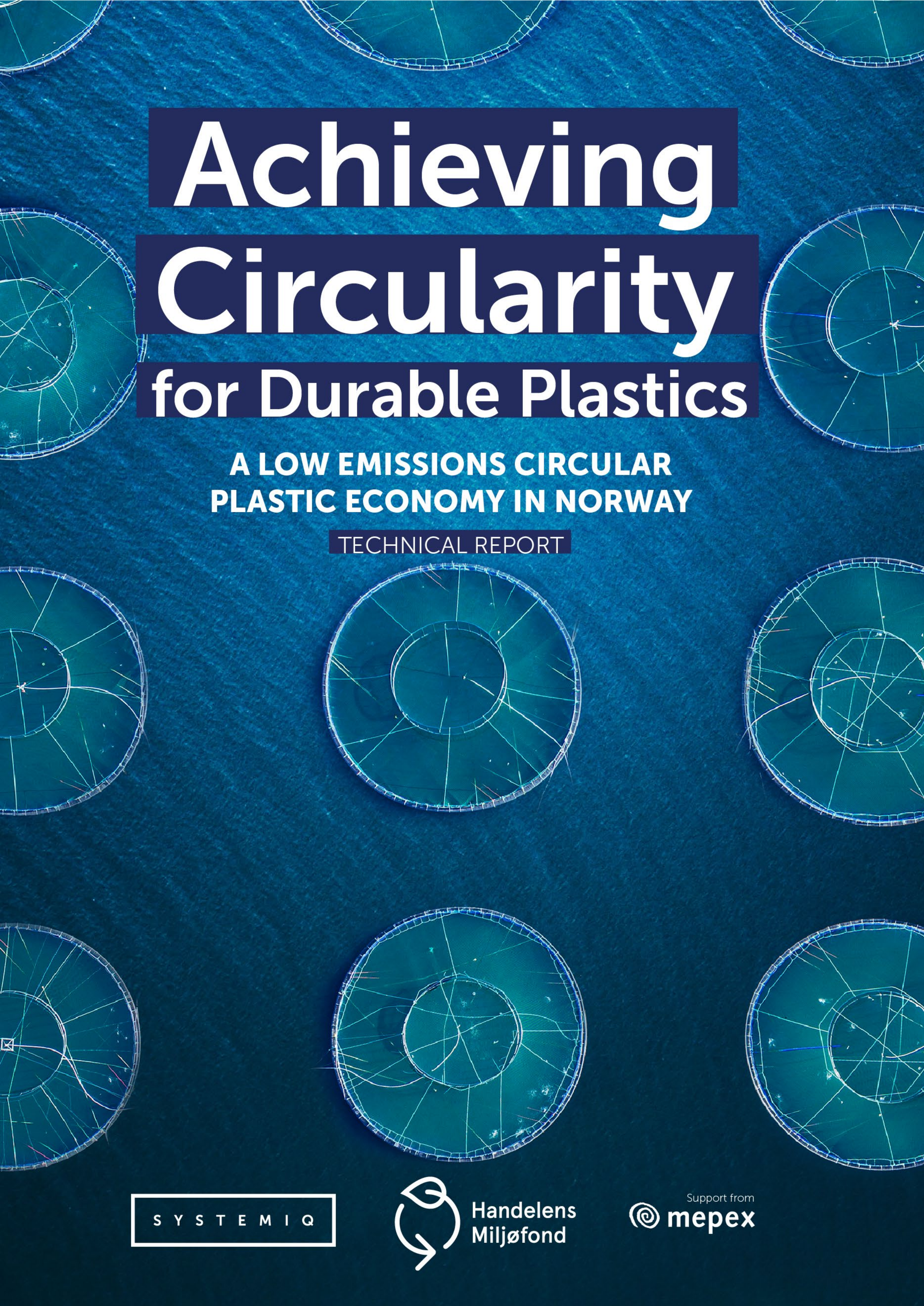


Achieving Circularity for Durable Plastics

A LOW EMISSIONS CIRCULAR PLASTIC ECONOMY IN NORWAY

TECHNICAL REPORT

SYSTEMIQ

Handelens Miljøfond

Support from mepex

Table of Contents

1. Introduction

The aim of this report is to provide a transparent overview of the assumption and methodology used in the model developed by SYSTEMIQ for Handelens Miljøfond with support from Mepex for the report titled: 'Achieving Circularity for Durable Plastics'. Note that this is the second phase of this modelling exercise; the report and technical appendix for the first phase can be found on our website.

The model provides a comprehensive mapping of the Norwegian plastics system and provides stakeholders with an understanding of the economic, environmental, and social implications of a business as usual (BAU) scenario in which only existing commitments are fulfilled, 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 Plastic categories

At the heart of the analysis is a model that simulates the main stocks and flows of plastic in five sub-systems: Construction, Automotive, Textiles, Fisheries and Aquaculture and Electrical and Electronic Equipment (EEE). The model simulates and projects these stocks and flows for each sub-system between 2020 and 2040.

For each of the sub-systems, a system map provides a visual representation of the stocks and flows, illustrating the various pathways that plastic can take through the system to each of the end-of-life destinations. The plastics in each sub-system are grouped into categories based on their common pathways and similar characteristics. For each of the system maps, and for each of the plastic categories within a sub-system, the annual stocks and flows of plastic in the system were quantified in tonnes for two scenarios: a baseline scenario, and a circularity scenario (see section 4 for a detailed description of the scenarios).

The model follows a basic mass balance approach in which the total mass flowing into each box in the system maps is equal to the mass of plastic following out of the box within a given year. To ensure the conservation of mass, the arrows flowing out of each box are quantified as a % which all sum to 100%; the volume flowing into each box is multiplied by the percentage assigned to each arrow in order to obtain the volume in tonnes. The initial top line volumes of demand and waste generation annually are defined inputs to the model (see section xx for a detailed description of the approach taken to define these volumes for each sub-system).

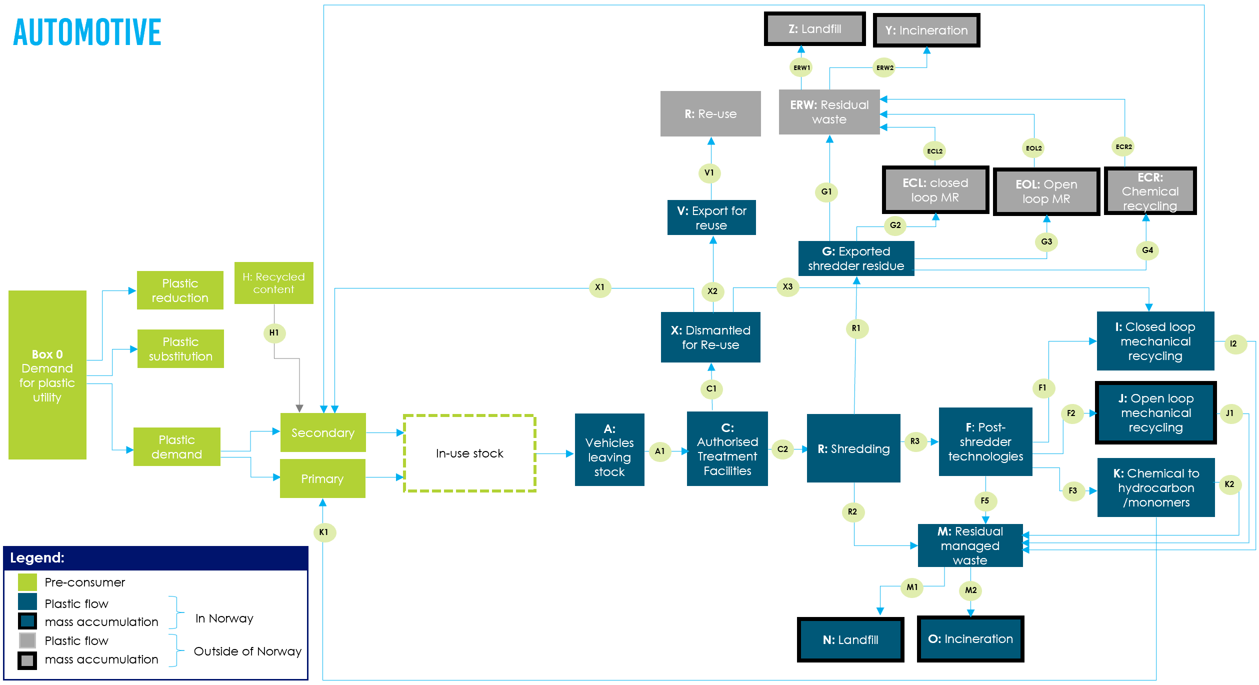
Additionally, the following metrics were also mapped to each flow in the system map.
(1) cost (NOK)
(2) GHG (CO2eq)
(3) employment (number of jobs created)

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

The following sub-sections provide the system maps used in the modelling of each sub-system and the plastic categories modelled. There are three distinct sections of each system map: pre-consumer (green), post-consumer plastic flows in Norway (blue) and post-consumer plastic flows outside of Norway.

2.1 Automotive

The system map used to model the automotive plastics system is given below.



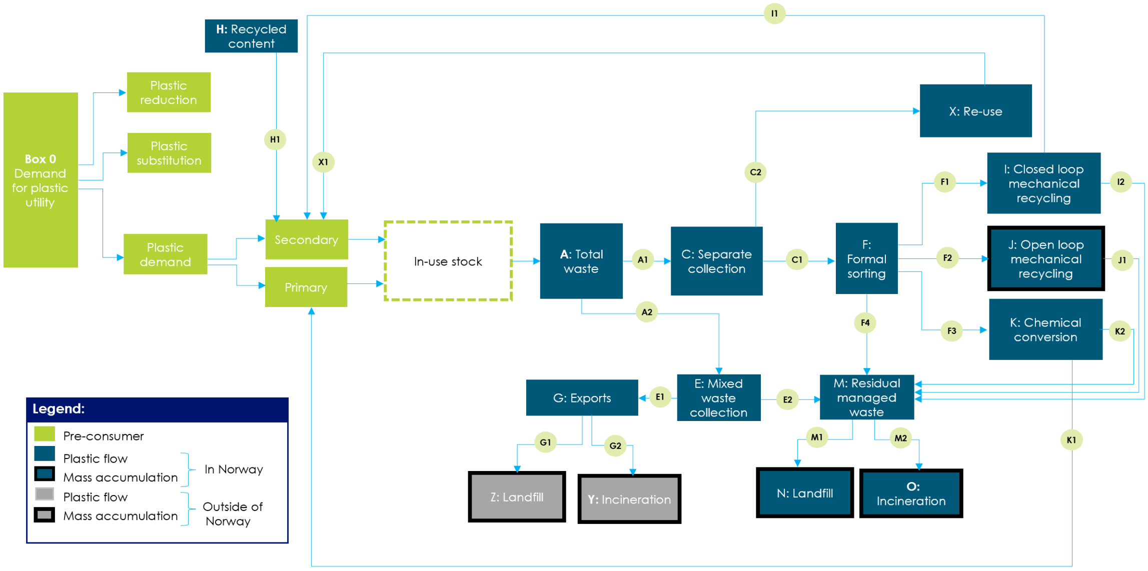
Automotive plastics were divided into three categories based on their pathways through the system map and other common characteristics, as shown in the exhibit below.

Plastic category	Use cases and attributes	Polymer type	Proportion of total demand
Large parts	• E.g. bumpers, fuel tanks, dashboards which have higher dismantling rates prior to shredding compared to other plastic components. • As a result, these components tend to have higher re-use and recycling rates	PP 58%, PE 42%	10%
Other Polyolefins	• Use cases include cable insulation, interior trims etc. • Higher rates of recovery can be achieved from shredder residue compared to other polymers.	PP 70%, PE 30%	28%
Other polymers/ multi-material	• Rarely dismantled prior to shredding • Use cases include car body parts, headlight lenses, instrument panel, seats etc. • Low recovery rates from shredder residue	PVC 6%, PA 9%, ABS,SAN 13%, PUR 26%, Other[1] 46%	62%

2.2 Construction

The system map used to model plastic products in construction and demolition is given below.

CONSTRUCTION & DEMOLITION



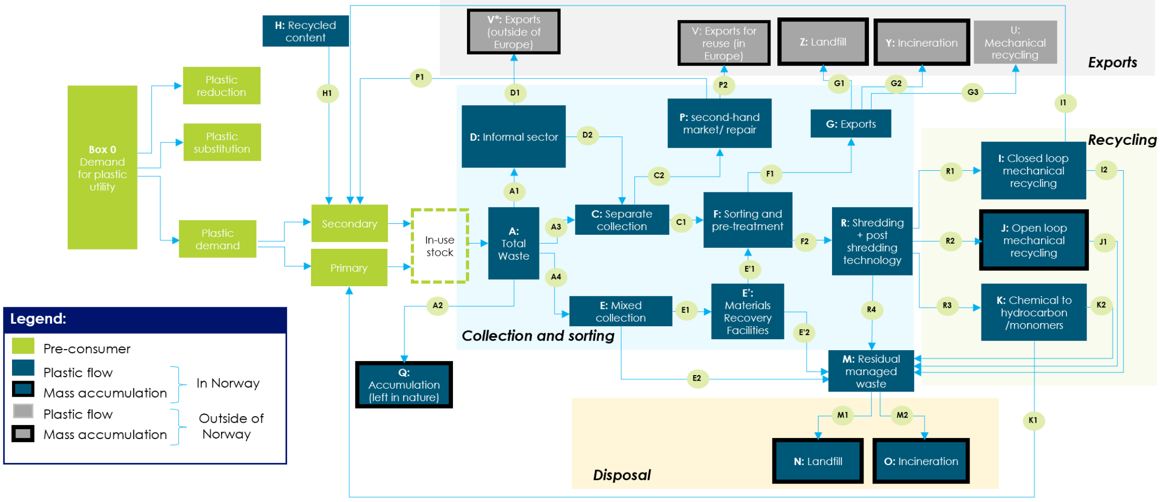
Plastic products in construction were grouped into five categories, based on their common pathways through the system: pipes, insulation, windows and profiles, roof products and other products (which includes flooring, roller shutters, film sheets etc.).

Plastic category	Use cases and attributes	Polymer type	Proportion of total demand
Pipes	• Use cases include all pipes except for district piping.	PP 18%, PE 45%, PVC 37%, GFRP 0%, Other 0%	37%
Insulation	• Includes insulation for buildings and other infrastructure such as bridges, tunnels but excludes road insulation	EPS 56%, XPS 44%	32%
Other products	• Use cases include flooring, roller shutters, films, sheets etc.	PVC 30%, SBS modified bitumen 33%, PA 9%, PP 20%, Other 8%	23%
Windows and profiles	• Includes all windows and door profiles.	PVC 6%, PE 79%, GRRP 12%, Other 3%	5%
Roof products	• Includes plastic roofing materials such as SBS modified bitumen and PE roofs	SBS modified bitumen 85%, roof PVC 15%	3%

2.3 Electronics

The system map used to model the stocks and flows of plastics in the EEE system is given below.

ELECTRICAL AND ELECTRONIC EQUIPMENT

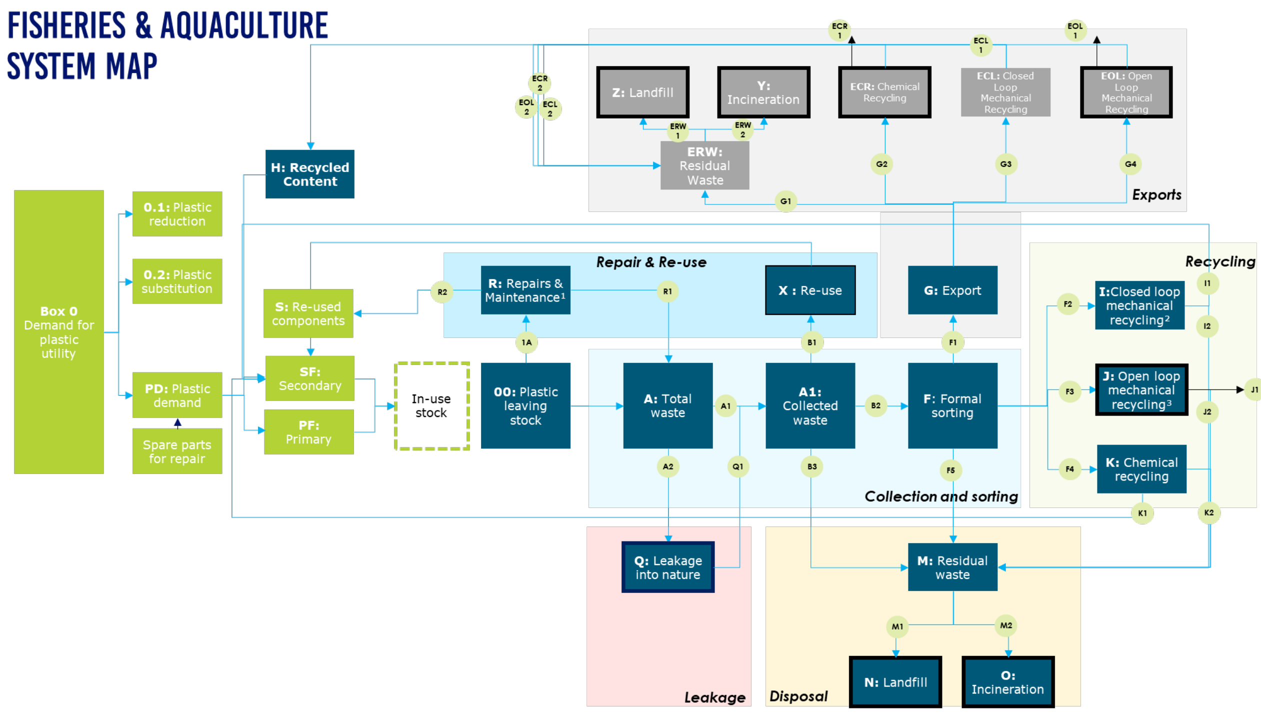


EEE products were grouped into four categories: large equipment, small equipment, screens and displays and large industrial cables. This is a simplification of the official WEEE classification system used in Norway in which the small equipment category includes small IT and telecoms, other small equipment, light sources and ionic smoke detectors; and the large equipment category covers heating and cooling equipment, large industrial equipment and other large products.

Plastic category	Use cases	Plastic content	Polymer type (PS, ABS, PC, PC/ABS, PP, PVC, PE, Other)	Proportion of total plastic demand
Small equipment	• Small IT a telecoms, other small equipment (products with measurements below 50 cm)	33%	11%, 18%, 4%, 46%, 0%, 1%, 20%	43%
Large equipment	• Heating and cooling equipment, other large products (50cm +), solar panels, large industrial equipment	14%	36%, 0%, 6%, 48%, 6%, 0%, 4%	35%
Large industrial cables	• Large industrial cables	30%	25%, 75%, 0%	18%
Screens and displays	• Screens, monitors and equipment containing screens with a surface of more than 100cm² • Cathode ray tubes (CRT), liquid crystal displays (LCD), light-emitting diode displays (LED)	16%	11%, 18%, 30%, 26%, 1%, 0%, 14%	4%

2.4 Fishing & Aquaculture

The system map used to model the plastics system is shown below



Plastics were divided into two categories based on their pathways through the system map and other common characteristics, as shown in the exhibit below.

	Included	Not included	
Fishing	Pelagic/bottom trawl Purse seine Danish/Scottish seine Gillnets Hooks and lines Traps and pots Long line Accessories/other incl ropes Trawl gear (rockhoppers, bobbins)	Trawl doors Trawl wire Recreational/sport fishing	>95% of total plastic weight in scope **Proportion of total plastic weight:** ▪ 76% nets ▪ 17% ropes ▪ 7% traps, floating devices, and others **Most problematic equipment:** ▪ Equipment that gets placed for longer time: ▪ Gillnets ▪ Traps
Aqua-culture	Mooring systems Floating rings Nets Brackets, railing Accessories/other incl buoyancy devices Feeding Systems	Land-based aquaculture Fish hatcheries	>95% of total plastic weight in scope **Proportion of total plastic weight:** ▪ 71% feeding pipes, cages, floating devices, walkways ▪ 18% nets ▪ 11% ropes **Most problematic equipment:** ▪ Feeding pipes ▪ Ropes

Polymer types:

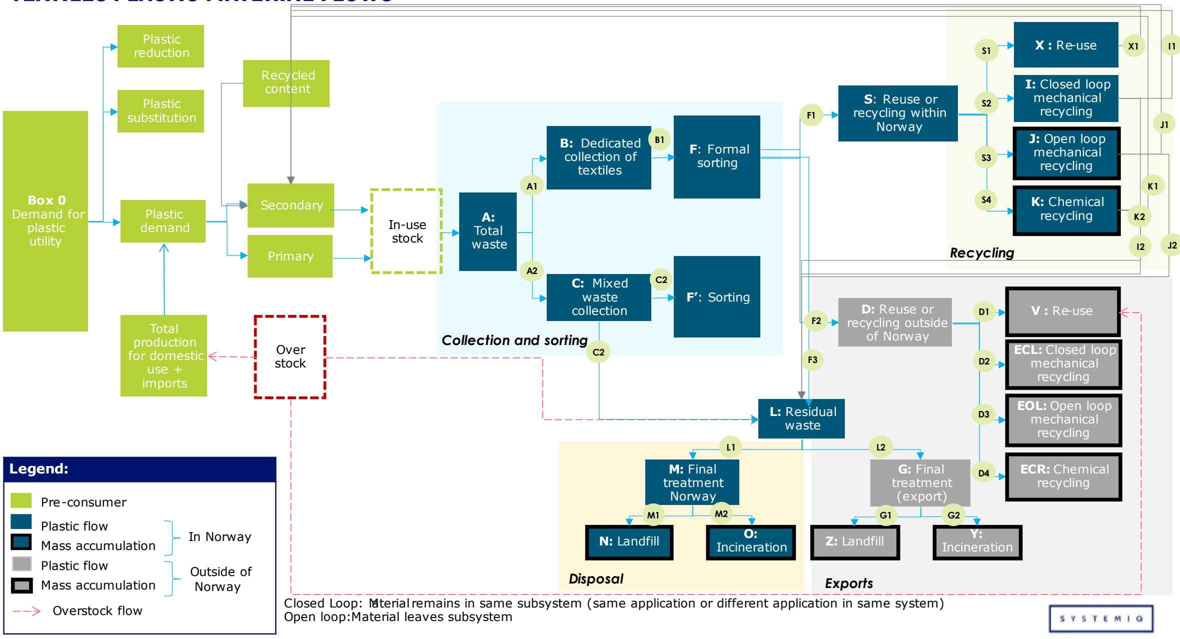
Polymer type	Acronym	Fisheries	Aquaculture	weighted average
Nylon 46	Other	47.00%	16.00%	19.10%
Polypropylene	PP	44.00%	11.00%	14.30%

Polyethylene	PE	9.00%	0.00%	0.90%
High density polyethylene	PE	0.00%	71.00%	63.90%
Polystyrene	PS	0.00%	2.00%	1.80%
Volume Proportion		10.00%	90.00%	

2.5 Textiles

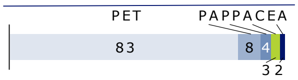
The system map used to model the textiles plastics system is given in the exhibit below. There are three distinct sections of the system map: pre-consumer (green), post-consumer plastic flows in Norway (blue) and post-consumer plastic flows outside of Norway (grey).

TEXTILES PLASTIC MATERIAL FLOWS



Textile plastics covers six product application, namely clothing, accessories, shoes, outdoor life, textile packaging and household textiles. The overall polymer composition of textiles is shown in the exhibit below.

TEXTILES: PLASTIC CONTENT

Plastic category	Plastic content in textiles	Polymer types	Total plastic waste (2020)	Yearly POM (2020)
Textiles	55%		~58.000 t	~64.000 t

Legend:	
PA	Nylon
PET	Polyester
AC	Acrylics
EA	Elastane
PP	Polypropylene

3. Demand and waste volume projections

Top line plastic demand and waste volumes were projected out to 2040 based on current trends in each of the 5 sectors. A stock and flow modelling approach were taken using the following equation to define the stock, demand, and waste volumes in year n+1.

$Stock_{n+1} = Stock_{n} + Demand_{n+1} – Waste_{n+1}$.

By defining either the annual stock or annual demand volumes based on current trends in the sector, and the waste volumes which is determined by past demand, the third variable in the equation (either demand or stock) can be calculated.

Lifetime probability distributions, modelled using a normal distribution, were used to simulate the lifetime lag of plastics in each sub-system, where the mean and standard distribution were specific to each of the different plastic applications. By applying this distribution to annual demand volumes in each year prior, waste volumes to 2040 were estimated.

3.1 Automotive

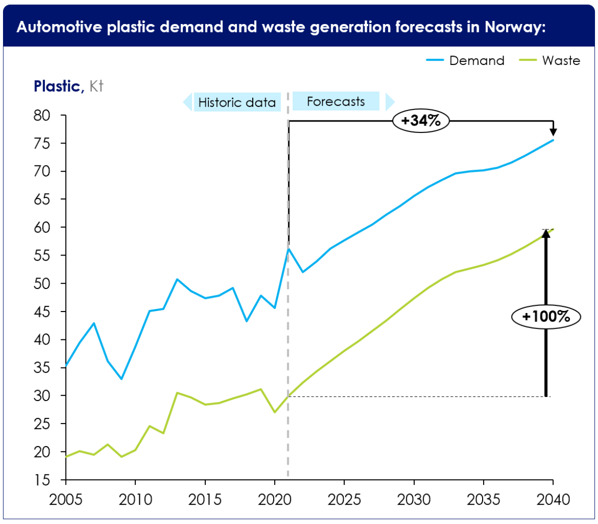
The vehicle stock in Norway was projected to 2040 based on vehicles per capita and population growth. From this projection and an assumed average vehicle lifetime of 17.9 years, annual demand and waste volumes were deduced.

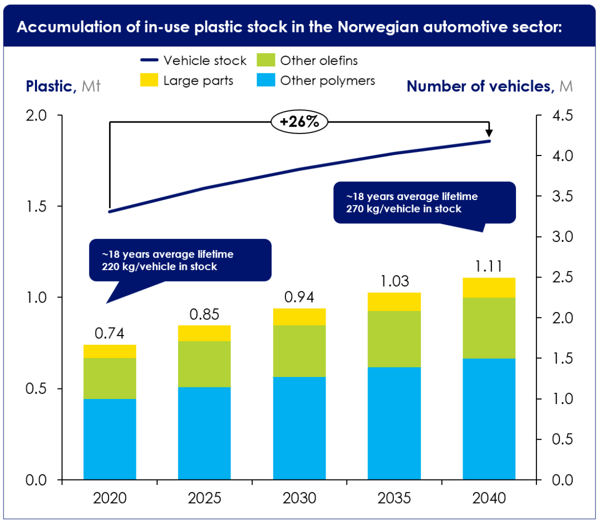
- Vehicle stock forecasts are based on the projected growth in vehicles per capita to a maximum of 0.68 at which it plateaus (equal to the current max. vehicles per capita in Europe).[1]
- Average mass of plastic in a vehicle is estimated to increase with increasing share of electric vehicles from ~246kg per vehicle to ~280kg per vehicle.
- Number of vehicles leaving stock per year estimated using lifetime probability distribution to account for the spread in lifetimes.
- Vehicles entering stock is the sum of replacements of vehicles leaving stock and new additions to stock (i.e. change in stock from year to year).

	Source	Projection methodology	2020	2030	2040
Vehicle stock (million)	Statistics Norway	Based on population projections from the world bank and vehicles per capita projections	3.3	3.8	4.2
Vehicles per capita	Calculated	Based on growth trends in the last 10 years with	0.62	0.66	0.68

		growth slowing down towards 2040			
Mass of plastic in average new passenger vehicle (kg)	Emilsson et al. (2019) – Swedish study, Kibira et al. (2011)	Based on a growing share of EVs and lightweighting trends	246	260	280
Average lifetime of passenger vehicles	Statistics Norway	Assumed constant	17.9	17.9	17.9
Vehicles leaving stock (thousands)	Statistics Norway	Projected using past demand and lifetime probability distribution	131	208	243
Vehicles entering stock (thousands)	Statistics Norway	Equal to change in stock plus replacements of vehicles leaving stock	185	252	270

The resulting demand, waste and stock projections are given below.





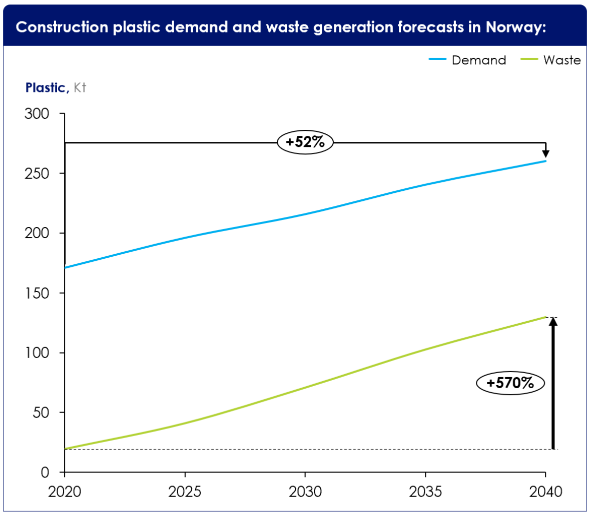
3.2 Construction

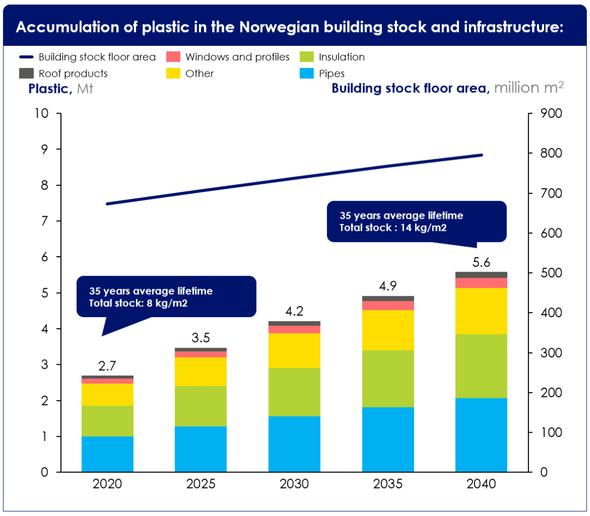
Plastic stock in buildings was projected to 2040 based on population and floor space per capita growth, as well the plastic use intensity in new buildings.

- Building stock floor area forecasts are based on the **projected growth in residential floor area per capita** which is projected to grow at an annual growth rate of **1.3%** based on historic growth.
- The model assumes that **residential floor area makes up 50%** of total floor area in Norway.
- Proportion of building stock demolished and rebuilt each year estimated using a lifetime **probability distribution to account for the spread in lifetimes**, with an average lifetime of 35 years.
- Demand for the construction of new floor area is the sum of replacements of building floor area leaving stock and new additions to stock (i.e. change in stock from year to year).
- Average plastic use intensity in new buildings is assumed to **remain constant at 23.5kg/m^2 through to 2040** (much higher than average plastic per m2 in current building stock ~5.6 kg/m^2)

	Source	Projection methodology	2020	2030	2040
Building stock (million m^2)	Statistics Norway[2]	Based on population projections from the world bank and floor area per capita projections	673	737	796
Residential floor area per capita	Calculated	Based on growth trends in the last 10 years with growth slowing down towards 2040. Assumes 50% of building stock is residential.	62.5	63.5	64.4
Plastic use intensity in new buildings (kg/m2)	Häkkinen et al. (2019) – Finnish study[3]	Assumed constant	23.5	23.5	23.5
Average lifetime of buildings	Geyer et al.[4]	Assumed constant	35	35	35

The resulting demand, waste, and stock projections are shown below.





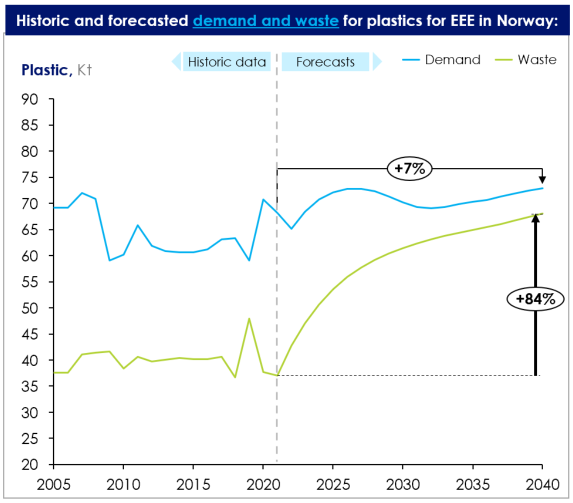
3.3 Electronics

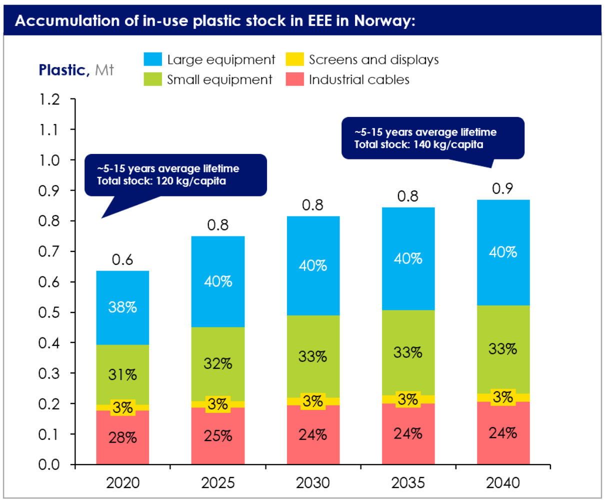
Plastic stock in EEE was projected to 2040 based on population growth and kg of stock per capita growth.

- Stock growth forecasts for each individual product category was calculated based on a growth in stock per capita, based on current and historic trends.
- The proportion of EEE discarded as waste each year was estimated using lifetime probability distributions for each individual product category to account for the spread in lifetimes, with average lifetimes ranging from 5 to 15 years.

	Source	Projection methodology	2020	2030	2040
Total stock per capita (kg/capita)	Calculated	Based on growth trends in the last 10 years with growth slowing down towards 2040.	118.4	140.5	140.8
Average lifetime	Geyer et al, ODI[4,5]	Based on growth trends in the last 10 years with growth slowing down towards 2040. Assumes 50% of building stock is residential.	5-15	5-15	5-15

The resulting projections in demand, waste and stock are given below.





3.4 Fishing & Aquaculture

Fisheries

- Plastic in stock, waste and demand was provided by the Norwegian Directorate of Fisheries in 2016. Mepex did a deep assessment to cross-check the data.
- Plastic stock forecasts are based on:
    1. Production
        - Expected max stock to reach 2.5Mt, inflection point 2021
        - Quotas not expected to change
    2. Efficiency - average mass of plastic equipment per tonne of Seafood caught
        - Weight of plastic equipment needed per tonne of fish has stabilised (change to larger vessels has already taken place, and # of vessels has stabilised)
- Plastic leaving stock is calculated based on an average lifetime of plastic equipment of 4 years, standard deviation of 1
- Plastic demand is a function of the additional stock needed for increased production plus the replacement of the waste volume (in a year that production decreases, equipment stock does not decrease)

	Source	Methodology	2020	2030	2040
Fisheries					
Production [Mt]	www.fiskeridir.no	Historic production and peaking of production by 2.5Mt	2.47	2.49	2.50
Weight of plastic used per weight of fish caught [t]	Norwegian Directorate of Fisheries (2016)	Plastic in stock / production (2016) -> remain constant	0.0087	0.0087	0.0087
Plastic Stock [t]	[6]	Production * weight of plastic used per tonne of fish caught	21.652	21.734	21.739
Plastic leaving stock [t]	[6]	As a function of demand with a normal distribution on	3.278	3.445	3.405

		the lifetime of the equipment			
Plastic entering stock [t]	6	= annual change in stock + plastic leaving stock	3.278	3.450	3.405

<u>Aquaculture</u>

- Plastic in stock, waste and demand was provided by the Norwegian Directorate of Fisheries in 2016. Mepex did a deep assessment to cross-check the data.
- **Plastic stock forecasts** are based on:
  1. <u>Production:</u>
     - Historic CAGR of **2.2%**
     - No maximum stock, but currently facing uncertain future (constraints include accessibility of fish feed, lice issues, new tax policies). On the other hand, innovation and move to offshore could change growth numbers.
     - CAGR of **1.2%** considered
  2. <u>Efficiency</u> - average mass of plastic equipment per tonne of Seafood caught
     - Weight of plastic equipment needed per tonne of fish is expected to reduce **2% until 2025**, and stabilize after (expected change to larger offshore farms requires larger cages and equipment – and potential trend to more metal in cages to avoid diseases)
     - The amount of plastic per type of equipment is assumed to remain stable
- **Plastic leaving stock** is calculated based on an **average lifetime** of plastic equipment of 10 years, standard deviation of 1
- **Plastic demand** is a function of the additional stock needed for increased production plus the replacement of the waste volume (in a year that production decreases, equipment stock does not decrease)

	Source	Methodology	2020	2030	2040
<u>Aquaculture:</u>					
Production [Mt]	www.fiskeridir.no	1.2% yearly growth based on CAGR historic production	1.99	2.26	2.59

Weight of plastic used per weight of fish caught [t]	Norwegian Directorate of Fisheries (2016)	Plastic in stock / production (2016) -> decrease due to efficiency and metal replacement until 2025, then stabilize	0.1263	0.1165	0.1165
Plastic Stock [t]	6	Production * weight of plastic used per tonne of fish caught	199.668	226.151	254.802
Plastic leaving stock [t]	6	As a function of demand with a normal distribution on the lifetime of the equipment	27.473	33.556	34.940
Plastic entering stock [t]	6	= annual change in stock + plastic leaving stock	29.294	36.238	37.971

3.5 Textiles

- **Plastic share in textiles POM is 55%.** This will remain constant until 2040
- Plastic demand is a function of population growth and historic textile plastics demand per capita
    1. Textiles **plastic demand per capita decreases 5% between** 2023 and 2040 to 12 kg/person
- Plastic waste is calculated based on textile lifetime:
    1. **Average lifetime of textiles is 4 years** with standard deviation of 2

	Source	Methodology	2022	2030	2040
Norway population [Mio.]	World bank projection		5.4	5.8	6.1
Textiles plastic put on market (historical data) [t]		= Imports – Exports + Production	70.441	NaN	NaN
Plastic in textiles consumption per capita [t/capita]		= tonnes of plastic in textiles / Population; 5% reduction between 2023 and 2040	0,0129	0.0125	0.0122
Textiles plastic demand [t]	[6]	=Population * Textiles plastic per person	70.441	72.783	75.184
Textiles plastic waste [t]	[6]	As a function of demand with a normal distribution on the lifetime of textiles	63.847	68.706	73.447
Textiles plastic stock [t]	[6]	= stock of previous year – waste + demand	389.516	427.342	464.303

4. Scenarios

Three main scenarios are modelled: a baseline scenario in which a continuation of current trends is assumed as well as some change due to existing policy and industry commitments; a systems change scenario in which upstream and downstream circularity interventions are applied ambitiously; and a Net Zero scenario in which, on top of the circularity interventions, abatement technologies on production and end of life are deployed to reduce remaining emissions in the system.

The table below provides an overview of the commonalities and differences between each of the modelled scenarios.

	Baseline scenario	Systems change scenario	Net Zero scenario
Time horizon	2020-2040		
Scope of products	Same scope of applications per sub-system		
Demand & waste volumes	BAU projections based on current trends + current commitments	BAU projections + current commitments and circularity levers	
Flow assumptions	projections based on current trends + current commitments	With current commitments and circularity levers applied	
Current commitments	All current commitments that meet criteria		
Circularity levers	None	Circularity levers applied	
GHG levers	Only decarbonization in line with IEA net zero 2050 assumptions		GHG levers applied aligned with 2050 Net Zero scenario
Emissions factors	based on current trends		Current trends + GHG levers
Chemical Recycling	none	Growth in line with EU I commitment	
Plastic & Polymer proportion	Polymer proportions remain constant		
Jobs	Same job factors per ton		
Costs	Same costs factors per ton		

5. Baseline Scenario

The baseline scenario is a projection of current trends, including any existing policy or industry commitments which meet the below criteria.

[Insert and explain current commitments criteria]

In the absence of current commitments, the assumption assigned to each flow (as a percentage) is assumed to remain constant over time to 2040. The sub-sections below provide a comprehensive list of all assumptions in the baseline scenario for each of the five sub-systems.

5.1 Automotive

There are no relevant current commitments for automotive plastics which meet the criteria. The ELV Directive target dates have already passed, and the targets have been met. The Revision of ELV has not yet been released and the contents remain unknown.

The table below provides a full list of the baseline assumptions.

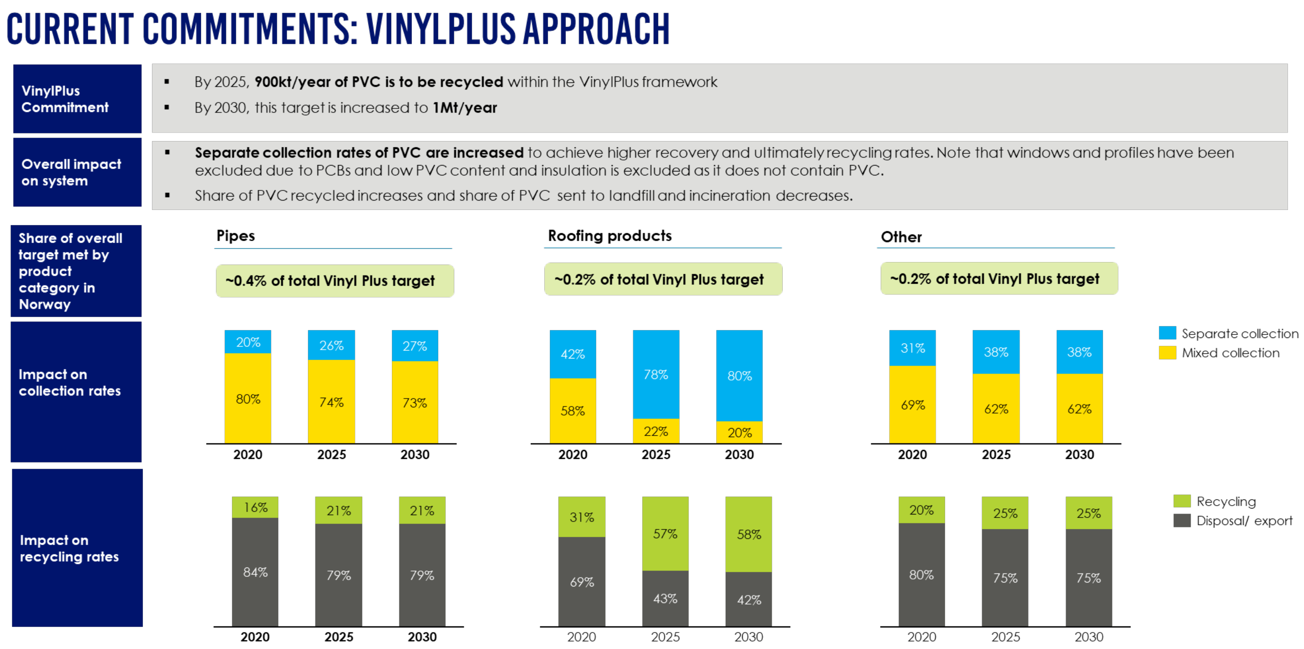
Flow variable	Model ID	Large parts	Other polyolefins	Other polymers
ELVs to ATFs	Arrow A1	100%	100%	100%
Dismantling	Arrow C1	5%	0%	0%
Shredding	Arrow C2	95%	100%	100%
Shredder residue exported	arrow R1	53%	53%	53%
Shredder residue to residual waste	arrow R2	48%	48%	48%
Shredder residue to post-shredder technologies	arrow R3	0%	0%	0%
Post-shredder technologies to closed loop Mechanical Recycling	arrow F1	5%	3%	0%
Post-shredder technologies to open loop Mechanical Recycling	arrow F2	34%	36%	20%
Post-shredder technologies to Chemical Recycling	arrow F3	0%	0%	0%
Post-shredder technologies to residual waste	arrow F4	61%	61%	80%
Closed loop recycled	Arrow I1	70%	70%	40%
Closed loop recycling losses	Arrow I2	30%	30%	60%
Open loop recycled	Arrow J1	70%	70%	40%
Open loop recycling losses	Arrow J2	30%	30%	60%

Chemically recycled	Arrow K1			
Chemical recycling losses	Arrow K2			
Dismantled for reuse in Norway	arrow X1	80%	100%	100%
Dismantled for reuse outside of Norway	arrow X2	20%	0%	0%
Dismantled for recycling	arrow X3	0%	0%	0%
Residual waste to landfill	arrow M1	40%	40%	40%
Residual waste to incineration	arrow M2	60%	60%	60%
Exports to residual waste	Arrow G1	100%	100%	100%
Exports to closed loop mechanical recycling	Arrow G2	0%	0%	0%
Exports to open loop mechanical recycling	Arrow G3	0%	0%	0%
Exports to chemical recycling	Arrow G4	0%	0%	0%
Exports open loop recycled	arrow EOL1	70%	70%	40%
Exports open loop recycling losses	arrow EOL2	30%	30%	60%
Exports closed loop recycled	arrow ECL1	70%	70%	40%
Exports closed loop recycling losses	arrow ECL2	30%	30%	60%
Exports chemically recycled	arrow ECR1	0%	0%	0%
Exports chemical recycling losses	arrow ECR2	0%	0%	0%
Exported residual waste to landfill	arrow ERW1	11%	11%	11%
Exported residual waste to incineration	arrow ERW2	89%	89%	89%

Source: various – Mepex analysis, expert interviews

5.2 Construction

One relevant current commitment was identified for construction: VinylPlus. Separate collection rates were assumed to increase over time in order to meet the PVC recycling rate targets for 2025 and 2030 set by VinylPlus. See approach below.



The table below provides a full list of the baseline assumptions. Not collection rates in the table below are for 2020; these are increased according to the collection rates given above for 2025 and 2030 in order to meet the VinylPlus targets.

Flow variable	Model ID	Pipes	Window profiles	Insulation	Roof produc ts	Other
Separate collection	Arrow A1	20%	58%	28%	42%	31%
Mixed collection	Arrow A2	80%	42%	72%	58%	69%
Separate collection to formal sorting	Arrow C1	100%	100%	100%	100%	100%
Separate collection to reuse	Arrow C2	0%	0%	0%	0%	0%
Mixed collection to export	Arrow E1	42%	42%	42%	42%	42%
Mixed collection to residual waste	Arrow E2	58%	58%	58%	58%	58%
reused	arrow X1	100%	100%	100%	100%	100%
Formal sorting to closed loop mechanical recycling	arrow F1	42%	0%	0%	64%	29%

Formal sorting to open loop mechanical recycling	arrow F2	38%	0%	65%	9%	36%
Formal sorting to chemical recycling	arrow F3	0%	0%	0%	0%	0%
Formal sorting to residual waste	arrow F4	20%	100%	35%	27%	35%
Closed loop recycled	Arrow I1	78%	78%	66%	78%	70%
Closed loop recycling losses	Arrow I2	22%	22%	34%	22%	30%
Open loop recycled	Arrow J1	78%	78%	66%	78%	70%
Open loop recycling losses	Arrow J2	22%	22%	34%	22%	30%
Chemically recycled	Arrow K1	-	-	-	-	-
Chemical recycling losses	Arrow K2	-	-	-	-	-
Residual waste to landfill	arrow M1	5%	5%	5%	5%	5%
Residual waste incineration	arrow M2	95%	95%	95%	95%	95%
Exports to landfill	Arrow G1	0%	0%	0%	0%	0%
Exports to incineration	Arrow G2	100%	100%	100%	100%	100%

Source: various – Mepex analysis, expert interviews

5.3 Electronics

There are no relevant current commitments for electronics which meet the criteria. The table below provides a full list of the baseline assumptions.

Flow variable	Model ID	Large equipment	Small equipment	Screens and displays	Industrial cables
Collection by informal sector	Arrow A1	9%	4%	7%	0%
Left in nature	Arrow A2	0%	0%	0%	41%
Separate collection	Arrow A3	91%	85%	88%	59%
Mixed collection	Arrow A4	0%	12%	5%	0%
Sorting and pre-treatment	Arrow C1	100%	99%	99%	100%
Reuse	Arrow C2	1%	1%	1%	0%
Illegal export	Arrow D1	90%	90%	90%	90%
Informal sector to separate collection	Arrow D2	10%	10%	10%	10%
Mixed collection to MRF	arrow E1	11%	11%	11%	11%
Mixed collection to residual waste	Arrow E2	89%	89%	89%	89%
Reuse in Norway	arrow P1	5%	5%	5%	5%
Reuse outside of Norway	Arrow P2	95%	95%	95%	95%
Exports for end of life treatment	Arrow F1	30%	30%	100%	30%
Shredding	Arrow F2	70%	70%	0%	70%
MRF to sorting and pre-treatment	Arrow E'1	5%	5%	5%	5%
MRF to residual waste	Arrow E'2	95%	95%	95%	95%
Shredding to closed loop mechanical recycling	Arrow R1	21%	7%	9%	0%
Shredding to open loop mechanical recycling	Arrow R2	62%	65%	85%	0%
Shredding to chemical recycling	Arrow R3	0%	0%	0%	0%
Shredding to residual waste	Arrow R4	18%	28%	6%	100%
Closed loop recycled	Arrow I1	60%	60%	60%	80%
Closed loop recycling losses	Arrow I2	40%	40%	40%	20%
Open loop recycled	Arrow J1	60%	60%	60%	80%

Open loop recycling losses	Arrow J2	40%	40%	40%	20%
Chemically recycled	Arrow K1	-	-	-	-
Chemical recycling losses	Arrow K2	-	-	-	-
Residual waste to landfill	arrow M1	7%	13%	0%	87%
Residual waste to incineration	arrow M2	93%	87%	100%	13%
Exports to residual waste	arrow G1	18%	28%	6%	100%
Exports to chemical recycling	arrow G2	0%	0%	0%	0%
Exports to closed loop mechanical recycling	arrow G3	21%	7%	9%	0%
Exports to open loop mechanical recycling	arrow G4	62%	65%	85%	0%
Exports open loop recycled	arrow EOL1	60%	60%	60%	80%
Exports open loop recycling losses	arrow EOL2	40%	40%	40%	20%
Exports closed loop recycled	arrow ECL1	60%	60%	60%	80%
Exports closed loop recycling losses	arrow ECL2	40%	40%	40%	20%
Exports chemically recycled	arrow ECR1	-	-	-	-
Exports chemical recycling losses	arrow ECR2	-	-	-	-
Exported residual waste to landfill	arrow ERW1	20%	13%	7%	87%
Exported residual waste to incineration	arrow ERW2	80%	87%	93%	13%

Source: various – Mepex analysis, expert interviews

5.4 Fishing & Aquaculture

There are no relevant current commitments for fisheries and aquaculture which meet the criteria. The table below provides a full list of the baseline assumptions.

Flow variable	Model ID	Fisheries	Aquaculture
Repairs & maintenance to total waste	arrow R1	5%	1%
Repairs & maintenance to reuse	arrow R2	95%	99%
Waste collected	arrow A1	90%	98%
Waste leaked into nature	arrow A2	10%	2%
Waste leaked into nature collected	arrow Q1	20%	20%
Collected waste to reuse	arrow B1	2%	2%
Collected waste to formal sorting	arrow B2	54%	54%
Collected waste to residual waste	arrow B3	44%	44%
Formal sorting to export	arrow F1	65%	75%
Formal sorting to closed loop mechanical recycling	arrow F2	0%	4%
Formal sorting to open loop mechanical recycling	arrow F3	20%	6%
Formal sorting to chemical recycling	arrow F4	0%	0%
Formal sorting to residual waste	arrow F5	15%	15%
Closed loop recycled	arrow I1	70%	75%
Closed loop losses	arrow I2	30%	25%
Open loop recycled	arrow J1	70%	75%
Open loop losses	arrow J2	30%	25%
Chemical recycling recycled	arrow K1	70%	70%
Chemical recycling losses	arrow K2	30%	30%
Residual waste to landfill	arrow M1	40%	40%
Residual waste to incineration	arrow M2	60%	60%
Exports to residual waste	arrow G1	0%	0%
Exports to chemical recycling	arrow G2	100%	45%
Exports to closed loop mechanical recycling	arrow G3	0%	0%
Exports to open loop mechanical recycling	arrow G4	0%	55%
Exports to open loop recycled	arrow EOL1	70%	75%
Exports to open loop losses	arrow EOL2	30%	25%
Exports to closed loop recycled	arrow ECL1	70%	75%
Exports to closed loop losses	arrow ECL2	30%	25%

Exports to chemically recycled	arrow ECR1	70%	70%
Exports to chemical recycling losses	arrow ECR2	30%	30%
Exports to residual waste to landfill	arrow ERW1	0%	0%
Exports to residual waste to incineration	arrow ERW2	100%	100%

Source: various – Mepex analysis, expert interviews

5.5 Textiles

- Dedicated collection of textiles expected to be in place in Norway by 2025. Dedicated textiles waste collection is expected to reach 85% collection rate by 2040. The increased amounts are expected to be of lower quality.

Flow variable	Model ID	Source/rationale	2020	2030	2040
Dedicated collection of textiles	B	EU Waste Framework Directive	23%	80%	85%
Mixed waste collection	C	EU Waste Framework Directive	77%	20%	15%

The table below provides a full list of the baseline assumptions.

Flow variable	Model ID	Textiles
Dedicated waste collection	Arrow A1	23%
Mixed waste collection	Arrow A2	77%
Dedicated collection to sorting	arrow B1	100%
Mixed waste collection to sorting	arrow C1	0%
Mixed waste collection to residual waste	arrow C2	100%
Sorting to reuse and recycling within Norway	Arrow F1	1%
Sorting to reuse and recycling outside of Norway	Arrow F2	91%
Sorting to residual waste	Arrow F3	8%
Reuse and recycling to reuse	Arrow S1	100%
Reuse and recycling to closed loop mechanical recycling	Arrow S2	0%
Reuse and recycling to open loop mechanical recycling	Arrow S3	0%
Reuse and recycling to chemical recycling	Arrow S4	0%
reuse	Arrow X1	100%
Closed loop recycled	Arrow I1	70%
Closed loop losses	Arrow I2	30%
Open loop recycled	Arrow J1	99%
Open loop losses	Arrow J2	2%
Chemical recycling recycled	Arrow K1	70%
Chemical recycling losses	Arrow K2	30%
Residual waste to disposal in Norway	Arrow L1	88%
Residual waste to disposal outside of Norway	Arrow L2	12%
Disposal to landfill in Norway	Arrow M1	0%
Disposal to incineration in Norway	Arrow M2	100%
Disposal to landfill outside of Norway	Arrow G1	10%
Disposal to incineration outside of Norway	Arrow G2	90%
Exports to reuse	Arrow D1	80%
Exports to closed loop mechanical recycling	Arrow D2	20%

Exports to open loop mechanical recycling	Arrow D3	0%
Exports to chemical recycling	Arrow D4	0%
Exports open loop recycled	arrow EOL1	99%
Exports open loop recycling to residual waste	arrow EOL2	2%
Exports closed loop recycled	arrow ECL1	70%
Exports closed loop recycling to residual waste	arrow ECL2	30%
Exports chemically recycled	arrow ECR1	70%
Exports chemical recycling to residual waste	arrow ECR2	30%

Source: various – Mepex analysis, expert interviews

6. System Change scenario

The System Change Scenario assumes that circularity interventions are applied ambitiously, concurrently and starting from 2023. This scenario benefits from the synergies among upstream and downstream circularity interventions across each of the 7 sectors.

6.1 Circularity levers

The System Change Scenario involved the modeling of circularity intervention impacts on the stocks and flows throughout each sub-system. A set of levers was defined for each sector and each lever was quantified based on best practice examples in other sectors and/or countries, future potential based on academic research, and expert opinions where data was unavailable.

Six categories of levers were modelled: reduction/elimination, reuse, substitution, mechanical recycling, chemical recycling and clean up to reduce leakage out of the system. The levers modelled in each category are shown below:

ELIMINATE & REDUCE	Rethink the product to eliminate or reduce demand for plastic
	Eliminate through extended lifetimes
	Reduce through sharing models
REUSE	Reuse through reuse models
SUBSTITUTION	Substitute for alternative materials
MECHANICAL RECYCLING	Design for recycling and dismantling
	Expand collection and sorting capacity and technologies
	Increase mechanical recycling capacity
CHEMICAL RECYCLING	Scale up chemical recycling
CLEAN UP	Reduce leakage out of system

Note that in the modelling of reuse and recycling, the recyclate output in year n is recycled content input in year n + 1 i.e. as the model operates on an annual basis we assume a lag between plastics being recycled and the recyclate being used in secondary production.

6.1.1 Automotive

Eight interventions were modelled in the automotive sector as given in the table below.

System area	System change lever	Description	Lever impact
Recycling	**Increase dismantling rates**	Increase rate of dismantling and design vehicles from inception to facilitate dismantling of individual components at end of life.	Increased recovery at dismantling stage and less plastic in shredder residue. (**Increases arrow C1**)
	Scale post-shredder technologies and mechanical recycling in Norway	Increase local capacity to handle shredder residue, reduce exports and scale both open and closed loop mechanical recycling	Less plastic exported for recycling/disposal outside of Norway. (**increases arrow R3**)
	Improve recovery from post-shredder technologies	Maximise use and effectiveness of PSTs to increase recovery of plastics from shredder residue.	Increased recovery rates of plastic from shredder residue for mechanical and chemical recycling. (**reduces arrow F5**)
	Design for recycling	Maximise recycling rates through simplicity of polymer and fewer polymer types, colouring, labelling etc.	Increased recoverability of plastics and reduce recycling losses. (**reduces arrows I2 and J1**)
	Increased uptake of recycled content	Expand relative share of closed loop recycling by creating demand for recyclates and through higher quality recycling	Larger volume sent to recycling. (**increases arrows F1 and F2**)
	Scale up chemical recycling	Identify the maximum scale for chemical conversion based on optimal finance, accelerated operational expansion and strong offtake	Recycling of mixed plastics in shredder residue. (**increases arrow F3)**
Reduction	**Increase reuse of dismantled components**	Increase the reuse of large dismantled parts e.g. bumpers, dashboards through standardising and simplifying design	Increased reuse of components that are dismantled
	Expand vehicle sharing, mobility-as-a-service and incentivise modal shift	Scale up the sharing economy, use vehicles more intensively, more efficient use of resources an shift to other modes of transport	Reduces the number of vehicles per capita

Note that the approach for chemical recycling was applied at a system-wide level rather than at a sub-system level; a description of the approach can be found in section 6.3.

Lever 1: Increasing dismantling rates

Under best known practices (e.g. in France), around 10%-11% of total plastic can be dismantled with current designs[1]. It is assumed that Norway can adopt these best practices by 2030.

Design for dismantling only has an impact after 2030, due to the in-use lifetime lag. Under design for disassembly principles we assume that 80% of large parts, 10% of other polyolefins and 10% of other polymers can be dismantled. (expert opinion)

This is supported by:

- Regulation which enforces that all professional in the maintenance and repair of vehicles are required to offer consumers recycled or remanufactured parts (e.g. as is the case in France).
- ATFs in Norway are seeing an increase in demand for second hand parts over new parts due to large cost differentials (source: Interview with Lars). This is particularly the case for insurance parts as insurance companies do not want to offer brand new parts to owners with older cars.
- The specific topics of the roadmap for revising the ELV Directive regarding plastics includes, specifically, the dismantling of plastic parts.
- Mandatory recycled content requirements of vehicles will incentivise design for disassembly to improve recoverability of plastic.
- Possible subsidies from governments – caravan recycling in Norway is subsidised due to lack of economic case of recycling

The impact of this lever on the system map flow assumptions is given in the table below.

Share of plastic dismantled (C1)	2020	2030	2040	Rationale/Assumption
Large parts	5%	30%	75%	• Assume adoption of best current practices by 2030 • After 2030 assume max. 80% of large parts dismantled (only from vehicles designed after 2025)
Other polyolefins	0%	7%	9%	• Assume adoption of best current practices by 2030 • After 2030 assume max. 10% of other polyolefins dismantled (only from vehicles designed after 2025)
Other polymers	0%	6%	9%	• Assume adoption of best current practices by 2030 • After 2030 assume max. 10% of large parts dismantled (only from vehicles designed after 2025)

Lever 2: Scale advanced post shredder technologies and mechanical recycling in (or near) Norway

- The driving assumptions is that the equivalent of 1 plant of 55 kt built by 2030 and a second plant of the same capacity built by 2040

This is supported by:

- EU directive on end-of-life vehicle recycling to be revised with focus on material specific recycling targets and mandatory recycled content targets.
- OEMs setting targets on recycled content and forming supply chain partnerships with recyclers increases demand for PST capacity.
- Potential for collaboration with other sectors (WEEE) and/or other Scandinavian countries (Sweden/Finland)

Assumptions	2030	2040	Notes
Total plastic waste from vehicles generated in Norway (t)	47,340	59,682	• Estimated volume of plastics from vehicles based on stock and flow model
Total plastic waste shredded from vehicles in Norway (t)	43,476	51,001	• Total volume of plastic minus dismantled components
% of plastic in shredder residue (extrapolated)	40%	45%	• Currently around 35%, extrapolated to 2040 based on plastic growth in vehicles
Total ASR in tonnes	118,350	132,627	• Calculated by diving plastic volume by % of plastic in shredder residue

Avg. capacity of plant in tonnes of ASR (varies widely)	55,000	55,000	• Varies between 10,000 t (VW-Sicon) to 100,000 t – midpoint used
Number of plants requried to treat all ASR	2.2	2.4	• Calculated by diving total ASR by avg. capacity of plant
Feasible number of plants	1	2	• Assumption on feasibility of number of plants built by 2030 and 2040 (this could be in collaboration with other Scandinavian countries and does not necessarily need to be situated in Norway)
% of ASR treated	46%	83%	

- An introduction and expansion of post-shredder technology (e.g. float sink tanks, cyclonic air separators, froth flotation etc.) across Norway achieve levels of recovery equivalent to best practice today by 2040. [7–9]

The impact of this lever on the system map flow assumptions is given in the table below.

Applies to all components	2020	2030	2040	Rationale/Assumption
Shredded plastics to PSTs (R3)	0%	46%	83%	• See table above
Shredded plastics to exports (R1)	53%	6%	0%	• See table above
Shredded plastics to disposal in Norway (R2)	48%	48%	17%	• See table above

Lever 3: Improve recovery of plastics from post-shredder technologies

The driving assumption is that best available technologies[7] are adopted which results in an improvement in the recovery rate of plastics from ASR, to levels achieved by more early-stage technologies e.g. Magnetic density separation (Germany).

This is supported by:

- EU directive on end-of-life vehicle recycling to be revised with focus on material specific recycling targets and mandatory recycled content targets.
- Scaling up of new technologies e.g. airflow technology and electrostatic separation techniques could improve recycling yield.

- OEMs setting targets on recycled content and forming supply chain partnerships with recyclers increases demand for PST capacity.
- Automotive industry could benefit from sorting technology innovation in WEEE and vice versa

Reducing PST losses (F5)	2020	2030	2040	Rationale/Assumption
Large parts	61%	44%	20%	Losses reduce from European averages to BAT – S-curve used to model technology penetration
Other polyolefins	61%	44%	20%	Losses reduce from European averages to BAT – S-curve used to model technology penetration
Other polymers	80%	68%	50%	Losses reduce from European averages to BAT – S-curve used to model technology penetration

<u>Lever 4: Design automotive plastic parts for recycling</u>

Driving assumptions:

- Recycling losses decrease to a minimum of 15% as a result of products designed for recycling e.g. through simplicity of polymer, fewer polymer types, no/less reinforced plastics and fewer additives and fillers.
    - Examples of DfR already e.g. Scania making mono-material components
- Minimal effect up to 2040 due to in-use lifetime lag.
- Other polymers achieve lower recycling rates due to composite structures and diversity of polymer types.

This is supported by:

- Mandatory recycled content requirements are likely to be introduced through the revision of the ELVD which incentivises design for recycling to ensure a high-quality supply of recyclates.
- Other European countries will likely feel the impact of this first as the avg. lifetime of vehicles in Norway is higher than the rest of Europe – likely to be adopted by rest of Europe

Mechanical recycling losses (I2/J1)	2020	2030	2040	Rationale/Assumption[9–11]

Large parts	30%	30%	23%	Recycling losses decrease to a minimum of 15% ONLY on vehicles PoM after 2025
Other polyolefins	30%	30%	23%	Recycling losses decrease to a minimum of 15% on ONLY vehicles PoM after 2025
Other polymers	60%	60%	47%	Recycling losses decrease to a minimum of 20% on ONLY vehicles PoM after 2025

Lever 5: Increase uptake of recycled content, to spur closed loop recycling

Driving assumptions:

- Share of closed-loop recycling increases at same rate as recycled content targets recommended by EuRIC. These targets are based on existing commitments made by OEMs.
- By 2040, recycled content reaches 40%[12] (on average), following the trajectory of the EuRIC targets.

This is supported by:

- OEMs testing short looping of raw materials via supply chain partnerships (e.g., Renault, Ford) which is likely to drive improvements in the share of closed-loop recycled content
- Mandatory recycled content requirements likely to be introduced.
- A growing number of publicly stated corporate commitments to use recycled content (e.g., Volvo aims for 25% by 2025).
- EPR systems could support closed loop systems
- Already suppliers offering virgin like compounds to the automotive sector containing 25%+ PCR content e.g. Borealis' Borcycle

Share of closed-loop recycling out of total recycling	2020	2030	2040	Rationale/Assumption
Large parts	13%	48%	63%	Share of closed-loop recycling increases at same rate as recycled content targets recommended by EuRIC (30% by 2030, 40% by 2040)
Other polyolefins	8%	46%	61%	Share of closed-loop recycling increases at same rate as recycled content targets

				recommended by EuRIC (30% by 2030, 40% by 2040)
Other polymers	2%	10%	20%	Share of closed-loop recycling increases at same rate as recycled content targets recommended by EuRIC (30% by 2030, 40% by 2040)

Lever 6: Increase reuse of dismantled components

Driving assumption:

- Under best known practices (e.g. in France), around 6% of total plastic is currently reused[13]; assume increase of reuse up to this level by 2040.

This is supported by:

- Regulation which enforces that all professionals in the maintenance and repair of vehicles are required to offer consumers recycled or remanufactured parts (e.g. as is the case in France)
- Mandatory recycled content requirements of vehicles will incentivise reuse.

Share of plastic dismantled and reused (C1*X1+ X2)	2020	2030	2040	Rationale/Assumption
Large parts	5%	7%	10%	• Reuse increases to 2040 to match max. reuse levels as seen in France
Other polyolefins	0%	3%	6%	• Reuse increases to 2040 to match max. reuse levels as seen in France
Other polymers	0%	3%	6%	• Reuse increases to 2040 to match max. reuse levels as seen in France

Lever 7: Expand vehicle sharing models and incentivize modal shift

Driving assumption:

- Vehicles per capita reduces from 0.61 in 2020 to 0.52 by 2030 and 0.26 by 2040 for all new additions to stock, driven by assumptions on the potential for shared mobility from the International Resource Panel.[14]

This is supported by:

- Shared mobility platforms already being introduced and adopted in some European countries e.g. Volvo on demand
- Ride hailing platforms such as Uber, Ruter, OsloBySykkel, MiVai, SammeVei etc. are becoming more prominent
- Norwegian shared mobility provider Bilkollektivet currently has 603 cars in Oslo and 15 in Stavanger and has been successful in terms of growing membership and usage; expected to continue growing

	2020	2030	2040	Rationale/Assumption
Vehicles stock in millions (baseline)	3.31	3.83	4.18	• Vehicle stock increasing due to growth in vehicles per capita as well as population growth
Vehicle stock in millions (shared mobility)	3.31	3.63	3.75	• Vehicle stock increasing due to growth in vehicles per capita as well as population growth • Reduced growth due to decreasing vehicles per capita
% reduction	0%	-5%	-10%	

6.1.2 Construction

Seven circularity interventions were identified for construction plastics:

System area	System change lever	Description	Lever impact
Recycling	**Expand separate collection**	Expand separate collection and shift towards modular design to facilitate dismantling at end of life.	Higher rates of separate collection of plastic from the construction waste stream which leads to a higher chance of recycling and cleaner plastic for recycling. (**Increases arrow A1**)
	Expand sorting capacity and improve quality of sorting	Maximise recovery of plastic in both on and off-site sorting.	Lower sorting losses as plastics constitutes less than 2%[1] of total C&D waste so it can often get 'lost' in the waste stream.(**reduces arrows F4**)
	Design for mechanical recycling	Maximise recycling rates through simplicity of polymer, colouring, labelling etc. and increase quality of recyclate.	Larger volume of high quality recyclates recovered in the recycling process. (**reduces arrows I2 and J1**)
	Increased uptake of recycled content	Expand closed loop recycling through improving the quality of recycled plastic.	Larger volume recycled in closed loop. Lower demand for virgin plastic. (**increases arrow F1**)
	Scale up chemical conversion	Identify the maximum scale for chemical conversion based on optimal finance, accelerated operational expansion and strong offtake	Recycling of mixed plastics in shredder residue. (**increases arrow F3)**
Reduction	**Increase reuse of components**	Maximise reuse of components at end-of-life through take back schemes and shifting from demolition to renovation.	Re-use of components, substituting virgin demand.
	Shift towards more compact living	Greater efficiency of plastic use. Less plastic used per person.	Reduced floor area thus reduced plastic demand

<u>Lever 1: Expand separate collection/ on-site sorting of plastic</u>

Driving assumptions:

- Separate collection rates for each product category increases towards a maximum of ~95% as specified by the Future Built criteria for plastics.[15]

- Products which are present in larger volumes, particularly those containing PVC as driven by VinylPlus are expected to have higher recovery rates.

This is supported by:

- Stricter enforcement of pre-demolition audit requirements, increased use of material passports and, in later years, modular building design enables non-destructive dismantling and recovery of separate materials.
- Likely to be supported by policy e.g. material-specific recovery targets and mandatory recycled content targets – many Ecolabelling initiatives e.g. Nordic Swan, Future Built etc. already have these requirements in place
- Monitoring systems such as VinylPlus have been successful; data is required to set industry targets

Share of waste sorted on site (A1)	2020	2030	2040	Rationale/Assumption
Pipes	20%	57%	95%	2030 value exceeds VinylPlus target and 2040 set by maximum separate collection rate of 95% achieved by 2040 (does not require modular design to achieve)
Windows and profiles	58%	69%	80%	2040 set by maximum separate collection rate of 80% achieved by 2040 (does not require modular design to achieve)
Insulation	28%	45%	63%	Assume that separate collection rates increase linearly to a max. of 80% by 2050 (requires some modular design)
Roofing materials	42%	80%	95%	2030 value governed by VinylPlus target and 2040 set by maximum separate collection rate of 95%
Other	31%	37%	50%	2030 value governed by VinylPlus target and 2040 set by maximum separate collection rate of 95% achieved by 2050 for 50% of the category (requires modular design - linear extrapolation in between 2030 and 2050), the other 50% continues to have low collection rates(e.g. sprayed applications, paints etc.)

Lever 2: Expand sorting capacity and improve quality of sorting

Driving assumption:

- Sorting losses decrease at steady rate due to the adoption of improved sorting technologies e.g. robotic sorting towards a min. of 10% as achieved by Finish ZenRobotics.[16]

- The current technical barriers of sorting are overcome when materials which reach a 50%/60% separate collection threshold.
- Insulation, windows, and profiles and other have lower recovery rates due to their lower quantities and the presence of legacy additives

This is supported by:

- Scaling up new automated sorting technologies and solutions such as robotic sorting could allow for more efficient and effective sorting as demonstrated by ZenRobotics.
- European Strategy for Plastics recommends that by 2030 sorting capacity is increased fourfold therefore regulatory pressures are likely to incentivise the adoption of such technological solutions.

Sorting losses (F4)	2020	2030	2040	Rationale/Assumption
Pipes	20%	17%	13%	Declines towards a min. of 10% by 2040; only applied to waste from consumption after 2000 due to additive content before then
Windows and profiles	100%	73%	33%	All considered a loss now due to PCB content. Decreases as PCB content declines. Declines towards a min. of 10% by 2040; only applied to waste from consumption after 2000 due to additive content before then
Insulation	35%	27%	16%	Declines towards a min. of 10% by 2040; only applied to waste from consumption after 2000 due to additive content before then
Roofing materials	27%	22%	14%	Declines towards a min. of 10% by 2040; only applied to waste from consumption after 2000 due to additive content before then
Other	35%	30%	24%	Declines towards a min. of 20% by 2040; only applied to waste from consumption after 2000 due to additive content before then

Lever 3: Design for mechanical recycling

Driving assumptions:

- Recycling losses decrease towards a minimum of 10% as a result of design for recycling e.g. through simplicity of polymer, colouring, labelling etc.
- Calculated based on a lifetime probability distribution with a mean of ~35 years hence minimal effect seen in a 30 year period.
- Styrenics achieve lower recycling rates due to challenges associated with high-quality mechanical recycling of styrene.

This is supported by:

- Nordic Swan (voluntary Eco label) already has recycled content requirements as well as recyclability requirements
- Mandatory recycled content requirements likely to be introduced in EU as part of the CEAP which incentivises producers to design for recycling in order to increase recycling rates; this could lead to a similar requirement being adopted in Norway.
- Construction plastics are often not visible (e.g. pipes, insulation etc.) so aesthetic requirements are not limiting.

Recycling losses (I2/J1)	2020	2030	2040	Rationale/Assumption
Pipes	22.0%	22.0%	21.9%	Declines towards a min. of 10% driven by design for recycling and adoption of best available technologies. Lifetime lag means limited impact before 2040.
Windows and profiles	22.0%	22.0%	21.9%	Declines towards a min. of 10% driven by design for recycling and adoption of best available technologies. Lifetime lag means limited impact before 2040.
Insulation	34.0%	34.0%	33.8%	Declines towards a min. of 10% driven by design for recycling and adoption of best available technologies. Lifetime lag means limited impact before 2040.
Roofing materials	22.0%	22.0%	21.9%	Declines towards a min. of 10% driven by design for recycling and adoption of best available technologies. Lifetime lag means limited impact before 2040.
Other	30.0%	30.0%	29.8%	Declines towards a min. of 10% driven by design for recycling and adoption of best available technologies. Lifetime lag means limited impact before 2040.

<u>Lever 4: Increase uptake of recycled content through closed-loop recycling</u>

Driving assumptions:

- Share of closed loop mechanical recycling is assumed to increase to match the increasing demand for recycled content.[17]
- Maximum levels of recycled content assumed for PVC – 50%, PE/PP – 80%, EPS – 80%[18]

This is supported by:

- CEAP is likely to introduce mandatory recycled content requirements, incentivising design for recycling to ensure high quality recyclates.

- Certain applications in the construction sector show good potential for uptake of recycled content (e.g. insulation materials, pipes etc.).
- The production of recyclate is tightly bound to the trend of the renovation ratio. The trend towards renovation means a higher amount of post-consumer waste would be available, thus increasing the potential for closed-loop recycling.

Share of closed-loop mechanical recycling out of total mechanical recycling (F1/(F1+F2))	2020[1]	2030	2040	Rationale/Assumption
Pipes	52%	72%	90%	Based on polymer mix, and maximum levels of recycled content for each polymer.
Windows and profiles	0%	18%	36%	Based on polymer mix, and maximum levels of recycled content for each polymer.
Insulation	0%	40%	80%	Based on polymer mix, and maximum levels of recycled content for each polymer.
Roofing materials	88%	90%	90%	Based on polymer mix, and maximum levels of recycled content for each polymer.
Other	44%	53%	62%	Based on polymer mix, and maximum levels of recycled content for each polymer.

<u>Lever 4: Increase reuse through take-back schemes</u>

Driving assumptions:

- Re-use restricted by destructive demolition techniques and already very long in-use lifetimes.
- Assume limited reuse potential restricted mainly to small proportion of pipes and profiles, and a larger proportion of insulation and roofing material
- Higher levels of reuse relies on modular and standardised design and therefore the maximum reuse potential is not reached before 2050 to due to in-use lifetime lag.

This is supported by:

- Trend towards modular building design improves recoverability of plastics.
- Modularity and durability typically go hand-in-hand. Modular design reuses and refurbishes ~80% of the components in the envelope of a building that can stand for 100 years or more, avoiding demolition[1].
- Ecolabelling e.g. through the Nordic Swan requires the use of digital logbooks/ material passports which facilitate the recovery of components with potential for reuse.

- Take back schemes – small but scaling e.g. Bewi takes back EPS, Vartdal Plast AS, Takes back EPS, Tarkett takes back PVC flooring, Interface AS takes back old floor tiles.

Reuse potential (C2)	2020[1]	2030	2040	Rationale/Assumption
Pipes	0%	2%	4%	Max. reuse of 5% of products put on market after 2000, plus reuse via modular design (only has impact after 2030)
Windows and profiles	0%	3%	8%	Max. reuse of 10% of products put on market after 2000, plus reuse via modular design (only has impact after 2030)
Insulation	0%	6%	15%	Max. reuse of 20% of products put on market after 2000, plus reuse via modular design (only has impact after 2030)
Roofing materials	0%	6%	15%	Max. reuse of 20% of products put on market after 2000, plus reuse via modular design (only has impact after 2030)
Other	0%	0%	0%	None

<u>Lever 5: Shift to more compact living</u>

Driving assumption:

- Constructed floor space per capita reduces following a shift towards more compact living and a reduction of floor space per capita from 63 m2/person today to 50 m2/person by 2040 (based on estimated achievable reductions in Canada).[14]

This is supported by:

- Trend towards smart and adaptable floor plans, peer-to-peer lodging, trendy smaller homes etc. enable more efficient use of space
- Companies like Airbnb and Spare Room are enabling more intensive use of buildings
- Other strategies include the shift towards work from home which reduces office space

Reduction in new demand (does not include replacements of waste)	2020[1]	2030	2040	Rationale/Assumption

All products	0%	11%	22%	Based on a 22% reduction in floor space per capita by 2040

6.1.3 Electronics

Eight interventions were modelled for Electrical and Electronic Equipment:

System area	System change lever	Description	Lever impact
Recycling	**Increase formal collection**	Maximise collection through formal system by improving convenience and by limiting theft	Increased separate collection of WEEE. (**Increases arrow A3)**
	Increase local shredding and recycling capacity	Increase local capacity to handle waste and reduce exports.	Less plastic exported for recycling/disposal outside of Norway. (**reduces arrows F2 and H4**)
	Improve yields from post-shredder sorting technologies	Maximise recovery by anticipating what the waste will look like in the next decade, what substances will enter legislation and thus what technologies are needed	Increased recovery rates for mechanical and chemical recycling. (**reduces arrow H5**)
	Design for recycling	Maximise recycling rates through simplicity of polymer and fewer polymer types, colouring, labelling etc.	Increased recoverability of plastics and reduce recycling losses. (**reduces arrows I2 and J1**)
	Increase closed-loop recycling	Expand closed loop recycling through improving the quality of recycled plastic and demand for recycled content .	Larger volume sent to closed-loop recycling. (**increases arrows H1 and H2**)
	Scale up chemical conversion	Identify the maximum scale for chemical conversion based on optimal finance, accelerated operational expansion and strong offtake	Recycling of mixed shredded plastics. (**increases arrow H3)**
Reduction	**Maximise reuse of appliances**	Maximise recycling rates through simplicity of polymer and fewer polymer types, colouring, labelling etc.	Increased recoverability of plastics and reduce recycling losses. (**reduces arrows I2 and J1**)
	Dematerialisation and shift to more compact appliances	Shifting to products which provide same service but with less material e.g. projectors instead of screens	Reduced demand.

<u>Lever 1: Increase formal collection</u>

1. Large equipment – no change, collection rates already high

Driving assumption:

- Collection rates of large equipment are already very high but can be increased further through reduction of theft.
- Assume minimum 5% theft achievable.
- Overall, we assume 75% of WEEE is collected through official channels currently, this is higher than the 55% estimated for Europe on average.[19]

This is supported by:

- One of the suggested improvement actions of the CWIT project (countering WEEE illegal trade) is to make collection points theft-proof by increasing surveillance and physical security; they also recommend that penalties are harmonised to simplify enforcement in trans-border cases.
- A combination of security investment, better on-site controls and more involvement of producer compliance schemes appears to have reduced WEEE theft significantly in a UK study.

Large equipment	2020	2030	2040	Rationale/Assumption
Formal collection (A3)	91%	93%	95%	• Norwegian Environment Agency statistics
Mixed collection/bins (A4)	0%	0%	0%	• Mepex Consult waste analysis, Østfoldforskning report 'THE NORWEGIAN WEEE FLOWS' (not yet published) and assumptions
Left in nature (A2)	0%	0%	0%	• Assumption
Informal sector (A1)	9%	7%	5%	• Østfoldforskning report 'THE NORWEGIAN WEEE FLOWS' (not yet published) and NRK article (news agency)

2. Small equipment – reduction in incorrect disposal and slight reduction in theft

Driving assumption:

- Increased formal collection by reduction of incorrect disposal e.g. throwing away appliances in mixed waste bins, and by reducing theft / informal sector activity. Pilot schemes and studies as part of the Critical Raw Material Closed Loop Recovery project indicate that there is significant opportunity to collect ~95% of small equipment through formal channels.[20]
- Overall, we assume 75% of WEEE is collected through official channels currently, this is higher than the 55% estimated for Europe on avg.[19,21]

This is supported by:

- Collection rates can be increased through **incentive return schemes** which are made convenient for the consumer – this has already proved to be successful in other sectors e.g. ELVs with Norway's scrap deposit scheme.
- This has also worked for batteries
- Fines for incorrect disposal (as is being trialled in some parts of Norway)

small equipment	2020	2030	2040	Rationale/Assumption
Formal collection (A3)	85%	90%	94%	• 100%- A4 – A2 – A1
Mixed collection/bins (A4)	12%	7%	2%	• Based on best examples of incentive return schemes etc. Results from study shows that by partnering with well

				known and trusted organisations, the public can overcome data security fears etc. Does not get to 0% due to lower value applications still being disposed of
Left in nature (A2)	0%	0%	0%	• None
Informal sector (A1)	4%	4%	4%	• No change – already low

3. Screens and displays – reduction in theft and incorrect disposal

Driving assumption:

- Increased formal collection by reduction of incorrect disposal to 0% (high value items, disposal should be low) and by reducing theft / informal sector activity to ~5%.
- Largest target of theft / informal sector activity so significant opportunity to recover more waste through stricter enforcement of law and entry restrictions
- Overall, we assume 75% of WEEE is collected through official channels currently, this is higher than the 55% estimated for Europe on avg.[19]

This is supported by:

- Collection rates can be increased through **incentive return schemes**[3] which are made convenient for the consumer – this has already proved to be successful in other sectors e.g. ELVs with Norway's scrap deposit scheme. This would reduce the level of mixed waste collection.
- Reducing theft (same as for large equipment)

Screens and displays	2020	2030	2040	Rationale/Assumption
Formal collection (A3)	88%	92%	95%	• 100%- A4 – A2 – A1
Mixed collection/bins (A4)	5%	2%	0%	• Based on assumption that through incentive return schemes, this can be reduced to 0
Left in nature (A2)	0%	0%	0%	• None
Informal sector (A1)	7%	6%	5%	• Greater enforcement of law and entry restrictions to collection points (as seen in COVID) could reduce theft to lower levels

4. Large industrial cables – reduction in proportion of cables left in nature

Driving assumption:

- Low collection rates of large industrial cables is mainly due to abandonment of cables in nature; through appropriate regulation and financial incentives, this could be reduced to 10% by 2040.

This is supported by:

- Collection rates can be increased through regulations (already exist)and enforcement of regulations.
- Regulation likely to be enforced soon – old cables are getting in the way of laying new cables.

Large industrial cables	2020	2030	2040	Rationale/Assumption
Formal collection (A3)	59%	75%	90%	• 100%- A4 – A2 – A1
Mixed collection/bins (A4)	0%	0%	0%	• None
Left in nature (A2)	41%	25%	10%	• Assume enforcement of regulation to collect old cables when being replaced
Informal sector (A1)	0%	0%	0%	• None

<u>Lever 2: Increase local shredding and recycling capacity</u>

Driving assumption:

- Current capacity to handle plastic waste from WEEE in Norway is estimated to be around ~30 kt (plastics) based on interviews with downstream manager of Revac and facility manager of Stena Recycling Norway.
- We assume an increase of 15% (~5 kt) by 2030 and a 30% increase (~10 kt) by 2040 of shredding and recycling capacity, limited to large equipment, small equipment, and industrial cables.

This is supported by:

- **Greater control over waste and its end of life destination**; by domesticating waste, Norway has great control over what happens to the waste.
- Smaller loops created to ensure greater control over the material and enable local/regional producers to use recyclate in new products. Recyclate production also creates a **revenue stream for local WEEE recyclers**.
- Many OEMs are setting recycled content targets e.g. LG, Sony, Apple and European recyclers are pushing regulation to introduce mandatory recycled content targets
- Treatement plants in Norway are not operating at full capacity currently (around 60%-70%, as there is potential to increase the volumes going to existing plants but

reducing exports to zero does not make sense due to economics and low volume sin Norway)

Proportion of waste treated domestically in Norway (F2)	2020	2030	2040	Rationale/Assumption
Large equipment	70%	80%	90%	• 15% increase in capacity by 2030, and 35% by 2040
Small equipment	70%	80%	90%	• 15% increase in capacity by 2030, and 35% by 2040
Screens and displays	0%	0%	0%	• Virtually all screens and displays currently exported (Sweden and Eastern Europe) – we assume no capacity in Norway
Large Industrial cables	70%	80%	90%	• 15% increase in capacity by 2030, and 35% by 2040

Lever 3: Improve sorting yields from PSTs

Driving assumption:

- 95% max recovery of PS, ABS, PP, PE from density separation followed by electrostatic separation, 60% max recovery of PC, PC/ABS due to overlapping density, 10% max recovery of other polymers and 0% of PVC
- Based on improved sorting yields on a polymer by polymer basis through advanced sorting technologies including sensor based technologies or solvent based technologies[22,23]; these technologies are already under development but require time and alliances between producers and recyclers
- Adding electrostatic separation after sink-float tanks improves yields[24]

This is supported by:

- Development of new technologies and processes e.g. Ad Rem and Hamos[4] jointly have developed a processing line that handles the complete plastic recycling chain using a unique float-sink tank process with pH neutral agent instead of salt to obtain the correct density followed by electrostatic separation
- Ambition of EU legislation is stepping up and Norway is likely to follow (based on ambition level in packaging etc.) – it is expected that material specific recycling targets may be introduced in the future which will require greater sorting and recycling of plastics from e-waste
- OEMs setting recycled content targets and will therefore require a stable supply of recyclates

Sorting losses (R4)	2020	2030	2040	Rationale/Assumption

Large equipment	18%	16%	15%	• Based on weighted avg. max sorting rate of polymers in mix: **95% max recovery of PS, ABS, PP, PE** from density separation followed by electrostatic separation, **60% max recovery of PC, PC/ABS** due to overlapping density, **0% of PVC and other polymers**
Small equipment	51%	39%	26%	• Based on weighted avg. max sorting rate of polymers in mix: **95% max recovery of PS, ABS, PP, PE** from density separation followed by electrostatic separation, **60% max recovery of PC, PC/ABS** due to overlapping density, **0% of PVC and other polymers**
Screens and displays	6%	6%	6%	• No improvement – losses already low
Large Industrial cables	100%	64%	29%	• Based on weighted avg. max sorting rate of polymers in mix: **95% max recovery of PS, ABS, PP, PE** from density separation followed by electrostatic separation, **60% max recovery of PC, PC/ABS** due to overlapping density, **0% of PVC and other polymers**

Lever 4: design for recycling

Driving assumption:

- Recycling yields can be improved by design for recycling and adoption of best available technologies - based on max. recycling yields on a polymer by polymer basis (90% for PP, PE and ABS, 80% for PS, 60% for PVC and PC, PC/ABS, 0% of other) [25,26]

This is supported by:

- Clear guidelines for design for recycling of plastics for EEE. [26]
- Ambition of EU legislation is stepping up and Norway is likely to follow (based on ambition level in packaging etc.) – it is expected that material specific recycling targets may be introduced in the future which will require greater sorting and recycling of plastics from e-waste
- Producers setting recycled content targets and will therefore require a stable supply of recyclates

Recycling yield (I1/J0)	2020	2030	2040	Rationale/Assumption

Large equipment	60%	70%	80%	• Assumed improvement from average polymer recycling rates to best in class by adoption of BAT by 2040
Small equipment	60%	65%	69%	• Assumed improvement from average polymer recycling rates to best in class by adoption of BAT by 2040
Screens and displays	60%	64%	67%	• Assumed improvement from average polymer recycling rates to best in class by adoption of BAT by 2040
Large Industrial cables	80%	81%	83%	• Assumed improvement from average polymer recycling rates to best in class by adoption of BAT by 2040

<u>Lever 5: increase uptake of recycled content via closed loop recycling</u>

Driving assumption:

- Based on industry examples of best practices, the recycled content of plastics in EEE increases to 17% by 2030 and 40% by 2040. [26,27]

This is supported by:

- Many OEMs are setting recycled content targets e.g. LG, Sony, Apple, Logitech (65%) and European recyclers are pushing regulation to introduce mandatory recycled content targets
- There is an opportunity to test short looping of raw materials via supply chain partnerships as is being done in the automotive sector which is likely to drive improvements in the share of closed-loop recycled content
- Regulation for mandatory recycled content likely (as is the case for packaging)

Share of closed loop recycling out of total Mechanical recycling	2020	2030	2040	Rationale/Assumption
Large equipment	25%	40%	63%	• Increased in closed loop recycling required to meet the recycled content targets of 17% by 2030 and 40% by 2040
Small equipment	10%	25%	48%	• Increased in closed loop recycling required to meet the recycled content targets of 17% by 2030 and 40% by 2040

Screens and displays	10%	25%	48%	• Increased in closed loop recycling required to meet the recycled content targets of 17% by 2030 and 40% by 2040
Large Industrial cables	30%	45%	68%	• Increased in closed loop recycling required to meet the recycled content targets of 17% by 2030 and 40% by 2040

Lever 6: increase reuse

Driving assumption:

- 2030 reuse based on recommended target for reuse of **5%** by Environment Committee, and by 2040 **7%** based on reuse rates in other countries e.g. Scotland
- We assume no reuse of cables and we assume that screens and displays have the most reuse potential (15%), and small and large equipment have a 7% reuse potential. The weighted average reuse of all these products (excluding cables) is around ~7%.

This is supported by:

- According to a study in Scotland[28], 23% of WEEE from Household Waste Recycling Centres could be reused with a small degree of refurbishment and repair.
- WEEE reuse is a significant employer opportunity particularly if carried out by social enterprises and has potential to employ 10 times more people per tonne of material processed than recycling activities.[29]
- In October 2011 the Environment Committee in the European Parliament voted in favour of a 5% target for reuse in the collection targets, a requirement for producers to provide information about preparation for reuse and treatment of the appliances they put on the market, requiring all collection schemes to provide for the separation of reusable WEEE at collection points and the adoption of European standards for preparation for reuse – yet to be approved
- Many B2B companies taking in used PCs – e.g. 3step IT[30]
- Ombrukt[31] – initiative by producers, refurb shops, dealers, and RENAS to put in place a system that can facilitate reuse – repair guarantees etc.

Separate collection sent to reuse (C2)	2020	2030	2040	Rationale/Assumption
Large equipment	1%	5%	7%	• Lower levels of reuse given they are typically used intensively; less reuse potential

Small equipment	1%	5%	7%	• Lower levels of reuse given the higher value of small equipment; typically resold by owner if there is reuse potential
Screens and displays	1%	10%	15%	• Highest levels of reuse assumed – recent studies[2] indicated strong market for quality second hand goods
Large Industrial cables	0%	0%	0%	• No reuse assumed

<u>Lever 7: shifting to more compact product design</u>

Driving assumption:

- Shifting to dematerialised/compact versions of products e.g. touchscreen products, virtual keyboards, projectors, instant boil taps etc. could reduce overall plastic demand by12% for large equipment, small equipment and screens.[5]

This is supported by:

- There is already a trend of moving to more compact designs for certain products e.g., smart phones and moving towards fewer multifunctional devices
- Opportunity for cost reduction (although likely to be marginal)

Demand	2020	2030	2040	Rationale/Assumption
Large equipment	0%	6%	12%	• Max 12% assumed based on initiatives to reduce over usage of plastics and dematerialise products by shifting to more compact equipment
Small equipment	0%	6%	12%	• Max 12% assumed based on innovative dematerialisation efforts e.g. shifting to touch screen products, instant boil taps to replace kettles etc.
Screens and displays	0%	6%	12%	• Max 12% assumed based on innovative dematerialisation efforts e.g. shifting to projectors etc.
Large Industrial cables	0%	0%	0%	• No reduction potential assumed

6.1.4 Fishing & Aquaculture

Fisheries:

Eight interventions were modelled for fisheries as given in the table below.

System area		System change levers	Description	Part of System Influenced	Lever impact description
Reducti on	1 a	Extend lifetime	Diagnose failures and design components with longer lifetimes. Create business models which support repair and reuse of fisheries and aquaculture components.	**Box 0.1 Plastic reduction**	Reduced plastic leaving stock on a yearly basis
	1 b	Small vessel restructuring	Restructuring of small vessels (<11 m) so quotas of 3 boats can be collected with 1.	**Box 0.1 Plastic reduction**	Reduced plastic leaving stock on a yearly basis
Substitu tion	2	Substitute plastic material for other	Substitute plastic material in equipment for non-plastic material or compostables where possible.	**Box 0.2 – increase substituted materials reducing plastic demand**	Lower demand for virgin plastic
Recycli ng	3	Scale up collection	Expand, facilitate, communicate and if required incentivizing collection of plastic waste.	**Arrow A1 – Increase total waste to collection** Arrow xx - reduce total waste to leakage	Larger volume recycled in closed/open loop. Lower demand for virgin plastic.
	4	Scale up cleaning & sorting	Expand sorting capacity of plastic waste and application of new technologies.	**Arrow B2 - Increase collection to formal sorting** Consequence: Arrow B3 - less collection to residual waste	Larger volume recycled in closed/open loop. Lower demand for virgin plastic.
	5	Design for recycling & dismantling	Maximise recycling rates through simplicity of polymer and fewer polymer types, colouring, labelling etc. Designing fishing and aquaculture equipment to facilitate the dismantling and separation of non-recyclable material.	**Arrow F5 - Reduce amount of formal sorting sent to residual waste** Consequence: Arrow F2/F3/G3/G4 – increase amount sent from formal sorting to mechanical recycling (Norway & abroad) **Arrow I2/J2 – Reduce recycling losses (design for recycling only)**	Larger volume recycled in closed/open loop. Lower demand for virgin plastic.
	6	Expand mechanical recycling	Open and closed loop. Increase the number of facilities that recycle fishing gear. Expand closed loop recycling through improving the quality of recycled plastic.	**Box I/EOL/ECL defining maximum of arrow F2/F3/G3/G4** Consequence: F1 (F5 % to remain as defined in lever 5)	Larger volume recycled in closed/open loop. Lower demand for virgin plastic.
	7	Scale up chemical conversion	Identify the maximum scale for chemical conversion.	**Arrow G5 – increase chemical recycling**	Larger volume recycled through chemical process.
Clean Up	8	Reduce leakage out of the system	Industry: avoid undeliberate loss of gear in ocean through designing for failsafe, reduce wear and tear, and putting in place recording and management best practices. Society: Support ocean retrieval efforts.	**Arrow A2 - reduce total waste to leakage** **Arrow Q1 – increased collection from nature**	Less leakage into nature.

Lever 1a: Extend Lifetime

Discarded due to lack of uncertainty on impact

Most fishers will repair and re-use up to the point the material starts breaking down

Focus should be on design improvements for gear and components most in use: Trawl nets, Purse/Danish seines, and variety of ropes. Lifetime can also be extended through better use of the gear.

Fisheries	2020	2030	2040	Rationale/source[32]
Box 0.1 Reduced demand for new plastic	0%	0%	0%	Uncertainty on lifetime impacts

Lever 1b: Small Vessel Restructuring

Restructuring of small vessels (<11 m) so quota of 3 boats can be collected with 1, can lead to a demand reduction of 10% by 2040[6]

Fisheries	2020	2030	2040	Rationale/source[32]

Box 0.1 Reduced demand for new plastic	0%	5%	10%	Weight of equipment varies significantly between 150 kg – 1000 kg. ~2000 vessels <11m * 250 kg * 67% = 335Kt reduction. 50% by 2030, 50% by 2040

Lever 2: Substitution

Feasibility is likely to be limited to non-critical components – overall effect on circularity will be negligible[32]

Substitution of plastic will be difficult due to the benefits of plastics in marine conditions

The type of gear defines if biodegradability should be assessed – ones that are easier lost should be prioritized (e.g. gillnets, traps)

Fisheries	2020	2030	2040	Rationale/source[32]
Box 0.2 – increase substituted materials reducing plastic demand	0%	1%	3%	Total weight of gear is expected to be very low as these are strips and small ropes. Unproven nascent technologies

Lever 3/4: scale up collection, cleaning & sorting

Formal sorting can increase from 54% to 85%, enabling higher volumes for recycling

Pre-sorting and cleaning are key given the level of contamination of the material (sediments, salts etc) [32,33]

Fisheries	2020	2030	2040	Rationale/source[32]
Collection: Box A1 – capacity	4000t	4000t	4000t	Today, all ports are obligated to have collection facilities but sorting depends on (network of) recyclers coming to the site. In reality, only about 33% of ports have this in place. (Depending on definition there are around 700 or 4000 ports in Norway vs 26 in Denmark) Sorting and cleaning does not happen in ports today. Capabilities of waste collectors vary widely and no regulation that industry needs to sort before sending to waste facility.

Sorting: Arrow B2 – increase collection to formal sorting	54%	75%	85%	Initially, higher growth can be expected due to the low hanging fruits. Experts see this as an ambitious number but driven by the EPR this could be feasible.

Lever 5: design for recycling & dismantling

Design for recycling can drive an uptake in the share of open-loop and chemical recycled volumes and reduce recycling losses

Material flowing from sorting the residual waste will decrease to 13% as more volume sorted can flow to recycling, given that materials are designed for recycling and manual labour will be reduced to do the disassembly and sorting of materials

Recycling losses decrease to a minimum of 15% by 2040 as a result of products designed for recycling, e.g. through simplification, reduction of polymer types, grouping of similar materials, and design for disassembly[32]

Recycling losses	2020	2030	2040	Rationale/source[32]
Arrow F5 - Reduce amount of formal sorting sent to residual waste	15%	14%	13%	Unlikely all material will be recyclable
Arrow I2/J2 – Reduce recycling losses	30%	25%	15%	• Today Nofir recycles between 66-75% of incoming material • Recycling technology will improve, but recycling rate for fisheries will remain lower than for aquaculture • This material gets incinerated

Lever 6: mechanical recycling

Open loop recycling will remain limited due to technical feasibility and available volume for recycling

Recycling in Norway will remain constant due to net volume increasingly flowing to chemical recycling

100% of volume in Norway is open loop recycling - due to contamination and complexity of the material[32]

Fisheries	2020	2030	2040	Rationale/source[32]
Norway Capacity	3000t	11000t	15000t	Capacity in 2022 is around 6Kt and 9Kt in 2025. Can increase to 11Kt by 2030 and 15Kt

				by 2040 (not considering nets through chemical recycling). Majority will be used by aquaculture, not fisheries.
Norway	**20%**	**20%**	**15%**	
Arrow F3: Norway – Open Loop	20% (350t)	20% (550t)	15% (453t)	Remainder of volume that can flow from formal sorting to recycling (100% - G2 - F5)
Arrow F3: Norway – Closed Loop	0%	0%	0%	Not possible for fishing gear
Abroad	**65%**	**66%**	**72%**	Driven by chemical recycling of nets only
Arrow G4: Abroad – Open Loop	0%	0%	0%	
Arrow G3: Abroad – Closed Loop	0%	0%	0%	
Arrow G2: Abroad Chemical	65%	66%	72%	See lever 8
Arrow F5: Formal sorting to residual waste	**15%**	**13%**	**10%**	See lever 5

<u>Lever 7: chemical recycling</u>

Chemical recycling capacity will remain the main circularity solution for fisheries considering >70% of volume are hard to recycle nets

chemical recycling seems to be most fit for nets, which represents ~76% of total plastic waste per year in aquaculture (~2kt)

Aquafill has a patent on the technology and the assumption is that they will increase their capacity, being able to manage 20% more nets from Norway by 2040 (fisheries & aquaculture combined). no chemical recycling will take place in Norway.

Assumption is that maximum 75% of the nets will be collected for recycling. [32]

Fisheries	2020	2030	2040	Rationale/source[32]
Arrow F4 – increase chemical recycling (inside Norway)	0%	0%	0%	Assume no chemical recycling will be done inside Norway (Quantafuel in very early development stage and lack of clarity on which industries they will focus)

Arrow G2 – increase chemical recycling (outside Norway)	65% (1136t)	66% (1765t)	72% (1915t)	Assume 75% of nets can be collected to be recycled by Aquafill (collection volumes will be less than assumed capacity expansion of Aquafill)

Lever 8: reduce leakage

Zero leakage into nature will be difficult to achieve - design for failsafe and good management practices can reduce leakage up to 60% and increase recovery from 20% to 30%

Some degree of loss is inevitable due to the marine environment conditions

Focus should be on design improvements for gear and gear components most lost: gillnets, traps & pots

Design for failsafe, better design to avoid wear and tear, and continuously improving management practices can reduce leakage into nature by 60% by 2040

Fisheries	2020	2030	2040	Rationale/source[32]
Arrow A2 – reduce in-use leakage into nature – LOSSES – 66%	8% (360t)	5.6% (30% avoided)	3.2% (60% avoided)	Up to 60% can be avoided through better management practices – event though Norway already has good management practices in place, majority of material found is discarded, and there is little effort to recover losses of cheaper materials such as gillnets and traps
Arrow A2 – reduce in-use leakage into nature – WEAR & TEAR – 33%	2% (90t)	1.4% (30% avoided)	1.2% (40% avoided)	40% of this can be avoided due to better design and equipment management (including not fish in harsh weather conditions and choices of how to catch such as lifting trawl vs sweeping trawl)
Arrow Q1 – increased collection from nature	90t (20%)	22%-25% recovered	25-30% recovered	Through tracing technology more can be recovered (i.e. equipment that float) – there will be a high cost for equipment that sinks. However most material gets stuck at seabed and will never be cleaned.

Aquaculture:

Eight interventions were modelled for fisheries as given in the table below.

System area		System change levers	Description	Part of System Influenced	Lever impact description
Reduction	1a	Extend lifetime	Diagnose failures and design components with longer lifetimes. Create business models which support repair and reuse of fisheries and aquaculture components.	**Box 0.1 – reduced demand for new plastic utility**	Reduced plastic leaving stock on a yearly basis. Higher proportion flowing to reuse and repair due to extended lifetime of gear
Substitution	2	Substitute plastic material for other	Substitute plastic material in equipment for non-plastic material or compostables where possible.	**Box 0.2 – increase substituted materials reducing plastic demand**	Lower demand for virgin plastic
Recycling	3	Scale up collection	Expand, facilitate, communicate and if required incentivizing collection of plastic waste.	**Box A1 – capacity**	Larger volume recycled in closed/open loop. Lower demand for virgin plastic.
	4	Scale up cleaning & sorting	Expand sorting capacity of plastic waste and application of new technologies.	**Arrow B2 - Increase collection to formal sorting** Consequence: Arrow B3 - less collection to residual waste	Larger volume recycled in closed/open loop. Lower demand for virgin plastic.
	5	Design for recycling & design for dismantling	Maximise recycling rates through simplicity of polymer and fewer polymer types, colouring, labelling etc. Designing fishing and aquaculture equipment to facilitate the dismantling and separation of non-recyclable material.	**Arrow F5 - Reduce amount of formal sorting sent to residual waste** Consequence: Arrow F2/F3/G3/G4 – increase amount sent from formal sorting to mechanical recycling (Norway & abroad) **Arrow I2/J2 – Reduce recycling losses (design for recycling only)**	Larger volume recycled in closed/open loop. Lower demand for virgin plastic.
	6a	Expand mechanical recycling capacity	Open and closed loop. Increase the number of facilities that recycle fishing gear. Expand closed loop recycling through improving the quality of recycled plastic.	**Box I/EOL/ECL defining maximum of arrow F2/F3/G3/G4** Consequence: F1 (F5 % to remain as defined in lever 5)	Larger volume recycled in closed/open loop. Lower demand for virgin plastic.
	6b	Increase uptake of recycled content (closed loop)	More closed loop recycling / consequence increased recycled content (within lever 6)	**Box H** – open/closed loop	
	7	Scale up chemical conversion outside Norway	Identify the maximum scale for chemical conversion.	**Arrow G5 – increase chemical recycling**	
Clean Up	8	Reduce leakage out of the system	Industry: avoid undeliberate loss of gear in ocean through designing for failsafe, reduce wear and tear, and putting in place recording and management best practices. Society: Support ocean retrieval efforts.	**Arrow A2 - reduce total waste to leakage** **Arrow Q1 – increased collection from nature**	Less leakage into nature.

Lever 1: extend lifetime

Re-use should be maximised through better gear design & recertification processes – this can decrease the need for virgin plastics 156kt between 2025 and 2040 (average reduction of 30% per year)

Mean lifetime can be expanded from 10 to 15 years reducing overall demand for virgin plastics by 45% between 2025-2040

Main opportunities are in floating collars, feeding pipes and ropes in mooring systems All equipment is designed to be long lasting It is expected feeding pipes lifetimes can be expanded through changing pressure from compressed air to water. Change chosen lifespan from 1 -> 3 year. Additionally, they can last longer if used underwater which can make them last even longer. Selected lifespan: 1->4 years. Floating collars, if repaired and recertified can add additional 15-20 years to current lifetime. Conservative selected lifespan: : 11->20 years. Ropes: ongoing research, not tested yet but possible to increase from 8 -> 10 years. Given that mooring systems have different parts consider lifespan of 8->9 years[32]

Aquaculture	2020	2030	2040	Rationale/source[32]
Box 0.1 Reduced demand for new plastic	0%	0%	-47%	Lifetime expansion from 10 to 15 average mean years - Floating collars: 11 -> 20 years - Feeding pipes: 1 -> 4 years - Mooring systems: 8 -> 9 years

				Yearly changes calculated in stock & flow model

Lever 2: substitution

Metals: Discard lever - substitution to metals is related to higher GHG emissions (see next slide). Also there is uncertainty how much plastics is replaced as it is expected additional plastic floating devices are needed to make the cages float

Biodegradables: Discarded as technology does not exist yet and feasibility is likely to be limited to non-critical components

Discard lever - substitution to biodegradable will be difficult due to the benefits of plastics in marine conditions

The type of gear defines if biodegradability should be assessed – ones that are easier lost should be prioritized (e.g. ropes, buoys)

Lever 3/4: scale up collection, cleaning & sorting

Up to 90% of waste collected can flow to formal sorting through better cleaning & sorting facilities

Pre-sorting and cleaning are key given the level of contamination of the material (sediments, salts etc)

Aquaculture	2020	2030	2040	Rationale/source[32]
Collection: Box A1 – capacity	25.000t	34.000t	36.000t	Key difference with fisheries is that aquaculture farms often work together with municipalities, as they are not based near a port. This lever is not relevant, there is enough collection capacity through municipality system. What needs to scale up is the capacity at sorting facilities Waste peaks at 36Kt with 10 year mean and 34Kt with 15 year mean with

Sorting: Arrow B2 – increase collection to formal sorting	54%	75%	90%	More waste could flow from collected to formal sorting by scaling up the port/municipality infrastructure, including presorting and cleaning. This will then flow through recycling facilities. There is more demand for aquaculture gear than fisheries so investments here are expected to be higher, and therefore higher % of sorting than for fishing. Aquaculture is already further developed, so less low hanging fruits.
Arrow B3 Decrease collection to residual waste	44%	23%	8%	Plug of 100% - B2 – B1
Arrow B1 Re-use	2%	2%	2%	Remains stable

<u>Lever 5: design for recycling & dismantling</u>

Design for recycling can drive an uptake in the share of open-loop and chemical recycled volumes and reduce recycling losses

Material flowing from sorting the residual waste will decrease to 10% as more volume sorted can flow to recycling, given that materials are designed for recycling and manual labour will be reduced to do the disassembly and sorting of materials

Recycling losses decrease to a minimum of 10% by 2040 as a result of products designed for recycling, e.g. through simplification, reduction of polymer types, grouping of similar materials, and design for disassembly

Aquaculture	2020	2030	2040	Rationale/source[32]
Arrow F5 - Reduce amount of formal sorting sent to residual waste	15%	13%	10%	Unlikely all material will be recyclable, but pipes and walkways are highly recyclable. Rigid HDPE most valued material.
Arrow I2/J2 – Reduce recycling losses	25%	20%	10%	Recycling technology will improve, and recycling rate for aquaculture will be better than fisheries. Current losses are mainly low-weight fractions (lifeskirts, fish hides, support material)

<u>Lever 6: Mechanical Recycling</u>

Closed loop recycling is more feasible for aquaculture, focus should be on development of local recycling

Recycling in Norway can grow from 10% to 50% by 2040

40% of this can be closed loop recycling, remainder 60% open loop recycling – given that type of material is in high demand it will be difficult to keep a higher proportion in the subsystem

Aquaculture	2020	2030	2040	Rationale/source[32]
Norway Capacity	3000t	11000t	15000t	Capacity in 2022 is around 6Kt and 9Kt in 2025. Can increase to 11Kt by 2030 and 15Kt by 2040 (not considering nets through chemical recycling)
Norway	**10%**	**45%**	**50%**	
Arrow F3: Norway – Open Loop	6% (900t)	27% (6700t)	30% (4600t)	Proportion 60% open loop / 40% closed loop Maximum available waste considering reduction of nets and reduction through other levers)
Arrow F3: Norway – Closed Loop	4% (600t)	18% (4500t)	20% (3100t)	Proportion 60% open loop / 40% closed loop Maximum available waste considering reduction of nets and reduction through other levers)
Abroad	**75%**	**42%**	**40%**	
Arrow G4: Abroad – Open Loop	55% (3200t)	45% (5900t)	2%	Reduce as chemical recycling volume increases. Open loop, not closed loop due to high value recyclate - assumption is that product will go to highest bidder considering shortage of recyclates we will have
Arrow G3: Abroad – Closed Loop	0%	0%	0%	
Arrow G2: Abroad Chemical	45%	55%	98%	See lever 8
Arrow F5: Formal sorting to residual waste	**15%**	**13%**	**10%**	See lever 5

<u>Lever 7: chemical recycling</u>

Chemical recycling seems to be most fit for nets, which represents ~26% of total plastic waste per year in aquaculture (~7Kt)

Aquafill has a patent on the technology and the assumption is that they will increase their capacity, being able to manage 20% more nets from Norway by 2040 (fisheries & aquaculture combined). No chemical recycling will take place in Norway.

Assumption is that maximum 75% of the nets will be collected for recycling

Aquaculture	2020	2030	2040	Rationale/source[32]
Arrow F4 – increase chemical recycling (inside Norway)	0%	0%	0%	Assume no chemical recycling will be done inside Norway (Quantafuel in very early development stage and lack of clarity on which industries they will focus)
Arrow G2 – increase chemical recycling (outside Norway)	45% (4900t)	55% (5900t)	98% (6900t)	Assume 20% increase of chemical recycling outside Norway – Aquafil expansion (patented technology). Assume maximum 75% of nets can be collected to be recycled.
Arrow G4 – decrease open loop recycling (outside Norway)	55%	45%	2%	

Lever 8: Reduce leakage out of system

Zero leakage into nature will be difficult to achieve - design for failsafe and good management practices can reduce leakage up to 30% and increase recovery from 20% to 30%

Some degree of loss is inevitable due to the marine environment conditions

Focus should be on design improvements for gear and gear components most lost: feeding systems, variety of ropes

Design for failsafe, better design to avoid wear and tear, and continuously improving management practices can reduce leakage into nature by 30% by 2040

Aquaculture	2020	2030	2040	Rationale/source[32]
Arrow A2 – reduce in-use leakage into nature – LOSSES – 66%	1.3% (300t)	1.2% (10% avoided)	1.1% (20% avoided)	• <0.2% of total stock get lost yearly (total loss is less than fisheries) • Norway already has good management practices in place. Weight is hard to reduce, number of items can be reduced (focus of current trainings)
Arrow A2 – reduce in-use leakage into nature – WEAR & TEAR – 33%	0.7% (150t)	0.5% (30% avoided)	0.3% (50% avoided)	• 50% of this can be avoided due to better design and equipment management, however very uncertain
Arrow Q1 – increased collection from nature	20%	22%-25% recovered	25-30% recovered	• Through tracing technology more can be recovered (i.e. equipment that float). But there will be a high cost for equipment that sinks, most small items get stuck at seabed and will never be recovered

6.1.5 Textiles

Nine interventions were assessed for textiles, whereas seven levers were modeled quantitively and two levers were assessed qualitatively, as given in the table below.

System area	System change lever	Description	Lever impact
Reduction	Facilitate domestic reuse	Expand infrastructure for re-use and second -hand markets. Facilitate and encourage repair markets.	C2C online sharing platforms **can reduce demand for plastic up to 20% by 2040**
	Extend lifetime	Extend lifetime of products through product and material design.	Qualitative lever
	Elimination	Fewer seasonal collections and multi-function garments. As well as reduced overproduction	A shift away from fast fashion towards fewer, smarter well tested collections and multi functional garments has the potential to **decrease demand for plastic up to 10% by 2040**
Substitution	Substitute plastic material for others	Substitute plastic material in textiles for nonplastic material, but only where superior substitute exists accounting for GHG emission across the life cycle.	Scaling the market share for alternative materials can **substitute up to 5% of plastic demand by 2040**
Recycling	Enhance sorting technology	Development of automatic sorting technologies that detect textiles in general as well as fiber composition and colors	More sophisticated and automated sorting technologies increase share available for reuse and recycling domestically **up to 25% by 2040**
	Expand mechanical recycling	Open and closed loop. Increase the number of facilities that recycle synthetic textiles.	Local mechanical recycling facilities can increase share of **closed-loop and open-loop recycling to 15%**
	Design for recycling	Maximize recycling rates through simplicity of polymer and fewer polymer types, coloring, labelling etc.	Design for recycling is an enabler for the previous lever. Improving textile quality and decreasing complexity of fiber composition will be essential to scale mechanical recycling
	Scale up chemical recycling	Identify the maximum scale for chemical conversion.	**Up to 14% can be chemically recycled** in 2040 taking feedstock from recycling losses and of formal sorting losses
Disposal	Reduce leakage out of the system	Industry avoiding unsold losses to the system from unfortunate return policies/practices.	Qualitative lever

Lever 1: Facilitate domestic reuse

Expanding re-use and second-hand markets as well as encouraging and facilitating repair infrastructure can reduce demand for virgin plastic and extend average lifetime depending on length of second use phase.

Focusing on Eco-design for durability, repairability can enable the shift to reuse and repair, since re-commerce models can extend average lifetime by 1.7 times.[34]

The second hand market in Europe is expected to grow.[35] This trend is assumed to apply to Norway. This lever models the potential of in-use phase C2C and C2B re-commerce like online sharing platforms.

Textiles	2020	2030	2040	Rationale/source
Box 0.1 Reduced demand for new plastic	0%	9%	20%	• 20% of overall utility demand is met by re-use, repair models by 2040

Lever 3: Elimination through fewer seasonal collections and more multi-functional garments as well as reduced overproduction

This lever models a shift away from the fast fashion credo (as envisioned by the EU strategy for sustainable and circular textiles) towards fewer, smarter and well tested collections as well as multifunctional garments, which has the potential to decrease demand for virgin plastic by up to 10% by 2040.

Assumption of technology development for better demand forecasting and stock management.[34] Additionally, smarter seasonal collections, with preceding testing phases like e-testing or pre-ordering are expected to reduce unnecessary production and design fails.

Textiles	2020	2030	2040	Rationale/source
Box 0.1 Reduced demand for new plastic	0%	4%	10%	• 10% decrease of overall utility demand by 2040 through fewer and smarter collections and multifunctional garments

Lever 4: Substitution of plastic in textiles with non-plastic materials

The substitution with bio-based plastic is covered in the supply side levers through a shift of feedstock. Hence, this lever only considers the substitution with non-plastic materials.

Production of organic cotton is unlikely to increase significantly by 2030[34] and substitution with animal fibers is considered to be less sustainable. Hence, substitution potential is limited to 5% of utility demand with alternatives materials like cellulose fibers by 2040, since alternative materials and their respective recycling technologies are being developed but still must be scaled

Textiles	2020	2030	2040	Rationale/source
Box 0.2 Reduced demand for new plastic through substitution	0%	2%	5%	• 5% of plastic in textiles substituted with alternatives like cellulose by 2040

Lever 5: Development of automatic sorting technologies

Novel sorting technologies like NIRS are being tested[36] and have the potential to automatically detect materials, fiber composition and quality of textiles. Sorting facilities are assumed to be integrated with pre-processing technologies.

Development and implementation of sophisticated sorting technologies increase the share of textile waste available for reuse and recycling domestically. The share of collected textile waste available for domestic reuse and recycling is expected to increase from 1% today to 67% by 2040.

Considering the scarcity of recyclates and the expected increase in investment and effort to collect and subsequently sort textile waste, the share of collected textile waste directly exported is expected to decrease from 91% today to 27% in 2040. However, given increasing collection rates total amount of exported volumes stay relatively steady over time.

The share of dedicated collected textile waste that goes to residual waste decreases from 8% today to 6% by 2040, given the implementation and scale up of novel recycling technologies and better design for durability.

Textiles	2020	2030	2040	Rationale/source
Arrow F1 – increase share of collected waste available to domestic reuse and recycling	1%	53%	67%	• 67% of collected textile waste is available to domestic reuse and recycling by 2040 • This corresponds to 57% of total waste
Arrow F2 – decrease share of collected waste exported for reuse and recycling	91%	41%	27%	• 27% of collected textile waste is exported for reuse and recycling by 2040 • This corresponds to 23% of total waste
Arrow F3 – decrease share of collected waste going to residual waste	8%	6%	6%	• 6% of collected textile waste is going to residual waste by 2040 • This corresponds to 5% of total waste

<u>Lever 6,7 & 8: Expand domestic mechanical and chemical recycling capacities and design for recycling:</u>

The uptake of novel recycling technologies to a large extend depend on fiber composition and textile quality, because fiber-to-fiber technologies for example are highly sensitive to fiber purity.

By 2030 36% of waste can be mechanically recycled, accounting for different key technologies. However, the split between open- and closed-loop mechanical recycling is highly debatable and depends to a large degree on the strict implementation of design guidelines and sorting technologies to enable recycling,.

Hence, the impact of different configurations for open- and closed loop mechanical recycling can be assessed in the model.

Textiles	2020	2030	2040	Rationale/source
Arrow S1 – Share of domestic reuse	0%	4%	5%	• 5% of textile waste is available to domestic reuse and recycling by 2040
Arrow S2 & 3 – Share of domestic closed loop and open loop mechanical recycling	0%	26%	36%	• 36% of textile waste is mechanically recycled by 2040

Arrow S4 – Share of domestic chemical recycling	0%	11%	16%	• 16% of textile waste is chemically recycled by 2040

6.2 Inter-sub-system material flows

Much of the mechanical recycling taking place today is open-loop i.e. the recyclates produced from one application are used in an entirely different application, and often in a different sector. Therefore, in order to map these inter-sub-system material flows, the destinations of recyclates from each of the 5 sub-sectors were defined and the proportions were quantified. The table below shows the destinations of recyclates from open-loop recycling in each sector. Note that this is net of any closed-loop recycling.

	Use/Destination								
	other	construction	auto	textiles	fisheries_aquaculture	WEEE	consumables	household	**Total**
construction	80%						20%		100%
auto	60%	20%				10%	10%		100%
textiles	100%								100%
fisheries_aquaculture	40%	0%	30%	15%		0%	0%	15%	100%
WEEE	70%	5%	14%	0%	0%		7%	5%	100%
consumables	30%	24%	6%	30%		1%		9%	100%
household	30%	24%	6%	30%		1%	9%		100%
Total									0%

Sources: For construction, consumables, auto and WEEE - https://publications.jrc.ec.europa.eu/repository/handle/JRC122453
Method notes: Splits of plastic feedstock coming from open loop destinations done across categories destination according to % of overall demand of category

6.3 Chemical recycling

Chemical Recycling is a nascent technology and capacities of the different technologies beyond 2030 are highly uncertain.

Allocation assumptions for the Norwegian market and each sector were made considering European capacity projections for each technology (pyrolysis, gasification, dissolution, and depolymerization) and availability of quality of waste streams and polymer types in Norway.

It was assumed that Norway would have access to roughly 2% of the 3.2Mt capacity (source: Plastic Europe) capacity based on its proportion of total European plastic consumption. This defined the full volume of chemical recycling for Norway.

- Technology mix :
  - 2020-2030:
    - It was assumed 80% of volume until 2030 is pyrolysis (excl depolymerization for F&A)
    - From 2025 there is ramp up of gasification
  - 2030-2040:
    - Ramp up of depolymerization and dissolution.
    - Linear growth of total and each technology

- How we allocated to each sector:
    - Phase 1: chemical recycling volumes fixed
    - Phase 2: allocation based on waste proportion and availability of polymers

- Volume: losses from mechanical recycling + formal sorting to waste (20% in 2030, 30% in 2040)
- Checked against availability of polymer types for each technology allocation

7 GHG reduction levers

All GHG reduction lever assumptions were European averages taken from the Planet Positive Chemicals report.

8 Jobs and costs

All cost and job assumptions were European averages taken from ReShaping Plastics.[37]

9 Bibliography

1. Motorisation rates in the EU, by country and vehicle type. *ACEA - European Automobile Manufacturers' Association* https://www.acea.auto/figure/motorisation-rates-in-the-eu-by-country-and-vehicle-type/ (2022).
2. Statistics Norway. *Dwellings, by type of building and utility floor space (M) 2007 - 2022*. https://www.ssb.no/en/statbank/table/06513/.
3. Häkkinen, Tarja, Kuittinen, Matti, Vares, & Sirje. *Plastics in buildings. A study of Finnish blocks of flats and daycare centres*. (2020).
4. Geyer, R., Jambeck, J. R. & Law, K. L. Production, use, and fate of all plastics ever made. *Science Advances* **3**, (2017).
5. Sam Pickard & Samuel Sharp. *Phasing out plastics - The electrical and electronic equipment sector*. (2020).
6. Mepex. *Assessment*. (2019).
7. GHK. *A study to examine the benefits of the End of Life Vehicles Directive and the costs and benefits of a revision of the 2015 targets for recycling, re-use and recovery under the ELV Directive*. (2006).

8. Ramboll. *Summary of 'Plastic Parts from ELVS'*. (2020).

9. Circular Plastics Alliance. *Automotive WG input for Deliverable 2: State of Play of Collection and Sorting*. (2020).

10. Circular Plastics Alliance. *CPA Roadmap to 10Mt – Untapped Potential Report*. https://ec.europa.eu/docsroom/documents/46956 (2021).

11. Antonopoulos, I., Faraca, G. & Tonini, D. Recycling of post-consumer plastic packaging waste in the EU: Recovery rates, material flows, and barriers. *Waste Management* **126**, 694–705 (2021).

12. EuRIC. *Position paper: Call for recycled plastic content in cars*. (2019).

13. ADEME. *Automotive Annual Report*. (2018).

14. International Resource Panel. *Resource Efficiency and Climate Change: Material Effciency Strategies for a Low-Carbon Future*. (2020).

15. FutureBuilt. *Future Built criteria for plastic use*. (2022).

16. Redling, A. ZenRobotics discusses how robots continue to improve C&D recycling. (2021).

17. Gardner, J. *Circular Plastics Alliance State of Play for collected and sorted plastic waste from construction*. (2020).

18. Watkins, E. *et al. Support to the Circular Plastics Alliance in establishing a work plan to develop guidelines and standards on design-for-recycling of plastic products*. https://publications.jrc.ec.europa.eu/repository/handle/JRC122453 (2020) doi:10.2760/936397.

19. Baldé, C. P., Wagner, M., Iattoni, G. & Kuehr, R. In-depth review of the WEEE Collection Rates and Targets. 142 (2020).

20. Innovate UK KTN. Take Back and Incentivised Return Trials in Northern England Result in Great Returns on WEEE Collection. https://ktn-uk.org/news/take-back-

and-incentivised-return-trials-in-northern-england-result-in-great-returns-on-weee-collection/ (2018).

21. NORSIRK, RENAS, RECIPO, & ERP NORGE. *WEEE Lost En Route*. (2022).

22. Mathilde Taveau, MSc. Ir. & Tom Caris, MSc. Ir. *How to recycle more WEEE plastics*. (2021).

23. Chris Slijkhuis. Improving the loops of plastics in electronics - BSEF. https://www.bsef.com/news/improving-the-loops-of-plastics-in-electronics/ (2022).

24. Paben, J. How one new system is handling a challenging stream. *Plastics Recycling Update* https://resource-recycling.com/plastics/2020/02/03/how-one-new-system-is-handling-a-challenging-stream/ (2020).

25. Circular Plastics Alliance. *State-of-play on collected and sorted plastic waste - Electronics and Electrical Equipment*. (2020).

26. PolyCE. *Circular guidelines for electrical and electronic equipment*. (2020).

27. ZVEI. *Plastic recyclates in the electrical industry*. (2021).

28. Zero Waste Scotland. Re-use of WEEE from household waste recycling centres (HWRCs). *Zero Waste Scotland* https://www.zerowastescotland.org.uk/research-evidence/reuse-weee-household-waste-recycling-centres (2015).

29. Marc, J. Reuse of WEEE: widening the cycle of materials. *Zero Waste Europe* https://zerowasteeurope.eu/2011/12/reuse-of-weee-widening-the-cycle-of-materials/ (2011).

30. Smart and Sustainable Technology Lifecycle Management | 3stepIT. https://www.3stepit.com/.

31. OmBrukt. https://www.ombrukt.no/english/213184 (2021).

32. Expert. Interview. (2022).

33. Deshpande, P, Philis, G, Brattebø, H & Fet, Annik. *Using Material Flow Analysis (MFA) to generate the evidence on plastic waste management from commercial*

fishing gears in Norway.

https://reader.elsevier.com/reader/sd/pii/S2590289X19300210?token=5361A132AEFF7529E79A4996B8B980DDDCBEDD70ACE4C116F5CF00850ECD063FCEA4387A83A5B7387D86554A55D6F7E5&originRegion=eu-west-1&originCreation=20230104175924 (2019).

34. McKinsey. *Fashion on Climate*. (2020).

35. 2022 Fashion Resale Market and Trend Report. https://www.thredup.com/resale/.

36. McKinsey Apparel, Fashion & Luxury Group. *Scaling textile recycling in Europe–turning waste into value*. (2022).

37. SYSTEMIQ. *ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.* https://www.systemiq.earth/reshaping-plastics/#report (2022).