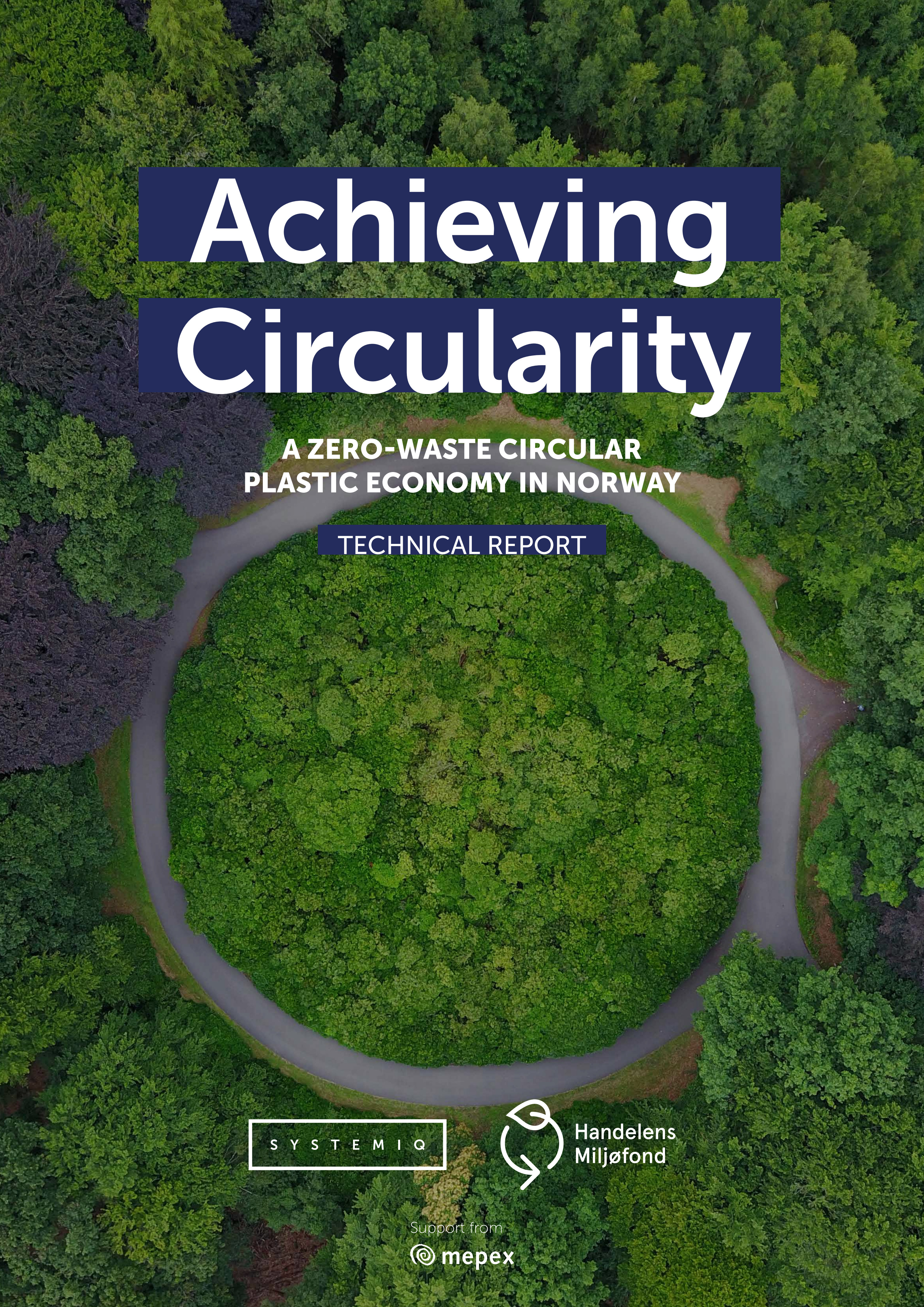


Achieving Circularity

A ZERO-WASTE CIRCULAR PLASTIC ECONOMY IN NORWAY

TECHNICAL REPORT

SYSTEMIQ

Handelens Miljøfond

Support from

mepex

Contents

1. Introduction

The aim of this report is to provide a transparent overview of the assumption and methodology used in the model and online tool developed by SYSTEMIQ for Handelens Miljøfond with support from Mepex. Taken together, this is a decision support tool that can help decision makers understand the economic, environmental, and social implications of business as usual (BAU), as well as the impact of different intervention strategies available to them.

The overall methodology is derived from the article 'Evaluating Scenarios Toward Zero Plastic Pollution' published in Science in July 2020 and authored by Lau et al. For more information regarding the Science article please consult the link below (article and supplementary information):

https://science.sciencemag.org/content/369/6510/1455

The Science article has been written on the basis of a global model developed by SYSTEMIQ and The Pew Charitable Trusts with a number of thought partner organizations and a panel of 17 experts for Breaking the Plastic Wave report. Aspects of the methodology which were updated from the global analysis to better fit the Norwegian system are described in this document. The report can be found in the link below:

https://www.systemiq.earth/breakingtheplasticwave/

2. System Map and Archetypes

System map

At the heart of our analysis is a model that simulates the main flows and stocks of the global plastic system (Exhibit 1 and 2). For each of the boxes and arrows in the system map, for each geographic archetype, for each of five plastic application categories (rigid mono-materials, flexible mono-materials, multi-layer/multi-material, beverage bottles, household goods and other), and under different scenarios, flows outlined in those maps were quantified in tons. Additionally, the following metrics were also mapped:

(1) cost (NOK or $)
(2) GHG (CO_{2eq})
(3) employment (number of jobs created)

Where data was unavailable, we made assumptions, the rationale for which will be outlined in this document.

Archetypes

Two archetypes with different system maps are used to depict the plastic waste generated by the Norwegian system: (a) Archetype 1: waste collected and processed in Norway (Exhibit 1), (b) Archetype 2: waste exported and therefore processed outside of Norway (Exhibit 2). A homogeneous archetype for all of Norway was selected as collection and treatment rates are broadly similar across all regions of Norway except for a small, negligible number of isolated areas and communities. As Norway exports over 60% of its plastic municipal Solid Waste (MSW), it is crucial to model the difference in volumetric fates as well as costs and GHG both within Norway and without. The 2 system maps below illustrate the differences between the two archetypes.

EXHIBIT 1: System map – Archetype 1: Norway

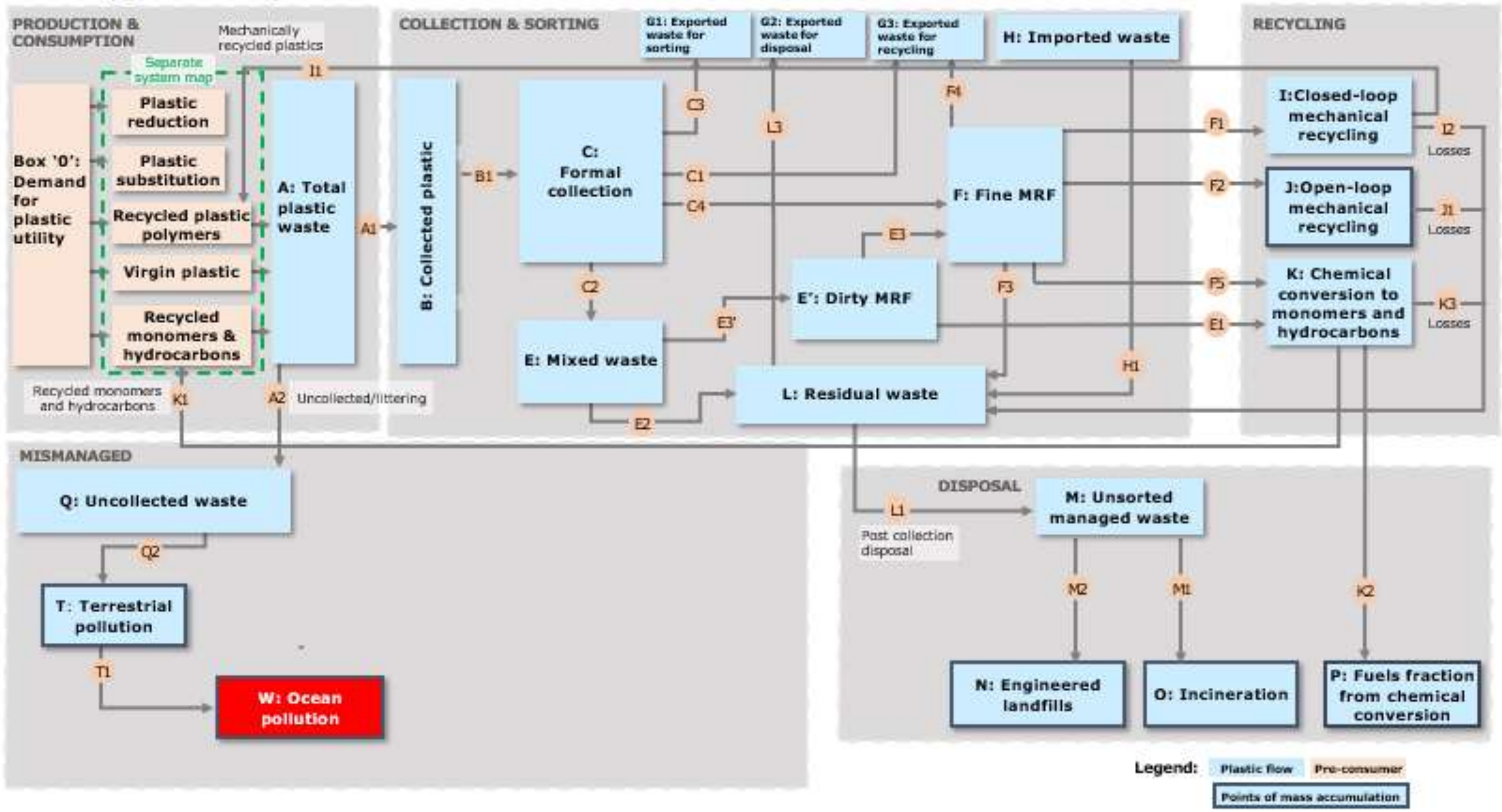
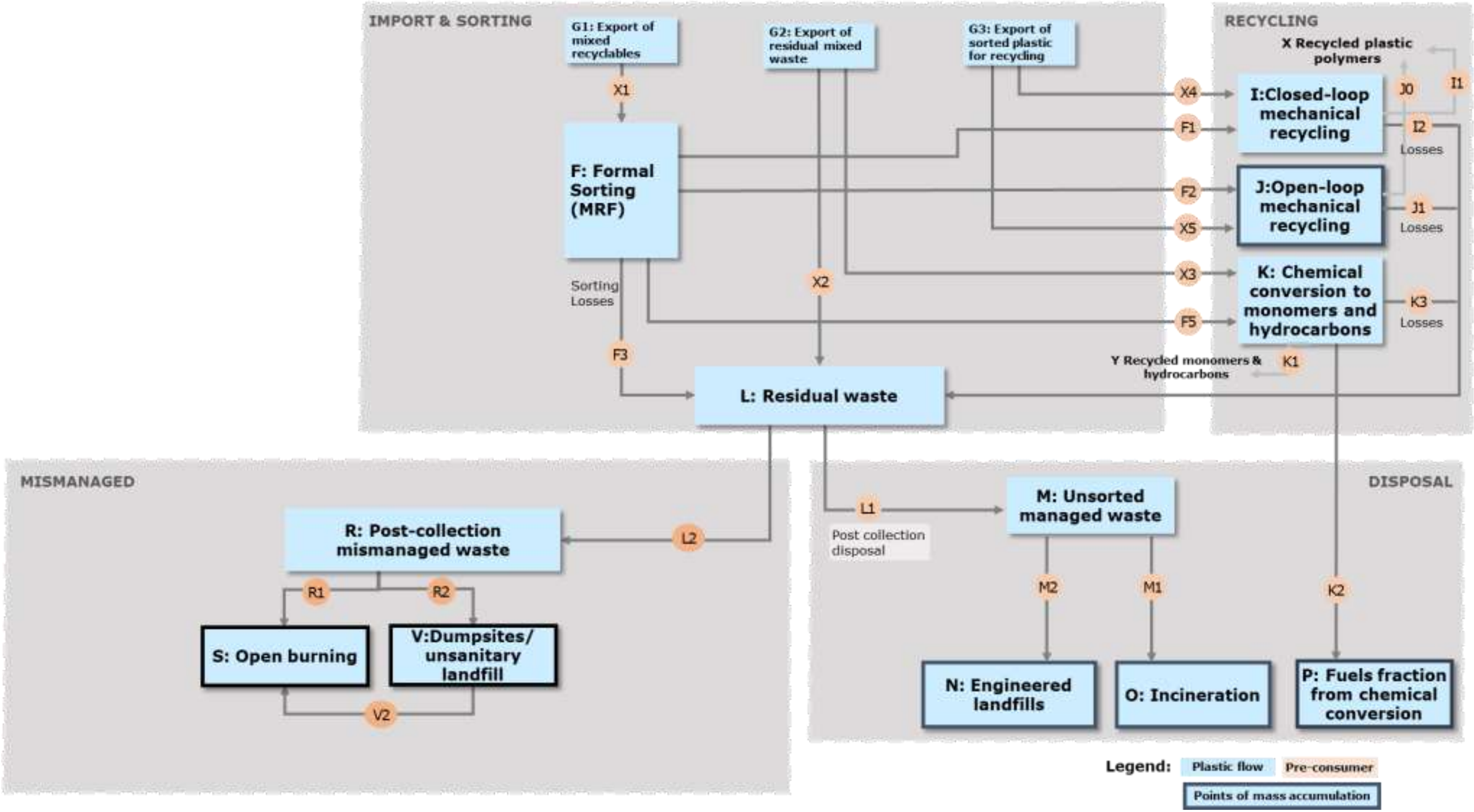


EXHIBIT 2: System map – Archetype 2: Exports



Thresholds

Through the new *Plastsimulator* online simulation developed for this project, users can modify 18 levers across 4-5 threshold points to understand the impact of changing those levers on economic, environmental, and social system indicators. Each threshold represents a possible value for a given lever in 2040. The summary of all thresholds for each of the levers can be seen below (Exhibit 3) and in the respective sections in this report.

Each lever in the *Plastsimulator* online simulation impacts one or more variables in the model. Once the 2040 model values are determined, the values for the years between 2019 and 2040 are generated assuming a linear trend between. The definition of each lever can be found in the online tool along with broad definitions of what each threshold value means for the model and what it takes to achieve such threshold. In this document, the exact threshold values for each lever are summarized in each specific section of the model.

For simplicity, thresholds are agnostic of the plastic category, meaning that discrete assumptions have been made to ensure that each plastic category is affected based on its relevancy to each of the levers. This was important to facilitate the user accessibility of the tool.

EXHIBIT 3: Threshold definitions for each lever

	Threshold 0	1	2	3	4
REDUCE					
Plastic elimination	No additional elimination	Low level of ambition	Moderate level of ambition	High level of ambition	
Shift to new delivery models	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
SUBSTITUTE					
Switch to Paper	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
Switch to compostables	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
RE-DESIGN					
Design for recycling	No additional implementation	Low level of implementation	Moderate level of implementation	High level of implementation	
SORTING					
Coverage of source separation	100% of municipalities collect plastic mixed with residual	25% of municipalities offering plastic source sortation	50% of municipalities offering plastic source sortation	85% of municipalities offering plastic source sortation	
Household source separation rate	Current adoption rate	Moderately improved adoption rate	Improved adoption rate	Highly/Greatly improved adoption rate	
Domestic share of sorting	18% waste sorted domestically (current rates)	25% waste sorted domestically	50% waste sorted domestically	75% waste sorted domestically	100% waste sorted domestically
Sorting Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
MECHANICAL RECYCLING					
Domestic share of mechanical recycling vs Exports	10% of sorted waste recycled domestically (current rates)	25% of sorted waste recycled domestically	50% of sorted waste recycled domestically	75% of sorted waste recycled domestically	100% of sorted waste recycled domestically
Domestic share of OL vs CL recycling	100% Open loop Recycling	25% Closed loop Recycling	50% Closed loop Recycling	75% Closed loop Recycling	100% Closed loop Recycling (current rates)
Mech .Recycling Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
chemical conversion					
chemical conversion development	100% of available feedstock for chemically recycling sent to incineration (current rates)	12.5% of available feedstock for chemically recycling processed	25% of available feedstock for chemically recycling processed	37.5% of available feedstock for chemically recycling processed	50% of available feedstock for chemically recycling processed
Output Mix: share of fuel vs new feedstock	100% to fuel	25% to new feedstock	50% to new feedstock	75% to new feedstock	100% to new feedstock
Chem. Recycling Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
EXPORTS					
Export fate control	Current trend	Moderately improved control of fate	Improved control of fate	Highly improved control of fate	
Domestic share of incineration vs Exports	0% incinerated domestically	25% incinerated domestically	56% incinerated domestically (current rates:)	75% incinerated domestically	100% incinerated domestically
CONSUMER BEHAVIOR					
Littering rate	High littering rate	Moderate littering rate	Low littering rate	Very low littering rate	

Scenarios

Three pre-defined scenarios exist in the tool. In addition to these pre-defined scenarios, users can create custom scenarios by moving the 18 levers as described above. The 3 pre-defined scenarios in the tool are:

1- **Scenario 1: Business as Usual (baseline)**: Assumes no intervention is made in relation to current plastic-related policy, economics, infrastructure, or materials, and that cultural norms and consumer behaviours do not change.

2- **Scenario 2: Central Sorting**: Assumes implementation of design for recycling guidelines, scale up of national uniform collecting mixed waste system (excluding food waste) and central sorting infrastructure to process all the plastic waste generated in Norway and considered in scope for this project, moderate development of recycling processing capacity, increased demand for recyclates, investment in sorting and recycling technologies efficiency and controlled export fate.

3- **Scenario 3: System Change Scenario**: Assumes that all ten system interventions are applied concurrently and ambitiously. This scenario benefits from the synergies among upstream and downstream interventions, as it is the only one that includes both.

In the insight report we refer to 6 scenarios:

1. **Business-as-usual (Business-As-Usual):** Assumes no intervention is made in relation to current plastic-related policy, economics, infrastructure, or materials, and that cultural norms and consumer behaviours do not change. This scenario corresponds to scenario #1 in the *Plastsimulator* online tool.
2. **Reduce and substitute:** Assumes dramatic reduction of plastic use through elimination, ambitious introduction of reuse and new delivery models, ambitious introduction, and investment in plastic substitutes when beneficial, and shift toward full implementation of design for recycling guidelines. This intervention would require strong policy interventions to regulate specific single-use plastics and incentivize design for reuse, reduce and re-design.
3. **Scale-up of a sorting backbone:** Assumes full implementation of design for recycling guidelines, moderate increase of sortation at source, scale up of national sorting infrastructure to process most of the plastic waste generated in Norway and considered in scope for this project, increased demand for recyclates, investment in sorting technologies efficiency and controlled export fate.
4. **Central sorting and recycling:** Assumes implementation of design for recycling guidelines, scale up of national uniform collecting mixed waste system (excluding food waste) and central sorting infrastructure to process all the plastic waste generated in Norway and considered in scope for this project, moderate development of recycling processing capacity, increased demand for recyclates, investment in sorting and recycling technologies efficiency and controlled export fate. This scenario corresponds to scenario #2 in the *Plastsimulator* online tool.
5. **Ambitious sorting and recycling scale up:** Assumes full implementation of design for recycling guidelines, moderate increase of sortation at source, scale up of national sorting infrastructure to process most of the waste generated in Norway, increased demand for recyclates, full development of recycling processing capacity, investment in sorting and recycling technologies efficiency, development of chemical conversion, and controlled export fate.
6. **System Change Scenario:** Assumes that all ten system interventions are applied concurrently and ambitiously. This scenario benefits from the synergies among

upstream and downstream interventions, as it is the only one that includes both. This scenario corresponds to scenario #3 in the *Plastsimulator* online tool.

The thresholds assumed for each of the scenarios described above can be found in appendix 1 (highlighted in yellow in the Exhibit A1-1, A1-2, A1-3, A1-4, A1-5 and A1-6).

In addition, while the tool set some boundaries in term of threshold, the user can still create more than 100,000 different scenarios using the 18 levers available. Note that the tool is agnostic meaning that (1) it provides a simple 'what if analysis' and (2) as such the availability of a scenario does not necessarily mean that this scenario is beneficial for system (3) the tool does not answer the question 'how' to make that scenario a reality (or what are the enablers to create that scenario). This tool aims to inform fact-based discussion around the economic, environmental, and social implication of alternative pathways and offers a few key indicators (GHG, circularity index, cost, employment) to understand the trade-offs between each.

Uncertainty

The quantity and global distribution of plastic pollution depend on a complex set of human actions and system components that are constantly in flux and unlikely to be measured—let alone modelled—with a high level of certainty. Accordingly, we designed a series of scenarios to better understand the extent to which near-term decisions affect future plastic pollution and the conditions likely to maximize circularity.

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 Norwegian plastic system. Because gaps exist in data on the generation, collection, recycling, disposal, and leakage of plastic waste, the model is unable to accurately measure all feedbacks in the system. Model design and construction required expert judgment to fill data gaps and estimate current and potential rates of change for the system components, which were then used to generate scenarios. 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.

Despite these limitations, the model results are informative as long as they are appropriately contextualized. This means that, rather than providing specific directions for government and industry decision-makers to pursue at individual locations, outputs should be viewed as a system-level assessment of potential futures based on a broad suite of actions and stakeholder priorities.

3. Waste generation and waste characterization

The first step is to quantify total demand for plastic waste generation for each of the plastic application categories (rigid mono-materials, flexible mono-materials, multi-layer/multi-material, beverage bottles, and household goods and others).

The foundation of our analysis is based on three components:

(1) current and projected population,
(2) current and projected plastic waste generation per capita, and
(3) current plastic waste composition (i.e., percentage of rigid mono-material, flexible mono-material, beverage bottles, household goods, and multi-layer/multi-material plastic waste)

The growth of the two first components (population and waste generation per capita) will define the growth of plastic waste generation in Norway until 2040 under business as usual. It will be defined as 'total utility of the system', meaning that it represents the total amount of utility needed by the system and will therefore be used as a baseline for the scenario analysis.

Population

National statistics published by Statistics Norway Population - SSB[1] were used to forecast population growth in Norway between 2019 and 2040. A CAGR of 0.44% was applied to the population in 2019 to obtain the population values between 2019 and 2040. Results are displayed below (Exhibit 4).

Plastic scope

Mepex estimates that 540,000 tons of plastic waste is generated in Norway per year. Of these, 54% is covered in this project. This scope includes all the waste defined as Municipal solid waste such as (1) packaging waste from consumers (2) household goods (3) waste from businesses which is similar to household as well as (4) all the packaging waste from industrial use and (5) other plastic waste types collected as part of municipal solid waste.

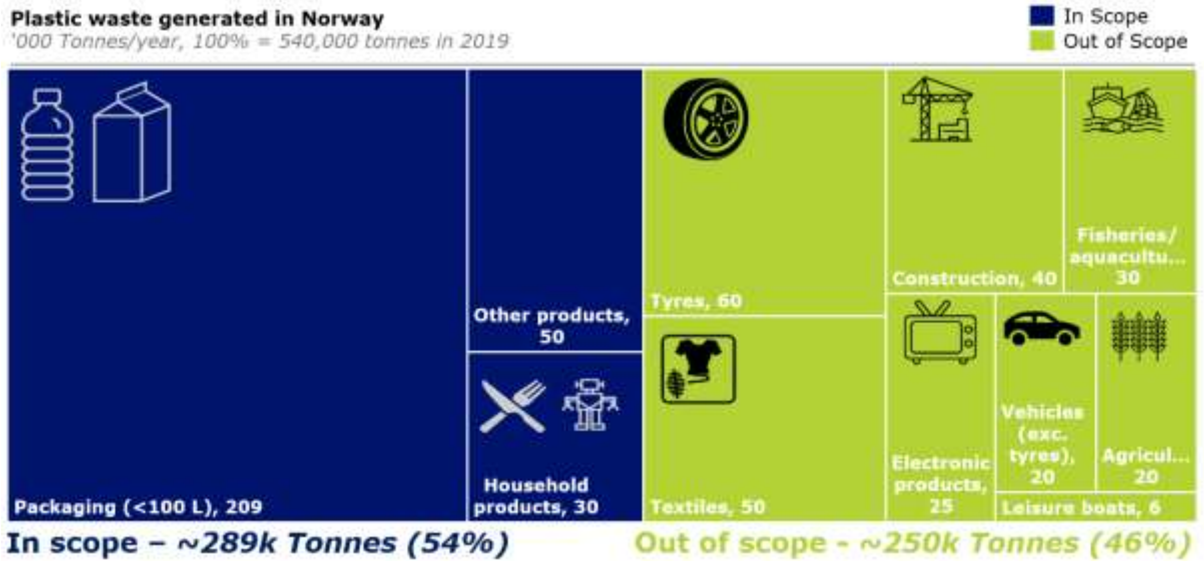
The plastic flows from the following fields and/or industries have been excluded from the analysis:

(1) Tyres and related thermosets polymers
(2) Textiles and fibre-based products.
(3) Construction materials
(4) Automotive plastic
(5) Electronics and related products
(6) Agricultural plastic waste (i.e. films)
(7) Fisheries and aquaculture
(8) Leisure boats

A summary of the total plastic waste generated in Norway as well as what is included and excluded from the scope of this project can be found below (Exhibit 4).

[1] https://www.ssb.no/en/befolkning/nokkeltall/population

EXHIBIT 4: Plastic scope of the project



Projected plastic waste generation per capita

To forecast plastic waste generation per capita from 2019 to 2040, the year-on-year growth rate of European plastic demand trajectory from Material Economics (the Circular Economy Report, PG. 78) below (Exhibit 5) was used as a reference point. While the analysis has a year-on-year growth rate, it is equivalent to an overall CAGR of 0.81% for plastic waste generation in Europe. Projections (2019-2040) were calculated using the year-on-year growth rate for European plastic waste generation from Material Economics starting from the per capita plastic waste generation analysis performed by Mepex for 2019. Total figures were then obtained by multiplying per capita plastic waste generation by respective populations for each year. Results are displayed below (Exhibit 6).

EXHIBIT 5: Material Economics (2018) regional plastic production growth estimates

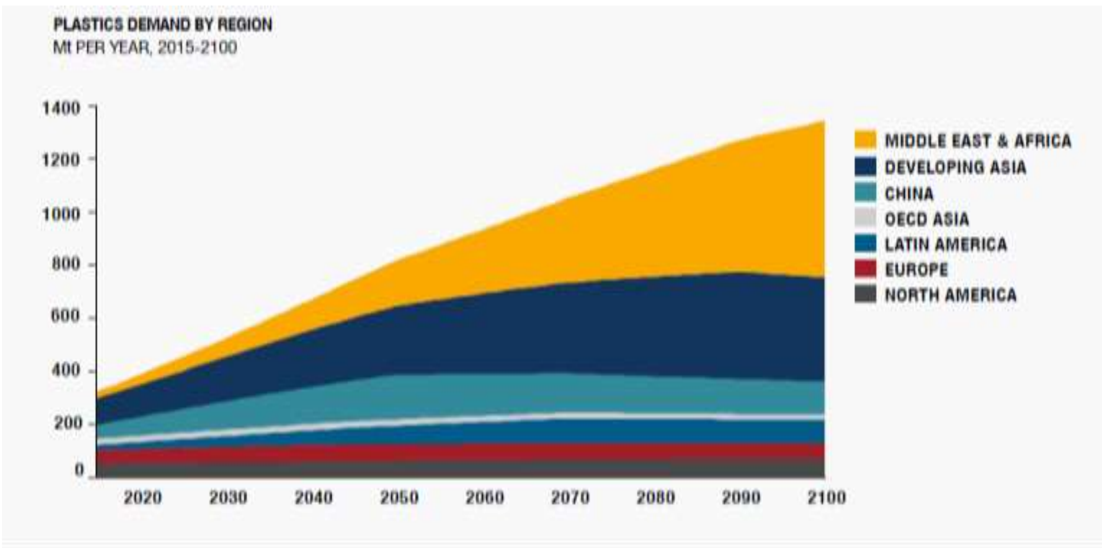


EXHIBIT 6: Plastic waste generation to 2040

	2019	2030	2040	CAGR 2019-2040
Norway Population[1] ***('000 capita)***	5,328	5,592	5,843	0.44%
Plastic waste generation per capita in Norway[2] ***(tons/cap/year)***	0.055	0.061	0.066	0.81%
Plastic Waste generation in Norway ***('000 tons)***	**289**	**335**	**376**	**1.19%**

(1) Statistics Norway Population - SSB
(2) Material Economics, the Circular Economy Report (PG. 78) (https://materialeconomics.com/publications/the-circular-economy)

Plastic application categories

This analysis distinguishes between different "plastic categories". Given that the current material flows, economics, and available solution sets for rigid mono-materials, flexible mono-materials and multi-material/multi-layer, bottles and household goods plastics are so different, we analysed these materials separately. A summary of those categories and sub-categories can be found below:

- **Rigid mono-materials** includes 6 sub-categories: (a) non-food-grade bottles, (b) other food grade packaging, (c) food service items inc. single-use plastic, (e) other packaging, (f) B2B packaging, and (g) expanded polystyrene (EPS).
- **Flexible mono-materials** includes 4 sub-categories: (a) carrier bags, (b) mono-material films, (c) food packaging film, and (d) B2B flexibles.
- **Multi-material and multi-layer** include 4 categories: (a) beverage cartons, (b) food service items, (c) sanitary and diapers, (d) other multi-layer or multi-material.
- **Beverage bottles** includes 2 subcategories of food grade beverage bottles collected via a consumer deposit system: (a) water bottles, (b) other beverage bottles.
- **Household goods and others** is considered a single category as detailed information is unavailable. Examples of items in this category include but is not limited to: (a) kitchen utensils, (b) storage boxes/bins, (c) toys, (d) sports equipment.

The waste characterization was obtained from detailed data from Mepex and products were aggregated by plastic categories to match the above. The share of those different plastic categories (i.e. rigids, flexibles etc.) was assuming to change according to analysis from the Breaking the Plastic Wave report based on Grand View market research analysis (Exhibit 7). In essence this research translates the current market trends of shift from rigids and bottles to flexibles which has been observed as a result of weight-lightening strategies.

EXHIBIT 7: Plastic waste composition to 2040

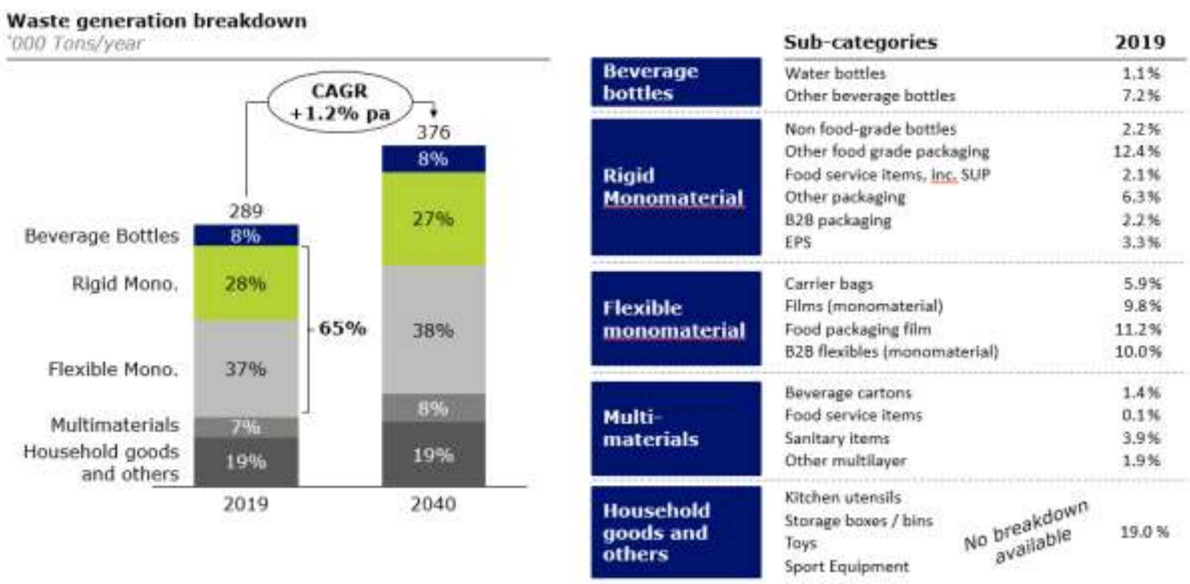
	2019[1]	2030	2040	CAGR 2019-2040[2]
Beverage Bottles	8.3%	8.1%	7.9%	-0.22%
Rigids monomaterials	28.5%	27.8%	27.2%	-0.22%
Flexible monomaterials	36.9%	37.4%	37.8%	0.11%
Multi-materials	7.4%	7.8%	8.2%	0.49%
Household Goods and Others	19.0%	19.0%	19.0%	0%

(1) Mepex analysis (2) SYSTEMIQ analysis based on Grand View market research.

A summary of the waste characterization and composition results can be found below (see Exhibit 8).

Detailed waste characterization (by sub plastic categories) was only used to calculate the potential of the reduce and substitute levers.

EXHIBIT 8: Plastic waste generation per capita growth between 2019 and 2040 and plastic waste characterization for 2019



Note that all plastic flows in this document are reported and calculated net, which mean that they exclude any residual organic waste, water or other impurities collected and transported with the plastic waste.

Virgin plastic production and conversion costs

An in-depth analysis was carried out at the request of SYSTEMIQ to determine accurate and representative costs for the production of virgin plastic in the EU and its subsequent conversion into applicable products. These costs were then applied to the Norwegian waste composition as shown above (Exhibit 7) to determine the costs applied in this project (Exhibit 9).

EXHIBIT 9: Cost per tonne of virgin plastic produced and converted

Process	Cost ($ per tonne of plastic produced/converted)		
	OPEX[1]	CAPEX[1]	TOTAL
Virgin plastic production	$1,697 (NOK 14,658)	$566 (NOK 4,886)	$2,262 (NOK 19,544)
Plastic conversion	$2,624 (NOK 18,030)	$875 (NOK 6,010)	$3,499 (NOK 24,039)

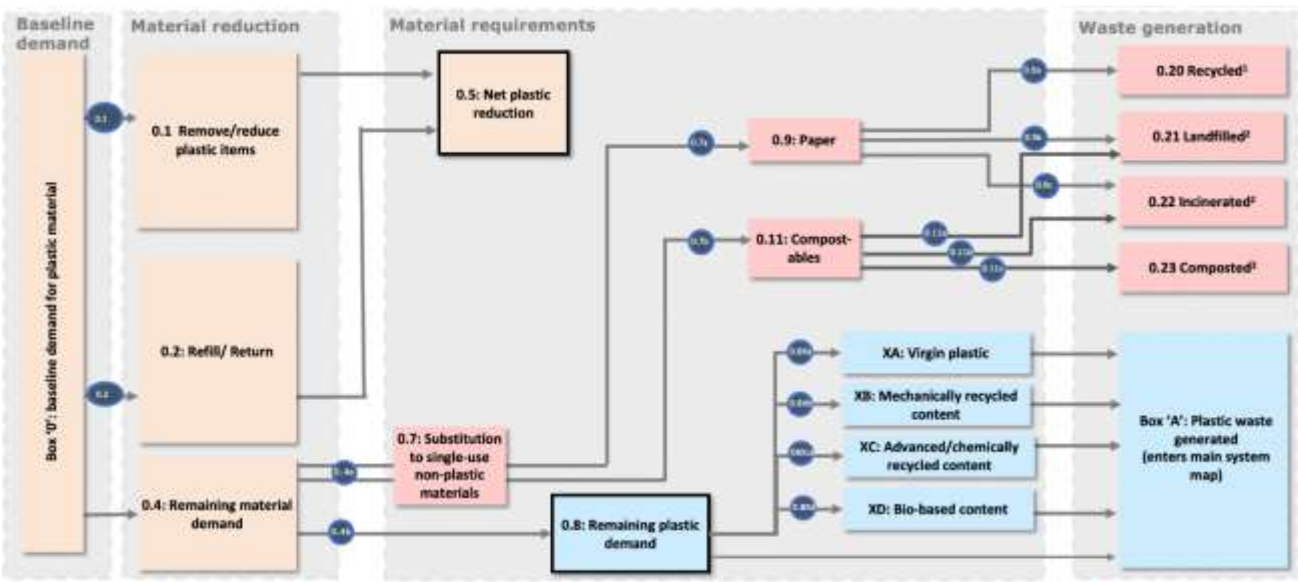
[1] Opex and Capex are allocated by a ratio of 3:1, used in the Global analysis. Note: NOK/USD XR: 8.64 (average over the last 12 months).

4. Reduce and substitute methodology

System map

The Reduce and Substitute system map simulates the main flows and stocks of the material requirement system (Exhibit 10). A material reduction section removes the unnecessary plastic from the baseline demand through eliminate and new delivery model solutions. From the left-over utility, a share of the demand is substituted through paper and compostable solutions, leaving the remaining plastic demand to enter the main system map.

EXHIBIT 10: System map – Reduce and Substitute



Definition

To construct the System Change Scenario, we first conceptualized two classes of system interventions, or wedges: reduce (intervention I) and substitute (intervention II). Each intervention encompasses multiple components that can collectively contribute to the overarching objective (e.g., reducing overall plastic in the system includes both elimination and reduction through new delivery models) each of which will be described and detailed in the methodology below.

A framework was developed to assess the potential for reduction and substitution of plastic utility demand, Box '0' in the system maps. This framework, as detailed in the sections below, consists of a three-step process:

(1) Municipal solid waste (MSW) data were categorized into 15 product applications and the four plastic categories.

(2) the maximum potential level to which BAU demand (Box '0') could be reduced (Box 0.5) was calculated by applying two 'reduce' levers to each product application; and

(3) the maximum potential level to which the remaining utility demand could be substituted by non-plastic materials (Box 0.7) was calculated, modelling two substitute materials.

The residual utility demand connects back to the main system map and is considered as the new total of plastic waste generated.

For Intervention I, we modelled two levers – eliminate and new delivery models. Definitions can be found below (Exhibit 11).

EXHIBIT 11: Reduce lever definitions and examples

Lever	Definition	Examples	Enablers
Eliminate	▪ Policy interventions, innovations and consumer behavior shifts which lead to reduced plastic material demand for low-utility plastic, that **does not require a replacement**	▪ Reduce over-packaging, develop packaging-free products, ban unnecessary plastics, increase utility per package ▪ Extend the life of household goods	▪ Regulation, targets, taxes and incentives such as EPR ▪ Consumer behavior ▪ Localized supply chains ▪ Innovation through virtualization and new product development
New delivery models	▪ Replacement of single-use products and packages with re-usable items **owned and managed by the user** ▪ **Services and businesses which provide the utility** previously furnished by single-use plastics, with reduced material demand	▪ Re-usables owned by consumers (eg water bottles, bags for life) ▪ Re-usables owned by institutions (eg cutlery, crockery, plastic pallets) ▪ Refill from dispensers, subscription services, concentrated product capsules, take-back services with reverse logistics and washing (eg SodaStream, AlGramo, LOOP, RePack) ▪ Package-as-a-service models (eg CupClub, Revolv, GoBox, packaging-free deliveries)	▪ Consumer behavior ▪ Regulation, targets, taxes, deposits ▪ Innovation through e-commerce, trackers, servitization, internet of things

For Intervention II, two levers around two potential materials for substitution were modelled. These two substitution materials (paper and compostables) were selected, as they are the most prevalent substitutes available today for replacing "problematic" plastics - films and multilayer flexibles, which have low recycling rates and a high leakage rate into the environment. We deliberately excluded aseptic cartons, glass, and metal as a single-use substitute because these materials were found to have potential negative trade-offs and unintended consequences, such as higher costs, and GHG emissions. Additionally, these materials are likely to substitute rigid packaging - especially bottles - which are less problematic. Coated paper was also excluded due to the lack of facilities available to recycle this material in Norway. A summary of those levers and definition can be found below (Exhibit 12).

EXHIBIT 12: Substitute lever definitions and examples

Lever	Definition	Examples
Paper	Substitute with **recyclable paper**, or other pulp-based or fibre-based material, ensuring that it is sustainably sourced. Paper recycling is widespread globally; for example, 85 per cent of paper and cardboard packaging is recycled in the European Union compared with just 42 per cent of plastic packaging. Paper substitutes are undergoing rapid innovation, leading to improved barrier properties and cost/weight performance. For nonfood applications, high recycled content is possible in current market conditions.	Plastic fruit and vegetable punnets, display trays, shrink wraps on drinks, paper substitutes for polystyrene foams, paper food service items (plates, cutlery, straws), paper wet-wipes .
Compostables	**Existing materials and new formats** under development (including nonplastic compostable materials—cellulosics, alginates, banana leaves, edible and ephemeral packaging as well as compostable plastics) that are **approved to meet relevant local compostability standards** (for example, industrial composting standard EN 13432 where industrial-equivalent composting is available and effective). These materials should be capable of disintegrating into natural elements in a home or industrial composting environment, within a specified number of weeks, leaving no toxicity in the soil. Compostables are most relevant where composting infrastructure exists or will be built, and for substituting thin plastic films and small formats. Substitution with compostable materials is most appropriate for products with low plastic recycling rates and high rates of food contamination, making co-processing with organic waste a viable option.	Banana leaves for takeaway food, fibre-based compostable-ready meal trays, seaweed pouches, compostable chips packets and tea bags

Reduce and substitute product application impact

Municipal solid waste (MSW) data was segmented into 15 plastic product categories with similar utility, which were categorized into the four plastic categories – beverage bottles, rigid monomaterial, flexible monomaterial, or multimaterial/multilayer. The applicability of each reduction and substitution lever to each product application was then assessed based on existing businesses, policies, available technologies, environmental trade-offs and consumer trends observed to date (Exhibit 13).

EXHIBIT 13: Applicability of interventions by product application

	Product application	Eliminate	New Delivery Models	Paper	Compostables
Bev. bottles	Water bottles		✓		
	Other beverage bottles		✓	✓	
Rigid mono-material	Food-grade bottles		✓	✓	
	Other food grade packaging	✓	✓	✓	
	Food service items, inc. SUP	✓	✓	✓	✓
	Other packaging	✓		✓	
	B2B packaging		✓		
	EPS				✓
Flex. mono	Carrier bags	✓		✓	✓
	Films (mono-material)	✓	✓	✓	✓
	B2B flexibles (mono-material)	✓			✓
Multi-material / multi-layer	Food service items	✓	✓	✓	✓
	Beverage cartons		✓		✓
	Sanitary items		✓	✓	✓
	Other multi-layers				

Limiting factor scoring framework

To assess the reduction or substitution potential of each product application, a limiting factor scoring framework was developed. This framework assesses four attributes related to the feasibility of a product application for plastic reduction or substitution: technology readiness level (TRL), performance, convenience, and cost. Each product application was scored on a scale of 1-4 (with 4 representing the most feasible option) against the four attributes based on expert panel consensus. The potential impact of policy intervention is not explicitly reflected in the framework. However, it was considered as an enabling factor in the assessment of the limiting factor score as it can accelerate TRL development and impact on the technology, cost, performance or convenience of an alternative material or delivery model. A summary of this limiting scoring framework can be found below (Exhibit 14).

EXHIBIT 14: Feasibility test attributes

a Technology test	b Performance test	c Convenience test	d Affordability test
Does a theoretical reduce (1st pass) or substitute (2nd pass) **intervention exist?**	Does the intervention satisfy **performance & health** requirements?	Is the intervention acceptable for **lifestyle and convenience?**	Are the **cost implications** of the alternative acceptable?
Yes: TRL 9, available in multiple locations	Yes: meets the minimum performance requirements for sustained utility	Yes: near or better than BAU	Yes: net savings to society, or broadly acceptable to consumers
Only at pilot: TRL 5-8	Mostly: does not meet performance requirements for certain applications	Mostly: consumers or supply chains would face challenges	Mostly: unacceptable in some consumer segments or products
Only in labs: TRL 1-4	Partially: limited applications only	Partially: eco-conscious consumer only	Partially: eco-conscious consumers only
No alternative available	Unacceptable health or performance risk	Unacceptable lifestyle change	Unacceptable cost increase

For each overall limiting factor score level, a potential market reach in 2030 and 2040 was assessed (Exhibit 15), based on expert panel consensus informed by the speed of historical socio-technological shifts of similar technologies, business models and policies.

EXHIBIT 15: Potential market reach test

Overall score	**2030 %** of serviceable market reached	**2040 %** of serviceable market reached
Green	50%	85%
Yellow	20%	50%
Orange	1%	10%
Red	0%	0%

For each reduce lever, the overall limiting factor level for a product application was determined (limited) by the lowest score among the four attributes. As such, the limiting factor score can be considered conservative. All four attributes were weighted equally. Summary of this analysis can be found in the tables below (Exhibit 16, 17, 18 and 19).

EXHIBIT 16: Reduce scores for Norway

Product application	Tech. test	Perf. test	Conv. test	Aff. test	Overall score	Reduction Rate 2040
Fresh fruits and vegetables						50%
Straws and stirrers						50%
Off-premise cutlery						10%
Other rigids						10%
Carrier bags						50%
Films						10%
B2B flex.						10%
Sachets						10%
Multilayers						10%
Wetwipe						10%
Other multi						10%

EXHIBIT 17: New delivery model scores for Norway

Product application	Tech. test	Perf. test	Conv. test	Aff. test	Overall score	Red. Rate 2040
Water bottles						50%
Other bev. bottles						50%
Other bottles						50%
Fresh fruits and veg.						50%
Pots and tubs						10%
Ready Meals						10%
Cups						80%
Lids						50%
Containers						50%
B2B rigids						80%
Films						10%
B2B flex.						50%
Sachets						50%
Multilayers						10%
Laminated Paper/Al						10%
Diapers						10%
Feminine hygiene product						10%

For the substitute levers, the overall limiting factor level, "overall substitutability," for each product application was defined as the limiting factor score of its best-rated substitute material. This process was used to avoid over-estimation, as it was assumed the possible speed of substitution away from plastic reflects the overall penetrability of the plastic-dominated market dynamics and the suitability and availability of all new materials, rather than each material alone. Assumptions were made regarding the allocation of plastic mass substituted among the two modelled substitute materials based on their relative scores.

EXHIBIT 18: Paper substitute scores for Norway

Product application	Tech. test	Perf. test	Conv. test	Aff. test	Overall score	Sub. Rate 2040
Fresh fruits and vegetables						80%
Ready meals trays and instant pot snacks						50%
Straws and stirrers						80%
Off-premise lids						10%
Containers						80%
Cutlery						80%
Other rigids						50%
Carrier bags						50%
Films						10%
Sachets						10%
Multilayers						10%
Cotton bud sticks						100%[1]
Wetwipes						80%

EXHIBIT 19: Compostables substitution scores

Product application	Tech test	Perf test	Conv test	Aff test	Overall score	Sub. Rate 2040
EPS						10%
Carrier bags						10%
Films						10%
B2B flex.						10%
Sachets						10%
Multilayers						10%
Laminated Paper/Al						10%
Wetwipes						10%
Sanitary						10%
Diapers						10%

The maximum potential market penetration rate was used to calculate the resulting reduction in plastic mass requirements for each product application and then aggregated to each plastic category.

This analysis derived from the Breaking the Plastic Wave report. Changes were made to reflect the Norwegian system based on feedback from Mepex team and expertise.

The levers were applied in a hierarchical order: (1) "eliminate," (2) "New delivery model," and (3) "substitute." Product applications that have high recyclability potential were given lower scores for paper substitution, to reflect the fact that mechanical recycling is often more desirable than substitution to alternative materials, all things considered.

Overall, the analysis above once applied based on the waste characterization described in the previous section, led to the following results:

- Reduce potential:
  - Eliminate: 8.1%
  - Reuse and new business models: 13.0%
- Substitution potential:
  - Paper: 4.1%
  - Compostables: 5.2%

The above values were used to define 'threshold 2' as an ambitious yet realistic average. In the *Plastsimulator* online simulation, the additional levers were calculated as followed threshold 0 assumed no intervention and thus was set to 0, threshold 1 was calculated as half of the values obtained for threshold 2 and threshold 3 as 1.5 times the values obtained for threshold 2. The rationale was to give the user the ability to set higher and lower ambition levels for those interventions given the relatively high uncertainties of those market dynamics in the future (see next section).

In the business-as-usual scenario, it was assumed that there would be no additional removal and substitution solutions for plastic over the years (threshold 0). In the system change scenario, a moderate increase in compostable substitution was assumed (threshold 1), while a higher rate was assumed for elimination, re-use and new business models, and paper substitution (threshold 2) (Exhibit 20).

***EXHIBIT 20:* Reduce and substitute thresholds by 2040**

	0	1	2	3
% Eliminate	0%	4.1%	8.1%	12.2%
% Re-use and New business models	0%	6.5%	13.0%	19.5%
% Paper substitution	0%	2.1%	4.1%	6.2%
% Compostable substitution	0%	2.6%	5.2%	7.9%

% refers to % of plastic utility reduced or substituted by 2040 for each lever as a weighted average from all plastic categories.

Reduce and Substitute enabling conditions and uncertainties:

Eliminate, re-use and new business models:

Policy drivers required to accelerate this intervention include the adoption of standards or regulatory requirements for plastic packaging that focus on elimination of avoidable packaging and product redesign, alongside regulation on uses of plastic with a high likelihood of leakage. Within innovation drivers, it is necessary to have a global uptake by multinationals of innovative models and commitments to long-term quantitative goals to eliminate and reuse packaging, as well as companies leveraging their global reach and R&D budgets to facilitate change. Within re-use and new delivery models, it is necessary to have regulatory and/or voluntary standards, consumer education, and reusable packaging targets to facilitate reuse and address hygiene concerns regarding food contact materials.

Paper:

Paper substitution drivers include policies and voluntary commitments to accelerate the expansion of paper collection and recycling, increase recycled content in paper, reduce contamination, and scale separate organic waste treatment that can accept compostable packaging.

Compostables:

Compostable substitution growth will depend on various enablers, such as (1) improved standards for compostability to ensure those materials can be composted in multiple environment (i.e. industrial compost, home compost, anaerobic digestor), (2) strong food-waste collection through regulation, (3) consumer behaviour change campaign to ensure compostables are disposed together with food waste, and (4) infrastructure and R&D investment to support the transition of current and new industrial processes to accept this new class of material. Note that the Norwegian context is likely to prove challenging to a large scaling of compostable due to its cold weather, its large fleet of anaerobic digestors which have stricter acceptance levels and thus for the compostables potential only threshold 1 was used in the different system change scenarios.

Reduce and substitute costs

For solutions to eliminate plastic items, the cost and emissions vary widely based on whether alternative solutions are needed after elimination, which are causing costs and GHG emissions themselves; or whether the elimination requires no alternative solution. In the table below, the differences between those two elimination types can be understood by examining the individual data points of the case studies feeding into the average cost numbers (Exhibit 20).

The production costs of substitute materials include the extraction, production, and conversion of the materials into packaging, and represents the cost that companies would pay for packaging excluding filling costs. The sources in the table refer to percent increases in cost for the combined production and conversion per equivalent virgin plastic package, incorporating the weight change associated with the new material as well as the cost change. These cost increase factors (e.g., compostables production being twice as expensive as plastics) are based on average cost increase of substitute packaging compared to their plastic counterparts. The cost values represent the cost per tonne of plastic substituted (Exhibit 20).

Example:

1. Virgin plastic production cost: $2,262
2. Plastic conversion cost: $3,499
3. Percentage increase for paper substitute due to weight and cost differences with paper = +67%
4. Paper cost per tonne of plastic substituted = ($2,262+$3,499) x 1.67 = $9,621

EXHIBIT 20: **Reduce and substitute thresholds by 2040**

Solution	$/t net plastic reduced for all plastic types	Source
Eliminate plastic items	$750 (NOK 6,480)	**Average of 6 case studies of cost reduction through elimination:** Glue Dots**: -59%** laser food labelling: **-73%** durable consumer reuse products: **-74%** Elimination of individual wrapping: -**100%** elimination of vegetable packaging: -**100%** straw removal: -**100%**
New delivery models	$5,387 (NOK 46 542)	Assuming combined production and conversion opex costs (-11%); capex costs (+7%) per tonne of virgin plastic moving to reuse
Paper	$9,621 (NOK 83,128)	67% higher costs than equivalent production and conversion cost of virgin plastic items, based on average cost increase of 9 items (see also BPW, 2020).
Compost ables	$11,523 (NOK 99,555)	100% higher costs than equivalent production and conversion cost of virgin plastic items, based on average cost increase of 4 items (see also BPW, 2020)

Note: NOK/USD XR: 8.64 (average over the last 12 months).

Design for recycling

Design for recycling is defined by the effort of facilitating recycling through an improvement in the manufacturing of plastic products and planning of processes used across the waste management system. Below are some examples of design for recycling:

- Investments in products that meet recycling specifications without sacrificing product safety, stability, or purity;
- Support for further innovation in sorting technologies to address pigments, additives, inks, and labels;
- Shifting consumer preferences driving higher demand for recycled content and higher recyclability of plastic products;
- Voluntary commitments by producers and retailers to increase recyclability and integrate recycled content in plastic products.

Design for recycling is complex to model as it impacts many aspects of the value chain. To simplify the modelling approach of design for recycling implementation three distinct modelling feature were included:

(1) Shift from multimaterials product category to flexible monomaterials. (i.e. substitution of multi-layered PE/PP packaging with multi-layered PE packaging). As industry is embracing circularity the share of 'hard-to-recycle' multimaterial will necessarily decrease to meet commitments;
(2) Increase sortation yield. As the products become fit for purpose and designed with end-of-life in mind, sorting technologies are more likely to capture them (i.e. black pigments) or new market will open-up (i.e. if higher quality material can be obtained);
(3) Increase recycling yield. As products become fit for purpose and designed with end-of-life in mind, the number of rejects/impurities in the recycling streams is likely to decrease (i.e. less residual PVC, similar pigments for PET bottles) leading to higher recycling yields overall.

Multimaterials are composed of 4 subcategories. In this analysis, it was assumed that sanitary items and beverage cartons are unlikely to be redesigned into recyclable mono-material plastic items as such we focused (1) on two sub-categories: multilayers food packaging and other multimaterials. For those two categories an 80% shift to monomaterials was assumed to be the most ambitious pathway possible by 2040, which translates to a shift of 30% from the multimaterials category to the flexible mono-materials category and becoming available for recycling. Availability for recycling does not necessarily translate into recyclability and will depend on the performance of the collection, sorting, and recycling system.

The above 30% shift calculated was used for the System Change Scenario and set as the most ambitious and therefore maximum threshold: threshold 3 for the Plastsimulator online simulation. Threshold 0 assumed no intervention and was set to 0. Thresholds 1 and 2 were calculated using a linear interval between threshold 0 and threshold 3. Threshold values for this lever can be found below (Exhibit 21).

The modelling of (2) and (3) is interlinked with other variables and therefore will be discussed in dedicated section of this document together with sorting and recycling yields and losses.

However, note that (1), (2) and (3) are linked under the same design for recycling lever and adjusting the threshold for this specific lever is necessarily affecting all of those variables at the same time.

EXHIBIT 21: **Design for recycling thresholds by 2040**

	0	1	2	3
% multimaterials shift to flexible monomaterials	0%	10%	20%	30%

5. Domestic collection and sorting

Plastic mass - collection

Total collection rate and littering rates

The availability of waste collection of municipal solid waste in Norway was assumed to be 100% across all geographies and plastic types. However, while 100% of the households and businesses have access to waste collection, not 100% of the waste is collected due to litter.

There is little data regarding litter rates in Norway or globally, the number assumed below for threshold 0 represent the best available data and consensus across a wide range of expert interviewed during the global study. Those estimates being considered high and conservative in the Norwegian context, the other threshold allow the user to explore the impact of different littering rates (Exhibit 22).

Once those littering rates have been defined the net collection rate can be calculated (Exhibit 23 – example for the business-as-usual scenario).

***EXHIBIT 22:* Littering rate thresholds per plastic categories by 2040**

	0	1	2	3
Beverage bottles	0.5%	0.37%	0.23%	0.1%
Rigid Monomaterials	2%	1.4%	0.8%	0.2%
Flexible Monomaterials	2%	1.4%	0.8%	0.2%
Multi-materials	2%	1.4%	0.8%	0.2%
Household goods and others	0.5%	0.37%	0.23%	0.1%

***EXHIBIT 23:* Overall collection rate and littering rate – business as usual scenario**

Norway – Business As Usual	2019	2030	2040
Collection rate	98%	98.3%	98.6%
Littering rate[1]	2%	1.7%	1.4%

(1) assuming starting point is threshold 0 and end point threshold 1 (see Exhibit 6)

Plastic mass – sortation at source

Collection system coverage

In Norway municipalities can choose which type of waste management system they offer to their communities. Collection system coverage includes the % of population for which municipalities have decided to provide communities with separated plastic waste sortation at source versus municipalities which are collected plastic together with residual waste (Exhibit 24). As of 2019, 85% of the population had access to plastic source sortation versus 15% had their plastic waste collected as mixed waste.

Note that this excludes beverage bottles which benefit from a nation-wide deposit system and are therefore treated separately (Exhibit 26).

***EXHIBIT 24:* Different type of collection system in Norway**

Collection systems in Norway	% population coverage	Aggregate population
Source Separation of Plastic and food waste	60.4%	85%
Source separation of plastic, not food waste	24.7%	
Source separation of food waste, plastic collected with mixed residual and sorted at central sorting facility in Norway	13.2%	15%
Source separation of food waste only	1.1%	
No source separation	0.7%	

Source: Mepex analysis based on Green Dot Norway data

Given that a few municipalities have made considerable investment in recent years in sorting MRF assets to sort mixed waste, it was assumed that those municipalities are unlikely to go back to source sortation collection. Therefore, the maximum threshold for this variable is 85%. The table below (Exhibit 25) shows the other threshold levels we included in the *Plastsimulator* online simulation.

***EXHIBIT 25:* Collection system coverage threshold by 2040**

% of the population	0	1	2	3
Access to plastic source sortation	0%	21%	42%	85%
Access to mixed collection	100%	79%	58%	15%

Collected for recycling rate

In Norway the share of collected for recycling rate (i.e., separated at source) is 34% (Mepex analysis). This consists of all plastic waste separated at source either by households or by businesses (arrow C3 and C4). It intrinsically means that the 66% of the plastic waste collected is collected as mixed waste in Norway (arrow C2).

In the BAU scenario it was assumed that the source separation rate remains constant over the years, as this rate has been plateauing during the past years. In the System Change Scenario a moderate increase in sortation rates was assumed (threshold 1) (Exhibit 26).

***EXHIBIT 26: Household* source sortation rate thresholds by 2040**

% of the population	0	1	2	3
Source separation rates	34%	40%	60%	80%

For beverage bottles the source sortation lever is applied to the current collection rate from the deposit system which is 85% in 2019 (Mepex analysis) and therefore this category is treated separately (Exhibit 27) (arrow C1 in the system map).

***EXHIBIT 27:* Deposit system efficiency threshold**

	0	1	2	3
% of bottle collected	85%	88%	92%	95%

It is important to note that in the Plastsimulator online tool, the lever 'Household Source Separation Rate' is affecting both the source separation rate and the deposit system efficiency. This simplification was made to reduce the number of lever available to the user. In the instance where threshold 0 is selected for the collection system coverage (Exhibit 25) (which is referred to as 'central system' in our insight report), the source separation rate is then set automatically to 0% for rigids, flexibles, multilayers and household goods and others, given at that point source sortation is not relevant anymore. In this specific configuration the 'Household Source Separation Rate' would only affect the efficiency of the deposit beverage bottle system.

Mixed collection

Mixed collection is assumed to make up all formal collection that is not explicitly collected for recycling (see Exhibit 7) which include all the waste from the population which does not have access to source sortation and the waste from the population which have access to sortation but does not sort plastic at source, as well as all the beverage bottles which are not capture through the deposit system. In effect any scenario would assume a share of mixed waste collection given sortation at source rate cannot reach 100%.

Informal sector

Despite the presence of a deposit system which very often leads to the presence of scavengers, this model assumes that there is no informal plastic waste collection in Norway.

Plastic mass – formal sorting

Domestic versus export for sorting materials

In the above section, the share of plastic which was sorted at source versus collected as mixed waste was calculated based on the collection system provided by the municipality (Exhibit 25) and based on the source separation rate of the population itself (Exhibit 27).

Waste can be sorted by two different types of facilities:

- Plastic waste sorted at source: in this case the plastic will be sorted by one facility sometimes referred to as 'fine MRF', the input of such facility is clean mixed plastic fractions.
- Mixed plastic waste: in this case the plastic waste will be sorted by two facilities sometimes referred to as 'dirty MRf' and 'fine MRF' sequentially. Note that in Norway (like other countries) those two facilities have been combined into one for the two existing and operating MRF in the country. The input of such facility is mixed plastic fraction with residual waste and organics.

As of 2019, 100% of the waste sorted at source is exported and sorted overseas, and 9% of the mixed waste is sent to central combined MRF facilities in Norway for rough and fine sorting. The remaining share is sent to incineration.

In the *Plastsimulator* online simulation the lever called 'domestic share of sorting' affect both of those flows simultaneously. Therefore, it assumes that a percentage as defined by the threshold (Exhibit 28) of this flow will be sorted domestically. For example, if the threshold is 1 and the percentage chose is 25%, the share of material sorted at source and sent to domestic MRF for fine sorting will increase from 0% to 25% linearly between 2019 and 2040. Simultaneously, the share of mixed waste collected and sent to domestic MRF for rough and fine sorting will increase from 9% to 25% linearly between 2019 and 2040. As explained above mixed waste include both streams: waste from population which do not have access to source sortation and waste from population which do have access to source sortation but do not separate plastic at source.

Source separated plastic which is not sorted domestically is assumed to be exported for sorting. Mixed plastic which is not sorted domestically is assumed to be disposed (domestically or not - see dedicated section).

It is important to understand that while our model assumes that sorted at source plastic can be exported for recycling, mixed waste can only be exported for incineration. Therefore, in the instance where this 'Domestic share of sorting' lever is on 0, the model will assume that the current capacity of mixed waste sorting in Norway will not increase and will remain 9%. This is important because in the case of a 'central system' selected for collection, it would mean that without additional sorting capacity ('Domestic share of sorting' lever is set on 0) all the mixed waste collected would be sent to incineration.

EXHIBIT 28: **Domestic share of sorting by 2040**

% of waste sorted domestically	**0**	**1**	**2**	**3**	**4**
From source separated plastic	0%	25%	50%	75%	100%
From plastic collected as mixed waste	9%	25%	50%	75%	100%

Sorting losses

Considerable quantities of plastic are thought to be discarded during the sorting stage, either because they are contaminated, have low value, are strong coloured, or do not arise in sufficient quantity to warrant separation and aggregation.

The table below (Exhibit 29) summarizes the loss rates of both facilities (fine MRF and combined dirty + fine MRF) for the single and combined steps, respectively (sum of arrow F3 and F5). 2019 data corresponds to current operational output obtained by Mepex. The 2040 values correspond to the maximum technological output those facilities can have assuming both design for recycling and sortation technology develop to their maximum potential. Note that it excludes the washing step which is assumed to happen at the recycling stage in this model.

EXHIBIT 29: Sorting loss rates and yields

	2019[1]		**2040[2]**	
	Loss rate	**Yield**	**Loss rate**	**Yield**
Dirty + Fine MRF loss rates	55%	45%	30%	70%
Fine MRF loss rates	35%	65%	20%	80%

(1) Mepex Analysis
(2) Maximum technological efficiency and design for recycling

The sorting losses can be influenced by two separate levers: design for recycling and or sorting efficiency. Each lever is assumed to have an equal impact on the sorting losses. The summary of the impact of both thresholds on those loss rates can be found below (Exhibit 30 and 31). The rational for such methodology is to say that not only better sorting technologies will be able to increase the performance of current machineries and sensors, but better design will also help to increase the overall share of material which can be sorted and which can find economically viable markets.

***EXHIBIT 30:* Dirty + Fine MRF yield threshold by 2040**

Design for recycling // Sorting technology	0	1	2	3
0	45%	49%	53%	57%
1	49%	53%	57%	61%
2	53%	57%	61%	65%
3	57%	61%	65%	70%

***EXHIBIT 31:* Fine MRF yield threshold by 2040**

Design for recycling // Sorting technology	0	1	2	3
0	65%	68%	70%	73%
1	68%	70%	73%	75%
2	70%	73%	75%	78%
3	73%	75%	78%	80%

Costs

Formal collection costs

Costs are assumed to stay flat over time as collection technology is deemed to be mature and will not be impacted greatly by learning curves over the foreseeable future. A summary of the collection cost used for this analysis can be found below (Exhibit 32).

***EXHIBIT 32:* Cost of collection ($/tonne of plastic)**

Archetype	Total cost all waste[1]	Weighted average (allocated for plastics)		
		OPEX	CAPEX[2]	TOTAL
Norway	$381 (NOK 3,292)	$381 (NOK 3,292)	$64 (NOK 552)	$445 (NOK 3,844)

Source: Mepex (1) and SYSTEMIQ (2) analysis

Note: NOK/USD XR: 8.64 (average over the last 12 months).

Collection costs are assumed to stay flat over time (in real terms), even as capacity (or throughput) increases. While efficiencies can be gained over time and with scale, it was assumed that Norway already has full provision of formal collection services and so any increase in plastic generation would not affect the collection rate significantly.

Collection costs are based on current operations in Norway where in most municipalities (>85% of the population) a dual collection system with both source separation of plastic and collection of residual waste is in place. This system is likely to be more expensive and it represents a net extra cost for source separation. The shift to single collection system (i.e. only mixed waste) has not been modelized in terms of cost in this study, additional analysis would be needed to understand such impact.

Formal sorting costs

The sorting costs used in our model were split into two categories, mixed waste sorted in a combined dirty MRF + fine MRF for rough and fine sorting, and plastic separated at source and then sorted in a fine MRF only. The combined dirty + fine MRF costs were derived from a Mepex estimate for the cost of sorting plastic in a mixed waste stream for existing Norwegian facilities. A factor of 1.5 was applied to this mixed waste cost to allocate the cost for only plastics in the waste stream based on an input/output analysis of such facility. The cost for fine sorting was obtained from SYSTEMIQ global analysis and was also allocated to plastic.

Allocating the cost burden of plastics to sorting operations is important, as they have a different impact compared to other materials. Although we found several sources which show the allocated costs (cost burden for plastics is approximately three times higher than that for the full suite of recyclables), they did not specify the method for doing so. The following reasons were suggested for this greater cost burden:

- Sorting is strongly influenced by the cost of machinery and labour, and these have been reported to be greater for plastics in comparison to other materials. Baling equipment (an expensive unit process in terms of capex and maintenance) is also heavily utilised due to the presence of plastics.
- Plastics represent ~50% of the storage burden for input and pre-baled sorted material whilst contributing just 15–20% of the mass.
- Intermediate PRFs (plastics sorting facilities) are often used due to needs for additional sorting before recycling, adding to and potentially doubling basic materials recovery facility (MRF) costs.
- If sorting is done manually, the mass collected per pick is significantly lower than other, denser materials such as paper and glass.

A summary of the sorting cost used in this analysis can be found below (Exhibit 33).

***EXHIBIT 33:* Formal sorting costs allocated for plastic ($/tonne of plastic)**

Sorting Type	OPEX	CAPEX	TOTAL
Rough + Fine Sorting[1]	$347 (NOK 2,994)	$122 (NOK 1,050)	$469 (NOK 4,044)
Fine Sorting only[2]	$156 (NOK 1,348)	$52 (NOK 449)	$208 (NOK 1,797)

Source: Mepex (1) and SYSTEMIQ (2) analysis

Note: NOK/USD XR: 8.64 (average over the last 12 months).

After estimating the OPEX and CAPEX of each technology today, costs were projected to 2040 by applying a 'learning curve' e.g. a percentage reduction in cost for every doubling of capacity. Sorting costs are assumed to improve slightly over time as knowledge of efficient sorting practices increases ('learning' or 'experience' rate). Here we assume that sorting technology is more mature than recycling technology and therefore propose a conservative learning cost reduction of 7% per doubling of capacity.

6. Domestic recycling and disposal

Definitions

Recycling is one of the major routes plastic waste can flow to in our system map and one of four levers which we use to model leakage abatement. We distinguish by closed loop and open loop mechanical recycling and chemical conversion (Exhibit 34).

EXHIBIT 34: Recycling definitions

Waste treatment	Definition
Closed loop	• For our model, this is mechanical recycling of plastic waste back into packaging, consumer, or household items destined to again become municipal solid waste (MSW) • An example would be the recycling of a plastic bottle to a plastic pen
Open loop	• For our model this is mechanical recycling of plastic waste into materials that do not become part of MSW (e.g. long-term applications like textiles, benches, etc.) • These recycled products are typically of lower value; this is sometimes referred to as 'down-cycling' • An example would be the recycling of a plastic bottle to a plastic drainage pipe
Chemical recycling	Chemical conversion to monomers and hydrocarbons • Chemical conversion via pyrolysis to break plastic materials into monomers and hydrocarbons (e.g., naptha) that can be recycled into all types of plastics - "P2P" for "plastics to plastics". Costs have been modelled using values for pyrolysis technology (rather than alternatives such as gasification and solvolysis)

To clarify, in our system map we do not consider chemical conversion to fuels as part of the 'Recycle' wedge but rather part of the 'Dispose' wedge. Consequently, it is included in the definitions for disposal. Due to its similarity in process, however, we have the assumptions for chemical conversion to fuels included in the chemical conversion section.

Mechanical recycling - plastic mass and flows

Once plastic has been sorted, the *Plastsimulator* online simulation allows the user to choose the share of plastic which will be recycled domestically versus sent for recycling overseas (Europe or international) (Exhibit 35) (arrow F4). Note that the current share of plastic recycled in Norway (2019) is 12% and almost exclusively driven by film recycling (Mepex analysis).

EXHIBIT 35: Domestic share of recycling by 2040

% of waste sorted domestically	0	1	2	3	4
Plastic waste recycled domestically	12%	25%	50%	75%	100%
Plastic waste exported for recycling	88%	75%	50%	25%	0%

The user can then choose which portion of the plastic waste recycled domestically will be recycled through closed loop recycling versus open loop recycling (Exhibit 36) (arrow F1 and F2). Note that currently 100% of the plastic waste recycled in Norway is considered closed loop recycling.

***EXHIBIT 36:* Domestic share of CL recycling vs OL recycling by 2040**

% of waste recycled domestically	0	1	2	3	4
Share of domestic recycling to CL	0%	25%	50%	75%	100%
Share of domestic recycling to OL	100%	75%	50%	25%	0%

For the system change and recycling scenarios, it was assumed that a share of open loop recycling was necessary to increase recycling rates beyond a certain value given the composition of the waste and the current market outlook for specific materials (i.e. polyolefins mixed) and therefore threshold 3 was chosen.

Note that the lever describe above (Exhibit 36) has no influence over the share of open loop versus closed loop recycling outside of Norway which was assumed constant overtime (see dedicated section on exports).

Mechanical recycling loss rates

We further introduced reprocessing loss rates (Arrows I2 and J1) to quantify the mass actually recycled through closed (Arrow I1) and open loop (Box J) mechanical recycling and the mass flowing to unsorted waste (Box L). These losses refer to losses in recycling only, and do not include sorting losses which are calculated separately. It includes losses from the washing steps and extrusion step (Mepex analysis) and is different for each plastic type (Exhibit 37). Threshold 0 correspond to current rates. Note that in this study losses and yield ae calculated for net plastic and exclude losses of residuals, water etc.

***EXHIBIT 37:* Estimated mechanical recycling loss rates in 2019**

% losses from	2019[1]
Beverage bottles	22.1%
Rigids monomaterials	15.5%
Flexible monomaterials	18.4%
Multimaterials	n/a
Household goods and others	n/a

(1) Mepex analysis for net plastic

Improvement of those loss rate is the function of two levers: (1) design for recycling (2) mechanical recycling technologies. Each lever is assumed to have an equal impact on the recycling losses. The summary of the impact of both thresholds on those loss rates can be found below (Exhibit 38, 39 and 40). The rational for such methodology is to say that not only better recycling technologies will be able to increase the performance of current machineries and processes, but better design will also help to increase the overall share of material which can be sorted, washed, and recycled without rejects and which can find economically viable markets.

EXHIBIT 38: Beverage bottles recycling loss rate by 2040

Design for recycling // Recycling technology	0	1	2	3
0	22.1%	20%	18%	16%
1	20%	18%	16%	14%
2	18%	16%	14%	12%
3	16%	14%	12%	10%

EXHIBIT 39: Rigid monomaterials recycling loss rate by 2040

Design for recycling // Recycling technology	0	1	2	3
0	15.5%	14.6%	13.7%	12.8%
1	14.6%	13.7%	12.8%	11.9%
2	13.7%	12.8%	11.9%	11%
3	12.8%	11.9%	11%	10%

EXHIBIT 40: Flexible monomaterials recycling loss rate by 2040

Design for recycling // Recycling technology	0	1	2	3
0	18.4%	17%	15.6%	14.2%
1	17%	15.6%	14.2%	12.8%
2	15.6%	14.2%	12.8%	11.4%
3	14.2%	12.8%	11.4%	10%

Mechanical recycling costs

For open loop and closed loop mechanical recycling, the following learning curves were assumed:

- OPEX: 7% decrease per doubling of capacity
- CAPEX: 7% decrease per doubling of capacity

The table below (Exhibit 41) presents the resulting costs in $/tonne *input*. Please note that the costs shown are those that would adhere to high environmental, health and safety standards. It is understood that in practice there is high variance around these costs due to aspects such as different technologies and standards used as well as vertical integration.

EXHIBIT 41: Mechanical recycling costs ($/tonne input)

Mechanical Recycling Type	OPEX	CAPEX	TOTAL
Closed Loop	$569 (NOK 4,916)	$160 (NOK 1,382)	$729 (NOK 6,299)
Open Loop	$410 (NOK 3,542)	$120 (NOK 1,037)	$530 (NOK 4,579)

Source: Breaking the Plastic wave report

Note: NOK/USD XR: 8.64 (average over the last 12 months).

Chemical conversion - plastic mass and flows

The chemical conversion mass input is sourced from the losses coming out of each sorting step (rough and fine sorting). As such chemical conversion does not compete with mechanical recycling for feedstock.

The development of chemical conversion capacity can be chosen by the user in the *Plastsimulator* online simulation tool. The user chooses what share of the feedstock available for chemical conversion will be used for chemical conversion (Exhibit 42), in other words what percentage of material not available for mechanical recycling and therefore sent to losses from the MRF will be able to be used for chemical conversion.

EXHIBIT 42: **Share of chemical conversion feedstock used by 2040 under different thresholds**

	0	1	2	3	4
Value	0%	12.5%	25%	37.5%	50%

As of today, there is no existing chemical conversion facility in Norway. In other countries this technology does not yet exist at industrial scale either.

As a baseline, the reprocessing loss rates of chemical conversion are assumed to be 50%, meaning that 50% of chemical conversion mass input is transformed into feedstock for new chemical products as referred to in this document as Plastic to Plastic (P2P) or into fuel as referred to in the document as Plastic to Fuel (P2F). Note that the P2P route would lead to additional losses due to the additional processing steps (i.e. cracking) which have not been taken into account in this analysis.

In the *Plastsimulator* online simulation the lever named 'chemical conversion technologies' allow the user to change this loss rates. Suggested values can be found below (Exhibit 43). Note that losses from chemical conversion of P2F and P2P technologies are assumed to be similar.

EXHIBIT 43: **Chemical conversion losses by 2040**

	0	1	2	3
Losses from chemical conversion	50%	43%	36%	30%

Source: SYSTEMIQ analysis

Additionally, the Plastsimulator online simulation allows the user to choose the share of chemical conversion which will be used for P2P vs P2F (arrow K1 and K2) (Exhibit 44).

EXHIBIT 44: **Share of P2P versus P2F by 2040**

	0	1	2	3	4
Losses from chemical conversion	0%	25%	50%	75%	100%

Chemical conversion costs

Similarly to mechanical recycling, we determined the annualised CAPEX and OPEX for P2F and P2P chemical conversion plants based on expert interviews and through consultation with companies working on chemical conversion technologies (Exhibit 45). Furthermore, when projecting the costs forward into 2040, we use the following learning curve assumptions:

- Opex: 7% decrease per doubling of capacity
- Capex: 7% decrease per doubling of capacity

EXHIBIT 45: Chemical conversion costs ($/tonne input)

Chemical conversion type	OPEX	CAPEX	TOTAL
P2P	$1298 (NOK 11,294)	$310 (NOK 2,681)	$1,184 (NOK 13,894)
P2F	$246 (NOK 2,125)	$101 (NOK 873)	$347 (NOK 2,998)

Source: SYSTEMIQ analysis based on Breaking the Plastic wave report

Note: NOK/USD XR: 8.64 (average over the last 12 months).

The cost of P2P was estimated as being the sum of the cost of P2F (source: Breaking the Plastic Wave report) plus 62% of the cost of virgin material to account for the fact that P2P chemical feedstock requires additional processing steps (i.e. cracking and polymerization) before it can be used as virgin plastic.

Recyclate sales price – mechanical and chemical conversion

The respective recyclate and pyrolysis oil / naphtha sale prices (Exhibit 46) were identified to be able to compute the end-to-end economics for each recycling technology. P2P and P2F sale prices have been given as $/tonne *plastic input* in order to allocate for plastic. Oil price is assumed static in the model, which is expected to be the main driver of price changes in any scenario.

EXHIBIT 46: Sale prices ($/tonne input)

Recycling Type	Sales prices
Closed Loop – Mechanical Recycling	$1218 (NOK 10,524)
Open Loop – Mechanical Recycling	$810 (NOK 6,998)
Plastic-to-Plastic – Chemical conversion	$2,036 (NOK 17,590)
Plastic-to-fuel – Chemical conversion	$637 (NOK 5,504)

Source: Breaking the Plastic Wave Report. Note: NOK/USD XR: 8.64 (average over the last 12 months).

Note that prices for of all the above are constantly fluctuating, additionally prices for P2F and P2P are based on immature technologies, therefore those cost are attached with a relatively high uncertainty and only used for the purpose of understanding differences between different scenarios.

Disposal

Definition

We distinguish between three types of disposal technologies: incineration, engineered landfill and chemical conversion for fuel (Exhibit 47). Dumpsites or unmanaged landfills are not included as they are considered mismanaged waste (i.e. see exports section for plastic waste sent for recycling in South East Asia).

Even though we consider Plastic to Fuel chemical conversion as disposal in our system map, for simplicity purposes we have included its methodology in the recycling section.

EXHIBIT 47: **Disposal definitions**

Waste treatment	Definition

Thermal treatment	• Process of combusting waste – either with or without energy recovery (World Bank disposal category: incineration)
	  • Energy capture could be in the form of electricity, heat, or refuse-derived fuel (RDF)
	  • Modern thermal treatment plants (modelled) are fitted with flue gas capture

Landfill	• Engineered landfills modelled (World Bank disposal categories: controlled landfills and sanitary landfills)
	  • Isolate the material completely from the environment
	  • Equipped with environmental protections (barriers, daily covering, methane capture, etc.) that do not leak into the environment.

Chemical conversion	Chemical conversion to fuels • Chemical conversion via pyrolysis to break down plastic materials into hydrocarbon fuels that are suitable for combustion rather than recycling back into plastics - "P2F" for "plastics to fuels". Costs have been modelled using values for pyrolysis technology (rather than alternatives such as gasification and solvolysis)

Disposal rates

Residual waste (box L in the system map) is the sum of (1) the plastic waste which is not sent to MRF for sorting (arrow E2), (2) the losses from MRFs and recycling processes and (3) the imports (see dedicated section).

Residual waste is either treated in Norway (arrow L1) or exported for incineration outside of the country (arrow L3). As of 2019, 62.5% of the residual waste was treated in Norway, the rest, 37.5%, was exported for incineration mostly in Sweden (see dedicated section). Note that if we exclude the imports, only 56% of the residual waste is treated in Norway while 44% is exported (Mepex analysis).

In the *Plastsimulator* online simulation the lever called 'domestic share of incineration vs exports' allows the user to explore different scenarios where more or less waste is incinerated domestically (Exhibit 48). Note that Norway already owns a significant amount of incineration capacity, by increasing the 'solution levers' (i.e. reduce, substitute, recycling), necessarily the amount of waste going to incineration decreases which generates some 'theoretical' incineration capacity. This has two implications:

- A scenario with 100% of residual waste being exported would be problematic for the existing asset utilization rates and sub-optimal economically speaking.

- For the different scenarios (except BAU) it was assumed that the share of domestic incineration would increase from 56% to 75% as it leads to no additional incineration capacity in Norway and therefore represent a more efficient use of the current assets. It was also assumed that 100% of domestic incineration was unlikely due to market economic reason and competition from Sweden.

***EXHIBIT 48:* Share of domestic incineration vs exports by 2040 under different thresholds**

	0	1	2	3	4
Value	0%	25%	50%	75%	100%

Given that Norway already benefits from an efficient waste management system, it was assumed that no waste leakage takes place post-collection. As such 100% of the residual waste generated and treated in Norway is sent to disposal in appropriate dedicated infrastructures in Norway (Box M). In other words, this assumes that no waste professional is dumping waste illegally in Norway (this practice has been documented numerous times in other countries).

Finally, it appears that as of 2019, 100% of the residual plastic waste in scope is incinerated and no landfilling takes place according to current regulations in place. This assumption was used throughout for all the plastic waste disposed in Norway until 2040.

Incineration – costs and sale prices

The OPEX and annualised CAPEX costs of incineration with energy recovery as well as sale prices for the energy sold was estimated (Exhibit 49 and 50). The costs were assumed flat toward 2040. Sale prices are given in $/tonne plastic *input* in order to allocate for plastic. Prices remain stable until 2040 as static electricity prices are assumed which are the main driver of price changes.

***EXHIBIT 49:* Incineration costs ($/tonne input)**

	OPEX	CAPEX	TOTAL
Incineration	$63 (NOK 540)	$53 (NOK 458)	$116 (NOK 998)

Source: Mepex analysis. Note: NOK/USD XR: 8.64 (average over the last 12 months).

***EXHIBIT 50:* Incineration sale prices ($/tonne input)**

	Sales price
Incineration	$50 (NOK 432)

Source: Mepex analysis. Note: NOK/USD XR: 8.64 (average over the last 12 months).

7. Mismanaged waste

The methodology used in the section below was developed during the global study and given the lack of specific studies in Norway was re-used here.

To account for the effects of proximity to water within each archetype, the proportion of the population living within one km of a river or coastal water (Zone A) was estimated using GIS. The rest of the population is therefore residing outside of that range (Zone B). The following database were used for this analysis:

- Coastline: "EEA Coastline" from European Environment Agency (2018) https://www.eea.europa.eu/data-and-maps/data/eea-coastline-for-analysis-2
- Rivers: "HydroRIVERS Europe", Global river network delineation derived from HydroSHEDS data at 15 arc-second resolution (2019) Citation: *Lehner, B., Grill G. (2013): Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes, 27(15): 2171–2186. Data is available at www.hydrosheds.org.*
- Population: Pop density Gridded Population of the World (GPW), v4 UN WPP-Adjusted 2020 Population Density, v4.11. (2018) Source: Center for International Earth Science Information Network - CIESIN - Columbia University
- Norway admin L0: GADM database (www.gadm.org), version 3.4 (2018)

As a result, it was found that 62% of the Norwegian population lives in Zone A (i.e., within 1 km of waterways) and 38% lives in zone B (i.e., over 1 km of waterways).

Subsequently, it was assumed that a portion of the plastic waste littered will enter the water (rivers, lakes, seas, oceans). This transfer can happen because of direct litter into the water or because of winds and precipitation. Transfer rates assumed for each Zone (a and B) can be found below for each plastic category (Exhibit 51). Transfer rates are assumed constant over time given they are the function of terrains and climates.

***EXHIBIT 51:* Transfer rates of litter from terrestrial to water**

% litter entering the water	Bottles	Rigids	Flexibles	Multi	Hh goods and others
Zone A	10%	35%	35%	10%	10%
Zone B	3%	8%	8%	3%	3%

The litter not transferred to the water is assumed to stay on the land and is reported as terrestrial leakage.

In the *Plastsimulator* online simulation, the user cannot change these values. The user can only change the litter rate (see dedicated section about collection rates).

8. Export Methodology

Exports have been treated largely the same in the export archetype as those within the Norway archetype but there are differences in how the initial flows were determined. First, this analysis is assuming there are three different types of export streams: (1) exports for sorting (Box G1), (2) exports for disposal (box G2), and (3) exports for recycling (box G3). Each stream is going to a different range of destination countries which is summarized in below (Exhibit 52).

***EXHIBIT 52:* Exports broken down by types and destinations[1]**

Type of waste	HH waste sorted at source	HH + B2B waste (residual)	HH waste sorted at Norway MRF	B2B waste sorted at Norway MRF	Bottles from deposit system
Stream	Arrow C3	Arrow L3	Arrow F4	Arrow F4	Arrow C1
Box	Box G1 (exported for sorting)	Box G2 (exported for incineration)	Box G3 (exported for recycling)		
Germany	76%		60%	17%	76%
Sweden		100%		6%	
Lithuania			20%	19%	
Rest of EU	24%		20%	37%	24%
Asia				22%	

(1) Combine sources from Norwegian Environmental Agency and Green Dot Norway

Specific data was obtained for the fate of Germany, Sweden, Lithuania, EU as an average and Asia (assuming lower and upper middle-income countries).

Sorting

Sorting methodology was the same than for Norway. Given only sorted at source waste was exported, only the fine MRF assumption for losses and cost were used.

Note that in the *Plastsimulator* online simulation the lever 'design for recycling' and 'sorting technology efficiency' are both having an effect to the fate of exports during the sorting step as well. The methodology and assumption are the same than for Norway.

Mechanical Recycling

The mechanical recycling methodology was the same than for Norway (i.e., losses and cost are assumed to be the same). The only difference is as regard to the share of plastic which goes to open loop recycling versus closed loop recycling (Exhibit 53). This share was estimated based on the European market for each material type and constant overtime given the purpose of this tool is to focus on the change of the Norwegian market and there is no evidence that this share will change on the European market in the coming years.

***EXHIBIT 53:* Share of CL vs OL for exports**

Stream	Bottles	Rigids	Flexibles	Multi	Hh goods and others
Closed Loop	95%	66%	25%	0%	0%
Open Loop	5%	34%	75%	0%	100%

Source: SYSTEMIQ analysis

Note that in the *Plastsimulator* online simulation the lever 'design for recycling' and 'sorting technology efficiency' are both having an effect to the fate of exports during the sorting step as well. The methodology and assumption are the same than for Norway.

Chemical conversion

The chemical conversion methodology was the same than for Norway (i.e. losses and cost are assumed to be the same). It was assumed that as of 2019 there is no waste generated in Norway which enter the few chemical conversion plants in activity. The growth of the chemical conversion sector as well as the share of P2P vs P2F is calculated similarly to the Norwegian system and based on the threshold used in the *Plastsimulator* online simulation.

The rationale for this is: if chemical conversion develops in Norway, it is likely that it will develop in Europe as well and therefore the plastic waste exported becomes an available feedstock for this. Additionally, the share of P2P vs P2F is likely to be controlled by Norwegian stakeholders which can decide where to exports and under which conditions, therefore it is likely that the same trends and share will be found in the chemical conversion occurring in Norway and through exports.

Plastic fate

Using the above export country analysis (Exhibit 11), the overall share of landfill versus incineration was calculated as a weighted average for each country. Data from PlasticsEurope (2018) was used to that purpose. The rationale was that while the plastic waste exported for disposal is assumed to be incinerated at 100%, the losses from the plastic waste exported for sorting and recycling are likely to follow the same path as any plastic waste in that country and given those countries still have landfills in operation the likelihood of the residual waste from those streams to enter a landfill can be estimated. Results can be found below (Exhibit 11, 12, 13, 14, 15) for each plastic category and under threshold 0 which was used for the baseline.

Mismanaged Waste

Exports to recycling in South-East Asia will incur losses in the recycling process. For those, the analysis is drawing from the global analysis and assumption to map the fate of those flow. A summary of the assumption used can be found here.

While the recyclate produced will follow conventional paths, the losses are assumed to follow the path of residual waste in those countries and therefore (1) 80% is dumped in legal yet unsanitary landfill and which is classified as mismanaged (2) 20% is assumed to be burnt in the open (practice widely spread among waste exporters).

Additionally, it is assumed that 60% of the plastic waste dumped in unsanitary landfill is also burnt due to either accident (unsanitary landfill do catch in fire regularly) or deliberate fires to free up space in overflowing landfill (current practice in many countries).

‘Traceability of export residues’ – an export specific lever

In the *Plastsimulator* online simulation, a lever was created to allow the user to account for the increase in control that countries have over their exports. It affects two separate variables (1) the amount of waste disposed to landfill from exports (arrow M2) (2) the amount of waste mismanaged from exports (arrow L2) (i.e. because export to developing countries with poor waste management infrastructure). The affect of this lever for each of the two variables for each plastic type can be found below (Exhibit 54, 55, 56, 57, and 58). The starting value (threshold 0) was calculated as explained in the above section (plastic fate) the ending value was assumed 0% meaning full control and traceability of all exports.

Note that given arrow L2 only applied to losses from recycling processes, only rigids and flexibles (which are indeed exported to south-east Asia) are impacted.

***EXHIBIT 54:* Thresholds for traceability of export residues lever for rigids**

Stream	0	1	2	3
Landfill (arrow M2)	2.4%	1.6%	0.8%	0%
Mismanaged (arrow L2)	0.5%	0.4%	0.2%	0%

***EXHIBIT 55:* Thresholds for traceability of export residues lever for flexibles**

Stream	0	1	2	3
Landfill (arrow M2)	5.1%	3.4%	1.7%	0%
Mismanaged (arrow L2)	3.6%	2.4%	1.2%	0%

***EXHIBIT 56:* Thresholds for traceability of export residues lever for multi**

Stream	0	1	2	3
Landfill (arrow M2)	0.5%	0.4%	0.2%	0%
Mismanaged (arrow L2)	0%	0%	0%	0%

***EXHIBIT 57:* Thresholds for traceability of export residues lever for bottles**

Stream	0	1	2	3
Landfill (arrow M2)	12.2%	8.1%	4.0%	0%
Mismanaged (arrow L2)	0%	0%	0%	0%

(note that those % seems disproportionally high due to very low absolute volumes)

***EXHIBIT 58:* Thresholds for traceability of export residues lever for HH goods**

Stream	0	1	2	3
Landfill (arrow M2)	3.1%	2.1%	1.0%	0%
Mismanaged (arrow L2)	0%	0%	0%	0%

Export Costs

$59/tonne (NOK 510) exported was used to account for transport from Norway to the destination country (source: Mepex analysis).

$27/tonne (NOK 233) was used as the capex cost for incineration of exports compared to $56 used for incineration in Norway (source: Breaking the Plastic Wave Report).

9. Import Methodology

According to an analysis from Mepex, mixed plastic packaging waste is imported to Norway (box H). It was assumed that 100% of the imports came from the UK and was sent directly to incineration.

Import volumes were obtained from Norwegian Environmental Agency and assumed to grow at the same rate as European plastic waste based on the Material Economics analysis mentioned above (see dedicated section on waste generation). Breakdown per plastic category was obtained based on an analysis from WRAP UK and change of this waste composition overtime was applied using the same methodology as Norwegian waste (see dedicated section on waste generation). Waste composition and volumes obtained for those imports can be found below (Exhibit 59 and 60).

EXHIBIT 59: UK plastic waste composition to 2040

	2019[1]	2030	2040	CAGR 2019-2040[2]
Beverage Bottles	9.4%	9.2%	9.0%	-0.22%
Rigids monomaterials	43.3%	42.2%	41.3%	-0.22%
Flexible monomaterials	23.8%	24.1%	24.3%	0.11%
Multi-materials	23.5%	24.5%	25.4%	0.35%

(1) WRAP UK (2) SYSTEMIQ analysis based on Grand View market research.

EXHIBIT 60: Import volumes projections

	2019[1]	2030	2040	CAGR[2] 2019-2040
Imports (tons)	33,369	36,773	39,510	0.77%

(1) Norwegian environmental Agency (2) Material Economics, the Circular Economy Report (PG. 78) (https://materialeconomics.com/publications/the-circular-economy)

Note that while our model accounts for imports (i.e. cost, GHG, jobs) and imports are discussed in the insight report, the wedges chart displayed in the *Plastsimulator* online simulation and insight report exclude imports and focus only on waste generated in Norway for visualization and communication purposes.

10. Feedstock and fate methodology

The results of this section are only available in the insights report (Achieving Circularity).. The *Plastsimulator* online simulation does not allow the user to access the variables nor visualize the results obtained in this section (i.e. feedstock and fate as wedges). Note that the overall cost, GHG and employment resulting from the overall analysis and displayed in the *Plastsimulator* online simulation includes cost, GHG and employment from fate and feedstock.

Feedstock

Current feedstock sources were estimated as followed:

- **Bio-based:** Mepex and Eunomia study for The Norwegian Environment Agency estimated that ~3% of the total consumption of plastic in Norway is bio-based.
- **Recycled content:** This number is not currently reported in Norway, however based on Mepex analysis, it was estimated that current packaging and household goods products comprised of 5-10% recycled content and therefore 7% was used for modelling purposed.

For outlook to 2040, this analysis merely consists of a 'what if' analysis. Therefore the 2040 and CAGR values obtained are purely fictive and only based on values which were deemed interesting. As such, this only must only be used to understand the impact of different growth rate for those feedstock technologies by 2040. A more thorough analysis would be necessary to understand which the relative likelihood of each of those variables.

Four separated scenarios were modelled (noted F for feedstock scenario) for which different assumptions were taken for the growth of bio-based and recycled content by 2040.

- Scenario F1: baseline
- Scenario F2: growth of bio-based feedstock
- Scenario F3: growth of recycled content use
- Scenario F4: growth of bio-based feedstock and recycled content use simultaneously

Summary of the variable for each scenario can be found below (Exhibit 61, 62 ,63, and 64). The share of each feedstock source was then applied to the total waste generated in Norway (Exhibit 6).

***EXHIBIT 61:* Share of the different feedstock sources for Scenario F1 - Baseline**

	2019	2030	2040	CAGR 2019-2040
Share of virgin	90%	80%	65%	-1.4%
Share of bio-based	3%	6%	10%	5.9%
Share of recycled content from Mechanical Recycling	7%	14%	25%	5.9%
Share of recycled content from Chemical conversion	0%	0%	0%	n/a

***EXHIBIT 62:* Share of the different feedstock sources for Scenario F2 – Growth of bio-based feedstock**

	2019	2030	2040	CAGR 2019-2040
Share of virgin	90%	78%	55%	-2.2%
Share of bio-based	3%	8%	20%	9.5%
Share of recycled content from Mechanical Recycling	7%	14%	25%	5.9%
Share of recycled content from Chemical conversion	0%	0%	0%	n/a

***EXHIBIT 63:* Share of the different feedstock sources for Scenario F3 – Growth of recycled content use**

	2019	2030	2040	CAGR 2019-2040
Share of virgin	90%	74%	40%	-3.5%
Share of bio-based	3%	6%	10%	5.9%
Share of recycled content from Mechanical Recycling	7%	18%	40%	8.3%
Share of recycled content from Chemical conversion	0%	2%	10%	24%

***EXHIBIT 64:* Share of the different feedstock sources for Scenario F1 – Growth of bio-based feedstock and recycled content use simultaneously**

	2019	2030	2040	CAGR 2019-2040
Share of virgin	90%	72%	30%	-4.8%
Share of bio-based	3%	8%	20%	9.5%
Share of recycled content from Mechanical Recycling	7%	18%	40%	8.3%
Share of recycled content from Chemical conversion	0%	2%	10%	24%

Note that those scenarios are distinct from the ones described in the other sections of this documents (referred to as system intervention scenarios). Therefore, each of the ‘feedstock’ scenario can be combined with any of the system intervention scenario.

Note that scenario F1 was used as default for all the results displayed in the insight report unless mentioned for cost, GHG and employment calculations. The same applies to the *Plastsimulator* online simulation given the above variables were not accessible for the user, scenario F1 was used in this case.

Fate

In order to make a fair comparison of plastic towards its potential substitute candidates, a rapid fate analysis was conducted for paper and compostables. Those were used to better take into account the end-of-life cost, GHG and employment footprint of those new technologies.

Paper and compostables were assumed undergoing two main end-of-life routes (i) recycling (either paper recycling or food-waste recycling for compostables) (ii) incineration (in the case it would be disposed).

Given a rapid analysis only was made for those streams, the share of each was assumed constant overtime. Summary of the value used for all scenarios can be found below (Exhibit 65, 66, and 67).

EXHIBIT 65: **Paper recycling and incineration rates**

	2019	2030	2040
Paper recycling rate	50%[1]	50%	50%
Paper incineration rate	50%	50%	50%

(1) Mepex analysis

EXHIBIT 66: **Compostable recycling and incineration rates**

	2019	2030	2040
Compostables recycling rate ***(based on food -waste recycling rates)***	60%[1]	60%	60%
Compostables incineration rate	40%	40%	40%

(1) Mepex analysis

EXHIBIT 67: **Cost of paper and compostable fate ($/tonne of input)**

	Total cost
Paper recycling	$594 (NOK 5,132)
Compostables end-of-life	$464 (NOK 4,010)

Source: SYSTEMIQ analysis

Note that the cost of incineration for paper and compostables was assumed to be the same as the one of plastic.

11. GHG methodology

In this section, the different assumptions taken to estimate the GHG emissions from the plastic value chain are listed. Note that the analysis does not account for changes in the energy mix over time. Even though it was acknowledged that the composition of the energy mix has a large influence on the greenhouse gas emissions of most included technologies, the detail that such an analysis would require is outside of the scope of this study. How current energy mixes will change is also deemed outside of scope for this study and we therefore assume that all emissions will be constant over time.

GHG emissions for each of these activities should be calculated using the following sources, boundary definitions, and assumptions (Exhibit 68).

EXHIBIT 68: **GHG assumption summary**

Activity	Production of GHG in tCO_2e per tonne of plastic input	Comments	Sources
Virgin plastic production	2.67	weighted average assessed by Material Economics	Breaking the Plastic Wave
Bio-based production	0.97	weighted average based on PE, PP and PET	SYSTEMIQ analysis
Plastic conversion	1.31		Breaking the Plastic Wave
Formal collection	0.02	based on emissions from average distance travelled by collection vehicles from front door to sorting plants using a German case study	Breaking the Plastic Wave
Formal sorting	0.10 0.05	– Mixed waste sorting (dirty + clean MRF) – Fine sorting (clean MRF)	Breaking the Plastic Wave
Closed loop mechanical recycling	0.53	Excluding avoided emissions from plastic production	SYSTEMIQ analysis
Open loop mechanical recycling	0.48	includes virgin material added to the mix, flake to pellet energy, bale to flake energy, transport to reclaimer	Breaking the Plastic Wave
Chemical conversion P2P	1.95	Assuming it equals to GHG from P2F + 62% GHG from virgin plastic to account for the processing steps of cracking and polymerization	SYSTEMIQ analysis
Chemical conversion P2F	0.3	This does not include the burning of fuel as this happens outside of the system map	Breaking the Plastic Wave
Incineration	2.50	An offset is included for displacing electricity generation that would have had otherwise occurred based on Norway energy mix	Breaking the Plastic Wave

Engineered Landfill	0.01	Assumes the degradation of plastics in a landfill without any other material (e.g. organics)	Breaking the Plastic Wave
Open burning	2.89	CO2e of combination of methane and carbon emissions of open burning	Breaking the Plastic Wave
Reduce - Eliminate	0.76	Assuming 81% reduction compared to plastic production and conversion	SYSTEMIQ analysis
Reduce - New Delivery Models	1.95	Assuming 51% reduction compared to plastic production and conversion	SYSTEMIQ analysis
Substitute - Paper	1.95	Assuming 51% reduction compared to plastic production and conversion	SYSTEMIQ analysis
Substitute - Compostables	5.09	Assuming 28% increase compared to plastic production and conversion	SYSTEMIQ analysis

12. Employment methodology

For the purpose of this analysis, the focus was on direct job creation. Note that only the long-term job implication of activities in the system map e.g. the number of jobs needed to run a recycling plant, but not the temporary jobs created to build the recycling plant were included. Similarly, only direct jobs were accounted for.

This analysis is based on research on labour intensity per activity on the system map expressed in number of full-time employees (FTEs) per 1000 tons of plastic. Labour intensity has been isolated for plastic waste. Assumptions can be found below (Exhibit 69).

EXHIBIT 69: Employment assumptions summary

System map component	FTE per 1000t of plastic	Notes and assumptions	Source
Virgin plastic production	8	Average figure based on IBISWorld and Goldstein & Electris assuming that 2018 total global plastic production was 361.5 Mt. This is based on PlasticsEurope's (2018) 3.88% plastic production CAGR.	IBISWorld (2018); Goldstein & Electris (2011)
Bio-based production	8	Assumed to be the same as virgin plastic production	
Virgin plastic conversion	5	Assuming the split of jobs between production and conversion for plastic reflects the split of opex costs between plastic production and conversion	Breaking the Plastic Wave
Formal collection	2.3	Based on EU data.	Deloitte (2015)
Formal sorting	1.7	Based on EU data	Deloitte (2015)
Closed loop MR	3	Based on EU data assuming that 'recycling' includes CLMR	Deloitte (2015)
Open loop MR	3	Based on EU data assuming that 'recycling' includes OLMR	Deloitte (2015)
Chemical conversion P2P	6.3	Assuming this equals to the employment of P2F + 62% of the employment for virgin plastic to account for the processing steps of cracking and polymerization.	SYSTEMIQ analysis
Chemical conversion P2F	1.3	Based on US data on pyrolysis plants	American Chemistry Council (2014)
Incineration w/ ER	0.1	Based on high income country data	Deloitte (2015); Goldstein & Electris (2011)
Engineered landfills	0.1	Based on high income country data	Deloitte (2015); Goldstein & Electris (2011)
Import (sorting)	1.7	Based on EU data, assuming that 'sorting' includes import sorting	Deloitte (2015)
Reduce – eliminate	0		Breaking the Plastic Wave
Reduce – New delivery models	13.3	Based on high income country data	Breaking the Plastic Wave
Substitute – Paper	18.5	Based on high income country data	Breaking the Plastic Wave
Substitute - Compostables	18.9	Based on high income country data	Breaking the Plastic Wave

13. Circularity index

In the *Plastsimulator* online simulation, the notion of circularity index was defined as the sum of the interventions which are considered circular including: reduce, substitution and recycling.

Therefore, for any given year the circularity index is defined as the sum of the plastic being reduced (elimination and new delivery models), substituted (paper and compostables), and recycled (mechanical recycling and P2P) divided by the total plastic utility (or waste generated under business-as-usual scenario as described in Exhibit 6). Note that P2F is excluded from this index.

This number is an index which value will necessarily be comprised between 0 and 1 and expressed as a percentage.

APPENDIX 1: Threshold tables for each scenario

EXHIBIT A1-1: Threshold definitions for the business-as-usual scenario

	Threshold 0	1	2	3	4
REDUCE					
Plastic elimination	No additional elimination	Low level of ambition	Moderate level of ambition	High level of ambition	
Shift to new delivery models	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
SUBSTITUTE					
Switch to Paper	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
Switch to compostables	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
RE-DESIGN					
Design for recycling	No additional implementation	Low level of implementation	Moderate level of implementation	High level of implementation	
SORTING					
Coverage of source separation	100% of municipalities collect plastic mixed with residual	25% of municipalities offering plastic source sortation	50% of municipalities offering plastic source sortation	85% of municipalities offering plastic source sortation	
Household source separation rate	Current adoption rate	Moderately improved adoption rate	Improved adoption rate	Highly/Greatly improved adoption ra	
Domestic share of sorting	9% waste sorted domestically (currer rates)	25% waste sorted domestically	50% waste sorted domestically	75% waste sorted domestically	100% waste sorted domestically
Sorting Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
MECHANICAL RECYCLING					
Domestic share of mechanical recycling vs Exports	10% of sorted waste recycled domestically (current rates)	25% of sorted waste recycled domestically	50% of sorted waste recycled domestically	75% of sorted waste recycled domestically	100% of sorted waste recycled domestica
Domestic share of OL vs CL recycling	100% Open loop Recycling	25% Closed loop Recycling	50% Closed loop Recycling	75% Closed loop Recycling	100% Closed loop Recycling (current rate
Mech .Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
chemical conversion					
chemical conversion development	100% of available feedstock for chemically recycling sent to incinerati (current rates)	12.5% of available feedstock for chemically recycling processed	25% of available feedstock for chemically recycling processed	37.5% of available feedstock for chemically recycling processed	50% of available feedstock for chemicall recycling processed
Output Mix: share of fuel vs new feedstock	100% to fuel	25% to new feedstock	50% to new feedstock	75% to new feedstock	100% to new feedstock
Chem. Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
EXPORTS					
Export fate control	Current trend	Moderately improved control of fate	Improved control of fate	Highly improved control of fate	
Domestic share of incineration vs Exports	0% incinerated domestically	25% incinerated domestically	56% incinerated domestically (current rates:)	75% incinerated domestically	100% incinerated domestically
CONSUMER BEHAVIOR					
Littering rate	High littering rate	Moderate littering rate	Low littering rate	Very low littering rate	

EXHIBIT A1-2: Threshold definitions for the Central Sorting scenario

	Threshold 0	1	2	3	4
REDUCE					
Plastic elimination	No additional elimination	Low level of ambition	Moderate level of ambition	High level of ambition	
Shift to new delivery models	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
SUBSTITUTE					
Switch to Paper	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
Switch to compostables	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
RE-DESIGN					
Design for recycling	No additional implementation	Low level of implementation	Moderate level of implementation	High level of implementation	
SORTING					
Coverage of source separation	100% of municipalities collect plastic mixed with residual	25% of municipalities offering plastic source sortation	50% of municipalities offering plastic source sortation	85% of municipalities offering plastic source sortation	
Household source separation rate	Current adoption rate	Moderately improved adoption rate	Improved adoption rate	Highly/Greatly improved adoption ra	
Domestic share of sorting	9% waste sorted domestically (currer rates)	25% waste sorted domestically	50% waste sorted domestically	75% waste sorted domestically	100% waste sorted domestically
Sorting Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
MECHANICAL RECYCLING					
Domestic share of mechanical recycling vs Exports	10% of sorted waste recycled domestically (current rates)	25% of sorted waste recycled domestically	50% of sorted waste recycled domestically	75% of sorted waste recycled domestically	100% of sorted waste recycled domestica
Domestic share of OL vs CL recycling	100% Open loop Recycling	25% Closed loop Recycling	50% Closed loop Recycling	75% Closed loop Recycling	100% Closed loop Recycling (current rate
Mech .Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
chemical conversion					
chemical conversion development	100% of available feedstock for chemically recycling sent to incineratic (current rates)	12.5% of available feedstock for chemically recycling processed	25% of available feedstock for chemically recycling processed	37.5% of available feedstock for chemically recycling processed	50% of available feedstock for chemicall recycling processed
Output Mix: share of fuel vs new feedstock	100% to fuel	25% to new feedstock	50% to new feedstock	75% to new feedstock	100% to new feedstock
Chem. Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
EXPORTS					
Export fate control	Current trend	Moderately improved control of fate	Improved control of fate	Highly improved control of fate	
Domestic share of incineration vs Exports	0% incinerated domestically	25% incinerated domestically	56% incinerated domestically (current rates:)	75% incinerated domestically	100% incinerated domestically
CONSUMER BEHAVIOR					
Littering rate	High littering rate	Moderate littering rate	Low littering rate	Very low littering rate	

EXHIBIT A1-3: Threshold definitions for the System Change Scenario

	Threshold				
	0	1	2	3	4
REDUCE					
Plastic elimination	No additional elimination	Low level of ambition	Moderate level of ambition	High level of ambition	
Shift to new delivery models	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
SUBSTITUTE					
Switch to Paper	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
Switch to compostables	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
RE-DESIGN					
Design for recycling	No additional implementation	Low level of implementation	Moderate level of implementation	High level of implementation	
SORTING					
Coverage of source separation	100% of municipalities collect plastic mixed with residual	25% of municipalities offering plastic source sortation	50% of municipalities offering plastic source sortation	85% of municipalities offering plastic source sortation	
Household source separation rate	Current adoption rate	Moderately improved adoption rate	Improved adoption rate	Highly/Greatly improved adoption ra	
Domestic share of sorting	9% waste sorted domestically (currer rates)	25% waste sorted domestically	50% waste sorted domestically	75% waste sorted domestically	100% waste sorted domestically
Sorting Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
MECHANICAL RECYCLING					
Domestic share of mechanical recycling vs Exports	10% of sorted waste recycled domestically (current rates)	25% of sorted waste recycled domestically	50% of sorted waste recycled domestically	75% of sorted waste recycled domestically	100% of sorted waste recycled domestica
Domestic share of OL vs CL recycling	100% Open loop Recycling	25% Closed loop Recycling	50% Closed loop Recycling	75% Closed loop Recycling	100% Closed loop Recycling (current rate
Mech .Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
chemical conversion					
chemical conversion development	100% of available feedstock for chemically recycling sent to incineratio (current rates)	12.5% of available feedstock for chemically recycling processed	25% of available feedstock for chemically recycling processed	37.5% of available feedstock for chemically recycling processed	50% of available feedstock for chemicall recycling processed
Output Mix: share of fuel vs new feedstock	100% to fuel	25% to new feedstock	50% to new feedstock	75% to new feedstock	100% to new feedstock
Chem. Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
EXPORTS					
Export fate control	Current trend	Moderately improved control of fate	Improved control of fate	Highly improved control of fate	
Domestic share of incineration vs Exports	0% incinerated domestically	25% incinerated domestically	56% incinerated domestically (current rates:)	75% incinerated domestically	100% incinerated domestically
CONSUMER BEHAVIOR					
Littering rate	High littering rate	Moderate littering rate	Low littering rate	Very low littering rate	

EXHIBIT A1-4: Threshold definitions for the Reduce and Substitute scenario

	Threshold 0	1	2	3	4
REDUCE					
Plastic elimination	No additional elimination	Low level of ambition	Moderate level of ambition	High level of ambition	
Shift to new delivery models	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
SUBSTITUTE					
Switch to Paper	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
Switch to compostables	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
RE-DESIGN					
Design for recycling	No additional implementation	Low level of implementation	Moderate level of implementation	High level of implementation	
SORTING					
Coverage of source separation	100% of municipalities collect plastic mixed with residual	25% of municipalities offering plastic source sortation	50% of municipalities offering plastic source sortation	85% of municipalities offering plastic source sortation	
Household source separation rate	Current adoption rate	Moderately improved adoption rate	Improved adoption rate	Highly/Greatly improved adoption ra	
Domestic share of sorting	9% waste sorted domestically (currer rates)	25% waste sorted domestically	50% waste sorted domestically	75% waste sorted domestically	100% waste sorted domestically
Sorting Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
MECHANICAL RECYCLING					
Domestic share of mechanical recycling vs Exports	10% of sorted waste recycled domestically (current rates)	25% of sorted waste recycled domestically	50% of sorted waste recycled domestically	75% of sorted waste recycled domestically	100% of sorted waste recycled domestica
Domestic share of OL vs CL recycling	100% Open loop Recycling	25% Closed loop Recycling	50% Closed loop Recycling	75% Closed loop Recycling	100% Closed loop Recycling (current rate
Mech .Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
chemical conversion					
chemical conversion development	100% of available feedstock for chemically recycling sent to incineratio (current rates)	12.5% of available feedstock for chemically recycling processed	25% of available feedstock for chemically recycling processed	37.5% of available feedstock for chemically recycling processed	50% of available feedstock for chemicall recycling processed
Output Mix: share of fuel vs new feedstock	100% to fuel	25% to new feedstock	50% to new feedstock	75% to new feedstock	100% to new feedstock
Chem. Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
EXPORTS					
Export fate control	Current trend	Moderately improved control of fate	Improved control of fate	Highly improved control of fate	
Domestic share of incineration vs Exports	0% incinerated domestically	25% incinerated domestically	56% incinerated domestically (current rates:)	75% incinerated domestically	100% incinerated domestically
CONSUMER BEHAVIOR					
Littering rate	High littering rate	Moderate littering rate	Low littering rate	Very low littering rate	

EXHIBIT A1-5: Threshold definitions for the Sorting scenario

	Threshold 0	1	2	3	4
REDUCE					
Plastic elimination	No additional elimination	Low level of ambition	Moderate level of ambition	High level of ambition	
Shift to new delivery models	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
SUBSTITUTE					
Switch to Paper	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
Switch to compostables	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
RE-DESIGN					
Design for recycling	No additional implementation	Low level of implementation	Moderate level of implementation	High level of implementation	
SORTING					
Coverage of source separation	100% of municipalities collect plastic mixed with residual	25% of municipalities offering plastic source sortation	50% of municipalities offering plastic source sortation	85% of municipalities offering plastic source sortation	
Household source separation rate	Current adoption rate	Moderately improved adoption rate	Improved adoption rate	Highly/Greatly improved adoption ra	
Domestic share of sorting	9% waste sorted domestically (currer rates)	25% waste sorted domestically	50% waste sorted domestically	75% waste sorted domestically	100% waste sorted domestically
Sorting Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
MECHANICAL RECYCLING					
Domestic share of mechanical recycling vs Exports	10% of sorted waste recycled domestically (current rates)	25% of sorted waste recycled domestically	50% of sorted waste recycled domestically	75% of sorted waste recycled domestically	100% of sorted waste recycled domestica
Domestic share of OL vs CL recycling	100% Open loop Recycling	25% Closed loop Recycling	50% Closed loop Recycling	75% Closed loop Recycling	100% Closed loop Recycling (current rate
Mech .Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
chemical conversion					
chemical conversion development	100% of available feedstock for chemically recycling sent to incineratio (current rates)	12.5% of available feedstock for chemically recycling processed	25% of available feedstock for chemically recycling processed	37.5% of available feedstock for chemically recycling processed	50% of available feedstock for chemicall recycling processed
Output Mix: share of fuel vs new feedstock	100% to fuel	25% to new feedstock	50% to new feedstock	75% to new feedstock	100% to new feedstock
Chem. Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
EXPORTS					
Export fate control	Current trend	Moderately improved control of fate	Improved control of fate	Highly improved control of fate	
Domestic share of incineration vs Exports	0% incinerated domestically	25% incinerated domestically	56% incinerated domestically (current rates:)	75% incinerated domestically	100% incinerated domestically
CONSUMER BEHAVIOR					
Littering rate	High littering rate	Moderate littering rate	Low littering rate	Very low littering rate	

EXHIBIT A1-6: Threshold definitions for the Recycling scenario

	Threshold 0	1	2	3	4
REDUCE					
Plastic elimination	No additional elimination	Low level of ambition	Moderate level of ambition	High level of ambition	
Shift to new delivery models	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
SUBSTITUTE					
Switch to Paper	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
Switch to compostables	No additional penetration	Low level of penetration	Moderate level of penetration	High level of penetration	
RE-DESIGN					
Design for recycling	No additional implementation	Low level of implementation	Moderate level of implementation	High level of implementation	
SORTING					
Coverage of source separation	100% of municipalities collect plastic mixed with residual	25% of municipalities offering plastic source sortation	50% of municipalities offering plastic source sortation	85% of municipalities offering plastic source sortation	
Household source separation rate	Current adoption rate	Moderately improved adoption rate	Improved adoption rate	Highly/Greatly improved adoption ra	
Domestic share of sorting	9% waste sorted domestically (currer rates)	25% waste sorted domestically	50% waste sorted domestically	75% waste sorted domestically	100% waste sorted domestically
Sorting Technology Efficiency	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
MECHANICAL RECYCLING					
Domestic share of mechanical recycling vs Exports	10% of sorted waste recycled domestically (current rates)	25% of sorted waste recycled domestically	50% of sorted waste recycled domestically	75% of sorted waste recycled domestically	100% of sorted waste recycled domestica
Domestic share of OL vs CL recycling	100% Open loop Recycling	25% Closed loop Recycling	50% Closed loop Recycling	75% Closed loop Recycling	100% Closed loop Recycling (current rate
Mech .Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
chemical conversion					
chemical conversion development	100% of available feedstock for chemically recycling sent to incineratio (current rates)	12.5% of available feedstock for chemically recycling processed	25% of available feedstock for chemically recycling processed	37.5% of available feedstock for chemically recycling processed	50% of available feedstock for chemicall recycling processed
Output Mix: share of fuel vs new feedstock	100% to fuel	25% to new feedstock	50% to new feedstock	75% to new feedstock	100% to new feedstock
Chem. Recycling Technology Efficienc	Current efficiency rate	Improved efficiency rate	Breakthrough technology	Huge Breakthrough technology	
EXPORTS					
Export fate control	Current trend	Moderately improved control of fate	Improved control of fate	Highly improved control of fate	
Domestic share of incineration vs Exports	0% incinerated domestically	25% incinerated domestically	56% incinerated domestically (current rates:)	75% incinerated domestically	100% incinerated domestically
CONSUMER BEHAVIOR					
Littering rate	High littering rate	Moderate littering rate	Low littering rate	Very low littering rate	