" before they reach their end-of-life and become waste that needs to be managed. The model needs to consider this to reflect the delayed impact that any upstream levers may have. For example, if plastic is eliminated in the construction of all houses starting in 2025, this would have very little impact in the model timeline to 2040, because these houses last an average of 40 years before creating waste. The model uses the following methodology to account for this:

1. For each plastic type three inputs are taken: plastic entering the stock, lifetime, and standard deviation of a given plastic type
2. The plastic entering stock input is distributed across future years in which it will become waste (reach end-of-life) via a Weibull distribution, which depends on the lifetime and standard deviation parameters of the plastic type.
3. These quantities of plastic becoming waste are added up for each year, yielding the waste created in every year by the previous years.
4. This function is also applied to "reduced" and "substituted" plastic utility to translate the utility quantities into the amount of waste that is reduced and substituted by this measure.

The resulting waste quantities are then modelled across the remainder of the system map.

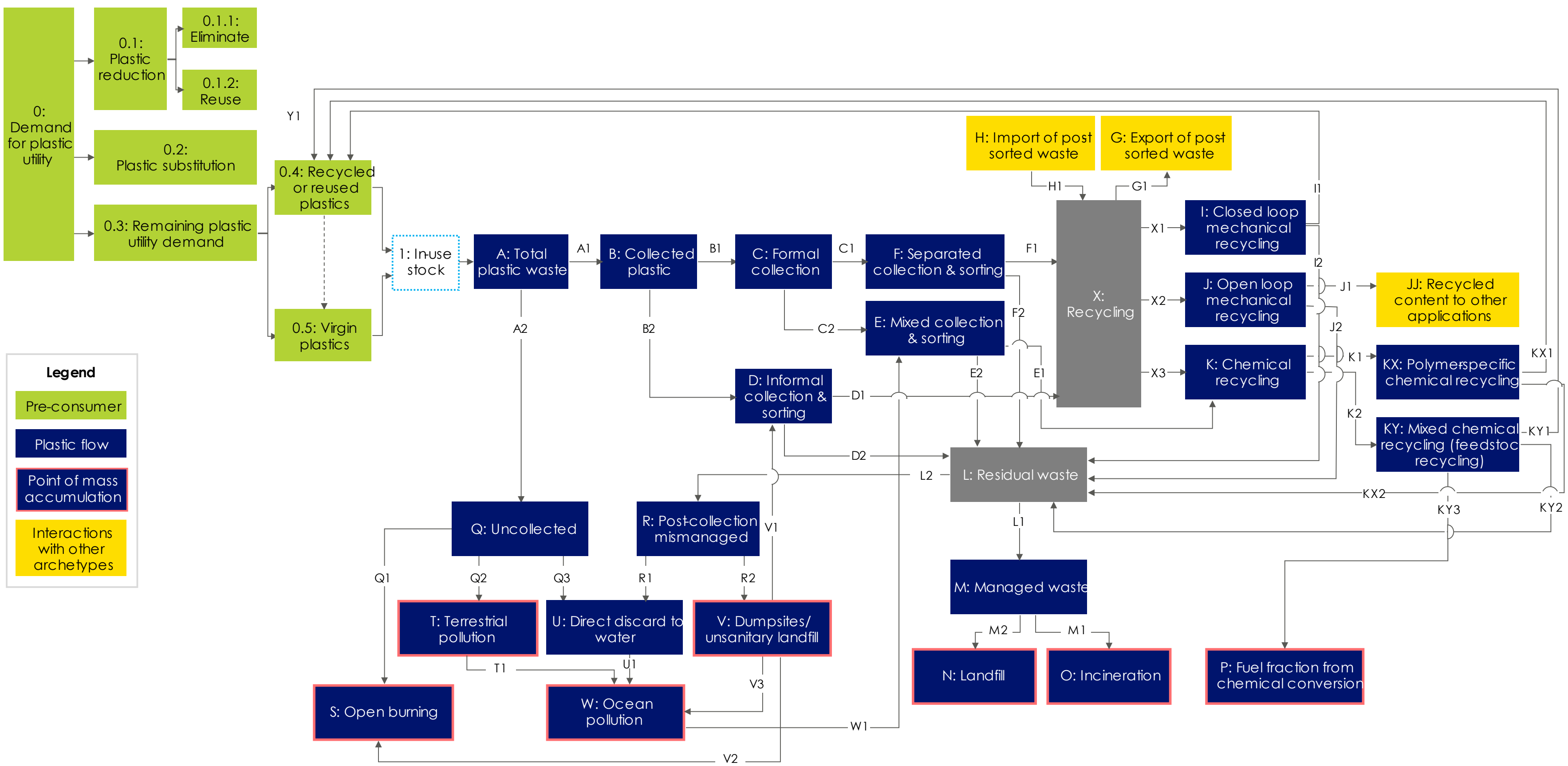
Table 4: Mean and standard deviation of plastic usage lifetime

Plastic category	Mean (years)	Standard deviation (years)	Source
Packaging	1	0	(Geyer, 2017)
Consumer goods	3	1	(Geyer, 2017)
Construction	35	7	(Geyer, 2017)
Transportation	13	3	(Geyer, 2017)
Textile sector - clothing	5	1.5	(Geyer, 2017)
Textile sector - others	5	1.5	(Geyer, 2017)
Electronics	8	2	(Geyer, 2017)
Agriculture	1	0	(FAO, 2021). 1 year as average across plastic categories
Fisheries	2 (R1, R2, R3) 1 (R4, R5, R6, R7, R8)	1	Systemiq, Handelens Miljøfond, and Mepex (2023) Adjusted with external expert validation
Aquaculture	8 (R1, R2, R3) 5 (R4, R5, R6, R7, R8)	1	Systemiq, Handelens Miljøfond, and Mepex (2023) Adjusted with external expert validation

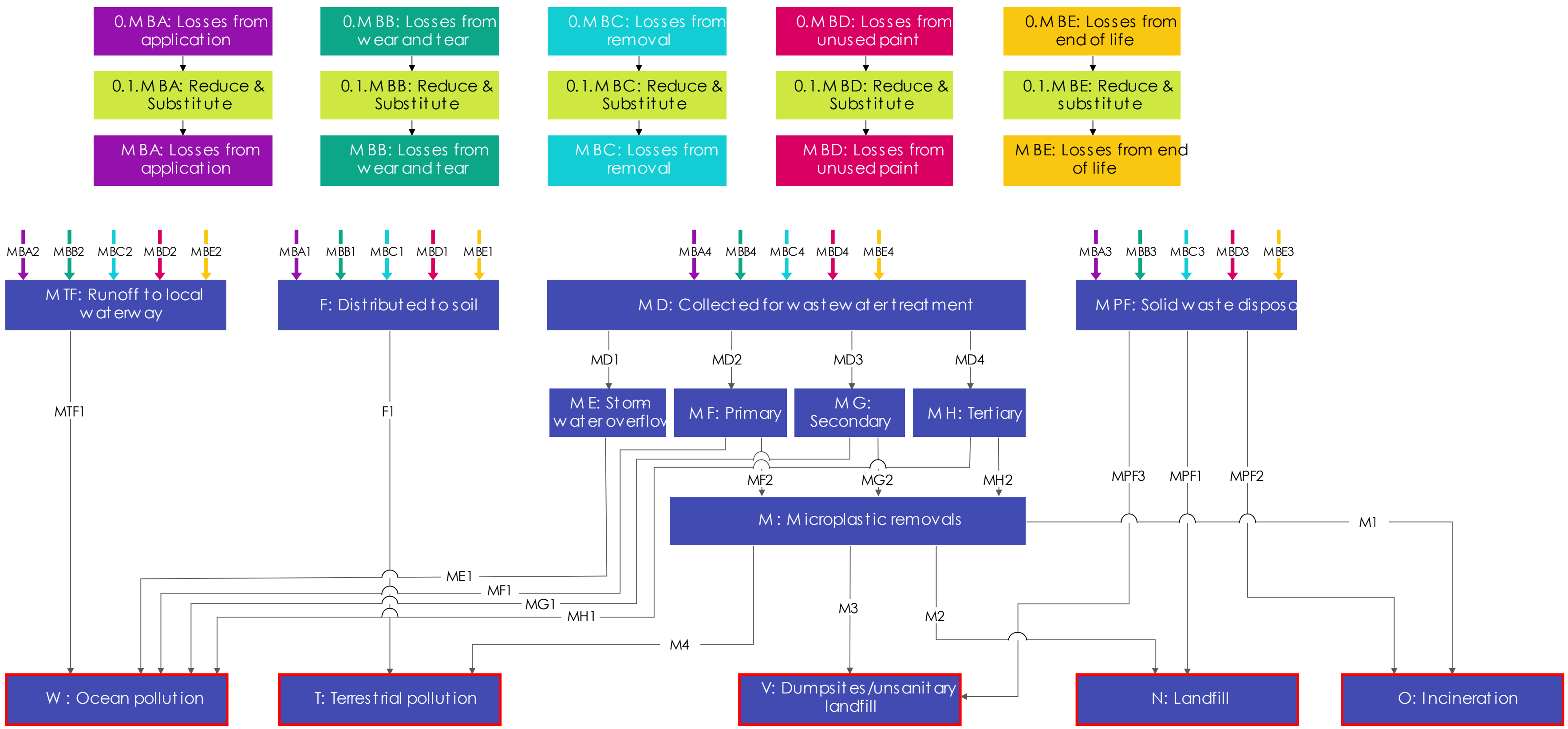
Sources: Geyer et al. "Production, use, and fate of all plastics ever made" Science Advances 3(7), 2017; Fisheries and Aquaculture: Systemiq, Handelens Miljøfond, and Mepex "Achieving circularity, A low-emissions circular plastic economy in Norway", 2023; Agriculture: FAO. 2021. Assessment of agricultural plastics and their sustainability. A call for action. Rome. https://doi.org/10.4060/cb7856en

6. Model architecture: System map

Example for the packaging & consumer goods system map:



Example for microplastics from paints system map:



For the remaining system maps, please refer to the appendix of this document.

For each sector a system map was developed to conceptualise key stocks and flows of the global plastic value chain. These system maps represent the foundation of the quantitative model. Each map consists of “boxes” which represent mass aggregation points in the model, and arrows, which represent mass flows. Boxes outlined in solid red lines represent places where plastic volumes accumulate.

The total volumes of plastic in the modelled system are determined in box 0, as demand for plastic utility. Throughout all further parts of the system map, percentage shares for each arrow then determine the flow of plastic and ultimately the final fates of the plastic waste.

The architecture of these maps was informed by previous assessments of plastic pollution including:

- The Pew Charitable Trusts and Systemiq (2020). “Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution”
- Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe
- Systemiq (2023). Achieving Circularity for Durable Plastics, A low-emissions circular plastics economy in Norway
- World Bank (2022). The Plastics Policy Simulator.
- Global Plastics Action Partnership (2022). National Analysis and Modelling Tool

Each map inhibits six broad categories to describe the various stages of plastic through its life cycle: production and consumption, collection and sorting, recycling, disposal, and mismanaged waste.

The packaging & consumer goods system mapped above represents the most detailed map of all sectors and was slightly modified to establish the system maps of the other sectors. The exception are the microplastics maps, which were developed individually for each type of microplastic, and only match the other system maps in their points of mass accumulation.

7. The Business as Usual Scenario

The Business as Usual Scenario models the trajectory that plastic demand and waste will take if no further policies and interventions are put into place until 2040. The Business as Usual Scenario relies on forecast on the increase of plastic consumption by region and by application (see table 3) and in existing data for each step in the system maps presented above (for example, collection rates, recycling yields, etc.). The data points for the Business as Usual Scenario are presented below.

Packaging & Consumer goods Baseline values

Table 5: Datapoints in the system map: Packaging and consumer goods

Steps in system map (Model ID) Value for 2019	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Collection rates (Arrow A1)	98%	98%	98%	85% (U) 45% (R)	97% (U) 45% (R)	80% (U) 45% (R)	80% (U) 45% (R)	65% (U) 45% (R)
Formal collection (Arrow B1)	100%	100%	100%	See notes	See notes	See notes	See notes	See notes
Segregated collection - Bottles (Arrow C1)	65%	29%	44%	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)
Segregated collection – Rigid mono-materials (Arrow C1)	42%	22%	44%	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)
Segregated collection – Flexible mono-materials (Arrow C1)	38%	15%	16%	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)
Segregated collection – Multi-layer Multi-materials (Arrow C1)	0%	0%	0%	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)
Segregated collection - Consumer goods (Arrow C1)	3%	0%	0%	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)	0% (U) 0% (R)
Informal collection for recycling (Arrow D1)	n.a.	n.a.	n.a.	95% (U) 95% (R)	95% (U) 95% (R)	95% (U) 95% (R)	95% (U) 95% (R)	95% (U) 95% (R)
Collected and sorted waste sent to disposal (Arrow F2)	20%	20%	20%	20%	20%	20%	20%	20%
Unsorted waste to post collection mismanaged (Arrow L2)	0%	0%	0%	45% (U) 70% (R)	0% (U) 50% (R)	45% (U) 70% (R)	45% (U) 70% (R)	95% (U) 95% (R)

Notes:

- In plastic packaging and for Regions R4-R8, the model differentiates between urban ("U") and rural ("R") to reflect the differences between those.
- There are varying levels of formal collection (Arrow B1) between different formats (see below), with the rest assumed to be collected by the informal sector.
  - **Urban R4**: bottles 55%, rigid mono-materials: 55%, flexible mono-materials 90%, multi-materials 100%, consumer goods 90%
  - **Urban + Rural R5**: bottles 55%, rigid mono-materials: 50%, flexible mono-materials 90%, multi-materials 100%, consumer goods 90%
  - **Urban R6**: bottles 50%, rigid mono-materials: 50%, flexible mono-materials 90%, multi-materials 100%, consumer goods 90%
  - **Urban+ Rural R7**: bottles: 20%, rigid mono-materials: 50%, flexible mono-materials 90%, multi-materials 100%, consumer goods 90%,
  - **Urban R8:** bottles: 50%, rigid mono-materials: 50%, flexible mono-materials 90%, multi-materials 90%, consumer goods 50%
- In **R4, R6, R8** no informal collection is considered in **rural** areas (B1 = 100%)
- In the Business as Usual Scenario, collection and recycling rates by 2040 are assumed to remain at the same levels as of 2019, with the following exceptions that are based on existing regulations and targets
  - Textiles R1: Separated formal collection 2019: 40% -> 2040 85%
  - Packaging R1: Segregated collection: Bottles 2019: 65% -> 2040: 90%; Rigid mono-materials: 2019: 42% -> 2040: 70%; Flexible mono-materials 2019: 38% -> 2040: 60%
  - Packaging R3: Segregated collection: Bottles 2019: 44% -> 2040: 50%; Rigid mono-materials: 2019: 44% -> 2040: 50%; Flexible mono-materials R3: 16% -> 2040: 17%

Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe; THE Charitable Trusts, Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution", EPA (2020) Advancing Sustainable Materials Management: 2018 Tables and Figures, NAPCOR (2021) PET Recycling Report, Plasteax (2023) Unpublished data, World Bank (2019) Urban and Rural Municipal Solid Waste in China and the Circular Economy, India Plastics pact (2022) Material Flow of PET Used in Packaging Applications in India for the year 2021-22.

Construction Baseline values

Table 6: Datapoints in the system map: Construction

Steps in system map Value for 2019 (Model ID)	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Collection rates (Arrow A1)	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %

Share of collection via formal systems (Arrow B1)	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Segregated collection for recycling- (Arrow C1)	29 %	29 %	29 %	0%	0 %	0 %	0 %	0 %
Collected and sorted waste sent to disposal (Arrow F2)	90%	90%	90%	100%	100%	100%	100%	100%
Losses of residual waste management (Arrow L2)	0%	0%	0%	45%	45%	45%	45%	95%

Notes: Assumed no recycling in regions R4 to R8.
Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe, THE Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution"

Transportation Baseline values

Table 7: Datapoints in the system map: Transportation

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Collection rates (Arrow A1)	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Share of collection via formal systems (Arrow B1)	78 %	78 %	78 %	20 %	20 %	20 %	20 %	20 %
Collected and sorted waste sent to disposal (Arrow F2)	82 %	82 %	82 %	100 %	100 %	100 %	100 %	100 %
Losses of residual waste management (Arrow L2)	0%	0%	0%	45%	45%	45%	45%	95%

Notes: No recycling in low-income countries (R4-R8) assumed
Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe, THE Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution"

Textiles baseline values

Table 8: Datapoints in the system map: Textiles

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Collection rates (Arrow A1)	100%	100%	100%	100%	100%	100%	100%	100%
Segregated Collection (Arrow B1)	40%	16%	20%	5%	10%	0%	30%	0%
Mixed collection to Chemical Recycling (Arrow E1)	0%	0%	0%	0%	0%	0%	0%	0%
Collected and sorted waste sent to disposal (Arrow F2)	10%	10%	10%	10%	10%	90%	90%	90%
Losses of residual waste management (Arrow L2)	0%	0%	0%	30%	30%	30%	30%	50%

Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe., THE Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution", Systemiq (2023). Achieving Circularity for Durable Plastics, A low-emissions circular plastics economy in Norway, R1: European Environment Agency (2023) EU exports of used textiles in Europe's circular economy, R2: EPA - Advancing Sustainable Materials Management: 2018 Tables and Figures, R5: World Bank (2019) Urban and rural municipal solid waste in China and the circular economy, R7: India plastic Pact (2022) Material Flow of PET Used in Packaging Applications in India 2021 - 2022 & Fashion For Good (2022) Wealth in Waste

Electronics Baseline values

Table 9: Datapoints in the system map: Electronics.

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Collection rates (Arrow A1)	100%	100%	100%	100%	100%	100%	100%	100%
Share of collection via formal systems (Arrow B1)	90%	90%	90%	95%	90%	95%	95%	95%
Segregated collection - (Arrow C1)	40%	10%	10%	3%	20%	0%	0%	0%
Informal collection –	10%	10%	10%	0%	0%	0%	0%	0%

(Arrow D1)								
Mixed collection to recycling (Arrow E1)	10%	0%	0%	0%	0%	0%	0%	0%
Collected and sorted waste sent to disposal (Arrow F2)	100%	100%	100%	100%	100%	100%	100%	100%
Losses of residual waste management (Arrow L2)	0%	0%	0%	50%	50%	96%	50%	96%

Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe, THE Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution", Systemiq (2023). Achieving Circularity for Durable Plastics, A low-emissions circular plastics economy in Norway, UNITAR (2022) Global E-waste Monitor, R1: Eurostat (2020) Total collection rate for WEEE, R2: US EPA (2018) Advancing Sustainable Materials Management: 2018 Tables and Figures, R4: UNITAR (2022) Regional E-waste Monitor for Latin America 2022, R6: Plasteax (2023) Unpublished Data, R8: UNEP (2023) & Maes, T., Preston-Whyte, F. E-waste it wisely: lessons from Africa. SN Appl. Sci. 4, 72 (2022).

Agriculture Baseline values

Table 10: Datapoints in the system map: Agriculture

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Collection rates (Arrow A1)	60%	60%	60%	60%	20%	20%	20%	20%
Share of collected waste to recycling (Arrow B1)	10%	10%	10%	10%	0%	0%	0%	0%

Note: Plastic applications in agriculture is one of the areas lacking the most data and research. The analysis uses the recent FAO report (see source below) to assume different levels of arrow values in the system map.

Sources: FAO. 2021. Assessment of agricultural plastics and their sustainability. A call for action. Rome. https://doi.org/10.4060/cb7856en

Microplastic Baseline values

Table 11: Datapoints in the system map: Tyres (microplastics)

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Releases on road (runway) to soil and air – Urban (Arrow MTA/B1)	41% (41%)	41% (41%)	41% (41%)	53% (53%)	53% (53%)	53% (53%)	53% (53%)	53% (53%)
Releases on road to soil and air – Rural (Arrow MTA/B1)	74%	74%	74%	86%	86%	86%	86%	86%
Releases on road (runway) runoff to local waterways – Urban (Arrow MTA/B2)	17% (17%)	17% (17%)	17% (17%)	35% (35%)	35% (35%)	42% (42%)	42% (42%)	42% (42%)
Releases on road runoff to local waterways – Rural (Arrow MTA/B2)	14%	14%	14%	14%	14%	14%	14%	14%
Releases on road (runway) captured in combined sewage – Urban (Arrow MTA/B3)	30% (30%)	30% (30%)	30% (30%)	13% (13%)	13% (13%)	5% (5%)	5% (5%)	5% (5%)
Releases on road captured in combined sewage – Rural (Arrow MTA/B3)	0%	0%	0%	0%	0%	0%	0%	0%
Releases on road (runway) captured in sustainable drainage – Urban (Arrow MTA/B4)	13% (13%)	13% (13%)	13% (13%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
Releases on road captured in sustainable drainage – Rural (Arrow MTA/B4)	12%	12%	12%	12%	12%	0%	0%	0%

Sources: The Pew and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution", Hann, S. Sherrington, C. et al "Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products" Eunomia, 2018

Table 12: Datapoints in the system map: Pellets (microplastics)

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Releases entering drains to runoff to local waterways (Arrow MND1)	33%	33%	33%	64%	64%	90%	90%	90%
Releases entering drains to captured in combined sewage (Arrow MND2)	37%	37%	37%	18%	18%	5%	5%	5%
Releases entering drains to captured in sustainable drainage (Arrow MND3)	30%	30%	30%	18%	18%	5%	5%	5%

Sources: Hann, S. Sherrington, C. et al "Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products" Eunomia, 2018

Paints

Table 13: 20 Datapoints in the system map: Paints (microplastics)

Steps in system map Value for 2019 (Model ID)	All regions
Releases from application (Box 0.MBA)	19%
Releases from wear and tear (Box 0.MBB)	44%
Releases from removal (Box 0.MBC)	33%
Releases from unused paint (Box 0.MBD)	4%
Releases from end of life (box 0.MBE)	0%

Steps in system map Value for 2019 (Model ID)	All regions
Releases from application to soil (Arrow MBA1)	34%
Releases from application to direct waterways (Arrow MBA2)	15%
Releases from application to collected for wastewater treatment (Arrow MBA4)	5%
Releases from application to captured in mixed waste (Arrow MBA3)	46%
Releases from wear and tear to soil (Arrow MBB1)	47%
Releases from wear and tear to direct waterways (Arrow MBB2)	10%
Releases from wear and tear to collected for wastewater treatment (Arrow MBB4)	24%
Releases from wear and tear to captured in mixed waste (Arrow MBB3)	19%
Releases from removal to soil (Arrow MBC1)	43%
Releases from removal to direct waterways (Arrow MBC2)	6%
Releases from removal to collected for wastewater treatment (Arrow MBC4)	20%
Releases from removal to captured in mixed waste (Arrow MBC3)	32%
Releases from unused paint to soil (Arrow MBD1)	20%
Releases from unused paint to direct waterways (Arrow MBD2)	2%
Releases from unused paint to collected for wastewater treatment (Arrow MBD4)	8%
Releases from unused to captured in mixed waste (Arrow MBD3)	70%

Sources: Paruta et al., "Plastic Paints the Environment" Environmental Action, 2022.

Microplastic Textile release

Table 14: Datapoints in the system map: Textiles (microplastics)

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Releases from hand washing to direct waterways Urban (Rural) (Arrow MSB1)	10% (27%)	10% (27%)	10% (27%)	19% (40%)	19% (40%)	56% (60%)	56% (60%)	56% (60%)
Releases from hand washing collected for wastewater treatment Urban (Rural) (Arrow MSB2)	90% (73%)	90% (73%)	90% (73%)	47% (29%)	47% (29%)	14% (1%)	14% (1%)	14% (1%)
Releases from hand washing to terrestrial leakage Urban (Rural) (Arrow MSB3)	0% (0%)	0% (0%)	0% (0%)	34% (31%)	34% (31%)	30% (21%)	30% (21%)	30% (21%)
Releases from washing machine to direct waterways Urban (Rural) (Arrow MSC1)	10% (27%)	10% (27%)	10% (27%)	53% (71%)	53% (71%)	86% (99%)	86% (99%)	86% (99%)
Releases from washing machine collected for wastewater treatment Urban (Rural) (Arrow MSC2)	90% (73%)	90% (73%)	90% (73%)	47% (29%)	47% (29%)	14% (1%)	14% (1%)	14% (1%)
Share of production releases to direct waterways Urban (Rural) (Arrow MSA1)	10% (27%)	10% (27%)	10% (27%)	53% (71%)	53% (71%)	86% (99%)	86% (99%)	86% (99%)
Share of Production releases to treatment of production effluent Urban (Rural) (Arrow MSA2)	90% (73%)	90% (73%)	90% (73%)	47% (29%)	47% (29%)	14% (1%)	14% (1%)	14% (1%)

Share of treatment of production effluent to ocean leakage Urban (Rural) (Arrow MSE1)	27% (27%)	27% (27%)	27% (27%)	27% (27%)	27% (27%)	27% (27%)	27% (27%)	27% (27%)
Share of treatment of production effluent to microplastic removals Urban (Rural) (Arrow MSE2)	73% (73%)	73% (73%)	73% (73%)	73% (73%)	73% (73%)	73% (73%)	73% (73%)	73% (73%)

Sources: The Pew and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution"; Hann, S., Sherrington, Ch., Jamieson, O., Hickman, M., Kershaw, P., Bapasola, A., Cole, G. 2018. Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products. Report for DG Environment of the European Commission; http://data.un.org/Data.aspx?d=ENV&f=variableID%3a164

Personal Care Products

Table 15: Datapoints in the system map: PCP (microplastics)

Steps in system map Value for 2019 (Model ID)	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Releases from wash-off to direct waterways (Arrow MPC1)	10%	10%	10%	63%	63%	86%	86%	86%
Releases from wash-off to collected for wastewater treatment (Arrow MPC2)	90%	90%	90%	47%	47%	14%	14%	14%
Releases from stay-on to direct to waterways (Arrow MPD1)	70%	70%	70%	60%	60%	50%	50%	50%
Releases from stay-on to collected for wastewater treatment (Arrow MPD2)	30%	30%	30%	40%	40%	50%	50%	50%
Releases from stay-on to direct to solid waste disposal (Arrow MPD3)	0%	0%	0%	0%	0%	0%	0%	0%

Sources: The Pew and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution"; UN data on wastewater treatment; Cosmetic Europe consumer survey 2018

Textiles, Personal Care Products, Paints

Table 16: Microplastics fate: Textiles, Personal Care Products, Paints (microplastics)

Steps in system map Value for 2019 (Model ID)	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Share of collected for waste treatment to stormwater overflow (Arrow MD1)	4%	4%	4%	6%	6%	6%	6%	6%
Share of collected for wastewater treatment to primary (Arrow MD2)	13%	13%	13%	34%	34%	34%	34%	34%
Share of collected for wastewater treatment to secondary (Arrow MD3)	50%	50%	50%	60%	60%	60%	60%	60%
Share of collected for wastewater treatment to tertiary (Arrow MD4)	33%	33%	33%	0%	0%	0%	0%	0%
Share of primary to ocean leakage (Arrow MF1)	27%	27%	27%	27%	27%	27%	27%	27%
Share of primary to microplastic removal (Arrow MF2)	73%	73%	73%	73%	73%	73%	73%	73%
Share of secondary to ocean leakage (Arrow MG1)	6%	6%	6%	6%	6%	6%	6%	6%
Share of secondary to microplastic removal (Arrow MG2)	94%	94%	94%	94%	94%	94%	94%	94%
Share of tertiary to ocean leakage (Arrow MH1)	2%	2%	2%	2%	2%	2%	2%	2%
Share of tertiary to microplastic removal (Arrow MH2)	98%	98%	98%	98%	98%	98%	98%	98%

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Share of Microplastics removal to incineration (Arrow M1)	22%	22%	22%	12%	12%	0%	0%	0%
Share of Microplastics removal to landfills (Arrow M2)	34%	34%	34%	22%	22%	2%	2%	2%
Share of Microplastics removal to dumpsite (Arrow M3)	1%	1%	1%	16%	16%	48%	48%	48%
Share of Microplastics removal to terrestrial pollution (Arrow M4)	44%	44%	44%	50%	50%	50%	50%	50%

Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe; The Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution"; P. Simpson, senior scientific officer, European Chemicals Agency, "REACH Restriction on Intentional Uses of Microplastics," (presentation, MICRO2018, Nov. 22, 2018), https://echa.europa.eu/ documents/10162/23668985/20181122_presentation_ simpson.pdf/6f9d4b7c-afe7-f868-bf48-92907b0f3a5d

Fisheries and Aquaculture baseline values

Table 17: Datapoints in the system map: Fisheries

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
General collection rates (Arrow A1)	93%	93%	93%	88%	88%	88%	88%	88%
Formal collection (Arrow B1)	95%	95%	95%	15%	50%	15%	15%	15%
Formal collection to recycling – (Arrow F1)	4%	4%	4%	1%	1%	1%	1%	1%
Losses of residual waste management (Arrow L2)	0%	0%	0%	47%	47%	47%	47%	96%

Notes:

- *Please note that little data is available in this field. We have therefore made some high-level assumptions to model the plastic flows in fisheries and aquaculture*
- A2 (non-collection rate) assumptions:
  - The losses from industrial fishing gear during gear use has been estimated at 2% (Kuzcenski et al. 2021; Richardson 2022)
  - Artisanal fishing sees more losses and can be identified through the size of fishing vessels. Small vessels for artisanal fishing use types of fishing gear that leads to more losses such as gillnets and pots and traps (Global Ghost Gear Initiative 2021). We assume that artisanal fishing leads to double the industrial fishing losses or 4% losses in the high-income regions and to quadruple the industrial fishing losses in the middle- and low-income regions, or 8%. This is especially as the middle- and low-income regions have around 50% of their fleet that represent non-motorised fishing vessels compared to virtually none in the high-income regions, which would lead to larger numbers of smaller-scale and poor quality gear and gear abandonment. This is especially the case for Asia (especially South and Southeast Asia) – which is home to more than 85% of the global fishing fleet and 90% of the global non-motorised fleet (FAO, 2022).
  - In addition to industrial and artisanal fishing, we have attempted to account for losses from illegal fishing. Illegal Unreported Unregulated (IUU) fishing index in middle- and low-income regions has an index around two times worse than the high-income regions (Global Initiative, Global Fishing Net Index 2021). We assume 1% losses in the high-income regions and 2% in middle- and low-income regions
- Arrow D1: We assume that this is equal to F1 (formal collection). These are no items widely collected by informal sector due its difficult recycling and degradation. We still assume some informal collection in Europe in very remote areas.

Sources:

- Arrow A1: Kuzcenski et al. "Plastic gear loss estimates from remote observation of industrial fishing activity" Fish and Fisheries 23 (1), 2022; Kuczenski et al. "A model for intensity of fishing gear" Journal of Industrial Ecology 26(2), 2021; Richardson et al "Global estimates of fishing gear lost to the ocean each year" Science Advances 8(41), 2022; Global Ghost Gear Initiative "The impact of fishing gear as a distinct source of marine plastic pollution" Ocean Conservancy, 2021; Global Initiative (Global Fishing Net Index 2021); FAO "The state of the World Fisheries and Aquaculture" 2022.
- Arrow B1: R1,2,3 external expert validation; R3,6,7,8 Poseidon Aquatic Resource Management Ltd, Vietnam and Indonesia report and external expert validation; R5 assumption fall between the two groups of regions
- Arrow F1: EU estimation and expert validation
- Arrow L2: R1,2,3 Reshaping Plastics; R4, 5, 6, 7, 8 Breaking the Plastic Wave, The and Systemiq, 2020

Table 18: Datapoints in the system map: Aquaculture

Steps in system map Value for 2019 (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
General collection rates (Arrow A1)	98%	98%	98%	93%	93%	93%	93%	93%
Formal collection (Arrow B1)	95%	95%	95%	50%	50%	15%	50%	15%
Share of sorted collection to recycling (Arrow F1)	10%	10%	10%	5%	5%	5%	5%	5%

Share of Informal collection to recycling (Arrow D1)	10%	10%	10%	5%	5%	5%	5%	5%
Losses of residual waste management (Arrow L2)	0%	0%	0%	47%	47%	47%	47%	96%

Notes:

- Arrow A2 (non-collection rate): R1, R2, R3 Systemiq, Handelens Miljøfond, and Mepex (2023) leading to 2% gear losses in Aquaculture; R4, R5, R6, R7, R8 Poseidon Aquatic Resource Management Ltd Indonesia report (6%) and use of bottles and containers as floater with large estimated loss (1%), leading to 7% of aquaculture gear losses.
- Arrow B1: R4, R5, R6, R7, R8, 80% of HDPE leads to higher collection than fisheries
- Arrow D1: We assume that this is equal to F1 (formal collection). More collection as 80% is composed of HDPE, although often degraded.

Sources:

- Arrow A1: Systemiq, Handelens Miljøfond, and Mepex "Achieving circularity, A low-emissions circular plastic economy in Norway", 2023; Poseidon Aquatic Resource Management Ltd Indonesia report, 2022.
- Arrow B1, D1, F2: Systemiq, Handelens Miljøfond, and Mepex "Achieving circularity, A low-emissions circular plastic economy in Norway", 2023); External expert validation
- Arrow L2: R1,2,3 Reshaping Plastics; R4, 5, 6, 7, 8 Breaking the Plastic Wave, The and Systemiq, 2020

Non-sector specific baseline values

Table 19: Mechanical recycling general values which are not specific to the sector

Steps in system map Value for 2019 (Model ID)	R1 – R8
Residual waste from mixed collection (Arrow E2)	100%

Notes: The Business as Usual Scenario assumes that mixed waste is not sorted in a way that allows to send any volumes to recycling, neither mechanical nor chemical.

Sources: THE Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution", World Bank (2022). The Plastics Policy Simulator, Global Plastics Action Partnership (2022). National Analysis and Modelling Tool

Table 20: Mechanical recycling general values which are not specific to the sector

Steps in system map Value for 2019 (Model ID)	Packaging	Textiles	Electronics	Construction	Transportation	Fisheries & Aquaculture
Losses from closed loop mechanical recycling (Arrow I1)	27%	30%	40%	27%	26%	27%
Losses from open loop mechanical recycling (Arrow J1)	27%	30%	40%	27%	26%	30%

Notes: Losses from open-/close-loop mechanical recycling are constant across regions

Table 21: Chemical recycling general values which are not specific to the sector

Steps in system map Value for 2019 (Model ID)	All regions
Polymer specific chemical recycling (Arrow K1)	0%
Polymer-specific chemical recycling yield to plastic (Arrow KKX1)	82%
Closed loop mixed waste chemical recycling (Arrow KY1)	50%
Fuel Fraction from mixed waste chemical recycling (Arrow KY3)	30%

Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.

Table 22: Managed waste general values which are not specific to the sector

Steps in system map Value for 2019 - (Model ID)	R1	R2	R3	R4	R5	R6	R7	R8
Incineration (Arrow M1)	68%	22%	43%	0%	40%(U) 0% (R)	0%	0%	0%
Landfill (Arrow M2)	32%	78%	57%	100%	60% (U) 100% (R)	100%	100%	100%

Notes: Incineration or landfill mix reflect the current share of each alternative by region. Only countries that have active incineration are reflected. For all other regions, it is assumed that 100% of all managed waste goes to landfills

Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe., THE Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution", R2: EPA - Advancing Sustainable Materials Management: 2018 Tables and Figures, R3: Plasteax (2023) unpublished data, R5: "World Bank Group (2019) Urban and Rural Municipal Solid Waste in China and the Circular Economy: A Brief Overview and Opportunities Going Forward, R7: India Plastics Pact (2022) Material Flow of PET Used in Packaging Applications in India for the year 2021-22

Table 23: Mismanaged general values

Steps in system map Value for 2019 (Model ID)	Mismanaged waste flows (example for packaging)			
	Urban		Rural	
	R1 – R3 Bottles/ Rigid mono-materials	R4-R8 Flexible mono-materials, multi-material / multi-layer, consumer goods	R1 – R3 Bottles/ Rigid mono-materials	R4-R8 Flexible mono-materials, multi-material / multi-layer, consumer goods
Share uncollected to open burning (Arrow Q1 NW)	22%	22%	60%	60%
Share uncollected to terrestrial pollution (Arrow Q2 NW)	58%	58%	20%	20%
Share uncollected to direct discard to water (Arrow Q3 NW)	20%	20%	20%	20%
Terrestrial dumping that leaks to water (Arrow T1 NW)	10%	35%	10%	35%
Share uncollected to open burning (Arrow Q1 FfW)	22%	22%	60%	60%
Share uncollected to terrestrial pollution (Arrow Q2 FfW)	78%	78%	40%	40%
Share uncollected to direct discard to water (Arrow Q3 FfW)	0%	0%	0%	0%
Terrestrial dumping that leaks to water (Arrow T1 FfW)	3%	8%	3%	8%
Share Post-collection mismanaged to direct discard to water (Arrow R1 NW)	5%	5%	5%	5%
Share Post-collection mismanaged to Dumpsite/unsanitary landfill (Arrow R2 NW)	95%	95%	95%	95%
Share dumpsite/unsanitary landfill to open burning (Arrow V2 NW)	22%	22%	60%	60%
Share dumpsite/unsanitary landfill to ocean pollution (Arrow V3 NW)	1%	8%	1%	8%
Share Post-collection mismanaged to direct discard to water (Arrow R1 FfW)	22%	5%	5%	5%
Share Post-collection mismanaged to Dumpsite/unsanitary landfill (Arrow R2 FfW)	78%	95%	95%	95%
Share dumpsite/unsanitary landfill to open burning (Arrow V2 FfW)	0%	22%	60%	60%
Share dumpsite/unsanitary landfill to ocean pollution (Arrow V3 FfW)	1%	3%	1%	3%

Notes:

- Where numbers are different it is differentiated between Near Water (NW) and Far from Water (FfW). NW population within 1km of ocean or rivers, FfW means all population further away than 1km from oceans or rivers.
- There are no mismanaged volumes from durable products (construction, transportation, electronics) or textiles because they are considered to end up in dumpsites

Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe., THE Charitable Trusts and Systemiq (2020). “Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution”, Systemiq (2023). Achieving Circularity for Durable Plastics, A low-emissions circular plastics economy in Norway, R2: EPA - Advancing Sustainable Materials Management: 2018 Tables and Figures, R5: World Bank (2019) Urban and rural municipal solid waste in China and the circular economy

Input for Jobs, GHG, OPEX, CAPEX data

Table 24: Job creation (Jobs/1000 metric tonnes/year)

Variable name	Jobs (Jobs/1000 metric tonnes/year)
Virgin plastic production (Box 0.5_jobs)	8.0
Plastic conversion (Box 0.3_jobs)	5.0
Formal collection (Box C_jobs)	2.8
Informal collection & sorting (Box D_jobs)	0.1
Sorting of separately collected waste (Box F_jobs)	2.0
Sorting of mixed collected waste (Box E_jobs)	0.1
Closed loop Mechanical Recycling (Box I_jobs)	3.0
Open loop Mechanical Recycling (Box J_jobs)	3.0
Polymer-specific chemical recycling (P2P) (Arrow KX1_jobs)	6.0
Mixed Chemical Recycling (P2P) (Arrow KY1_jobs)	6.0
Mixed Chemical Recycling (P2F) (Arrow KY3_jobs)	2.0
Incineration (Box O_jobs)	0.1
Engineered landfills (Box N_jobs)	0.1
Reduce – Eliminate (Box 0.1.1_jobs)	0.0
Reduce – Reuse (Box 0.1.2_jobs)	15.2
Substitute (Box 0.2_jobs)	54.9

Notes: Table 24 applies to all regions and plastic categories.

Table 25: Greenhouse Gas Emissions

In tCO2e/metric tonnes) – of each step, not of the full cycle

Variable name	tCO2e/metric tonnes
Virgin plastic production	2.7
Plastic conversion	1.3
Formal collection	0.1
Informal collection & sorting	0.1
Sorting of separately collected waste	0.1
Sorting of mixed collected waste	0.1
Closed loop Mechanical Recycling	0.8
Open loop Mechanical Recycling	0.8
Polymer-specific chemical recycling (P2P)	1.6
Plastic to Fuel (P2F)	0.7
Incineration	1.4
Engineered landfills	0.1
Reduce – Eliminate	0.0
Reduce – Reuse	1.6
Substitute	2.5

Notes

- Table 25 applies to all regions and plastic categories.
- When analysing GHG emissions, the scope of the study covers the production, without the extraction phase, and end-of-life carbon emissions only. The use-phase emissions benefits of plastic (e.g., insulation of buildings, light-weighting of vehicles, and more) are not quantified within this study although they are considered in the analysis.
- To calculate the full GHG emissions of a chemical recycling cycle of one metric tonne, the following must be added together: KX1 + KY1 + plastic conversion and KX1 + KY3 + plastic conversion.

Table 26: Capital Expenditure

CAPEX, in $/metric tonnes annualised versus total asset duration and tonnage capacity

Variable name	Model ID	CAPEX ($) (R1, R2, R3)	CAPEX ($) (R4, R5)	CAPEX ($) (R6, R7, R8)
Virgin plastic production	Box 0.5_capex	338	338	338
Plastic conversion	Box A_capex	223	223	223
Formal collection	Box C_capex	64	32	26
Informal collection & sorting	Box D_capex	0	0	0
Sorting of separately collected waste	Box F_capex	51	38	25
Sorting of mixed collected waste	Box E_capex	51	38	25
Closed loop MR	Box I_capex	160	120	120
Open loop MR	Box J_capex	120	90	90
Polymer-specific chemical recycling (P2P)	Arrow KX1_capex	67	51	51
Mixed chemical recycling (P2P)	Arrow KY1_capex	56	42	42
Mixed chemical recycling (P2F)	Arrow KY3_capex	153	115	115
Incineration	Box O_capex	28	21	21
Engineered landfills	Box N_capex	23	23	17
Reduce - Eliminate	Box 0.1.1_capex	0	0	0
Reduce - Reuse	Box 0.1.2_capex	259	194	194
Substitute	Box 0.2_capex	300	300	300

Notes:

- Fore Textiles, agriculture, Transportation, Fishery and Aquaculture: For Reduce (Box 0.1) Capex is $0 in all regions because plastic is eliminated for those sectors and no Capital is needed for that.
- For Construction, Electronics: For Reduce (Box 0.1) Capex is $300 in all regions because for those sectors, plastic is substituted with other materials which requires capital expenditure.
- The baseline numbers are for High income regions (R1, R2, R3). For Upper Middle Income regions discounts factors between 50% - 100% are applied depending on variable, for Lower Middle income regions discount factors between 40% - 100% are applied depending on variable. This is calculated to account for differences in income depending on regions and subsequently the cost (The PWE and Systemiq (2020).

Table 27: Operational Expenditure

OPEX, in $/metric tonnes per year)

Variable name	Model ID	OPEX ($) (R1, R2, R3)	OPEX ($) (R4, R5)	OPEX ($) (R6, R7, R8)
Virgin plastic production	Box 0.5_opex	1,013	1,013	1,013
Plastic conversion	Box A_opex	668	668	668
Formal collection	Box C_opex	149	75	60
Informal collection & sorting	Box D_opex	315	315	315
Sorting of separately collected waste	Box F_opex	156	117	78
Sorting of mixed collected waste	Box E_opex	156	117	78
Closed loop MR	Box I_opex	569	427	285
Open loop MR	Box J_opex	410	308	205
Polymer-specific chemical recycling (P2P)	Arrow KX1_opex	457	343	228
Mixed chemical recycling (P2P)	Arrow KY1_opex	2,197	1,647	1,098
Mixed chemical recycling (P2F)	Arrow KY3_opex	402	302	201
Incineration	Box O_opex	191	96	77
Engineered landfills	Box N_opex	8	8	6
Reduce - Eliminate	Box 0.1.1_opex	0	0	0
Reduce - Reuse	Box 0.1.2_opex	1,159	869	869
Substitute - Production	Box 0.2_prod_opex	3,449	3,449	3,449
Substitute - Waste management (EOL)	Box 0.2_eol_opex	647	324	259

Notes:

- For Textiles, agriculture, Transportation, Fishery and Aquaculture: For Reduce (Box 0.1) Opex is $0 in all regions because for those sectors plastic is eliminated and on operational expenditure is needed for that
- For Construction, Electronics: For Reduce (Box 0.1) Opex is $4,096 in all regions because for those sectors, plastic is substituted with other materials which requires capital expenditure.
- Metrics: Job creation: Jobs/1000 metric tonne/year; Reduce: Jobs/metric tonne reduced; Substitute: Jobs/metric tonne substituted
- The baseline numbers are for High income regions (R1, R2, R3). For Upper Middle Income regions discounts factors between 50% - 100% are applied depending on variable, for Lower Middle income regions discount factors between 40% - 100% are applied depending on variable. This is calculated to account for differences in income depending on regions and subsequently the cost (The PWE and Systemiq (2020).

Sources: Systemiq (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe., The PEW Charitable Trusts and Systemiq (2020). "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution, Systemiq & The Recycling Partnership (2021) Plastic IQ

8. The Global Rules Scenario

The Global Rules Scenario estimates the impact in the system map from a series of ambitious yet realistic policies across 4 pillars. The exhibit below shows the policies that were included:

FIGURE 7 **15 policy interventions in the Global Rules Scenario**

The full package of policies that builds the Global Rules Scenario includes policies that:

- Have been modelled as inputs: this means that certain parameters are fed as inputs into the model, for example an EPR fee, or an impact from new designs, and the model calculates the impact of such input metrics on the plastic stock and flows.
- Have been modelled as outputs: Mainly the targets. These are outputs of the model, for example the resulting reduction in virgin volumes in the system or the collection rates reached by 2040 in each region. Despite being outputs from the model, they are guided by the calibration of the inputs above.
- Have not been modelled, and are presented qualitatively in the report: Some policies are not connected to the model and are discussed qualitatively in the report (in these cases it is clearly stated at the beginning of that section)

The following sections explain how each policy was modelled and designed.

Policy intervention #1 – Targets to reduce virgin plastic volumes

In this analysis, the virgin reduction targets are not an input into the model, but rather an output. Targets presented in the report are shown as a series of ranges differentiated by regions. All other policy interventions combined result in the virgin plastic reduction reached by the Global Rules Scenario. The levels of virgin plastic reduction are therefore shown to provide ranges of what a potentially target. Ranges are shown in table 28 and are relative to 1) 2019 volumes and 2) 2040 Business as Usual volumes, each split by geography.

Table 28: Virgin plastic reduction by 2040 in the Global Rules Scenario

Virgin plastic reduction by 2040 in the Global Rules Scenario as a result of all policies	Relative to 2019 volumes	Relative to 2040 Business as Usual volumes
USA and Canada	-63%	-73%
Europe	-56%	-66%
Japan, Republic of Korea, and Oceania	-51%	-65%
China	-36%	-62%
Central and South America	-38%	-60%
South and Southeast Asia, and Eurasia	+7%	-38%
Africa and Middle East	+8%	-48%
India	+56%	-48%
Global	**-30%**	**-58%**

In the report, the drivers behind the reduction are explained in detail.

Policy intervention #2 – Virgin plastic fees to fund solutions across the plastic life cycle

In the analysis, virgin plastic fees are conceptualised to raise funds relative to the amount of virgin plastic volumes. In the Global Rules Scenario, the fee would be applied at a national level, likely to national plastic producers (if the country produces plastic) and to importers of products containing virgin plastic. The revenue is invested in the same region where it is raised, i.e., the same region as where consumption is.

These revenues are assumed to be invested to expand solutions across the plastic lifecycle, including incentives for new models like reuse, as well as waste collection, sorting and disposal infrastructure. Through increased collection and sorting these revenues would increase the supply of recycled plastics, thus reducing volumes of virgin plastics in the system.

In theory, fees on virgin plastics could decrease plastic demand over time; however, this analysis found no publicly available data to support this. Therefore, the model behind this analysis does not consider any impact on plastics demand from applying virgin plastic fees, even though this may be the case. However, when applying fees to virgin plastics the model does consider recycled plastics to gain market share over time. Empirical evidence exists that recycled plastics can grow in market share at the expense of virgin plastics (EMF, 2022; US Plastics Pact, 2021; NAPCOR, 2021), even when recycled plastics traded at a premium relative to virgin plastics (e.g. recycled plastics in the US trading at 10–20% higher prices versus virgin plastics (ICIS, 2022)).

The virgin plastic fee methodology is explained below.

1. **Revenue**
   - A certain fee per tonne of plastic is applied (see table below), calibrated by region since the fees could be passed on to consumer prices.
   - The revenues are calculated by multiplying virgin plastic consumption volumes in each region by the fee per tonne applied
   - The fee is assumed to grow over time to give industry time to adapt
   - The virgin fee is non-eco-modulated: it is applied equally to any ton of virgin plastic across all sectors
2. **Administrative costs** to run the fund and its administration are assumed to cover 30% of the total revenues. The remaining 70% is assumed to be invested in solutions.
3. **Allocation of revenues** is split along the value chain.
   - **Allocating revenue to upstream solutions:** Out of the revenues invested in solutions, 30% is subtracted as investment into upstream measures (direct impact of these investments was not modelled).
   - **Allocating revenue to downstream solutions**: The remaining revenue is allocated to building out collection, sorting and controlled disposal infrastructure by the public sector. Recycling and reuse investments on the other hand are assumed to be private sector investments. For collection, sorting, and controlled disposal, revenue is allocated as follows:
     i. In R1, R2, R3 (advanced collection and disposal infrastructure), revenue allocated to segregated collection schemes
     ii. In R4 to R8, revenue is allocated to expand collection, sorting, and disposal. The share that each part of the value chain receives is in direct proportion to their costs, such that the capacity for each will increase by the same tonnage amount (assumption that the value chain scales simultaneously).
4. **Estimating the increase in capacity of collection, sorting and controlled disposal from the estimated revenue**: The model assumes the fee will start taking effect from 2025. The generated revenues are allocated to expand capacity by comparing revenue raised to the cost (OPEX and CAPEX) of each step in the value chain for one ton of plastic waste. This comparison follows this process:
   i. For each step (collection, sorting, controlled disposal), the "dollar cost per tonne of plastic waste" is scaled by a factor. This is to account for the fact that plastic is mostly not collected, sorted, or disposed of in isolation, and in many waste streams will be managed with other waste materials (paper, metals, mixed waste).
   ii. For example, a factor of 4 is applied to collection cost per ton of plastic waste from packaging and consumer goods. This factor is estimated comparing to data of collecting all waste, not just plastics.
   iii. Then the allocated dollar revenue to that step is divided by that scaled cost, to result in an incremental capacity (in tons) from that investment
   iv. The capacity addition is calibrated with region-specific levels of implementation, to acknowledge different levels of difficulty to expand systems in each region: 100% in R1-3, 85% in R4-5; and 70% R6-8
5. **Increasing capacity in the system map**: The capacity addition of each value chain step, is then added to the baseline tonnage value to calculate the new levels of collection, sorting, or disposal. Revenue invested will materialise capacity addition one year later to account for time required for establishing the added capacity. Hence, with financial policies starting in in 2025, the first addition in capacity would materialise in 2026. Capacity is added until either 2040 is reached, or a maximum constraint (e.g., 98% collection rate) is reached. Note: because costs are annualised both for OPEX and CAPEX, each ton of capacity added will need to be paid for again in all other years that follow.

Table 29: Virgin plastic fees across regions

Region	Virgin Plastic Fee considered	
	By 2030	**By 2040**
Europe, USA and Canada, Japan, Republic of Korea, Oceania	US$1,000/ton	US$2,000/ton
China, Central/South America and the Caribbean	US$750/ton	US$1,500/ton
India, Eurasia, South and South-East Asia, Africa and the Middle East	US$500/ton	US$1,000/ton

The model leveraged ranges in OECD's Global Plastics Outlook Policy Scenarios to 2060, adapting to a 2040 timeline, and with some modifications by region. The Global Rules Scenario assumes these fees applied only to virgin plastic.

Policy intervention #3 – Application-specific levers to reduce plastic consumption

Some policies applied In the Global Rules Scenario only apply to specific sectors and therefor require specific demand measures as explained below.

Table 30: Reduction of consumption and reduction of losses in fishing gear

Sector	**Reduction consumption levels by 2040 relative to Business as Usual 2040 (Model ID - Arrow 0.1)**	**Source / Rationale**
Construction	30% by 2040 versus 2040 Business as Usual in R1, R2 R3, R4, and R5	The scenario leverages exiting estimates from the *Phasing Out Plastics* report (ODI, 2020). The reduction potential is based on 1) lower demand for plastic materials 2) A move away from demolishing buildings before the end of their useful life towards compact cities that prioritise renovation and refurbishment; 3) substitution of plastic through voluntary and mandatory standards, better quality, and 4) more comparable full-lifecycle data. This would lead to material choices based on lifetime cost which favours other materials than plastics (ODI, 2020).
Transportation	17% by 2040 versus 2040 Business as Usual in R1, R2, R3, and R5	The scenario leverages exiting estimates from the *Phasing Out Plastics* report (ODI, 2020) which models a reduction of plastic demand vs a business as usual scenario though an increase of Mobility as a Services (MaaS) business models which lead to higher utilisation of cars and thus less cars purchased / produced. MaaS models include ridesharing, car-sharing, mobility-as-a-service, and managed fleets of shared vehicles, with a combination of governments encouraging increased vehicle utilisation, occupancy, and lifespan and thus a reduction in total cars sold in 2040 compared with the BAU scenario, resulting in lower demand for plastic (ODI, 2020).
Textiles	32% in R1, R2, R3, R5 24% in R4, R6, R7 0% in R8	A 32% reduction in textiles comes 1) from a ban on the destruction of unsold textiles (from overproduction and returns, ACE Hub, 2023; EEB, 2021); and 2) a mandate to limit fast fashion which is aimed at reversing the trend of diminished wears per item so that textiles are again used longer and thus less items are bought (EU, 2022).
Electronics	50% R1, R2, R3, R4, R5	A 50% reduction in electronics comes from a combination of 1) a ban on the destruction of unsold items (Euroactive, 2023) and 2) longer lifespans through right to repair combined with a repairability index (France, 2020; EMF, 2021). The scenario also leverages exiting estimates from the *Phasing Out Plastics* report. The reduction in plastic demand is achieved by 1) changing the design of electronics by 2050 through modular design for disassembly to facilitate reuse and extend product life; and 2) the substitution of plastics with other materials: metals, wood, and ceramics could replace the use of PP and PE for structural uses and casings and the use of PUR and PS for insulation (ODI, 2020).
Agriculture	50% reduction in relative to 2040 Business as Usual in R1, R2, R3, R4 and R6 0% reduction relative to 2040 Business as Usual in R5, R7 and R8	Plastics in agriculture are an area with limited data / evidence of reduction potential. The analysis assumes expansion of product lifespans (e.g., via higher thickness of mulching films) can double, reducing relative consumption by half versus Business as Usual. Key source: FAO. 2021. Assessment of agricultural plastics and their sustainability. A call for action. Rome. https://doi.org/10.4060/cb7856en

Sector	**Reduction of losses by 2040 (Model ID – Arrow A1)**	**Source / Rationale**
Fisheries and Aquaculture	98% in R1, R2, R3 96% in R4, R5, R6, R7, R8	We assume that the losses from the mere use of fishing gear based on different fishing methods cannot be reduced, assuming the same share of each type of fishing methods. Reduction of fishing gear losses originates from the reduction in intentional gear abandonment possible through the implementation of gear marking, controls, and awareness campaigns as well as through the reduction of fishing gear conflict, increase in gear vessel storage, and gear maintenance. In R1, R2, R3 we assume we can reduce the losses of artisanal fishing to the level of industrial fishing. For R1, R2, R3 the losses are reduced to 2% compared to 2019 baseline (Richardson 2022). In R4, R5, R6, R7, R8 due to the very large share of artisanal fishing, we assume losses from fishing gear are reduced to 4% compared to 2019 baseline (2% from industrial gear and 2% from artisanal gear). We also assume that IUU becomes almost non-existent through new policies such as gear marking and the implementation of international agreements.

Note: The reduction level (Arrow 0.1 in system map) represents the reduction in plastic consumption in 2040 in the Global Rules Scenario relative to the consumption in 2040 in the Business as Usual Scenario.

Policy intervention #4 – Bans on avoidable or unnecessary single-use plastic packaging

Avoidable or unnecessary plastic can refer to "products that can currently be reduced or substituted with non-plastic fit-for-purpose alternatives and/or can be eliminated entirely without compromising the consumer's access to the product, inability to meet health or safety regulations, or causing undesirable environmental outcomes" (Raubenheimer, K., Urho, N.2020).

The Global Rules Scenario assumes a series of bans on single use plastic applications, increasing gradually, where plastic use would be avoided entirely by 2040. This would translate to those plastic volumes being eliminated, shifted to multi-serve, reuse, or refill alternatives, or replaced by other materials that exhibit better environmental performance. These measures can also trigger changes in product design and the exploration of new product concepts that offer the same functionality with better impacts. Bans on intentionally added microplastics are also in the scenario, covered in the microplastics chapter (see Policy Intervention #14 and #15). **The Global Rules Scenario does not consider** substitution of current plastics with bio-based plastics, biodegradable plastics, oxo-degradable plastics, or compostable plastics (except for some specific applications in agriculture). Uncertainty remains regarding the role of these solutions in the future, and caution is necessary based on available evidence (EIA, 2018).

For the Global Rules Scenario, a specific list of plastic applications was assumed to be in scope for these bans. As a starting point, the analysis includes bans on single-use plastic applications from European Union's Single Use Plastic Directive (EU Commission, 2023), both enacted and under discussion. This includes plastic applications such as bags, straws, cutlery, takeaway containers, and microbeads. The scenario also includes additional bans on applications not presently covered by the European Union's regulations, where alternatives could be developed by 2040. To select appropriate applications beyond European Union's regulations, the Global Rules Scenario builds on past analysis on technological, financial, performance, and behavioural constraints (The Pew and Systemiq, 2020). For instance, in this scenario there is a gradual banning of flexible multi-layer sachets, when assuming alternatives can be developed (e.g., reuse, mono material films, other materials) to provide equivalent barrier properties if these demonstrate better environmental impact.

The **single use plastic applications considered in the Global Rules Scenario sets bans by 2040 on:**

- Food service disposables and take away food and beverage single use plastic applications (straws, stirrers; on-premises food service disposables; off-premises plastic cups, lids, containers, clamshells, and cutlery)
- Plastic pots, tubs and trays for vegetables and fruits (not applied for dairy, meat, ready meals)
- Single use plastic bags.
- Plastics in logistics and business-to-business for single use applications such as films to wrap pallets, e-commerce, or single-use crates for beverages.
- Multi-material / multi-layer sachets only if better choices are available (e.g., mono materials, other materials)

To estimate the potential reduction of plastic consumption from these bans, the analysis assumes global implementation by 2040 and compares the relative volume impacted versus the total consumption of plastic in a household, differentiating by regions. The impact of these bans is estimated together with the reuse targets as they may impact the same products

For those volumes impacted, the analysis assumes the most likely outcome of the ban: elimination (consumption ceases to exist), shift to reuse models, or replacement with other materials, based on past analysis on technological, financial, performance, and behavioural constraints (The Pew Charitable Trusts and Systemiq, 2020).

Policy intervention #5 – Mandatory reuse targets on avoidable single-use plastic packaging

Reuse models refer to new delivery models that replace avoidable single-use plastic applications in favour of alternatives that are used in multiple cycles of consumption. It encompasses multiple solutions (EMF, 2023): refillable containers at home, refill on the go, return at home, and return on the go. This section therefore only covers the distinct reuse models for packaging, reuse systems in other sectors are covered in policy interventions related to plastic reduction and product durability (policy interventions #3 and #7).

Reuse targets, in the context of this model, are policies by which final distributors, e.g., retailers, food service providers, are mandated to cover a percentage of their volumes of sales through reuse models. The Global Rules Scenario includes reuse targets in beverages, food service, business to business applications (e.g., logistics) and, for certain regions, incentives for reusable sanitary and female hygiene products. To select the appropriate reuse target levels for each plastic application, the Global Rules Scenario builds on past analysis to accommodate for technological, financial, performance, and behavioural constraints (The Pew Charitable Trusts and Systemiq, 2020). In addition, selecting the right reuse targets leverages current targets under discussion for the EU PPWR (EU, 2023) and existing reuse targets in France (EU, 2020 and

Zero Waste Europe, 2021). Leveraging past analysis (The Pew and Systemiq, 2020) the Global Rules Scenario assumes lower targets for Low- and Middle-Income countries to accommodate for specific challenges to scale reuse and refill models depending on the local context. For example, if the quality of the water supply is poor, solutions where consumers carry and refill reusable bottles are not feasible. These challenges, however, do not necessarily prevent reuse models from scaling, but transitional costs may be higher and adoption slower. Reuse targets for sanitary products in high-income economies are also included in the scenario, assuming they will be accompanied by incentives for adoption or taxation on single-use alternatives.
As a first step estimates are used from previous studies to determine the average plastic consumption per household in tonnage, split by product categories and application. This result in tonnage is then matched against the list of reuse targets and bans in the Global Rules Scenario. With this result the total reuse targets are modelled per household for bans and reuse targets. Based on those results a decision is taken if the volume is eliminated, becomes reuse model, or is replaced. Elimination, replacement, reuse together result in a total number of reductions of plastic consumption.

The Global Rules Scenario reuse targets apply to the following single use plastic applications:

- **Beverages** (sodas, water, alcoholic): 25% of the volume of sales to be via reuse models in High Income regions, and 15% in the rest of the world.
- **Household products** (e.g., cleaning, personal care): Same as beverages.
- **Transport packaging and business-to-business plastics:** Impacting plastic uses such as films to wrap pallets or single-use crates, to shift to 100% reuse designs.
- **Takeaway food and beverage containers:** As these applications are also in the scope of the single use bans mentioned before, 100% of these designs would be either eliminated or shift to reuse models.

Table 31: Average composition by plastic category of packaging and consumer goods plastics

Plastic format	Product Application	Product Application sub-category	R1, R2, R3	R4, R5. R6, R7, R8
Bottles	Water bottles	• Water bottles	1%	1%
	Other food-grade bottles	• Other (milk, soda, sparkling water)	5%	3%
		• Remainder	2%	1%
Rigid mono-material	Non-food-grade bottles	• Non-food-grade bottles	5%	3%
	Food service disposables	• Straws, stirrers	0%	0%
		• On-premise food service disposables	1%	1%
		• Off-premise plastic cups	1%	1%
		• Off-premise lids	1%	1%
		• Off-premise containers & clamshells	1%	0%
		• Off-premise cutlery	0%	0%
	Pots tubs and trays	• Fresh fruit/vegetables trays, pots, etc.	2%	1%
		• Pots/tubs for liquids, creams, dairy	2%	1%
		• Meat tray	1%	1%
		• Ready meals trays, instant pot snacks	1%	0%
		• Other	2%	1%
	B2B packaging [rigid]	• B2B packaging [rigid mono-material]	4%	2%
	Other	• Remainder	7%	8%
Flexible mono-material	Carrier bags	• Carrier bags	13%	8%
	Films [mono-material]	• Films [mono-material]	4%	30%
	B2B films	• B2B films [mono-material]	16%	7%
Multi-material / multi-layer	Sachets / multilayer	• Sachets	4%	15%
		• Multilayer flexibles	4%	3%
	Laminates	• Laminates for paper and aluminum	1%	0%
Household goods	Multi-material goods	• Household multi-material	2%	2%
	Sanitary, diapers and hygiene (plastic portion)	• Sanitary	17%	1%
		• Wet wipes	1%	0%
		• Cotton bud sticks	0%	0%
		• Diapers	0%	1%
	Rigid goods	• Household rigid mono-material	1%	4%
Total consumption per average household			100%	100%

Notes and sources:

- The United Kingdom is used as proxy country for average consumption in R1 to R5. Various sources are analysed to aggregate in one estimate of the composition (Defra, UK Gov database, WRAP)
- Philippines, Indonesia, India, Vietnam data as proxy for R6 to R8. Various sources are analysed to aggregate in one estimate of the composition (e.g., Sustainable Waste Indonesia, SwAch Pune, GAIA)

These plastic categories and their share in the total composition are then "matched" to the bans and reuse targets. The purpose here is to estimate, out of the total plastic packaging consumed, how much of its volume is impacted by each ban.

For the volumes impacted, past work from The Pew Charitable Trusts and Systemiq “Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution”) guides the analysis on what is the **most likely alternative: elimination from consumption, shift to reuse models or substitution by other materials, as shown in Table 32:**

Table 32: Connection of the packaging volumes composition versus the selected bans and reuse targets

Packaging and consumer goods plastics – Mix by application					Result
Plastic format	Product Category	Product sub-category	Single Use plastic bans	Reuse targets	Assumption
Bottles	Water bottles	Water bottles	×		
	Other food-grade bottles	Other (milk, soda, sparkling water)	×	15%-25%	Shift to reuse and refill models: 25% (concentrate, capsules, bulk) for Global North; 15% for Global South
		Remainder	×		
Rigid mono-material	Non-food-grade bottles	Non-food-grade bottles	×	15%-25%	Shift to reuse and refill models: 25% (concentrate, capsules, bulk) for Global North; 15% for Global South
	Food service disposables	Straws, stirrers	✓		**Substitute with other material (e.g., paper / coated paper):** Total ban, product disappears
		On-premise food service disposables	✓		Shift to reuse and refill models: All on-premise become reusable formats
		Off-premise plastic cups	✓		**Substitute with other material (e.g., paper / coated paper):** We assume 100% of off premise applications substituted
		Off-premise lids	✓		**Substitute with other material (e.g., paper / coated paper):** We assume 100% of off premise applications substituted
		Off-premise containers & clamshells	×	40%-80%	**Substitute with other material (e.g., paper / coated paper):** We assume 100% of off premise applications substituted
		Off-premise cutlery	✓		**Eliminated (demand eliminated):** Total ban, product disappears
	Pots tubs and trays	Fresh fruit/vegetables trays, pots, etc.	✓		**Eliminated (demand eliminated):** Total ban, product disappears
		Pots/tubs for liquids, creams, dairy	×		
		Meat tray	×		
		Ready meals trays, instant pot snacks	×		
		Other	×		
	B2B packaging [rigid mono-material]	B2B packaging [rigid mono-material]	×		
	Other rigid mono-material	Remainder	×		
Flexible mono-material	Carrier bags	Carrier bags	✓		Shift to reuse models
	Films [mono-material]	Films [mono-material]	×		
	B2B films [mono-material]	B2B films [mono-material]	×	30%-90%	Shift to reuse and refill models as well as elimination: : to straps and no films, to reusable films
Multi-material / multi-layer	Sachets and multilayer flexibles	Sachets	×		High barrier coated paper and other alternatives
		Multilayer flexibles	×		High barrier coated paper and other alternatives
	Laminates	Laminates for paper and aluminum	×		High barrier coated paper and other alternatives
Household goods	Household goods [multi-material]	Household multi-material	✓		Ban of 10% for household multi-material products **Eliminated (demand eliminated):** Sharing economy, virtualising, leasing
	Sanitary, diapers and hygiene (plastic portion)	Sanitary	×	0% - 50%	Shift to reuse and refill models: Only in high income regions, being incentivised
		Wet wipes	×		
		Cotton bud sticks	×		
		Diapers	×		
	Household goods [rigid mono-material]	Household rigid mono-material	✓		Ban for 10% pf household rigid mono-material products

The scenario assumes all plastic categories are in scope globally. Reuse targets vary by region based on concerns from experts on its feasibility to implement: 25% for Europe, US and Canada, Australian Japan, New Zealand, Republic of Korea and 15% for all other regions.

Policy intervention #6 – A phaseout of problematic plastic products, polymer applications and chemicals of concern

Global criteria or a phase out of problematic plastics products, polymers applications and chemicals of concern have not been quantified in the modelling exercise. They are presented qualitatively to provide relevant context to the reader when necessary. Please refer to the main report to for more details on how this point is discussed.

Policy intervention #7 – Design rules for safe reuse, repair, durability and cost-effective recycling in local contexts

In the model, design policies improve collection, recycling yields and shift formats from hard to recycle multi materials to mono materials and rigids formats. These policies are applied equally to all sectors or plastic categories.

Table 33: Effects of design for recycling policies in packaging sector and resulting changes of arrows

Sector	Variable / System ID	Format	2019	2040	Comments and Sources
Packaging And Consumer Goods	Sorted collection sent to disposal (not recycling) Arrow F2	Bottles	20 %	10%	Antonopoulos, Ioannis & Faraca, Giorgia & Tonini, Davide. (2021). Recycling of post-consumer plastic packaging waste in the EU: Recovery rates, material flows, and barriers.
		Rigids	20 %	10%	
		Flexibles	20 %	10%	
	Mechanical Recycling process losses Arrows I2 / J2	Bottles	27 %	7 %	The PEW Charitable Trusts and Systemiq (2020). “Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution”
		Rigids	27 %	7 %	
		Flexibles	27 %	7%	
		Multi material or multi-layer formats	27 %	7 %	Assumption: no recycling of multi material or multi-layer formats

	D4R: Shift from flexible-mono-material to mono-material rigids	Multi material shifts to rigid formats	0 %	45 %	Assumption: Design for recycling over time will shift 45 % of multi-materials to flexible-mono-materials, and 45% of flexibles to rigids. It is assumed that in some cases multi-material packaging is still needed because of e.g., better barrier towards oxygen and other performance criteria.
	D4R: Shift from multi-material to mono-material flexible packaging	Multi material shifts to mono material flexible formats	0 %	45 %	

Table 34: Design for recycling and design for durability policies in Fisheries and Aquaculture

Sector	Variable/ System ID	Sub-sector	2019	2040	Comments and Sources
Fisheries – Design for Durability	Box 0.1	Fisheries	R1-R8: 0%	R1-R3: 50% R4-R8: 75%	Increased durability of gear from fisheries will reduce the demand for gear. Assumption: The average durability of gear can reach the level of Norway: 4years This would lead to increasing the lifespan for fisheries gear from 2 to 4 years for R1-R3 and from 1 to 4 years for R4-R8 (Systemiq, Handelens Miljøfond, and Mepex 2023)
Aquaculture – Design for Durability	Box 0.1	Aqua-culture	R1-R8: 0%	R1-R3: 33% R4-R8: 66%	Increased durability of gear from aquaculture will reduce the demand for gear. Assumption: The average durability of gear can reach the level of Norway: 15years This would lead to increasing the lifespan for aquaculture gear from 10 to 15 years for R1-R3 and from 5 to 15 years for R4-R8 This is based on an average of upper level range of lifespan for various gear: floating collar expected to have a lifespan of 20 years, 4 years for feeding pipes, 9 years for mooring systems (Systemiq, Handelens Miljøfond, and Mepex 2023)
Fisheries & Aquaculture – Design for Recycling	Arrow B1	Fisheries and Aqua-culture	R1-R3: 95% R4-R5: 50% R6-R8: 15%	R1-R3: 95% R4-R8: 85%	Increased collection resulting from the implementation of EPR scheme, mandatory port collection, and gear marking and the reduction of problematic polymers
Impact of Design for Recycling	Arrow F1	Fisheries	R1-R3: 4% R4-R8: 1%	R1-R3: 75% R4-R8: 65%	Assumption: The share of sorted collection going towards recycling would increase through better designs to reach the level of Norway for R1-R3. It has been adjusted to 65% for R4-R8 to account for the feasibility and ramp up of infrastructure (Systemiq, Handelens Miljøfond, and Mepex 2023)
Impact of Design for Recycling on recycling type	Arrow X1	Aqua-culture	0%	30%	Out of the 80% HDPE used in aquaculture, we expect 30% to go towards closed loop recycling

Notes:

- Fishing nets cannot be recycled closed-loop. Fishing nets will be either recycled through open-loop recycling or chemical recycling. The large share of HDPE in aquaculture will make it possible to shift a share of the recycling volumes towards closed-loop recycling.

Sources:

- Systemiq, Handelens Miljøfond, and Mepex "Achieving circularity, A low-emissions circular plastic economy in Norway", 2023

In the other sectors, Design for recycling targets are assumed to maximise recycling rates through simplicity of polymer, fewer fillers and additives and fewer polymer types. In these sectors, the rate for sorted waste losses is halved as new designs enter the in-use stock (in system map terms, the Arrow F2 is reduced gradually, until reaching a 50% reduction by 2040). The analysis uses estimates from Phasing Out Plastics report (ODI, 2020) to calibrate towards the maximum recycling rates achievable in each sector (e.g., 40% in transportation plastics).

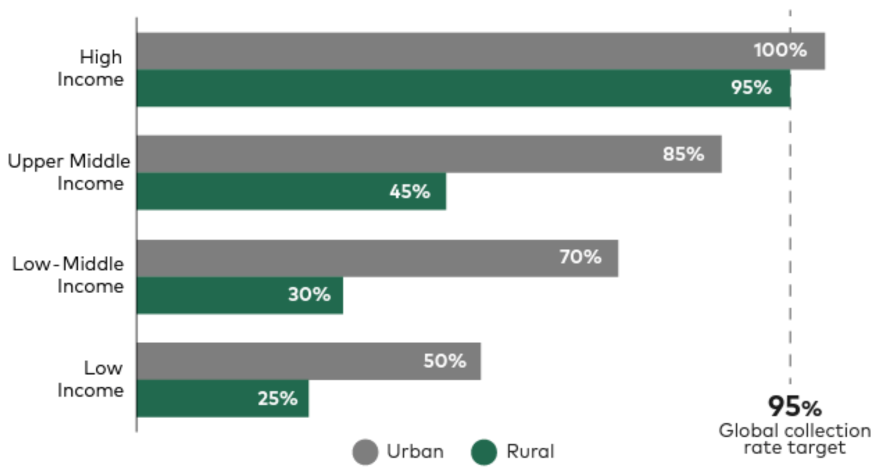
For durables, changes in design also include the reduction of plastic demand through different interventions, which are based on the Phasing Out Plastics report (ODI, 2020). For **electronics**, a 50% reduction of plastic use in in Europe, the US and Canada, Japan, Republic of Korea, Australia, New Zealand, China, as well as Central, South America and the Caribbean by 2040 compared to the Business as Usual is modelled. This is achieved by first changing the design of electronics by 2050 through modular design for disassembly to facilitate reuse and extend product life; and second, the substitution of plastics with other materials: metals, wood, and ceramics could replace the use of PP and PE for structural uses and casings and the use of PUR and PS for insulation (ODI, 2020). For **agriculture,** the Global Rules Scenario assumes design rules to extend the lifespan for plastic applications in agriculture with the purpose of reducing demand. This is achieved through re-design of e.g., mulching films that enable reuse or a substitution of non-degradable plastics with biodegradable plastic for applications that necessarily end up in the soil such as coatings for seeds, fertilisers, or pesticides.

Policy intervention #8 – Targets for collection and recycling rates

After the Business as Usual Scenario used collection rate data from What a Waste 2.0 with its regional differentiation, the synergies of the policy interventions, in particular policies 2, 4, 6, 7, 9, have lead to a 95% collection rate in the Global Rules Scenario. In this analysis, the collection targets are not an input into the model, but rather an output based on the resulting collection rate following the implementations of the policy interventions. The collection rates of the Global Rules Scenario have therefore become the collection target for all sectors.

FIGURE 11 **Collection rates of municipal solid waste in 2019**

The model leverages estimates of collection rates of municipal solid waste from the World Bank's "What a Waste 2.0"

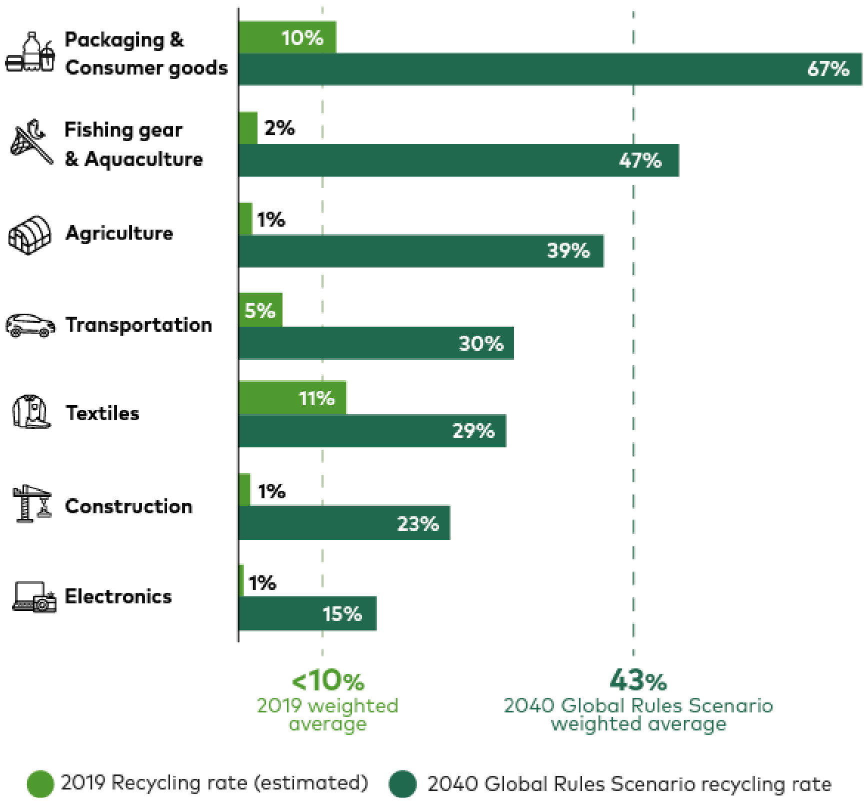


All numbers are subject to rounding

Similarly, recycling rates originate from existing recycling rates by sectors today. Under the impact of policy interventions 3, 4, 6, 7, 8 in particular and following feasibility discussions with experts and based on existing literature, global recycling rates could increase to the following level differentiated by sectors.

FIGURE 12 **Plastic recycling rates by sector in the Global Rules Scenario in 2019 and 2040**

The Global Rules Scenario requires a substantial increase in the recycling rates of all plastic applications



In the scenario mechanical recycling is prioritized versus chemical recycling. Of all the 2040 recycling capacity in this scenario, ~90% is mechanical recycling. The rest is chemical recycling for certain types plastic waste that mechanical recycling cannot process. All numbers are subject to rounding

Policy intervention #9 – Eco-modulated EPR schemes applied across all sectors

Extended Producer Responsibility (EPR) refers to schemes where industry players, who place products containing plastics on the market, pay a fee that is used to fund the collection, sorting, recycling, or disposal of the waste materials from its use. Fees are assumed to likely be passed to consumers (although this is not part of the model). EPRs are considered effective policies for achieving circularity targets and to raise significant funds that can be deployed towards solutions. EPR is perceived as one of the top policy instruments and there is high level of consensus that it should be scaled.
This model does not consider any EPR impact on overall plastic demand and considers the plastic demand as inelastic (i.e., major shocks in oil prices did not translate to significant fluctuations of demand for plastic products). This section explains how EPRs were conceptualised and the methodology to estimated impact in the system map.

In the Global Rules Scenario EPR fees will be applied to all sectors and eco-modulated (i.e., higher fees for materials harder to recycle). They will grow over time and differ based on each region, as shown in the exhibit. The fees are assumed to be collected and invested at national level, also paying for the administration of the EPR scheme itself. The share of investment that each part of the value chain receives in the model is in direct proportion to their cost. Investments in recycling infrastructure and reuse models are assumed to mainly be taken by the private sector as these sectors would generate profits from these investments. The scenario assumes regions with Deposit Return Schemes (DRS), particularly in bottles, would apply both the EPR fee and the deposit, with the deposit being returned to the consumer after depositing the used item in the correct channel.

1. **Revenue per policy:**
   - A certain fee per tonne of plastic is applied, differentiated by region and format.
   - These fees are multiplied by the volumes of plastic waste to estimate a total revenue raised.
   - EPR fees will start taking effect 2 years after the Treaty's completion, in 2026.
2. **Administrative costs:**
   - 30% of the revenue is deducted as assumed to be expended in administration costs, 70% will be invested into waste management.
3. **Allocation of revenues:**
   - **EPR fees will be collected and invested at national level**; implementation levels will be 100% in high-income countries; 85% in upper-middle income countries (e.g., China and Brazil); and 70% in lower-middle income and lower income countries (e.g., India and Indonesia)
   - **Allocating revenue to downstream solutions:** The remaining revenue is allocated to building out collection, sorting and disposal infrastructure by the public sector. For collection, EPR fees will be used to collect all waste, not just plastic (as plastic is not generally collected in isolation). For collection, sorting, and controlled disposal, revenue is allocated as follows:
     i. In R1, R2, R3 (advanced collection and disposal infrastructure), revenue allocated to sorted collection schemes
     ii. In R4 to R8, revenue is allocated to expand collection, sorting, and disposal. The share that each part of the value chain receives is in direct proportion to their costs, such that the capacity for each will increase by the same tonnage amount (assumption that the value chain scales simultaneously).
4. **Estimating the impact in capacity of investing this revenue**: This allocated revenue to expand capacity in each step is compared to the OPEX and CAPEX cost in that step for one ton of plastic waste (see table 24 and 27). This comparison follows this process:
   i. For each step (collection, sorting, disposal), the "dollar cost per tonne of plastic waste" is scaled by a factor. This is to account for the fact that plastic is generally not collected, sorted or disposed of in isolation, and in many waste streams will be managed with other waste materials (paper, metals, mixed waste).
   ii. For example, a factor of 4 is applied to collection cost per ton of plastic waste from packaging and consumer goods. This factor is estimated comparing to data of collecting all waste, not just plastics.
   iii. Then the allocated dollar revenue to that step (e.g., collection) is divided by that scaled cost factor, to result in an incremental capacity (in tons) from that investment
   iv. The capacity addition is calibrated with region-specific levels of implementation, to acknowledge different levels of difficulty to expand systems in each region: 100% in R1-3, 85% in R4-5; and 70% R6-8
5. **Increasing capacity in the system map**:
   - The capacity addition of each value chain step is then added to the baseline tonnage value to calculate the new levels of collection, sorting, or disposal. Revenue invested will materialise capacity addition 1 year later to account for time required for establishing the added capacity. Hence, with financial policies kicking in in 2025, the first addition in capacity would materialise in 2026. Capacity is added until either 2040 is reached, or a maximum constraint (e.g., 98% collection rate) is reached. Note: because costs are annualised both for OPEX and CAPEX, each ton of capacity added will need to be paid for again in all other years that follow.

Table 35: EPR fees across regions

EPR fees US$ per plastic ton	**Europe, USA and Canada, Japan, Republic of Korea, Oceania**		**China, Central/South America, and the Caribbean**		**India, Eurasia, South and South-East Asia, Africa, and the Middle East**	
	2030	2040	2030	2040	2030	2040
Bottles	100	400	50	350	50	300
Other packaging rigids	100	600	100	525	100	450
Mono-flexibles packaging	150	800	150	700	100	600
Multi-materials packaging	200	1,000	200	875	150	750
Household goods	200	1,000	200	875	150	750
Textiles	100	500	100	375	50	250
Durables (would apply to electronics, transportation, construction, and agriculture*)	100	500	100	375	50	250
Fishing and aquaculture gear	150	800	150	700	100	600

*Not all agricultural plastics are durables, some are single use.

Policy intervention #10 – Controls for a just transition for the informal sector

Promoting a just transition for waste pickers has not been quantified in the modelling exercise. It is explained qualitatively to ensure that labour and human rights are protected and respected by governments and industry to ensure a just and inclusive transition for the informal sector. Please refer to the main report to for more details on how this point is discussed.

Policy intervention #11 – Restrictions on plastic waste trade

Due to lack of data and transparency it is not possible to provide accurate numbers of exported plastic waste, however some sources estimate current plastic exported waste from developed economies to developing within ranges of 1 to 4 million MT per year (UN Comtrade 2023; IPEN 2023). In the scenario modelling, through this policy the plastic waste exports between regions (Arrow G1) are set to 0% for all sectors.

Sources: Karlsson, T, Dell, J, Gündoğdu, S, and Carney Almroth, B. Plastic Waste Trade: The Hidden Numbers. International Pollutants Elimination Network (IPEN), March 2023, UN COMTRADE https://comtradeplus.un.org/

Policy intervention #12 – Global standards on the controlled disposal of waste that cannot be prevented or safely recycled

The analysis first activates the levers for reducing consumption and expanding recycling. However, there are plastic volumes that will not get reduced or recycled, especially in plastic applications in construction, transportation, textiles, or electronics. These volumes have often been in use for years, and generally include designs and formulations that prevent recycling (e.g., fire retardants additives in electronics, PCV pipes in construction). In these cases:

- The model allocates the volume to waste management systems disposal (engineered landfills or incineration plants)
- The Global Rules Scenario maintains the same share of incineration versus disposal as the baseline between 2019 and 2040. As a result:

a) In R1/2/3/5, where incineration is part of the existing capacity mix, the Global Rules Scenario results in a proportion of the waste being managed through incineration (see table below)

b) In R4/6/7/8 the scenario prioritises landfills, as this requires less investment and operational costs, and can be easily downscaled if needed overtime, and) GHG emissions are lower.

Table 36: Controlled Disposal

Steps in system map	R1	R2	R3	R4	R5	R6	R7	R8
Incineration (M1) – Baseline 2019	68%	22%	43%	0%	40%(U) 0% (R)	0%	0%	0%
Landfill (M2) – Baseline 2019	32%	78%	57%	100%	60% (U) 100% (R)	100%	100%	100%
Incineration (M1) – both Business as Usual & Global Rules Scenario 2040	84%	17%	43%	0%	50%	0%	0%	0%
Landfill (M2) – both Business as Usual & Global Rules Scenario 2040	16%	83%	57%	100%	50%	100%	100%	100%

Policy intervention #13 – Mitigation and removal programmes for legacy plastics in the environment

The model does not feature management of legacy plastics already in nature quantitively. Instead, mitigation and removal programmes for legacy plastics already in the environment are covered qualitatively. Please refer to the main report to for more details on how this point is discussed.

Policy intervention #14 – Upstream policies to reduce microplastics use and emissions
Policy intervention #15 – Downstream policies to capture microplastics, followed by controlled disposal

Table 37: Microplastics policies

Sector	Variable/ System ID	Policy	2019	2040	Comments and Sources
Microplastics from paint	Box 0.1MBA Box 0.1MBB Box 0.1MBC	Upstream reduction through elimination and reduction	0%	Box 0.1MBA 60%	**Reduction of architectural paint**: Shift the architectural sector (90%) to from plastic-based paint to alternatives such as mineral paint. Architectural sector represents 33% of leakage rate and 48% of paint pollution, leading to 16% reduction in 0.1 MBA / 0.1MBB / 0.1MBC compared to Business as Usual scenario.

				Box 0.1MBB/ Box0.1MBC 30%	**Preventive maintenance** reduces losses from paint wear and tear (0.1 MBB) and paint removal (0.1 MBC) by 50% in all paint sectors, leading to 14% reduction of 0.1MBB / 0.1MBC relative to Business as Usual scenario **Reduce of loss from paint application**: Reduction by 30% of loss from paint application (0.1 MBA) relative to Business as Usual scenario though high-precision paint gun
Microplastics from paint	Arrow MBC3	Collection at source	32%	85%	85% of microplastic emitted from paint removal could be captured through sanding vacuum
Microplastics from paint	Arrow MPF3	Downstream waste management	Wide variation	0%	Assume no use of dumps for solid waste disposal
Microplastics from Personal Care Products	Box 0.1MPC Box 0.1MPD	Upstream reduction though ban	0%	100%	Ban on intentionally added microplastics would lead to no microplastics from personal care products
Microplastics from tyres	Box 0.1.MSA	Upstream reduction	0%	26%	Eco-driving can reduce tyre abrasion by 6% relative to Business as Usual scenario by minimising abrasion from breaking and turning at higher speed Shared mobility can reduce tyre abrasion by 20% from using less vehicles per capita (accounting for the fact that R1-R3 has a greater opportunity to reduce car use through shared mobility than R4-R8).
Microplastics from tyres	Box 0.1.MSA	Upstream reduction though design	0%	17%	Study has found a 36% possible reduction in tyre abrasion between different design of existing tyres. In our model, the loss rate for tyres from cars is 102g/1000km, (compared to the average from this comparative study which is 118g/1000km). The tyre design with lowest abrasion from the study (95g/1000km) leads to 17% microplastics reduction relative to the Business as Usual scenario.
Microplastics from tyres	Arrow MTA3	Downstream waste management	30%	55%	Assuming based on estimates that 95% of tyre abrasion could be captured in the pores of very open asphalt concrete. To be collected would requires water or vacuum cleaning twice a year. Combined sewage can capture around 95% of microplastic losses and can theoretically be applied on highways and on urban roads (58% of roads). Out of 7.7Mt total tyres losses, 4.5Mt occurs on highways and urban roads and 95% can theoretically be captured, leading to 55% being capture for downstream waste management
Microplastics from textiles	Box 0.1.MSA Box 0.1.MSB Box 0.1 MSC	Upstream reduction though design and Collection at source	0%	R1-R3 91% R4-R8 84%	Loss per kg of textile machine washed shift from the model average based on current textile washed (179.7mg/Kg) to the lowest emitting textiles with 24mg/kg leading to 85% reduction in R1-R3. We are leaving more leeway in R4-R8 with 75% reduction relative to the Business as Usual scenario We add the impact that washing machine filters can have, with a likely 64% capture efficiency of microplastics from textiles. This leads to 91% and 84% reduction relative to the Business as Usual scenario
Microplastics from textiles	Arrow MSC1	Collection at source	R1-R3 9% urban R4-R8 between 52%-86%	R1-R3 2% urban R4-R8 10%	We assume that by 2040 only minimal washing machine in R1, R2, R3 would not be connected to the wastewater system (2%) and only 10% would not be connected in R4-R8 with the growth in urbanisation and infrastructure.
Microplastics from pellets	Box 0.1 MNA Box 0.1.MNB Box 0.1.MNC	Upstream reduction	0%	40%	Given that the minimum pellet leakage rate is of 0.010 (compared to 0.025 currently), we assume that better pellet management practices can reduce pellet mismanagement by 40% relative to the Business as Usual scenario
Microplastics from pellets	Arrow MND 2	Collection at source and downstream waste management	R1-R3: 37% R4-R5: 18% R6-R8: 5%	70%	We assume that the installation of storm drain screens would have equivalent filtering efficiency to primary wastewater treatment, equivalent to 70% of microplastics losses redirected to combined sewage

All microplastics (Textiles, Paint, PCP)	Arrow MD3 + MD4	Downstream waste management	Wide variation	100%	Arrow MD3 + Arrow MD4 = 100% to ensure that at minimum secondary wastewater treatment are implemented in urban contexts and capturing >90% microplastics
All microplastics	Arrow M4	Downstream waste management	R6-R8	0%	Ban on sewage sludge laid on land
All microplastics	Arrow M3	Downstream waste management	R1-R3: 1% R4-R5:16% R6-R8:48%	R1-R3: 0% R4-R8:10%	No use of dump in the R1, R2, R3, large reduction in the R4-R8 to 10%

Sources:

- Microplastics from paint: Paruta et al., "Plastic Paints the Environment" Environmental Action, 2022.; Liverseed et al "Comparative emissions of random orbital sanding between conventional and self-generated vacuum systems" Annals of Occupational Hygiene 57(2) 2012.
- Microplastics from tyres: Wang, Y.; Alessandra, B.M. Evaluation of Eco-Driving Training for Fuel Efficiency and Emissions Reduction According to Road Type. Sustainability 2018; ETRMA, Silvestro D., Gielen G. 2019; Kole et al "Wear and Tear of Tyres: A Stealthy Source of Microplastics in the Environment" International Journal of Environmental Research and Public Health, 2017; Van Duijnhove, N., Denier van der Gon, H. and Hulskotte, J. Emissieschattingen Diffuse Bronnen Emissieregistratie-Bandenslijtage Wegverkeer. Delft, 2014; Sundt, P., Syversen, F., Skogesal, O., & Shultze, P-E. (2016). Primary microplastic-pollution: Measures and reduction potentials in Norway. Norwegian Environment Agency.
- Microplastics from textiles: PFN Plastic Footprint Network; De Falco, F et al. "Development and Performance Evaluation of a Filtration System for Washing Machines to Reduce Microfiber Release in Wastewater" Water Air Soil Pollution, 2021; De Falco, F et al. "Evaluation of microplastic release caused by textile washing processes of synthetic fabrics" Environmental Pollution, 2018; De Falco, F.; Cocca, M.; Avella, M.; Thompson, R. "Microfiber Release to Water, Via Laundering, and to Air, via Everyday Use: A Comparison between Polyester Clothing with Differing Textile Parameters" Environ. Sci. Technol, 2020; Napper, I. and Thompson R. "Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions" Marine Pollution Bulletin 112 (1-2), 2016.
- Microplastics from Pellets: Hann, S., Sherrington, Ch., Jamieson, O., Hickman, M., Kershaw, P., Bapasola, A., Cole, G. 2018. Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products. Report for DG Environment of the European Commission

9. Feedstock allocation and output in recycling

In the analysis, once volumes are collected and sorted for recycling, the model allocates that feedstock between mechanical recycling (which can end up as closed loop or open loop) and chemical recycling (only plastic to plastic conversion). In this allocation, the scenario **prioritises mechanical recycling, promoting close-loop over open-loop, versus chemical recycling.** Closed loop mechanical recycling refers to recycling processes that output products of similar quality to the input without any 'downcycling' and it implies that the material is used for similar product applications. Open-loop mechanical recycling on the other hand is defined as mechanical recycling with distinct “downcycling”. Chemical recycling is understood as a process that converts plastic waste back into its basic chemical constituents which can be used to reproduce new plastic materials. Chemical recycling includes the subcategories depolymerisation, gasification and pyrolysis. Chemical recycling is assumed to occur only in high-income (HI) countries (including Europe, HI Asia, US, Canada) and China since chemical recycling plants and their investments have been announced or are in process.

In the Business as Usual Scenario, the feedstock allocation remains unchanged over the years (Baseline values taken from Reshaping Plastics and Breaking The Plastic Wave).

The feedstock allocation rules for the **Global Rules Scenario in 2040** are as follows (linear interpolation from 2019 to 2040):

- In the Global Rules Scenario, we assume that 10% of mixed waste from packaging, consumer goods, electronics, and textiles (represented by Box E in our model) is allocated to chemical recycling. This is based on the potential scale-up of gasification technologies. The remaining mixed waste is allocated to residual waste. No mechanical recycling of mixed waste is assumed.
- For separately collected waste (Box F), we allocate waste to closed loop mechanical recycling depending on the availability and readiness of technology and infrastructure. The increase is due to D4R measures in the specific category.
- Closed-loop recycling (Arrow X1) for bottles and rigid packaging is likely to be scaled in high income countries and design-for-recycling can be easily implemented. That’s why 95 % is allocated to closed loop recycling in the Global Rules Scenario for high income countries (R1, R2, R3). For all other regions (R4-R8) it is assumed to be less.
- For flexible packaging, household goods, electronics and construction, closed-loop recycling is assumed to be less scalable and ranges of 0% to 50% is allocated to closed loop recycling.
- All multi-material plastic is allocated to chemical recycling due to the complexity and challenges of separating different types of plastic for mechanical recycling.
- In the Global Rules Scenario, we anticipate a high chemical recycling potential (>20% allocation) for textiles, flexibles, multi-materials, and household goods since 1) no suitable mechanical recycling possibilities could be found and 2) an alternative chemical recycling process exists (polyester textiles suitable for depolymerisation, flexible packaging suitable for pyrolysis feedstock). In the other categories, only 5 % of the sorted waste was allocated to chemical recycling corresponding to waste which is too contaminated for mechanical recycling.

In the Global Rules Scenario in countries with chemical recycling, sorted-for-recycling bottles and rigids are 95% mechanically recycled; sorted-for-recycling flexible packaging and consumer goods are 50% mechanically recycled; multi-material packaging is only chemically recycled; sorted-for-recycling textiles are 50% mechanically recycled, sorted-for-recycling plastics in electronics, construction and transport are 95 % mechanically recycled, 10 % of mixed waste across all categories is chemically recycled, the rest is send to residual waste.

Additionally, another Global Rules Scenario was modelled where chemical recycling was completely avoided, and only the potential of mechanical recycling was applied. All other values are the same as in the Global Rules Scenario with Chemical recycling.

Table 38: Feedstock Allocation packaging and consumer goods

		R1, R2, R3			R5			R4, R6-R8		
Category	**Model ID**	**2019**	**2040 Business as Usual**	**2040 Global Rules Scenario**	**2019**	**2040 Business as Usual**	**2040 Global Rules Scenario**	**2019**	**2040 Business as Usual**	**2040 Global Rules Scenario**
Bottles	**X1**	50%	50%	95%	0%	0%	90%	0%	0%	50%
	X2	50%	45%	0%	100%	95%	5%	100%	100%	50%
	X3	0%	5%	5%	0%	5%	5%	0%	0%	0%
	E1	0%	0%	10%	0%	0%	10%	0%	0%	0%
	E2	100%	100%	90%	100%	100%	90%	100%	100%	100%
Rigid packaging	**X1**	30%	30%	95%	0%	0%	90%	0%	0%	50%
	X2	70%	65%	0%	100%	95%	5%	100%	100%	50%
	X3	0%	5%	5%	0%	5%	5%	0%	0%	0%
	E1	0%	0%	10%	0%	0%	10%	0%	0%	0%
	E2	100%	100%	90%	100%	100%	90%	100%	100%	100%
Flexible packaging	**X1**	30%	30%	50%	0%	0%	50%	0%	0%	50%
	X2	70%	65%	10%	100%	95%	10%	100%	100%	50%
	X3	0%	5%	40%	0%	5%	40%	0%	0%	0%
	E1	0%	0%	10%	0%	0%	10%	0%	0%	0%
	E2	100%	100%	90%	100%	100%	90%	100%	100%	100%
Multi-material packaging	**X1**	0%	0%	0%	0%	0%	0%	0%	0%	0%
	X2	0%	0%	0%	0%	0%	0%	100%	100%	100%
	X3	100%	100%	100%	100%	100%	100%	0%	0%	0%
	E1	0%	0%	10%	0%	0%	10%	0%	0%	0%
	E2	100%	100%	90%	100%	100%	90%	100%	100%	100%
Household goods	**X1**	0%	0%	50%	0%	0%	50%	0%	0%	50%
	X2	100%	95%	30%	100%	95%	30%	100%	100%	50%
	X3	0%	5%	20%	0%	5%	20%	0%	0%	0%
	E1	0%	0%	10%	0%	0%	10%	0%	0%	0%
	E2	100%	100%	90%	100%	100%	90%	100%	100%	100%

Notes

- X1 = sorted waste to closed loop recycling
- X2 = sorted waste to open loop recycling
- X3 = sorted waste to chemical recycling
- E1 = mixed waste to chemical recycling
- E2 = mixed waste to residual waste (not recycled, sent to disposal)

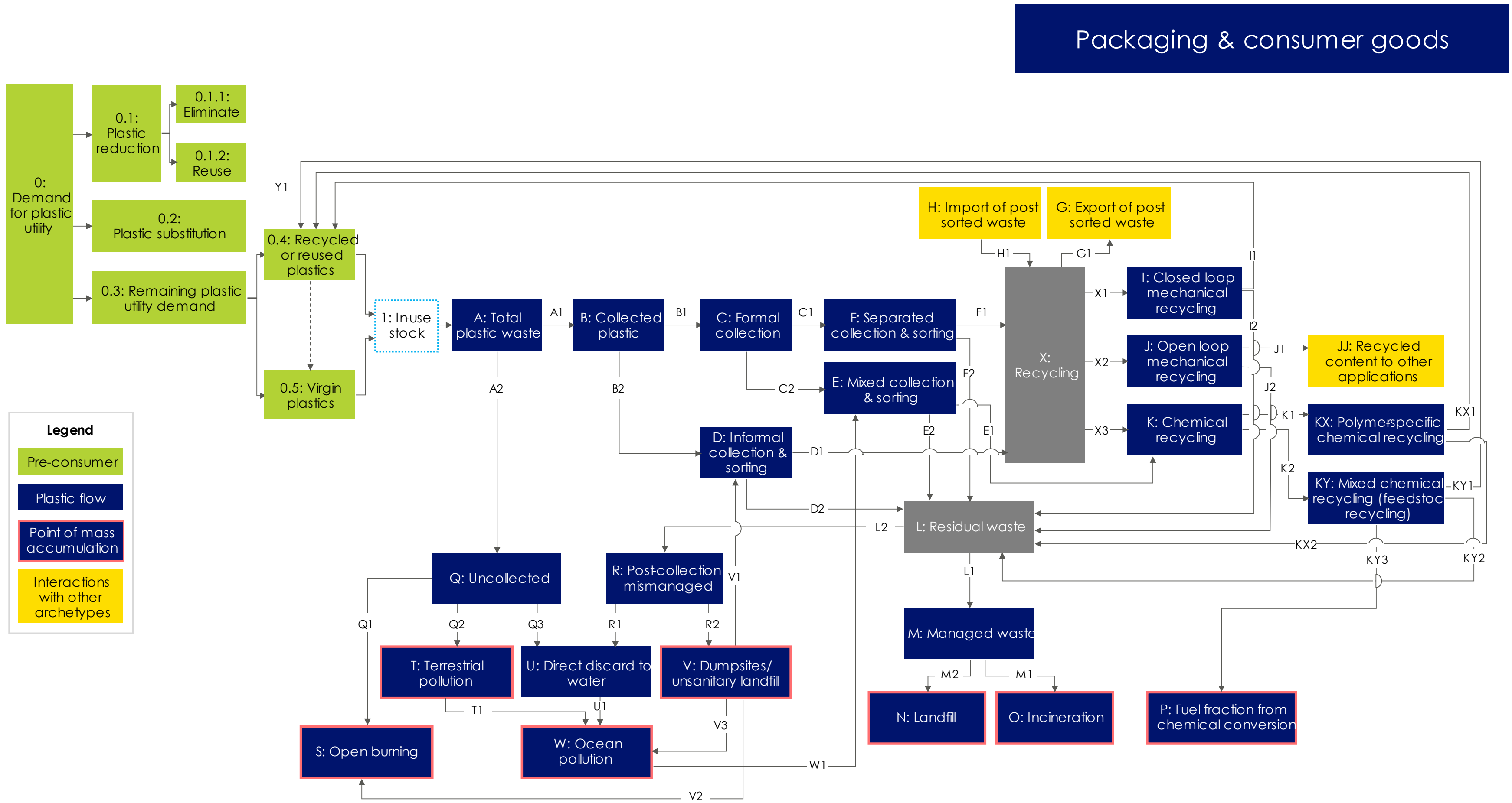
Table 39: Feedstock Allocation for the other categories

	Region:	R1, R2, R3			R5			R4, R6-R8		
	Model ID	2019	2040 Business as Usual	2040 Global Rules Scenario	2019	2040 Business as Usual	2040 Global Rules Scenario	2019	2040 Business as Usual	2040 Global Rules Scenario
Textiles	X1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	X2	100%	95%	50%	100%	95%	50%	100%	100%	100%
	X3	0%	5%	50%	0%	5%	50%	0%	0%	0%
	E1	0%	0%	10%	0%	0%	10%	0%	0%	0%
	E2	100%	100%	90%	100%	100%	90%	100%	100%	100%
Electronics	X1	0%	0%	50%	0%	0%	50%	0%	0%	50%
	X2	100%	95%	45%	100%	95%	45%	100%	100%	50%
	X3	0%	5%	5%	0%	5%	5%	0%	0%	0%
	E1	0%	0%	10%	0%	0%	10%	0%	0%	0%
	E2	100%	100%	90%	100%	100%	90%	100%	100%	100%
Construction	X1	0%	0%	50%	0%	0%	50%	0%	0%	50%
	X2	100%	95%	45%	100%	95%	45%	100%	100%	50%
	X3	0%	5%	5%	0%	5%	5%	0%	0%	0%
Transport-Tyres	X1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	X2	100%	95%	95%	100%	95%	95%	100%	100%	100%
	X3	0%	5%	5%	0%	5%	5%	0%	0%	0%
Transport – General	X1	0%	0%	40%	0%	0%	20%	0%	0%	20%
	X2	100%	95%	55%	100%	95%	75%	100%	100%	80%
	X3	0%	5%	5%	0%	5%	5%	0%	0%	0%
Fishing gear	X1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	X2	99%	90%	90%	99%	90%	90%	100%	100%	100%
	X3	1%	10%	10%	1%	10%	10%	0%	0%	0%
Aquaculture	X1	0%	0%	30%	0%	0%	30%	0%	0%	30%
	X2	99%	90%	60%	99%	90%	60%	100%	100%	70%
	X3	1%	10%	10%	1%	10%	10%	0%	0%	0%

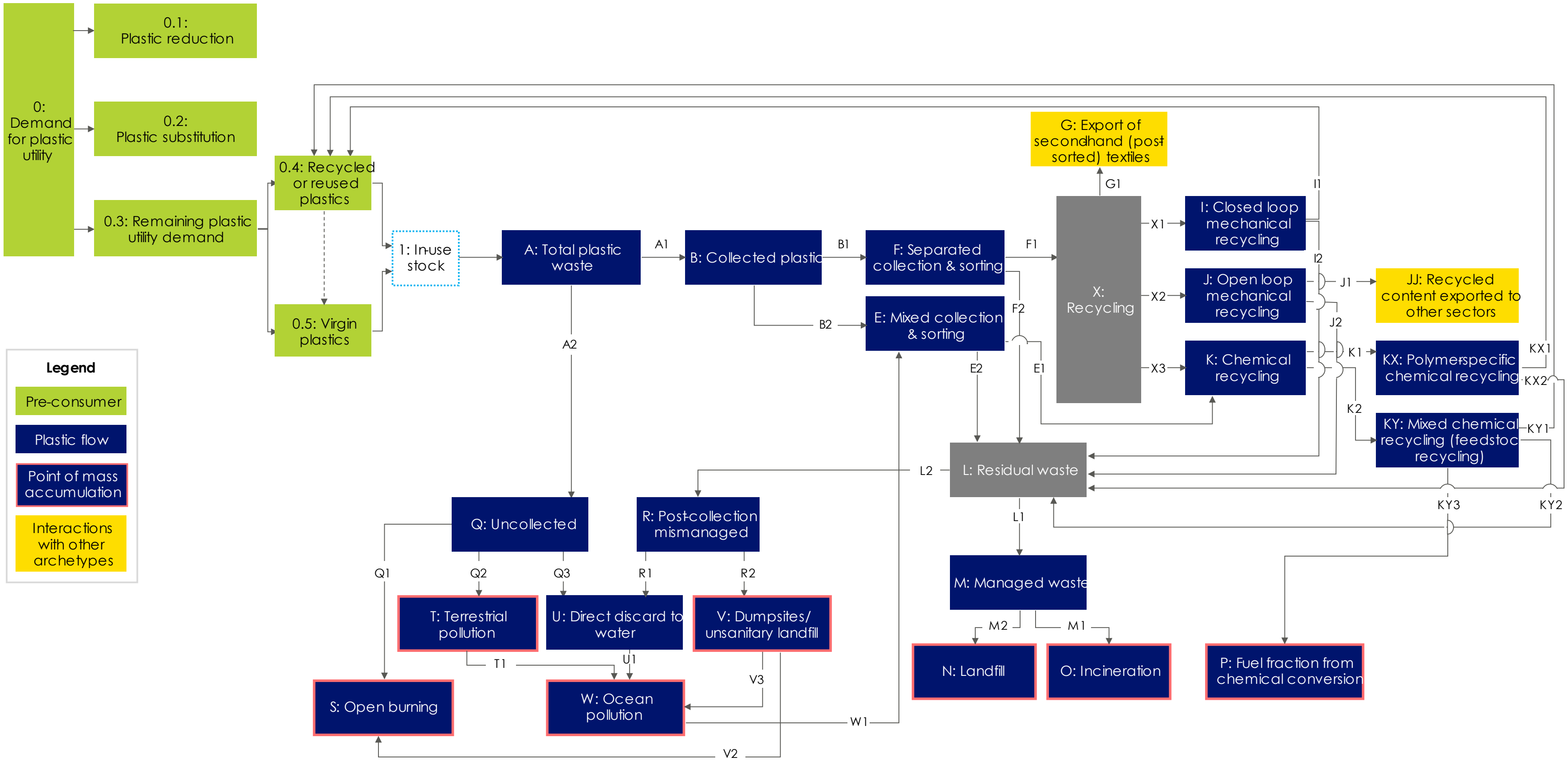
Notes:

- X1 = sorted waste to closed loop recycling
- X2 = sorted waste to open loop recycling
- X3 = sorted waste to chemical recycling
- E1 = mixed waste to chemical recycling
- E2 = mixed waste to residual waste (not recycled, sent to disposal

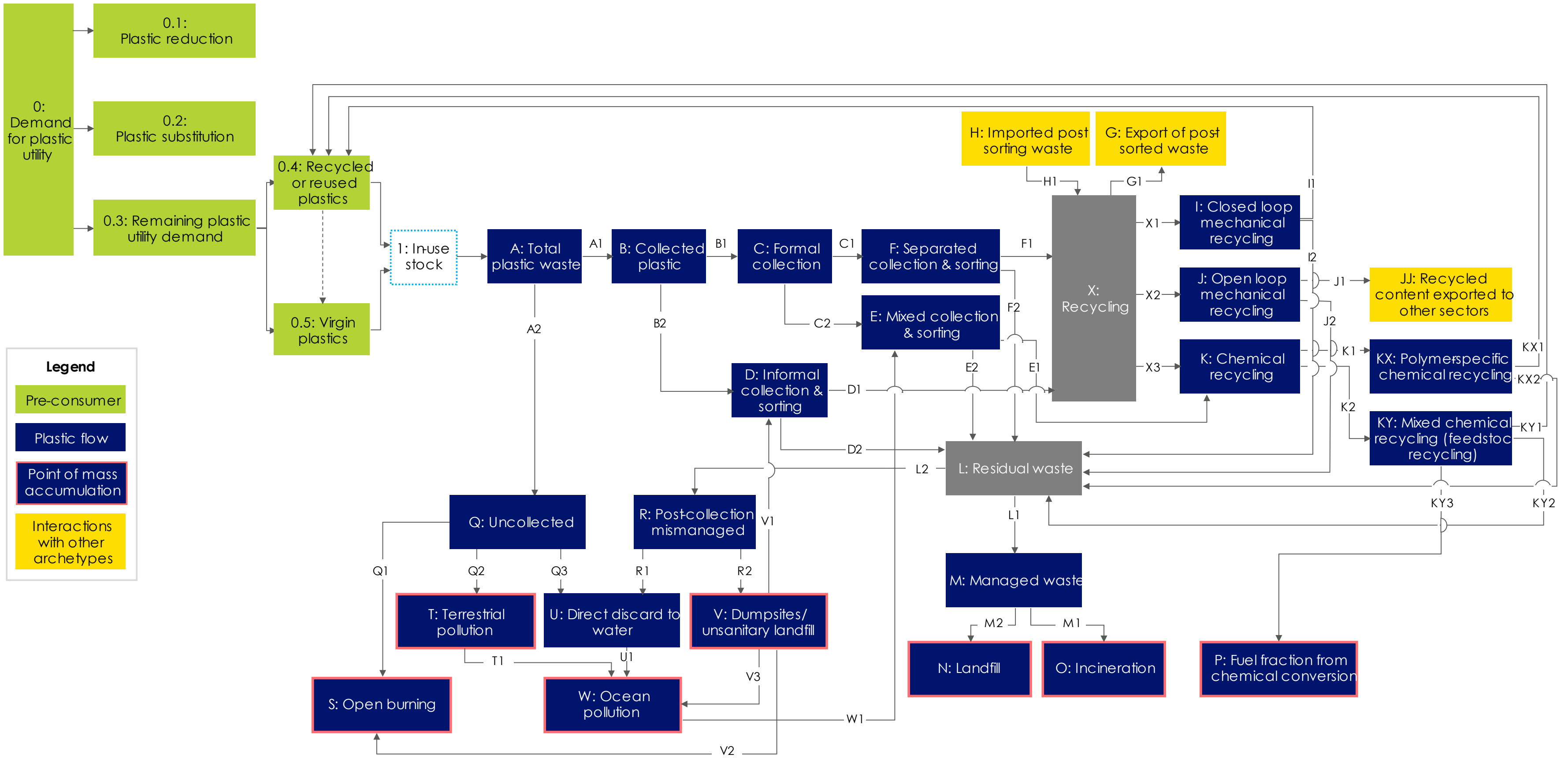
10. System maps of all plastic sectors



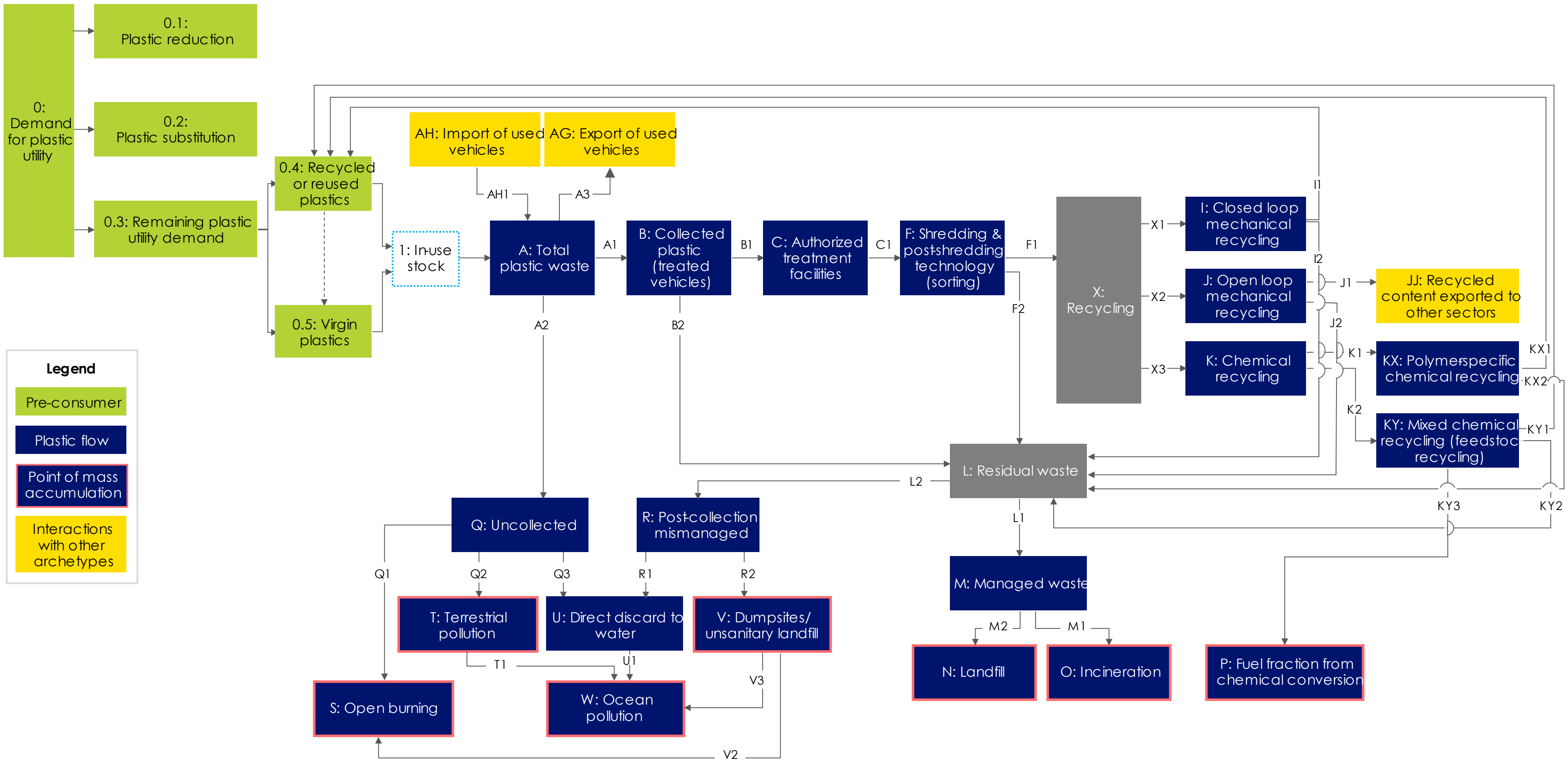
Textiles


0: Demand for plastic utility
0.1: Plastic reduction
0.2: Plastic substitution
0.3: Remaining plastic utility demand
0.4: Recycled or reused plastics
0.5: Virgin plastics
1: In-use stock
A: Total plastic waste
A1
A2
B: Collected plastic
B1
B2
F: Separated collection & sorting
F1
F2
E: Mixed collection & sorting
E1
E2
G: Export of secondhand (post sorted) textiles
G1
X: Recycling
X1
X2
X3
I: Closed loop mechanical recycling
I1
I2
J: Open loop mechanical recycling
J1
J2
JJ: Recycled content exported to other sectors
K: Chemical recycling
K1
K2
KX: Polymer-specific chemical recycling
KX1
KX2
KY: Mixed chemical recycling (feedstock recycling)
KY1
KY2
KY3
L: Residual waste
L1
L2
M: Managed waste
M1
M2
N: Landfill
O: Incineration
P: Fuel fraction from chemical conversion
Q: Uncollected
Q1
Q2
Q3
R: Post-collection mismanaged
R1
R2
S: Open burning
T: Terrestrial pollution
T1
U: Direct discard to water
U1
V: Dumpsites/ unsanitary landfill
V2
V3
W: Ocean pollution
W1
Legend
Pre-consumer
Plastic flow
Point of mass accumulation
Interactions with other archetypes

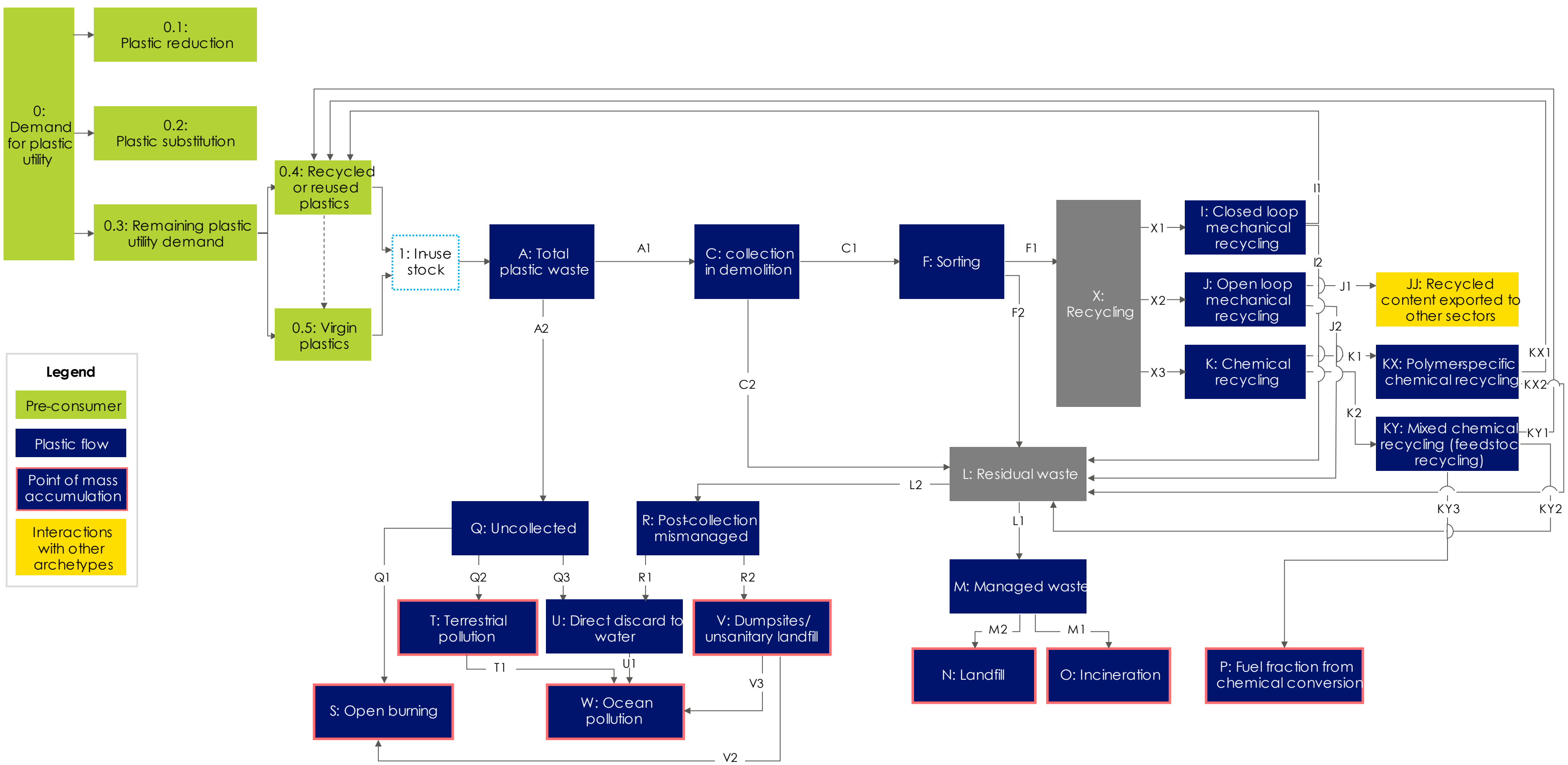
Electronics



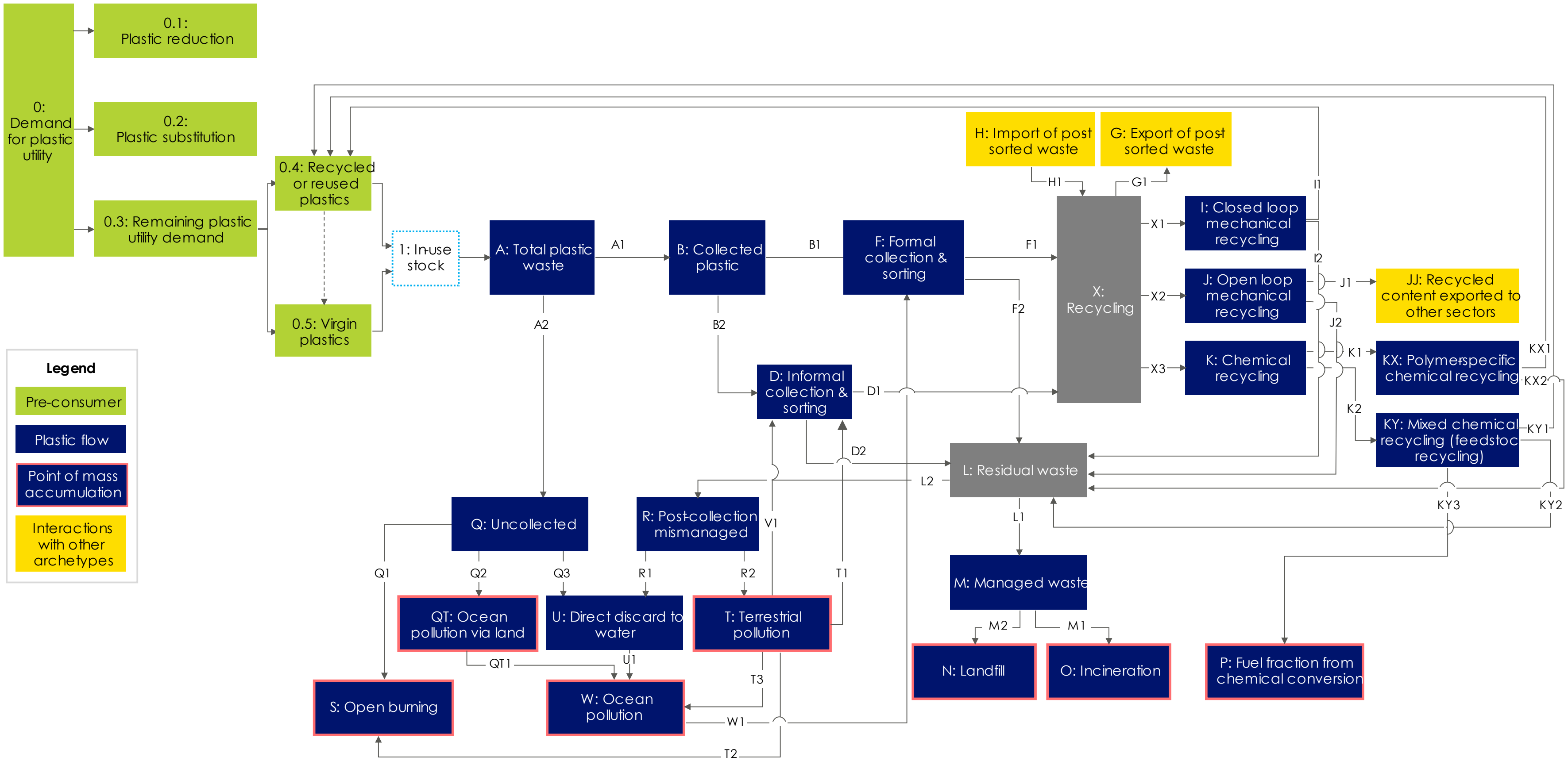
Transportation

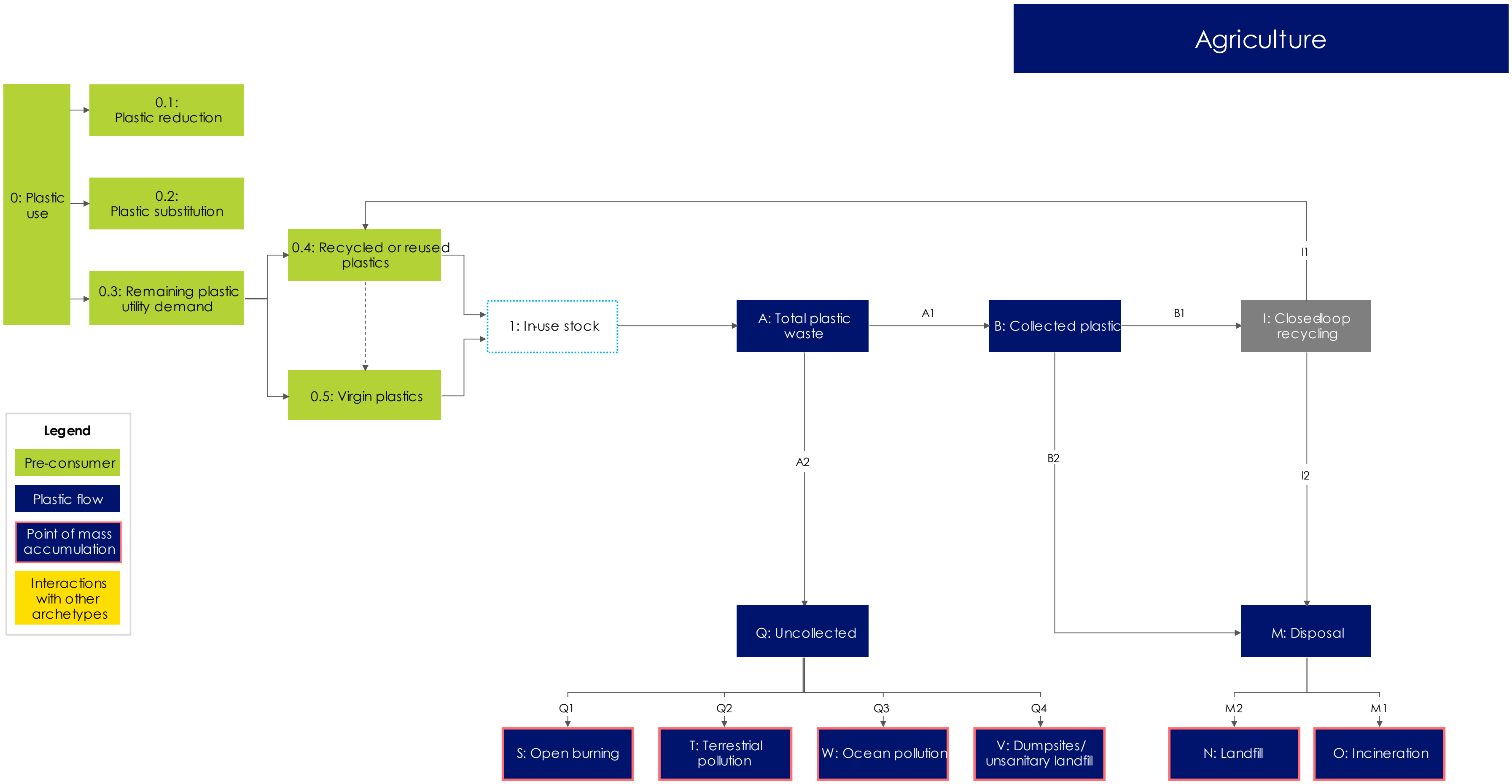


Construction



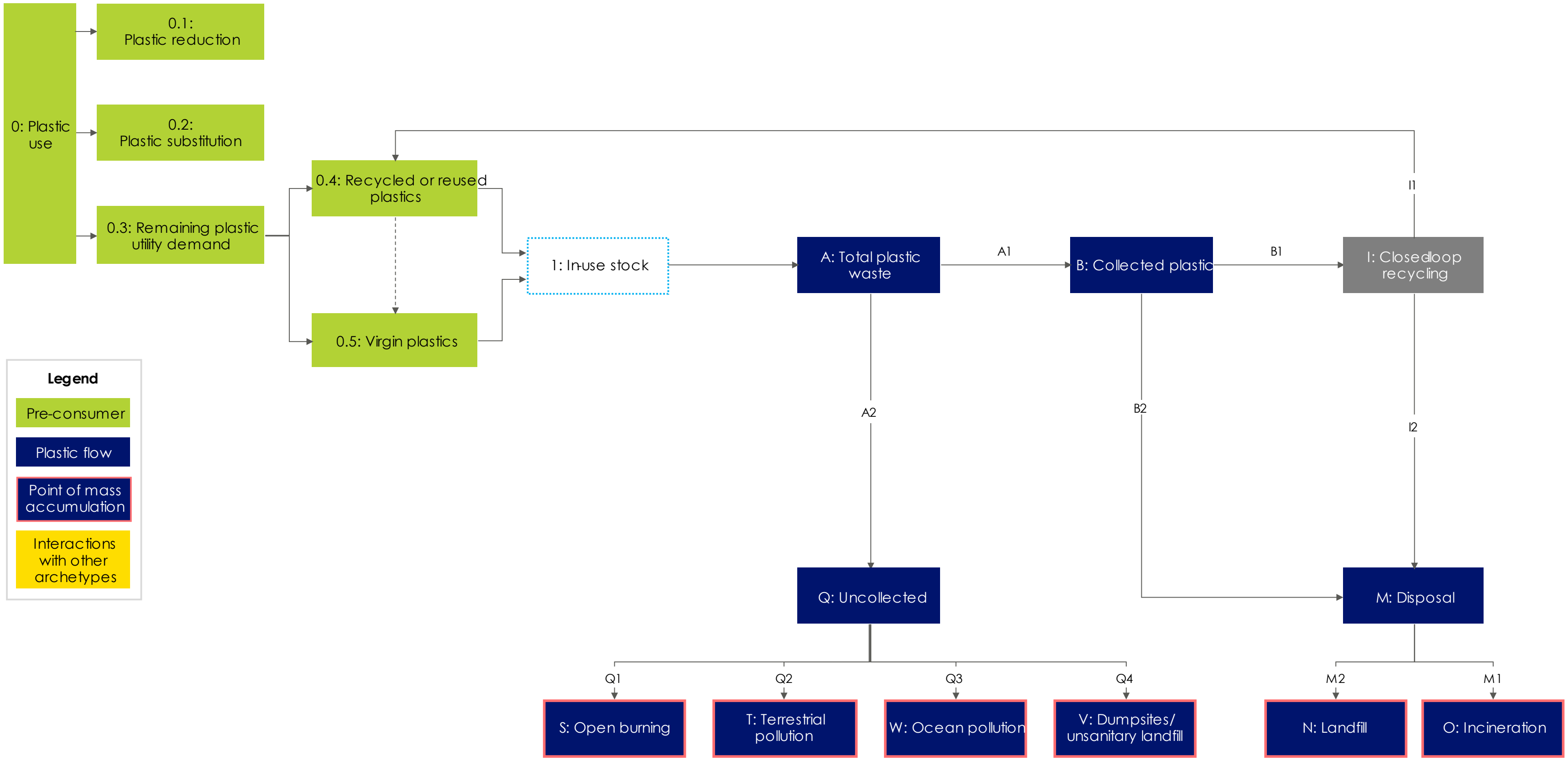
Fisheries & Aquaculture





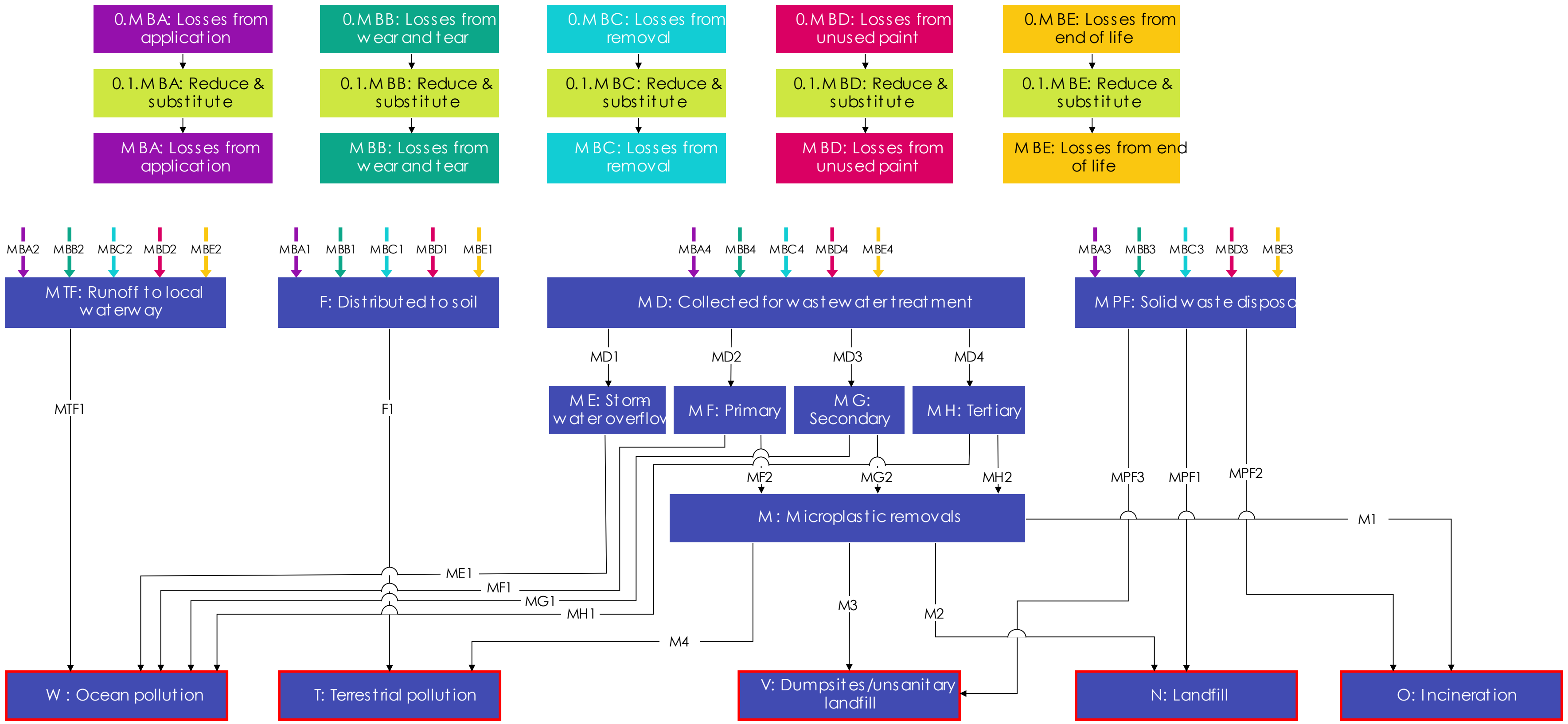
Agriculture
0: Plastic use
0.1: Plastic reduction
0.2: Plastic substitution
0.3: Remaining plastic utility demand
0.4: Recycled or reused plastics
0.5: Virgin plastics
1: In-use stock
A: Total plastic waste
A1
B: Collected plastic
B1
I: Closed-loop recycling
I1
A2
B2
I2
Q: Uncollected
M: Disposal
Q1
Q2
Q3
Q4
M2
M1
S: Open burning
T: Terrestrial pollution
W: Ocean pollution
V: Dumpsites/ unsanitary landfill
N: Landfill
O: Incineration
Legend
Pre-consumer
Plastic flow
Point of mass accumulation
Interactions with other archetypes

Others

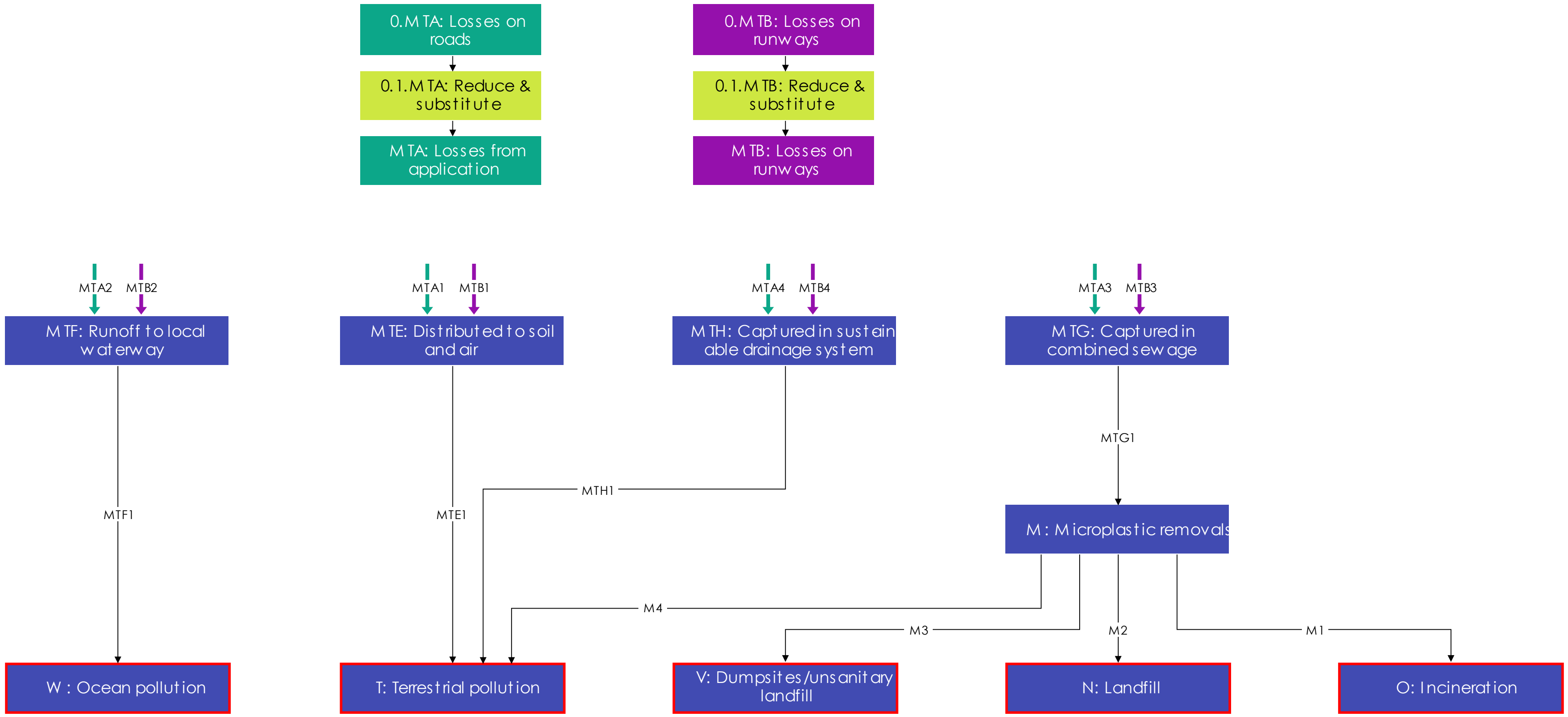


0: Plastic use
0.1: Plastic reduction
0.2: Plastic substitution
0.3: Remaining plastic utility demand
0.4: Recycled or reused plastics
0.5: Virgin plastics
1: In-use stock
A: Total plastic waste
A1
B: Collected plastic
B1
I: Closed-loop recycling
I1
A2
B2
I2
Q: Uncollected
M: Disposal
Q1
Q2
Q3
Q4
M2
M1
S: Open burning
T: Terrestrial pollution
W: Ocean pollution
V: Dumpsites/ unsanitary landfill
N: Landfill
O: Incineration
Legend
Pre-consumer
Plastic flow
Point of mass accumulation
Interactions with other archetypes

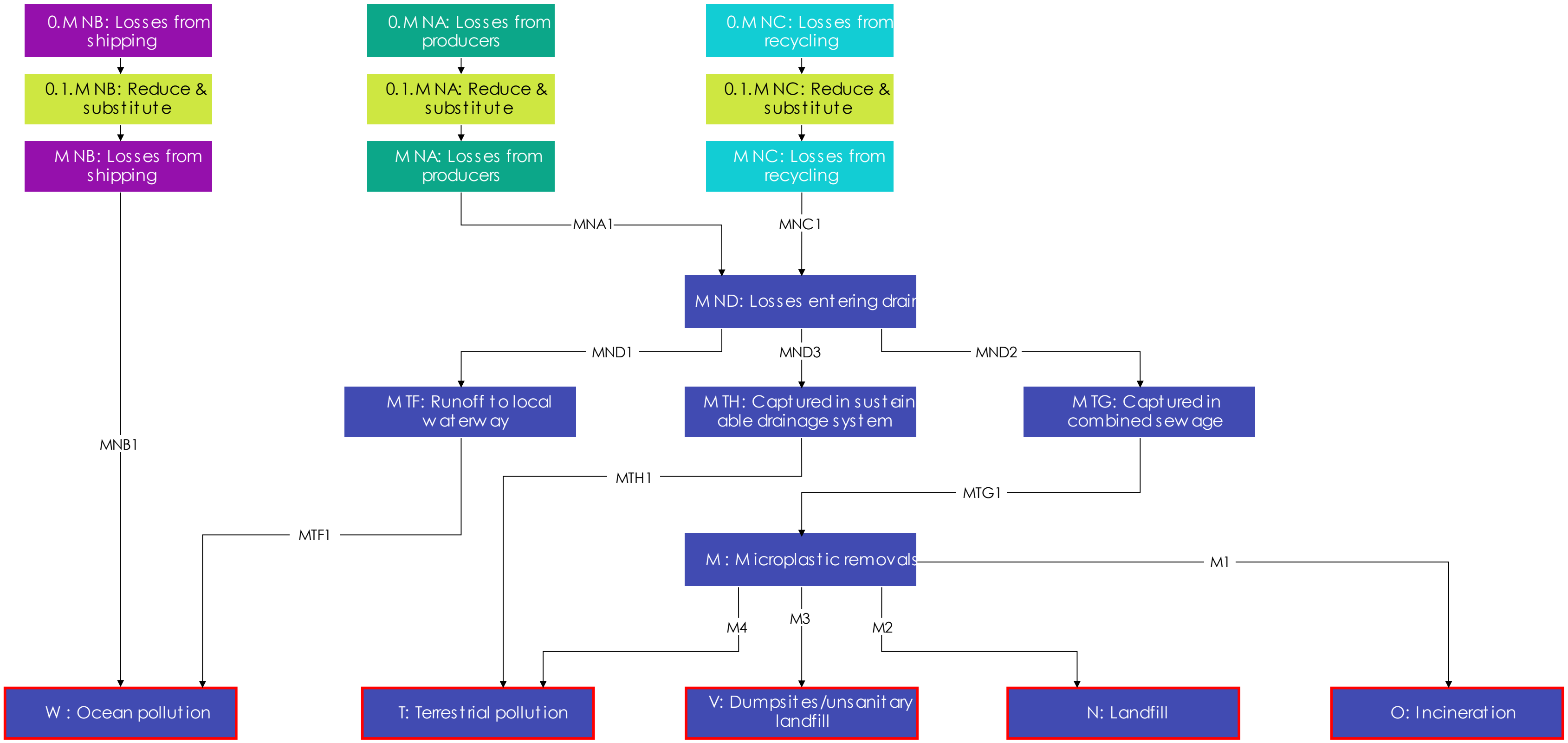
Microplastics – Paints



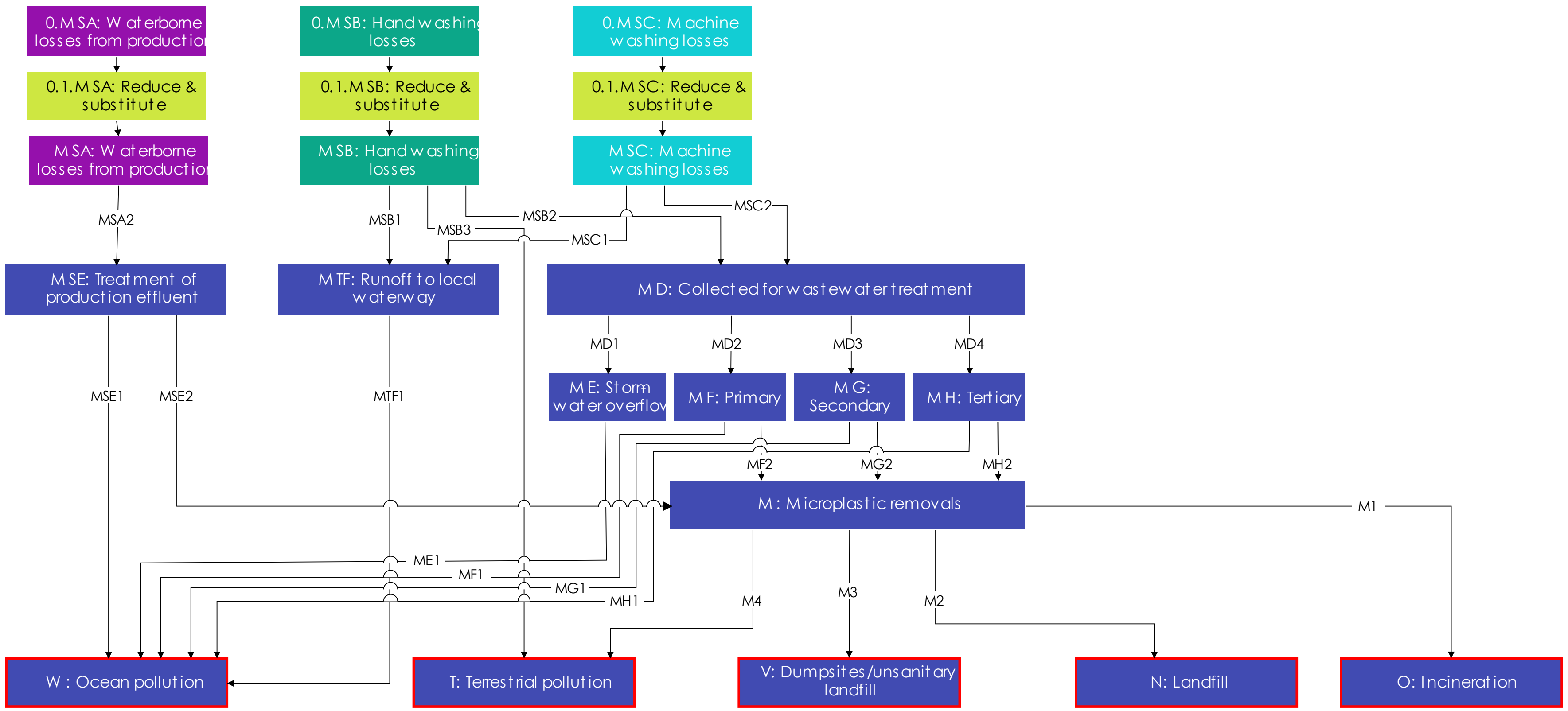
Microplastics – Tyre abrasion



Microplastics – Pellets



Microplastics – Synthetic textiles



Microplastics – Personal Care Products