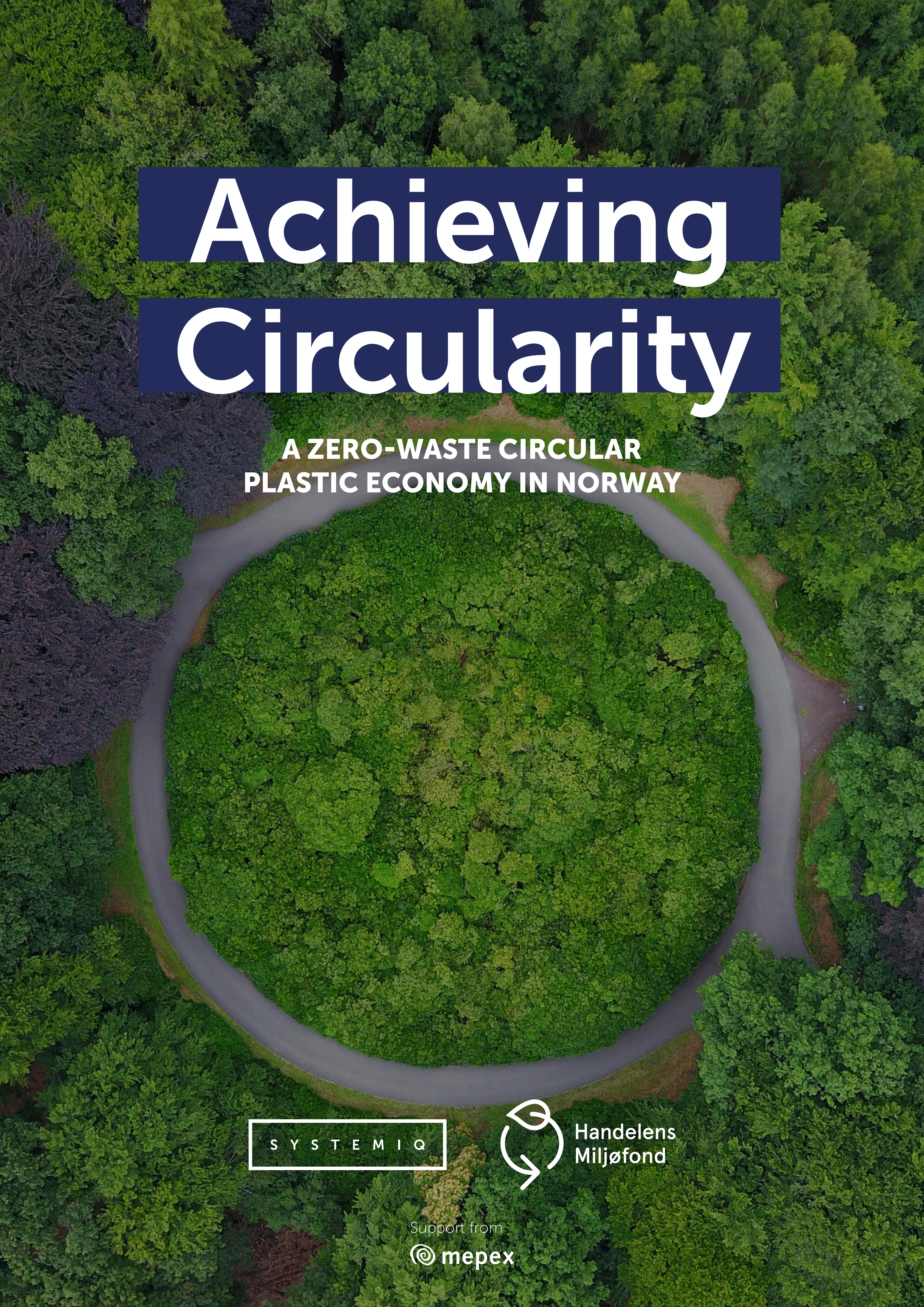
Achieving Circularity

A ZERO-WASTE CIRCULAR PLASTIC ECONOMY IN NORWAY



SYSTEMIQ

Handelens Miljøfond

Support from

mepex

About Handelens Miljøfond (Norwegian Retailers' Environment Fund)

The Norwegian Retailers' Environment Fund is Norway's largest private environmental fund, Norway's most important measure in complying with the EU Plastic Bags Directive. It supports national and international projects that reduce plastic pollution, increase plastic recycling and reduce the consumption of plastic bags. It's vision is to make a significant and lasting difference to the environment.

About SYSTEMIQ

SYSTEMIQ is a B Corp founded in 2016 to drive the Paris Agreement and the Sustainable Development Goals by transforming markets and business models in three key economic systems: land use, materials, and energy. In 2020, SYSTEMIQ and The Pew Charitable Trusts published "Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution," an evidence-based roadmap that shows how industry and governments can radically reduce ocean plastic pollution by 2040, upon which this report is based. The findings of our analysis were published in the peer-reviewed journal, Science. To learn more, visit www.systemiq.earth.

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About Mepex

Mepex is a Norwegian independent consultancy firm specializing in waste management, recycling and circular value chains. Our aim is to be a catalyst for change, contributing to making the circular economy a reality through resource efficient and climate friendly solutions. We combine analytical competence with extensive experience in design, construction, and operation of waste management infrastructure to support authorities, municipalities, organisations, and businesses in formulating strategies and achieving their environmental goals.

Design & Editorial:

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Preface

Plastic is an icon of prosperity and an example of how a linear model of consumption undermines Earth's planetary limits. The goal of this study is to accelerate the transition to a zero-waste circular plastic economy in Norway by providing both a sensible roadmap and a new scenario analysis digital tool that is science-based, practical and accessible. Our hope and belief are that this work will strengthen the collaboration between industry and the public sector in the search for a better plastic system for Norway based on a shared and accepted fact base.

In July 2020, SYSTEMIQ and The Pew Charitable Trusts, together with the Ellen MacArthur Foundation, the University of Leeds, the University of Oxford, Common Seas, and a panel of 17 global experts, published a first-of-its-kind analysis of the global plastics system, with results suggesting the existence of a comprehensive, integrated, and economically attractive pathway to greatly reduce the plastic pollution entering our ocean. "Breaking the Plastic Wave" was a 24-month project driven by a conviction that a new evidence base was required to plot a science-based pathway out of the plastics crisis. Through "Achieving Circularity" we are now broadening and deepening the impact of this work by adapting and applying the model and scenario tool to Norway.

With the help of a panel of six Norwegian experts with relevant backgrounds and perspectives, and in partnership with the Norwegian consultancy Mepex, we translated what is perhaps the most comprehensive plastic system modelling tool to the Norwegian context. This has enabled us to create an analysis that evaluates various strategies and system interventions in the plastic system and quantifies the associated economic, environmental, and social implications of each pathway. Our objective is to help guide policymakers, industry executives, investors, and civil society representatives through the highly complex, sometimes controversial, and often data-poor plastic landscape as they advance in their quest to achieve a zero-waste circular plastic economy. At the heart of our work is the core belief that any system-level challenge can only be addressed through a smart combination of policy, technology, funding, and consumer engagement. At first these may seem slow, but once in place they can unfold significant momentum beyond what had previously been thought possible. The plastics challenge in Norway is may be no different.

The zero-waste circular plastic economy vision is one which designs out waste and pollution, eliminates unnecessary production and consumption, keeps products and materials in the economy, and safely collects and disposes waste that cannot be economically processed, permanently stopping plastic pollution, increasing material circularity, and reducing GHG emissions.

Providing the evidence and insight needed to realise this vision is our project's "North Star".

Martin R. Stuchtey
Founder & Managing Partner
SYSTEMIQ

Eirik Oland
CEO
Handelens Miljøfond

Endorsements

"Plastic pollution is one of the greatest environmental issues of our time. The report *Achieving circularity - Creating a zero-waste circular plastic economy in Norway* comes at a critical time, as we are quickly reaching Earth's planetary boundaries. Plastic products are a vital part of a circular economy, and this study provides a system-wide evidence base that will help guide the way forward.

No one actor can make this change alone. To achieve the required system change, we need to work together, addressing different parts of the value chain, as part of a greater plan. This report provides that greater plan. Addressing issues concerning plastic reduction, substitution, sorting, recycling and design, inspires change, and will hopefully accelerate the necessary transition. We endorse this contribution."

Ivar Horneland Kristensen,

CEO, Virke (The Federation of Norwegian Enterprise)

Anne-Cecilie Kaltenborn,

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Acknowledgements

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Executive Summary

Despite its modest size, Norway is recognised on the world stage as a leading authority, funder, and exemplar fighting against and producing knowledge on plastic pollution in the environment, both domestically and globally. However, what is less well known is that Norway's own plastic system is fundamentally misaligned with both a zero-waste circular plastic economy and the goals of the Paris Agreement on climate change and relies heavily on waste-to-energy incineration and waste exports. Over 72% of Norwegian household plastic waste and plastic packaging waste is ultimately sent to waste-to-energy incineration while less than 25% is recycled[1]. Under business-as-usual , these trends will be exacerbated – creating tangible economic and environmental risks for industry, ecosystems and communities.

We examine six alternative scenarios for the Norwegian plastic system and conclude that, while there are no silver bullets, building a zero-waste circular plastic economy in Norway is technically achievable and economically viable using existing solutions. Our System Change Scenario identifies 10 system interventions that together deliver an ambitious circular economy transition in Norway and generate ample economic, environmental and social benefits. To achieve this transformation, the 10 system interventions need to be implemented concurrently, ambitiously, and starting immediately.

System Intervention #1: Reduce plastic consumption to avoid over 20% of projected plastic waste generation by 2040. This requires consolidated action to ensure (1) that avoidable plastic is systematically eliminated at source and (2) that new delivery models (including reuse systems) are developed and deployed at scale. This system intervention reflects a reduction from 65 kg of plastic consumption per capita per year by 2040 under our Business-As-Usual scenario to 51 kg (compared to 54 kg today), based on the plastic in our project scope, which is household plastic waste and household and industry plastic packaging waste, representing 54% of the total plastic waste generated in Norway.

System Intervention #2: Substitute plastic wherever feasible and beneficial to prevent an additional 7% of plastic generation by 2040. Our analysis shows that, when accounting for unintended consequences, two materials are suitable replacements for plastics in certain applications: paper and compostable materials. Up to 15,000 tonnes (mostly of packaging) can be substituted with paper and up to 10,000 tonnes with compostables, when these materials are compatible with existing Norwegian end-of-life solutions and do not make current sorting and recycling operations more complex.

1 All references to plastic in this report refer to household and industry packaging waste and household plastic waste.

System Intervention #3: Implement ambitious design for recycling standards for all plastic products and packaging put on the market. Design for recycling interventions – such as removing certain polymers, additives and pigments, or shifting from multimaterials to monomaterials – have many benefits and are a prerequisite for any ambitious recycling target. Benefits include, increasing the share of plastic that is recyclable, increasing the value of recycled plastic, reducing losses in the sorting and recycling process, and the overall boosting and scaling up of recycling economics.

System Intervention #4: Create new markets for different types of recycled plastic content to support the full potential of sorting and recycling technologies. Stimulating market demand is a critical factor to ensure the implementation of a zero-waste circular plastic economy. Demand for recyclates needs to be stronger and more diverse, both in Norway and globally, to encourage the trade of a wider variety of recycled plastic grades. We estimate that new markets with a total annual turnover of NOK 1.4 billion could be developed in Norway by 2040.

System Intervention #5: Increase sorting capacity 16-fold to over 220,000 tonnes to enable a zero-waste circular plastic strategy. The lack of sorting infrastructure is by far the main bottleneck to achieving any recycling target in Norway. Increasing this capacity would allow Norway to significantly divert plastic from waste-to-energy incineration to recycling and help drive the transition to a circular economy.

System Intervention #6: Scale up mechanical recycling capacity by 10 times to over 100,000 tonnes to ensure resilience and traceability. Investing in its domestic infrastructure would mitigate the risk of Norway needing to rely on competitive EU or other recycling markets to achieve its recycling targets.

System Intervention #7: Invest in sorting and recycling innovation to burst through technological ceilings and unlock higher recycling rates. Our analysis shows that any ambitious recycling target necessarily relies on technology improvements to push the boundaries of current manufacturing processes.

System Intervention #8: Develop plastic-to-plastic chemical conversion locally to unlock recycling opportunities for materials that cannot be recycled mechanically and provide feedstock for food grade applications. We estimate that a 36,000-tonne industry could emerge in Norway by 2040 (input raw plastic material), driving local investments, recycling targets, and jobs. Chemical conversion – when optimised for greenhouse gas (GHG) emissions – has the potential to raise the technical recycling ceiling and increase recycling rates nationally.

System Intervention #9: Control the fate of plastic waste exported outside Norway to achieve a near-zero plastic pollution footprint. The risk of Norwegian plastic waste ending up in landfills in the EU, in unsanitary landfills in the Global South, or being burnt illegally is low but still existent, and can be further mitigated by more careful monitoring of exports under the Basel Convention and other mechanisms.

System Intervention #10: Create an innovation fund to encourage, support and enhance innovation across the plastic value system. Achieving the vision of a zero-waste circular plastic economy in Norway will require technological advances, new business models, significant spending, and – most crucially – accelerated upstream innovation. This massive innovation scale-up requires a focused and well-funded R&D agenda, including moon-shot ambitions.

Securing the outcomes of the 10 system interventions modelled under the System Change Scenario will not be possible without significant changes in the business models of firms that produce and use plastic and its substitutes; major upgrades in the recycling and waste disposal industries; a transformation in the criteria applied by investors; and considerable shifts in consumer behaviour. These changes are all feasible, but they depend on the Norwegian Government introducing substantial incentives to encourage more sustainable business models and eliminate virgin plastic feedstock's current cost advantage over recycled materials. Policies designed to deliver a reliable set of incentives and targets can create the conditions needed to implement the integrated System Change Scenario.

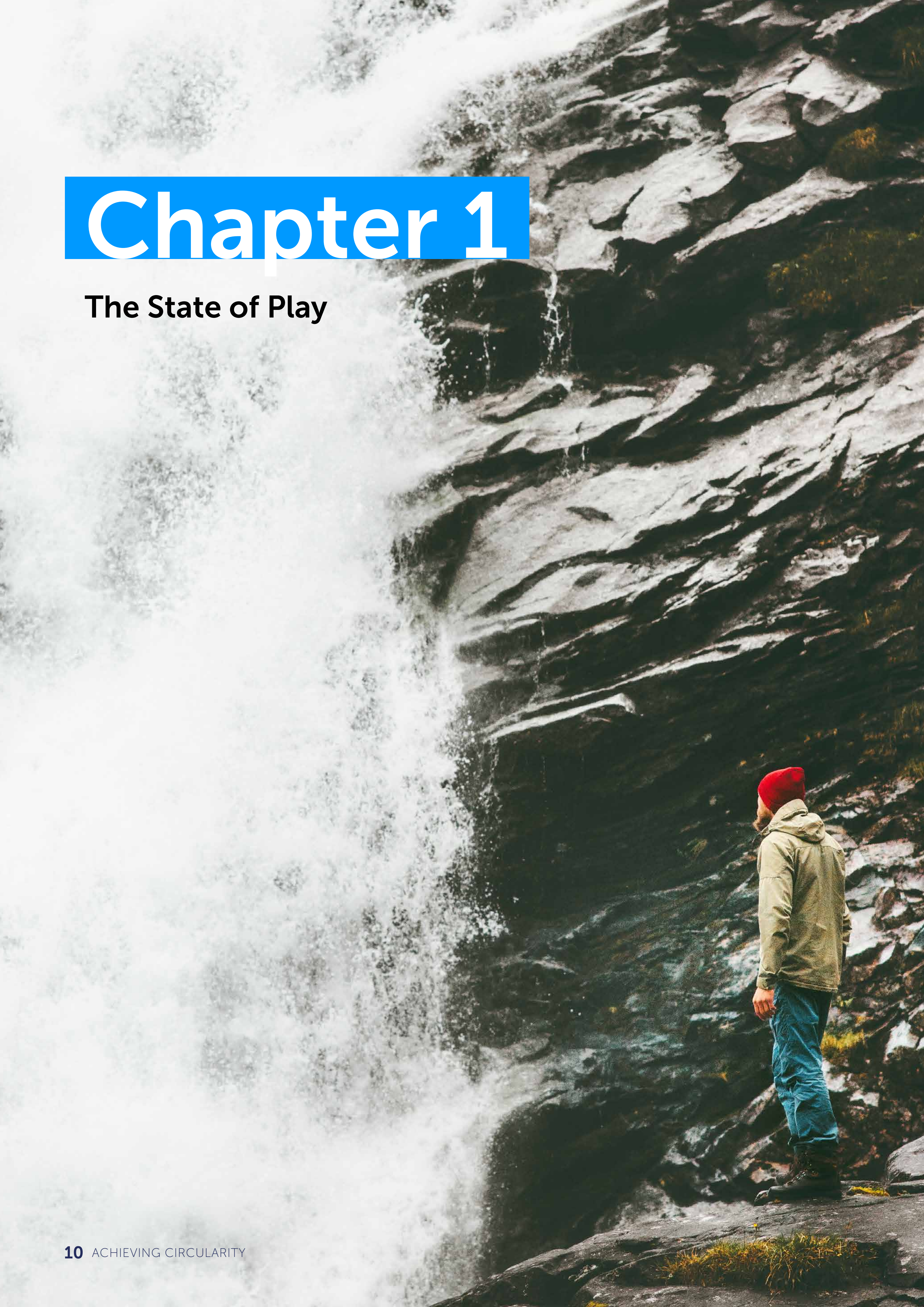
The shift to a circular economy is not just a matter of principle or ideology – it is backed by sound economic and business logic. The cost of incinerating over 200,000 tonnes of plastic waste every year and producing new virgin material is significant: over NOK 100 million a year by our estimates. When coupled with the opportunity cost of that material, it becomes too large to ignore. Embarking on the journey to a zero-waste circular plastic economy will unleash major opportunities for companies ahead of the curve, ready to embrace new business models that unlock value from circulating materials rather than from the endless extraction and conversion of fossil fuels. Large new value pools will be created around better design, better materials, better delivery models, improved sorting and recycling technologies, and smart collection and supply chain management systems.

However, while the System Change Scenario will deliver a meaningful shift toward a circular plastic economy in Norway, it is still insufficient to create a plastic system that is truly aligned with the goals of the Paris Agreement. By our estimates, even the ambitious System Change Scenario only reduces GHG emissions by 24% by 2040. Additional decarbonisation levers – outside the scope of this project – will also need to be deployed to achieve a net-zero carbon plastic system by mid-century.

In addition to analysing six pathways and quantifying the economic, environmental and social implications of each, as summarised in this report, this project also developed an open-access, dynamic scenario analysis tool that gives decision-makers across industry, government, civil society and the financial sector the opportunity to develop their own science-based scenarios based on the data set we collected. We invite all stakeholders in the Norwegian plastic system to test our Plastsimulator.

Chapter 1

The State of Play



Norway is at the forefront of the global plastic and sustainable ocean agenda yet falling short in achieving a zero-waste circular plastic economy

Norway is a global leader in plastic policy and circularity innovation

Norway has been actively concerned about the impact of plastic packaging on the environment for decades. Its first beverage packaging plastic tax was introduced as early as the 1970s and, in 1994, the tax was divided into two per unit – a basic tax for single-use containers and a variable tax which varies as a function of packaging return rates. In 1999, Norway was a pioneer in the introduction of a formally regulated, national plastic deposit return system (DRS) with a focus on plastic beverage bottles. But, interestingly, the DRS system itself was not set up by the authorities, instead the government put a regulation into force with requirements for the return systems (including deposit rates if a deposit system is in place) and a related tax system, leaving return companies flexibility to develop their own ways of operating and incentives for achieving high collection rates. This was later incorporated into Norway's 2004 waste regulations. Between 2018 and 2020, the scheme achieved return rates of around 85-90% for PET bottles[2] – proving to be one of the most effective in the world.

In parallel, in 1997, Grønt Punkt Norge (Green Dot Norway) was established to manage the extended producer responsibility (EPR) commitments of the industry. Since 2017[3], and following the implementation of relevant EU legislation including Directive 94/62/EF on packaging and packaging waste, EPR schemes for packaging have been mandatory. Today it is estimated that Grønt Punkt Norge covers approximately 75% of plastic packaging put on the market, while competing companies have been established[4]. In addition, a landfill ban regulating biodegradable (organic) waste streams, such as food-waste entered into force in 2009.

"When measured against the ambition to become a zero-waste circular plastic economy, Norway's current efforts are falling significantly short."

From an innovation standpoint, Norway is home to several technology leaders and solution providers in plastic waste and plastic pollution. Examples include:

- Collection systems – e.g. return vending machine (RVM) systems, TOMRA
- Sorting technologies – e.g. TOMRA
- Recycling technologies - e.g. Quantafuel, Othalo, Recycls
- Alternative materials - e.g. the R&D provider SINTEF Ocean, Sulapac
- Enabling technologies - e.g. Empower
- Clean-Up technologies - e.g. Spilltech, LoVeMar
- Disposal technologies - e.g. Fortum Oslo Varme (FOV), one of the first company in the world to try carbon capture and storage on an incinerator.

But there is a significant gap in achieving a zero-waste circular plastic economy domestically

Norway's plastic system is better than most: 85% of people have access to separation at source[5] and most of the remainder has access to mixed waste collection that is sorted in advanced specialised material recovery facilities (MRFs). Additionally, reported recycling rates are higher than the global average (especially for bottles), consumers prioritise environmental concerns, and Norway has one of the most successful EPR programmes in the world.

And yet – when measured against the ambition to become a zero-waste circular plastic economy (see Box 1.) – Norway's current efforts are falling significantly short. We estimate that more than 72% of Norwegian plastic waste is sent to waste-to-energy incineration, meaning the plastic industry is still predominantly a resource intensive, linear system.

The bottle deposit system is successful by any international standard, but beverage bottles represent less than 10% of Norway's plastic waste[6]. This successful scheme actually runs the risk of distracting society from other plastic products that have low recycling rates despite representing the lion's share of plastic waste. Furthermore, the deposit system could be acting as a disincentive to introducing plastic bottle reduction measures that are more environmentally impactful than recycling. Even the addition of the new EPR schemes

2 Data from Green Dot Norway
3 Regulations 1.9.2017 and 1.1.2018
4 Mepex estimate analysis based on Green Dot Norway data
5 Mepex analysis based on Green Dot Norway data
6 Mepex Analysis

and requirements for sorting plastics currently being developed cannot alone turn Norway into a zero-waste circular plastic economy.

Norway's entire plastic system, and especially its heavy reliance on fossil-based feedstock and incineration, needs to undergo significant changes if it wants to lead the world in building a zero-waste circular plastic economy. This report provides a science-based analysis of the different strategies available to achieve this goal, while accounting for potential trade-offs. Starting from the way the system operates in 2019 and drawing outlooks up to 2040, we focus on the main circularity levers of reduction, substitution and recycling – which together make up the "circularity index" –- and then highlight potential gaps. The circularity index is defined in this report as the sum of reduced, substituted and recycled plastic utility, divided by the total plastic utility[7].

Zero-waste circular plastic economy vision:

This is an economy where waste is designed out, products are kept in use, and material value is recirculated to the maximum extent of technical capabilities with the ultimate goal of regenerating natural systems. Plastic consumption is limited to unavoidable items and plastic products are designed for recycling and recycled using existing technology that is economically viable at scale. Use of recycled content is the norm, leading to highly efficient markets for plastic recyclates. Waste-to-energy incineration is used as a last resort technology for unavoidable and unrecyclable products. This framework aims not only to promote resource-aligned models but also to put people and the planet back at the centre of the system.

This agenda will strengthen Norway's leadership on ocean health and marine litter

With just over 5 million inhabitants, Norway already has a disproportionate impact on the global ocean agenda. As a founding member and co-chair of the High Level Panel for a Sustainable Ocean Economy, Norway is leading the way towards a future that has a healthy ocean and, more specifically, "stopping land-based pollution" among its core pillars. Norway is also playing a key role in the plastic and marine litter discussions at the United Nations Environment Assembly, where support is growing for the establishment of a global agreement on plastics that could lead to a new international instrument similar to the Paris Agreement. Norway is at the forefront of this global effort[8].

In parallel, in 2018 Norway launched the Norwegian Development Programme to Combat Marine Litter and Microplastics, an ambitious initiative to fight ocean plastic pollution globally. With the goal of supporting Sustainable Development Goal (SDG) 14.1 to significantly reduce marine pollution by 2025, the programme will deploy approximatively NOK 1.6 billion (approximatively US$ 200 million) between 2019 and 2022. It is prioritising several key catalytic action points: (1) development of sound land-based waste management systems; (2) scale-up of research programmes that contribute to finding technological solutions; and (3) supporting initiatives that increase marine litter awareness, including beach clean-ups.

Norway's marine litter leadership and credibility is diminished, however, by the fossil-fuel intensive, linear system it uses to manage its own plastic waste. Establishing a successful zero-waste circular plastic economy domestically would have a powerful demonstration effect on other countries and put Norway at the centre of the global stage for this critical challenge.

The European Union is stepping up ambition levels and expectations

In 2018, the European Commission adopted the European Strategy for Plastics and, in 2020, as a cornerstone of the European Green Deal, the new Circular Economy Action Plan presented ambitious measures to support the transition to a circular economy in Europe, including a boost for recycling. Recent amendments to the EU Packaging and Packaging Waste Directive also set new targets for the recycling of packaging waste: 65% by 2025 and 70% by 2030, including material specific targets for plastic packaging of 50% by 2025 and 55% by 2030.[9] In addition, the EU recently adopted a new definition for recycling (used in this report), which now excludes losses from sorting and recycling processes, thus creating a de facto technical ceiling[10]. Legislation related to the ambitions

7 Plastic utility is defined in this report as the total consumer benefit from consuming a good or a service provided by plastic products in a business-as-usual scenario, measured in tonnes of plastic.
8 Nordic Ministerial Declaration adopted in October 2020.
9 https://ec.europa.eu/environment/topics/waste-and-recycling/packaging-waste_en
10 An understanding that technological limitations will prevent recycling from nearing 100%.

set out in the Circular Economy Action Plan also includes a landfill ban for recyclables by 2025 and a resource efficiency target of 30% by 2030, aimed at stimulating demand for recyclate materials within the EU. Minimising the export of waste and tackling illegal shipments are mentioned as areas of attention for the coming years. As substantial parts of the legislation related to the European Green Deal and new Circular Economy Action Plan fall within the scope of the European Economic Area (EEA) Agreement, Norway is contributing to the development of these initiatives and will play an active role in their implementation.

The EU's vision is to incentivise circular, waste-free business models that reduce consumption through reverse logistics, take back systems, and re-use and/or repair schemes. It will encourage brands to re-think their packaging strategies by ensuring the right materials are used for the right applications, taking end-of-life into account. Key to the development of EU legislation is the empowerment of consumers by broadening their consumption choices and highlighting key environmental trade-offs in products, for example in terms of durability and reparability. Harmonising the separate collection of waste and an ambitious product policy framework across the EU – including measures on labelling, standards, and product requirements – are also high on the agenda to ensure the benefits of the design-for-recycling guidelines are maximised.

This is a clear call to action for Norway to build a zero-waste circular plastic economy and continue to lead the way towards ambitious environmental policies.

About this project: A science-driven scenario model to quantify the economic, environmental and social implications of different plastic pathways

In July 2020, SYSTEMIQ and The Pew Charitable Trusts published "Breaking the Plastic Wave" to provide a science-based pathway to dealing with the plastic challenge on a global level. "Breaking the Plastic Wave" was independently peer-reviewed and published in the scientific journal *Science*. Through the "Achieving Circularity" report we are bringing the "Breaking the Plastic Wave" approach and framework to the Norwegian context. It relies on a model designed to quantify key flows and stocks in the plastic system and assess the economic, environmental and social impacts of different pathways available to transform the Norwegian plastic system.

A more complete explanation of our approach, methodology, and detailed assumptions can be found in the technical report.

The goal of this analysis is to provide a new evidence base to inform Norwegian decision-makers across government, business, civil society, and academia as they evaluate complex trade-offs, set targets, and implement solutions to the plastic challenge.

To help this process, we also developed the *Plastsimulator*, an open-access, dynamic scenario analysis tool that allows stakeholders to create their own scenarios and evaluate the benefits, risks and trade-offs of different system choices. By giving everyone access to this science-based, practical and democratised tool, we hope to accelerate the transition to a zero-waste circular plastic economy in Norway and beyond.

EXHIBIT 1:

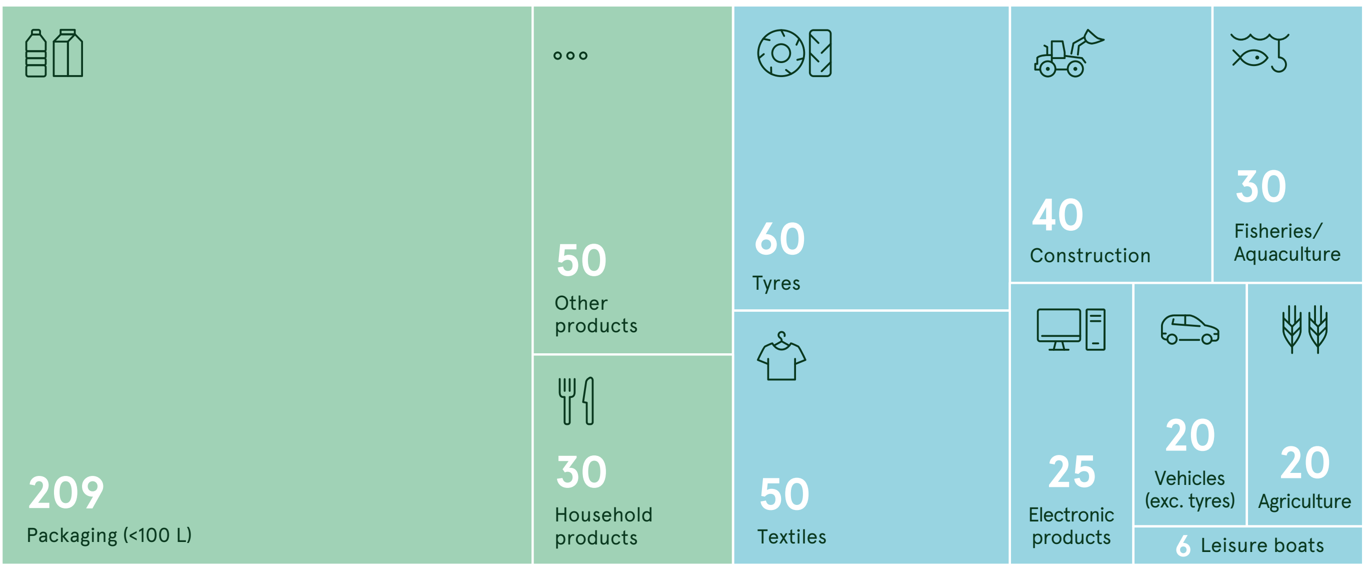
Project Scope

THE PROJECT SCOPE COVERS ~54% OF THE PLASTIC WASTE GENERATED IN NORWAY

Plastic waste generated in Norway

`000 Tonnes/year, 100% = 540,000 tonnes in 2019

In Scope   Out of Scope



In scope

~289k Tonnes (54%)

Out of scope

~250k Tonnes (46%)

Project scope

The plastic analysed in this project includes plastic waste from both households and industry and is close to the definition of Municipal Solid Waste (MSW) used in the EU Waste Framework Directive[11]. It encompasses all post-consumer plastic packaging and non-electrical household goods as well as waste generated by commercial activities that is similar to household waste by nature. We expanded this scope to also include industrial packaging so that all plastic packaging waste generated in Norway is covered in this project. The project scope represents approximately 54% of the total plastic waste generated in Norway, as shown in Exhibit 1[12]. It excludes the following main categories: electronics, textiles, automotive industry (including tyres), construction materials, agricultural plastic waste and waste coming from aquaculture and fisheries, and other small industrial waste streams. Primary microplastics[13] are also not analysed in this study.

Plastic waste in Norway is collected by municipalities directly or through private waste hauling companies. It can be collected as a single product stream (e.g. through a deposit system), a single waste stream (e.g. mixed plastic sorted at source by businesses or households), or as mixed waste along with other materials and residuals, depending on the product application or assumption made.

Scenarios

Our analysis defines 10 system interventions and models the most important economic, environmental, and social implications of applying different combinations of these changes to the system at different ambition levels. Six possible scenarios for achieving a zero-waste circular plastic economy in Norway, each comprising a different combination of system interventions, are presented in this report, as shown in Exhibit 2.

EXHIBIT 2

System interventions modelled under each scenario

Reduce · Substitute · Recycle · Dispose

	System interventions	Baseline Scenario: Business-as-usual (BAU)	Upstream Scenario: Reduce & Substitute	Downstream scenarios: Scale-up sorting	Downstream scenarios: Central sorting	Downstream scenarios: Ambitious recycling	Integrated Scenario: System Change
Upstream	1 Reduce growth in plastic consumption		✓				✓
Upstream	2 Substitute plastic with suitable alternative materials when beneficial		✓				✓
Upstream	3 Re-design products for recycling		✓	✓	✓	✓	✓
Downstream	4 Create new market for different types of recyclates			✓	✓	✓	✓
Downstream	5 Increase sorting capacity in Norway			✓	✓	✓	✓
Downstream	6 Scale up mechanical recycling capacity				✓	✓	✓
Downstream	7 Invest in innovation to improve current existing technology				✓	✓	✓
Downstream	8 Scale up chemical recycling				✓	✓	✓
Downstream	9 Control export fate			✓	✓	✓	✓
Downstream	10 Innovation fund						

11 DIRECTIVE 2008/98/EC of the European Parliament on waste
12 Vi må gjenvinne mer plast. Slik skal vi få det til. - HMF (handelensmiljofond.no), 2021
13 Primary microplastics are defined as microplastic particles which enter the environment in that state, as opposed to secondary microplastics, which arise from the fragmentation of macroplastic leakage.

"Our analysis models the economic, environmental, and social indicators that matter of each scenario"

1

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

2

Scenario 2 - Reduce and Substitute: Assumes ambitious reduction of plastic use through elimination, ambitious introduction of reuse and new delivery models, ambitious investment in and introduction of plastic substitutes where beneficial, and a shift toward full implementation of design for recycling guidelines. This scenario maximises reduction and substitution until they reach technical, economic, political or environmental limits. It requires strong policy interventions to regulate specific short-lived plastics and incentivise business model redesign and product redesign for reuse and reduction.

3

Scenario 3 - Scale-up of the Sorting Backbone: Assumes full implementation of design for recycling guidelines, moderate increased sorting at source, scale-up of national sorting infrastructure to process most of the plastic waste included in the project scope, increased demand for recyclates, investment in sorting technology efficiency, and controlling the fate of exports.

4

Scenario 4 - Central Sorting and Recycling Scale-up: Assumes full implementation of design for recycling guidelines, scale-up of a uniform national mixed waste collection system and central sorting infrastructure to process all plastic waste in the project scope, moderate development of recycling processing capacity, increased demand for recyclates, investment in sorting and recycling technology efficiency, development of chemical conversion, and controlled export fate[14].

5

Scenario 5 - Ambitious sorting and recycling scale-up: Assumes full implementation of design for recycling guidelines, moderate increase of sorting at source, scale-up of national sorting infrastructure to process most of the plastic waste included in the project scope, increased demand for recyclates, full development of recycling processing capacity, investment in sorting and recycling technology efficiency, development of chemical conversion, and controlled export fate[14].

6

Scenario 6 - System Change Scenario: Assumes all 10 system interventions are applied concurrently and ambitiously. This scenario benefits from the synergies between upstream and downstream interventions as it is the only one that includes both.

14 Scenario 4 and 5 only differ in the collection system. In scenario 4, plastic waste is collected as mixed waste with other residuals while in scenario 5 the current collection system is assumed with moderate improvements in the source separation of plastic.

We categorised the fate of plastic utility into five "wedges" representing possible responses to the plastic challenge:

REDUCE: Reduction of plastic production and consumption without substituting with other short-lived materials. Sub-wedges include eliminating plastic (e.g. product redesign, reduced overpackaging, and plastic bans), and new product delivery models (e.g. re-use, refill services, shifting products to services, e-commerce, and dispensers).

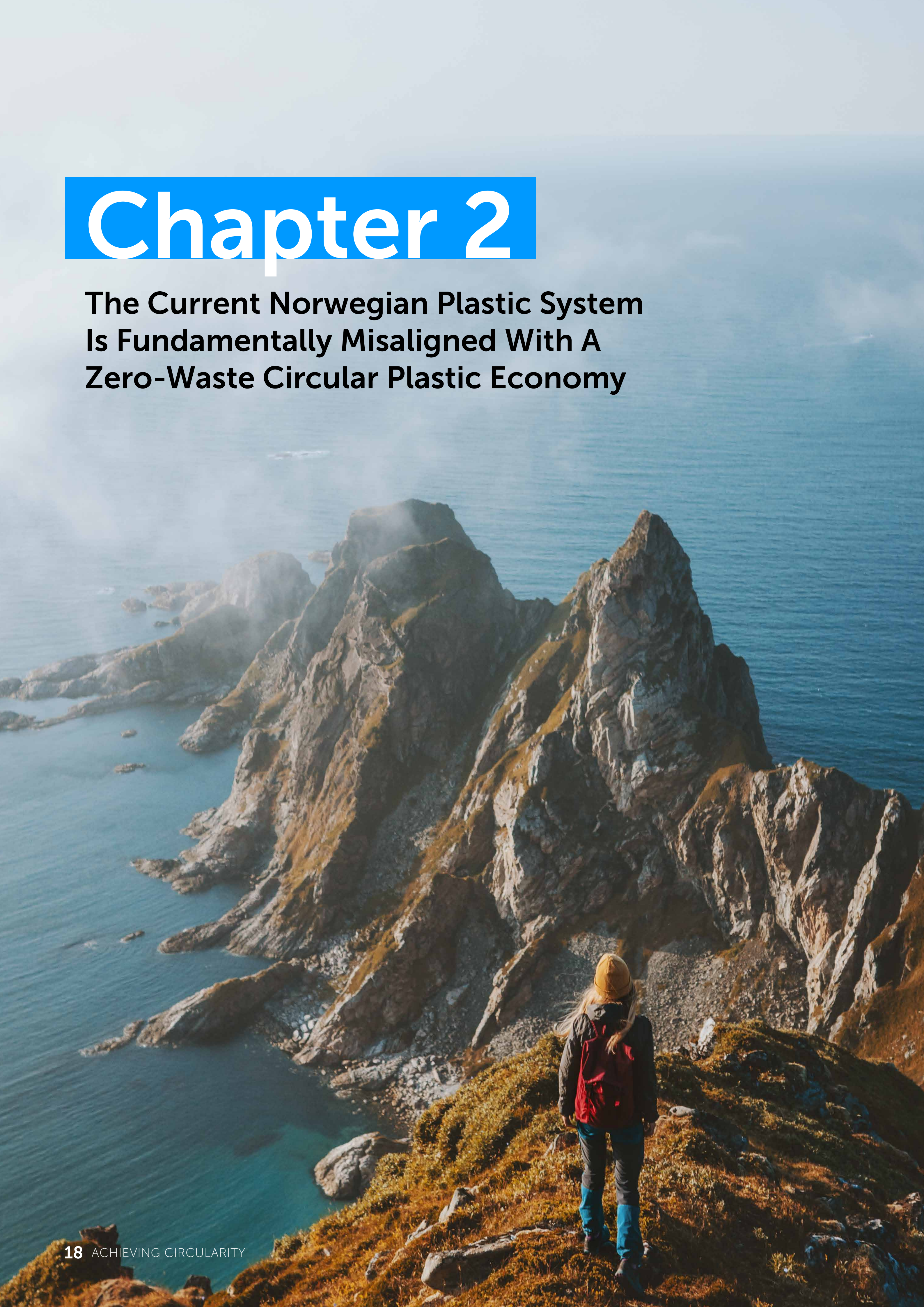
SUBSTITUTE: Substitution (where beneficial) with alternative materials that meet functional requirements for specific applications but are more easily recyclable or compostable after use. Sub-wedges include paper, and industrially compostable or home-compostable materials. This wedge includes substitutions with single-use materials only; multi-use substitutions are included under "Reduce", even if they do not completely reduce the system's material requirements.

RECYCLE: Recycling of products or materials. Sub-wedges include mechanical closed-loop recycling, mechanical open-loop recycling, and plastic-to-plastic chemical conversion systems that produce new packaging, products, or feedstock. Plastic-to-fuel chemical conversion is not included.

DISPOSE: Controlled disposal of plastic waste in ways that prevent leakage to the ocean. Sub-wedges include sanitary landfills (but not dumpsites), waste-to-energy incineration, and plastic-to-fuel technologies.

MISMANAGED: Any plastic waste that is not included in the other four wedges is considered mismanaged waste. This includes waste that is open burned, or either dumped directly on or leaked into land or waterways. This category includes all environmental plastic pollution.

The detailed project methodology, as well as a full list of assumptions and sources, can be found in the technical report.



Chapter 2

The Current Norwegian Plastic System Is Fundamentally Misaligned With A Zero-Waste Circular Plastic Economy

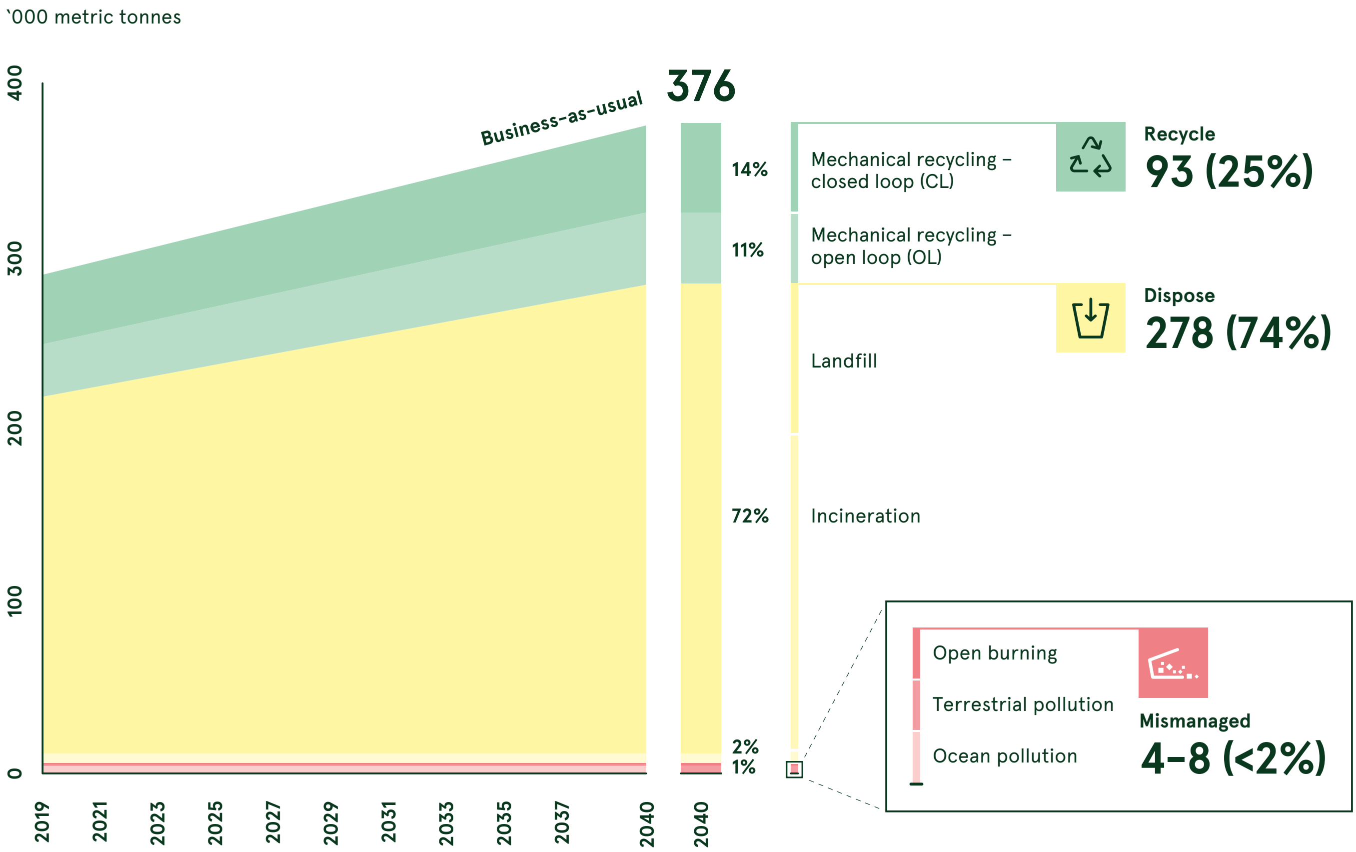
A risky pathway: The Norwegian plastic system relies heavily on waste-to-energy incineration and waste exports

Over 72% of Norwegian plastic is ultimately sent to waste-to-energy incineration facilities (including 37% incinerated outside of Norway), while only up to 25% is recycled in practice, excluding losses (Exhibit 3). Further modelling under the Business-As-Usual scenario shows that the mass of Norway's plastic waste (in the project scope) could grow from 289,000 tonnes in 2019 to 376,000 tonnes in 2040, equivalent to a compound annual growth rate (CAGR) of 1.2%. This growth is predominantly driven by Norway's rising population (from 5.3 million inhabitant in 2019 to 5.8 million in 2040[15]) and by increasing waste generation per capita (from 54 kg/cap/year in 2019 to 64 kg/cap/year in 2040[16]). Waste disposal (defined as waste-to-energy incineration, sanitary landfilling, and plastic-to-fuel chemical conversion) could therefore grow from 212,000 tonnes in 2019 to 278,000 tonnes in 2040 (an 31% increase).

EXHIBIT 3

Plastic fate under the Business-As-Usual scenario: a wedges analysis

WE PROJECT UP TO 25% OF NORWEGIAN PLASTIC WILL BE RECYCLED BY 2040 UNDER BUSINESS-AS-USUAL



Waste generated in Norway excluding imports; includes waste that is treated in Norway and exported.

This "wedges" shows the share of treatment options for the plastic that enters the system over time under the Business-as-usual scenario. Any plastic that enters the system has a single fate, or a single "wedge". The Recycle wedge accounts for the plastic that is recycled in the system, either mechanically or chemically. The Dispose wedge includes plastic that cannot be reduced, substituted, or recycled but is managed in a way that ensures that it does not leak into the environment. All other plastic is considered Mismanaged.

15 Statistics Norway Population – SSB (https://www.ssb.no/en/befolkning/nokkeltall/population)
16 Material Economics, the Circular Economy Report (PG. 78) (https://materialeconomics.com/publications/the-circular-economy)

This expected growth in waste-to-energy incineration has significant consequences for Norway's economy, and climate commitments:

- **Waste-to-energy incineration greenhouse gas (GHG) emissions represent up to 4% of Norway's climate budget by 2030**
  Waste-to-energy incineration offers an effective alternative to landfill by reducing both the volume and mass of waste. Modern waste-to-energy incinerators also produce moderate amounts of electricity and heat, which can be used as an alternative to purely fossil-based sources, but they are considered a "skyfilling"[17] waste management solution. However, continued waste-to-energy incineration of plastic creates a big GHG problem for Norway compared to the mechanical recycling of plastic and decarbonisation of electricity production through renewables.

  Norway's cumulative carbon budget is 194 million tonnes of CO_{2eq} by 203018. Under Business-As-Usual, we estimate that 11% of this, or 21 million tonnes of CO_{2eq}, will be used by the plastic system. Waste-to-energy incineration alone – which we estimate to generate 2.5 tonnes of CO_{2eq} /tonne of waste incinerated19 – represents approximately 37% of this, amounting to 4% of Norway's total carbon budget. Incineration also creates a need for more virgin material, which accounts for 36% of plastic sector emissions. Continuing this practice will make it extremely difficult for Norway to meet its target of reaching net-zero carbon by mid-century. Carbon capture and storage could provide a way to limit incineration emissions but, while a pilot by Fortum Oslo Varme (FOV) and Norcem is ongoing, it has not yet proven economic viability at scale.

- **Plastic waste-to-energy incineration is a missed economic opportunity to recover significant value**
  Waste-to-energy incineration is an emblematic "linear" solution that contradicts the fundamental concept of a zero-waste circular plastic economy. The EU waste hierarchy20 restricts its use to unavoidable and unrecyclable plastic waste generated after maximum efforts to design plastic waste out of the system and design for recycling. By burning waste material to recover its energy, Norway is not only wasting the intrinsic value of the material but is actually paying to do so – at an annual cost of over NOK 100 million, by our estimates. From an economic perspective, this represents a missed opportunity to build a profitable industry on the back of what today is an externality.

17 Skyfilling is defined as the action of releasing GHGs from waste into the atmosphere as opposed to landfilling.
18 Miljødirektoratet: https://www.miljodirektoratet.no/tjenester/klimatiltak/karbonbudsjettet/
19 Adjusted for Norway energy mix.
20 https://ec.europa.eu/environment/green-growth/waste-prevention-and-management/index_en.htm

Rectifying this requires bringing more value back to post-consumer waste.
Improvements in packaging design, sorting, and recycling technologies, along with a functioning market with higher and more diverse demand as well as higher prices for recycled plastics, means that more and more post-consumer plastics will have a positive value for recyclers. A transition away from incineration and towards recycling therefore makes strong economic sense over time, and this process can be accelerated and incentivised through extended producer responsibility (EPR) policies.

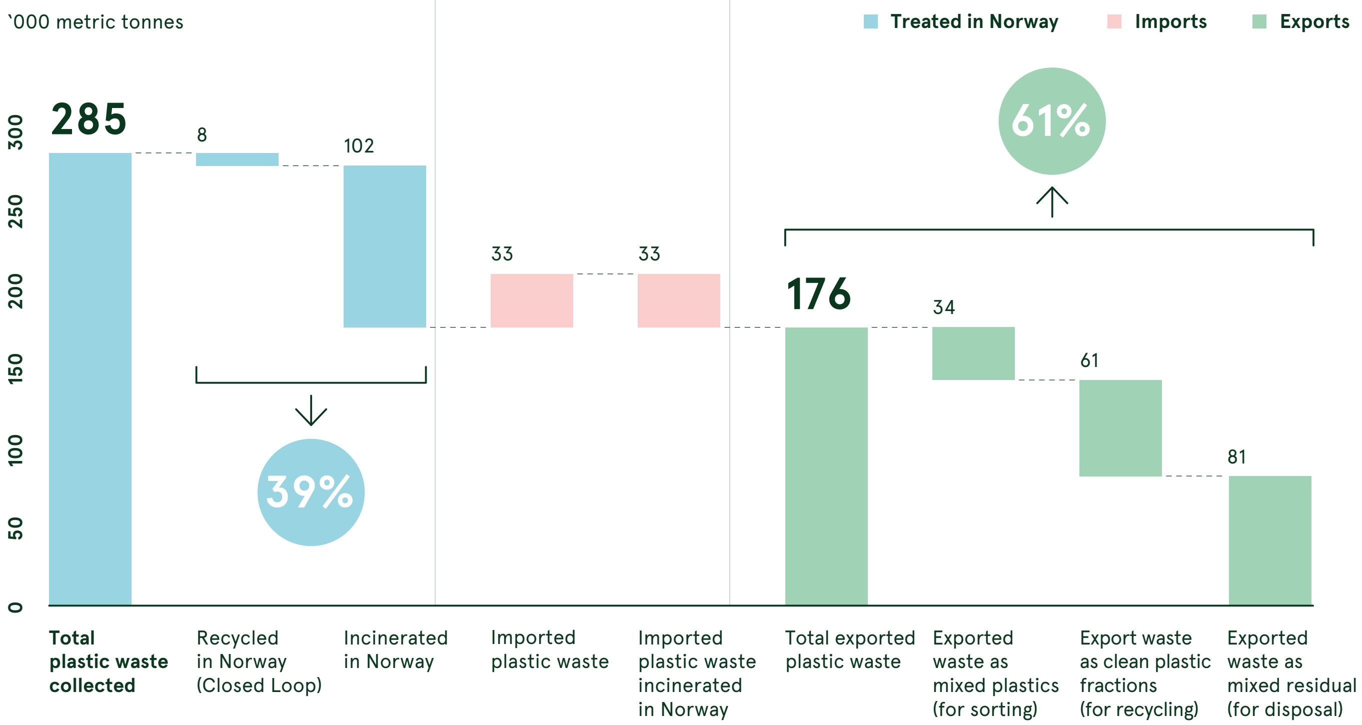
Another problem is that incineration may be hindering the growth of the recycling industry, as large incinerators compete for materials with high calorific value, including plastic. Incinerators require constant "feeding" during their entire lifespan (25 to 50 years) to maximise their financial output, triggering demand for low value waste feedstock with high plastic content. This might create a "lock-in" effect and impede the development of more desirable solutions, such as better sorting and recycling facilities, making it more difficult to improve recycling rates. Ultimately, these unintended consequences might act as incentives to maintain less advanced sorting technologies and create negative demand and supply feedback loops for secondary plastic materials prices.

- **Waste-to-energy incinerators and pollution**
  It is well documented that the combustion of municipal solid waste can result in the release of pollutants21. However, research in the UK and France indicates that well-managed modern incinerators, like those in Norway, are unlikely to pose significant health risks22,23,24 or contribute significantly to air pollution. This is because such incinerators can reduce atmospheric emissions by controlling the temperature, the composition of input material, and the speed of material flows in the furnace, and by cleaning the flue gas. Apart from flue output, incinerators produce two solid outputs: bottom ash and fly ash. Bottom ash is an inert material mostly comprised of minerals that can be valorised for road construction, although concerns regarding its toxicity have been raised. Fly ash consists of airborne emissions, is considered hazardous and needs to be disposed of in hazardous waste landfill sites[25].

EXHIBIT 4

Fate of plastic waste collected in Norway in 2019

WE ESTIMATE 61% OF NORWEGIAN PLASTIC IS TREATED OUTSIDE OF NORWAY



21 National Research Council (US) Committee on Health Effects of Waste Incineration. Washington (DC): National Academies Press (US); 2000.
22 Air Quality Consultants, Health Effects due to Emissions from Energy from Waste plant in London (May 2020)
23 Parkes, Brandon, et al. "Risk of congenital anomalies near municipal waste incinerators in England and Scotland: Retrospective population-based cohort study." *Environment international* 134 (2020): 104845.
24 Nzihou, Ange, et al. "Dioxin emissions from municipal solid waste incinerators (MSWIs) in France." Waste management 32.12 (2012): 2273-2277.
25 Setoodeh Jahromy, Saman, et al. "Fly ash from municipal solid waste incineration as a potential thermochemical energy storage material." Energy & Fuels 33.7 (2019): 5810-5819.

The Norwegian plastic system is heavily reliant on exports[26] – much more so than most other countries in the Global North, to a large extent due to Norway's size. Our analysis shows that, in 2019, only 109,000 tonnes (39%), of the plastic waste collected in Norway was processed in Norway, while 176,000 tonnes (61%) was exported (Exhibit 4). Exports are made up of three main streams: clean plastic fractions for recycling, such as beverage bottles from deposit schemes (61,000 tonnes or 35%); mixed plastic from source sortation (34,000 tonnes or 19%); and mixed waste (81,000 tonnes or 46%). As Exhibit 5 shows, we estimate that 61% of exports go to waste-to-energy incineration, with the largest share coming from unsorted waste.

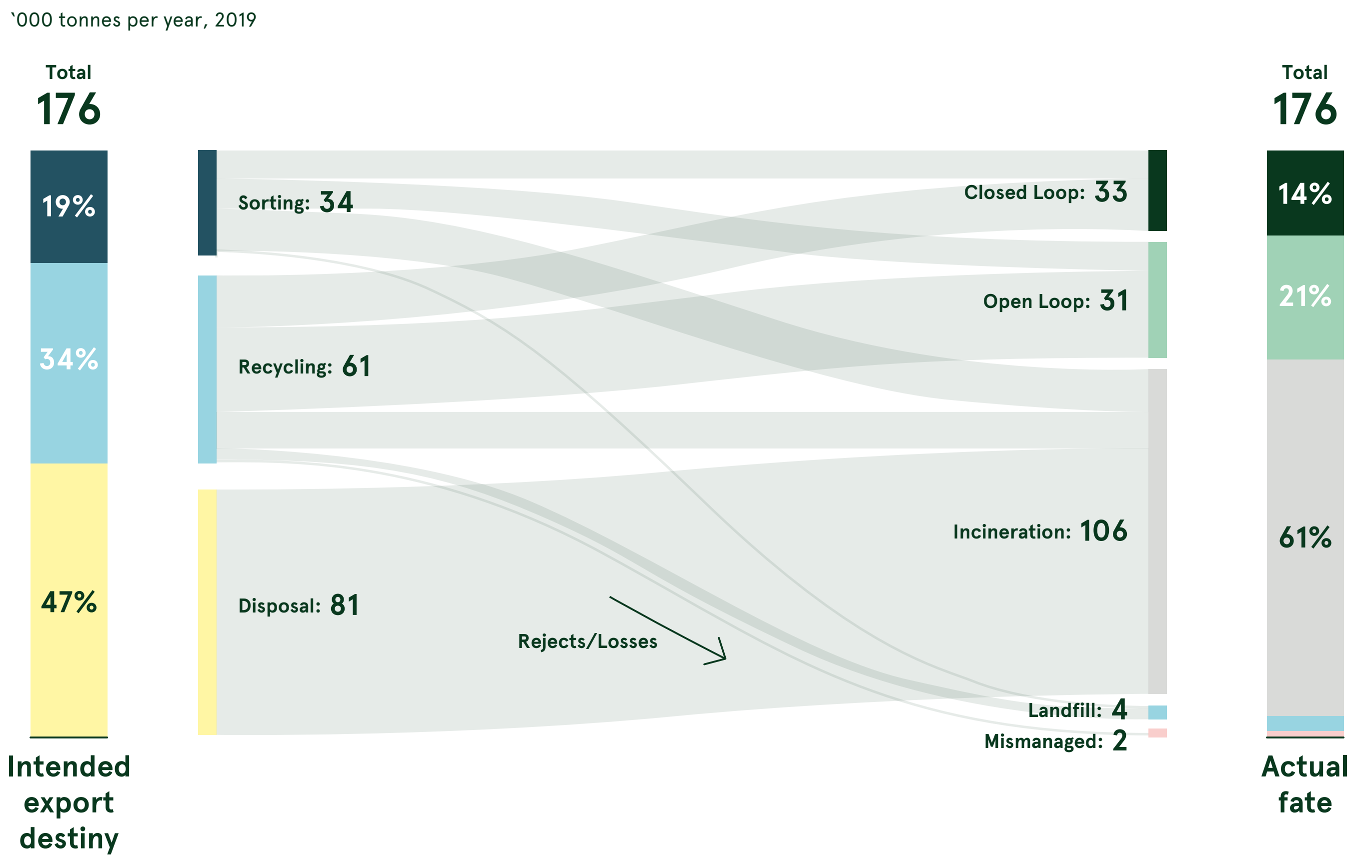
Exporting plastic waste risks a loss of control over its final destination and prevents Norway from meeting its zero landfill and zero littering policies, at least abroad. While exports to EU countries are not generally considered problematic, the ultimate fate of the rejects and/or losses from exports is potentially exposing Norway to a landfill footprint which contradicts its national ban. Our analysis shows that up to 5,000 tonnes of plastic waste from Norway might find its way to European landfills. Although Norwegian authorities have reporting mechanisms in place and conduct frequent inspections of the industry, an even better traceability of the fate of export residues – in addition to improved design for recycling, measures to boost the demand for recyclables, and more effective sorting of waste – is essential if Norway wants to achieve a zero plastic to landfill footprint in the future.

Exports of business-to-business (B2B) packaging waste outside of the EU, and notably to South East Asia (e.g. Vietnam, Malaysia), expose Norway to the risk of its plastic being disposed of in unsanitary landfills, leaked to waterways, and/or burnt openly. Such exports require more thorough monitoring to ensure that safe and environmentally sound recycling is taking place. Current practices, and the lack of proper waste management facilities (such as well managed waste-to-energy incinerators or sanitary landfills) in some countries, present a significant risk for Norway (as well as most European countries). While it is difficult to put an exact figure on these flows, we estimate that between 1,000 and 2,000 tonnes of Norwegian plastic waste may be at risk of being disposed of in unsanitary landfills, leaked to waterways and/or burnt openly every year. Recent changes in the Basel Convention, including the amendment signed in May 2019 that entered into force in 2021, following a Norwegian initiative, clarify the way plastic waste can be internationally traded and bring additional types of plastic waste into the existing control mechanism known as the

EXHIBIT 5

Breakdown of plastic waste exports in Norway

OVER 60% OF EXPORTED NORWEGIAN WASTE IS ESTIMATED TO BE INCINERATED



26 All exports data is from a Mepex Analysis based Norwegian Environmental Agency and Green Dot Norway sources from export declarations; the fate of those exports is based on an analysis by SYSTEMIQ.

Prior Informed Consent (PIC) Procedure. The amendments also specify measures to support implementation, especially by developing countries.

Finally, it is worth noting that, as a result of economic opportunities, Norway also imports waste to be incinerated with energy recovery in Norway. We estimate that approximatively 33,000 tonnes of plastic waste were imported for waste-to-energy incineration in 2019 – most of which came from the United Kingdom (and is not included in the figures in this chapter). That means 24% of the plastic waste incinerated in Norway is imported.

"Over 72% of Norwegian plastic is ultimately sent to incineration, while only up to 25% is recycled in practice"

No silver bullets: Single-solution strategies cannot achieve a zero-waste circular plastic economy

Our analysis shows that none of the scenarios that include only upstream interventions (defined as pre-consumer interventions, such as reduction, substitution, or design for recycling) or only downstream interventions (defined as post-consumer interventions, such as collection, sorting, recycling and disposal) is satisfactory from a socio-economic or environmental perspective.

Upstream Scenario: Reduce and Substitute

For the Reduce and Substitute scenario, we model upstream system interventions: ambitious plastic reduction, substitution with other materials (when beneficial), and design for recycling. Upstream design innovations like these are known to be critical in shifting to a circular economy and often have the best combination of cost, performance, and convenience. Under the Reduce and Substitute scenario – where upstream interventions are scaled to their maximum foreseeable potential within technical, economic, and climate constraints – the circularity index[27] increases from 25% today and under Business-As-Usual to 47%, a significant improvement. However, there is only a marginal increase in the recycling rate – from 25% to 27% – due to the development of design for recycling, and not fundamentally change to the current incineration paradigm. While this scenario reduces the demand for plastic products by 28% and decreases GHG emissions by 17%, relative to Business-As-Usual, it also leads to a net loss of jobs. The fact that the Reduce and Substitute scenario does not effectively deal with unavoidable plastic waste, highlights the importance of pairing upstream and downstream interventions.

"None of the scenarios that include only upstream or only downstream interventions is satisfactory from a socio-economic or environmental perspective".

Downstream Scenarios: Scale-up of the Sorting Backbone; Central Sorting and Recycling Scale-up; Ambitious Sorting and Recycling Scale-up

Next, we model a series of scenarios centred on predominantly downstream system interventions. In the Scale-up of the Sorting Backbone scenario, we assume a moderate increase in sorting at source and the strong development of sorting infrastructure (for both sorted at source and mixed waste), paired with design for recycling and breakthrough sorting technology innovation by 2040. This scenario brings the recycling rate and circularity index up to 55%. Despite representing a big improvement over Business-As-Usual, this scenario highlights the technical limitations of downstream solutions, even with ambitious system improvements. This scenario is also moderately beneficial compared to other single-strategy scenarios as it allows GHG emissions to be reduced by 12%, due to a reduction in waste-to-energy incineration, at no additional net cost for the system and while providing domestic job creation in material recovery facilities (MRF). It demonstrates that sorting is the cornerstone of any strategy to increase recycling rates.

The Central Sorting and Recycling scenario relies on the scale-up of a uniform national mixed waste collection system (excluding food waste) and central sorting infrastructure able to process all the plastic waste generated in Norway, paired with design for recycling and breakthrough sorting and recycling technology by 2040. In addition, mechanical recycling and chemical conversion are scaled-up as ambitiously as realistically feasible. This scenario brings the recycling rate and circularity index up to 57% and reduces GHG emissions by 11% compared to Business-As-Usual by 2040.

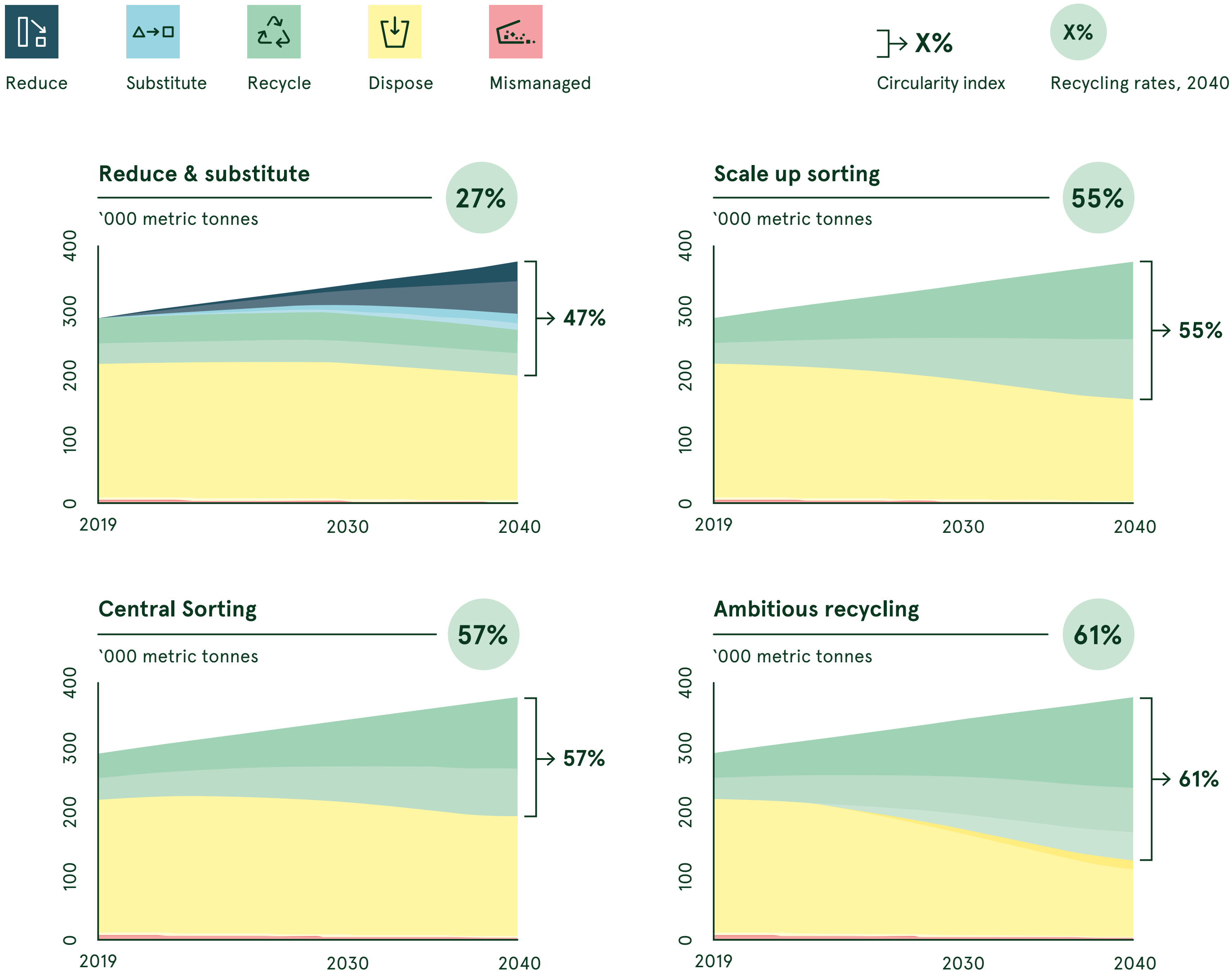
In the Ambitious Sorting and Recycling Scale-up scenario, we assume that design for recycling, sorting, mechanical recycling, and chemical conversion are scaled up as ambitiously as can be realistically imagined. This scenario allows Norway to meet EU recycling targets and reach a comfortable 61% recycling rate and similar circularity index. At this point there is little room for additional improvements in the system given technological limitations at each step (through losses in sorting and recycling). It is therefore unlikely that recycling rates can get any higher under the current paradigm, even assuming ambitious technological improvements. This scenario achieves only a 13% reduction of GHG emissions compared to Business-As-Usual by 2040, due to the expansion of the energy-intensive chemical

27 Reminder: the circularity index is defined as the sum of plastic utility reduced, substituted and recycled, divided by the total plastic utility.

EXHIBIT 6

Plastic waste fate under different scenarios

NONE OF THE "SILVER BULLET" STRATEGIES GENERATE A SIGNIFICANT REDUCTION IN WASTE DISPOSAL



Those "wedges" show the share of treatment options for the plastic that enters the system over time under four scenarios. Any plastic that enters the system has a single fate, or a single "wedge." The Reduce wedge represents plastic utility that has been fulfilled without using physical plastic. The Substitute wedge reflects plastic utility that has been fulfilled by alternative materials such as paper or compostable materials. The Recycle wedge accounts for the plastic that is recycled in the system, either mechanically or chemically. The Dispose wedge includes plastic that cannot be reduced, substituted, or recycled but is managed in a way that ensures that it does not leak into the environment. All other plastic is considered Mismanaged.

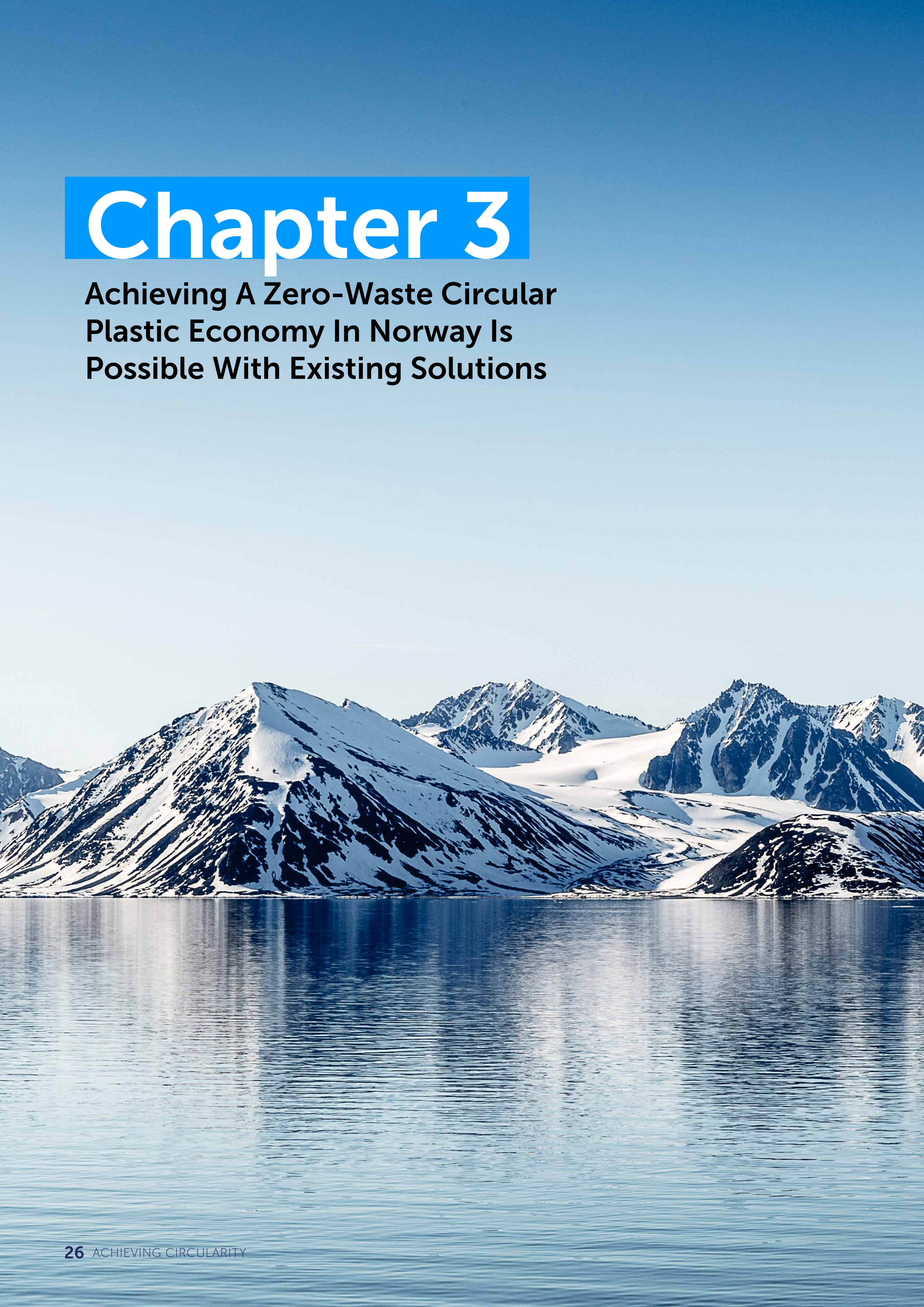
conversion industry. However, it generates a 16% growth in employment in the plastic sector by 2040 compared to Business-As-Usual and a reduction in system cost, driven by favourable assumptions in recycling economics.

As shown in this chapter, the shift to a circular economy is not a matter of principle or ideology – it is backed by sound business logic. The cost of sending over 200,000 tonnes of plastic to waste-to-energy incineration every year and producing new virgin material is enormous – over NOK 100 million by our estimates. When coupled with the opportunity cost of that material, and the business opportunities offered by new ventures and business models, the costs of not transitioning to a circular economy become too large to ignore.

In the next chapter, we show how embarking on the journey to a zero-waste circular plastic economy creates significant opportunities for companies ahead of the curve, ready to embrace new business opportunities that unlock value from circulating materials rather than from the extraction and conversion of fossil fuels. Large new value pools can be created around better design, better materials, better delivery models, improved sorting and recycling technologies, and smart collection and supply chain management systems.

Chapter 3

Achieving A Zero-Waste Circular Plastic Economy In Norway Is Possible With Existing Solutions



Size of the prize: An integrated zero-waste circular plastic strategy offer Norway multiple environmental, economic and social benefits

The System Change Scenario achieves considerable benefits across multiple dimensions in the Norwegian plastic system: increased recycling rates, lower virgin plastic consumption, reduced waste-to-energy incineration, lower greenhouse gas (GHG) emissions, and less mismanaged waste. And all these benefits come at a comparable economic cost, without job losses, and can be achieved using existing solutions – if the 10 system interventions explained in this chapter are implemented across the entire value chain. Put simply, it is not the lack of technical solutions that is preventing a zero-waste circular plastic economy and decarbonised plastic system in Norway, but rather insufficiently ambitious regulatory frameworks, business models, incentives, and funding mechanisms. If we overcome these challenges, the full potential of the System Change Scenario can be realised, as summarised in Exhibit 7.

EXHIBIT 7

Comparison of system outcomes between Business-As-Usual and the System Change Scenario

THE SYSTEM CHANGE SCENARIO PROVIDES CONSIDERABLE BENEFITS AT NO TRADE-OFF TO SOCIETY

2040		BUSINESS-AS-USUAL	vs.	SYSTEM CHANGE SCENARIO
A MORE SUSTAINABLE AND CIRCULAR PLASTIC INDUSTRY	Plastic demand	376k tonnes		271k tonnes
	Fossil-based plastic production	245k tonnes		176k tonnes
	Incineration	272k tonnes		108k tonnes
	Recycling	93k tonnes		154k tonnes
	GHG	2.0mt CO_{2eq}		1.5mt CO_{2eq}
	Unwanted fate of plastic	8-12k tonnes		1-3k tonnes
AT NO TRADE OFF FOR SOCIETY	Cost	349bn NOK		342bn NOK
	Jobs	5.5k jobs		5.7k jobs

Definitions:

Plastic utility: Total satisfaction met from consuming a good or a service provided by plastic products in a business-as-usual scenario.

Plastic demand: Total amount of plastic demand for packaging and other household goods projected in 2040.

Fossil-based plastic production: Total amount of virgin plastic production in 2040.

Incineration: Total amount of plastic waste generated in Norway and incinerated with energy recovery either in Norway or outside of Norway in 2040 (excluding imports).

Recycling: Total amount of waste recycled in Norway or internationally from the waste generated in Norway, including mechanical recycling and chemical conversion (but excluding plastic-to-fuel technology).

GHG emissions: Total 2040 life cycle assessment emissions of all plastics (and substitutes), including production, conversion, collection, sorting, mechanical recycling, chemical conversion, waste-to-energy incineration, landfill, and open burn.

Unwanted fate of plastic: Total amount of plastic waste ending up as litter in Norway or which through exports has a high likelihood to enter landfill (in EU) or end up in a dumpsite or burnt in the open (in Asia).

Costs: Cumulative present value of net costs incurred between 2021 and 2040 (capex and opex) incurred by all waste generated in Norway (including revenue streams) across the entire plastic value chain (i.e. plastic production, packaging conversion, collection, sorting, recycling and disposal including export costs, as well as the same cost for substitute materials, and estimated costs for new business models).

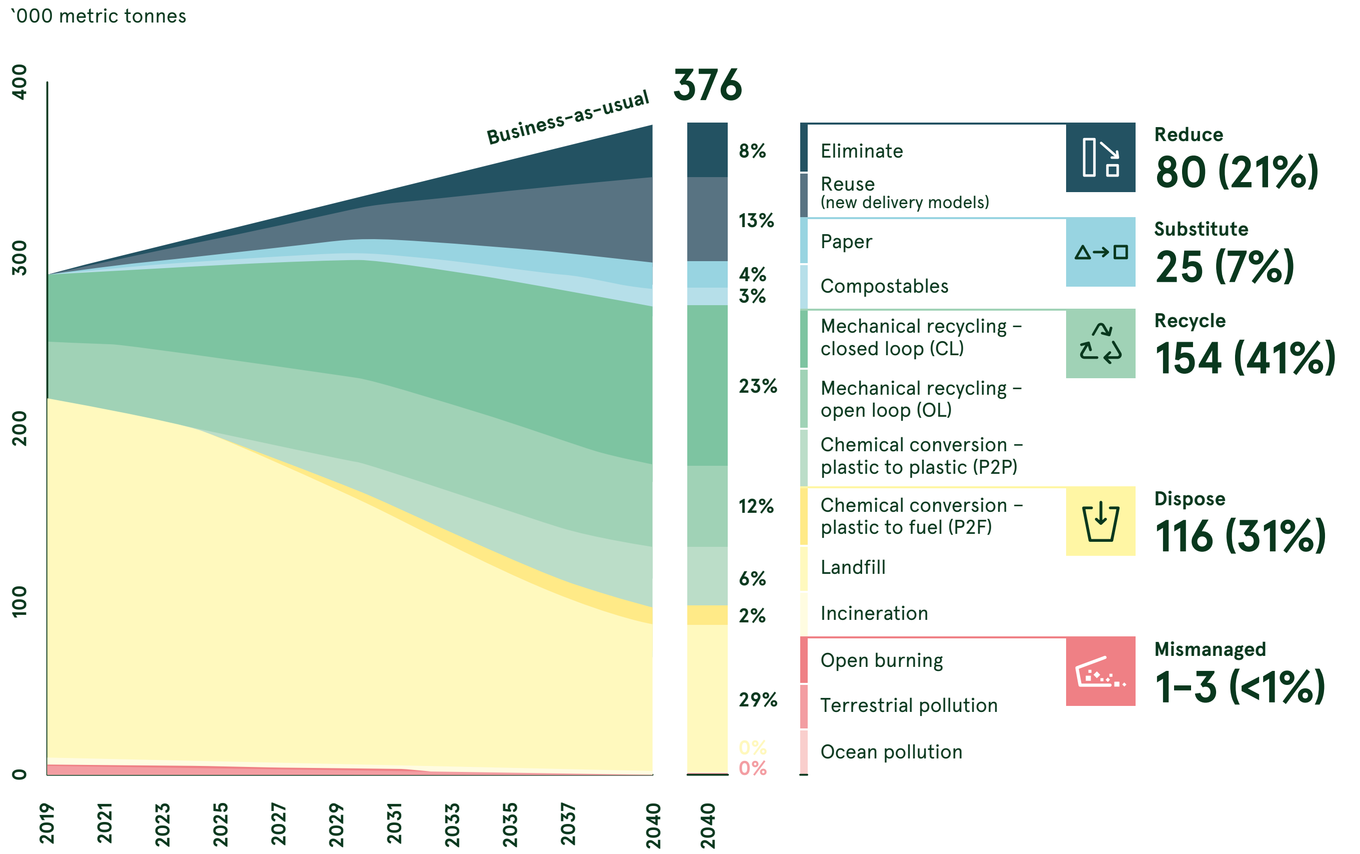
Job creation: Number of direct jobs in 2040 for all plastics (and substitutes), including production, conversion, collection, sorting, mechanical recycling, chemical conversion, waste-to-energy incineration, landfill, as well as new delivery models. This number include jobs in Norway and outside of Norway, the share of which could not be estimated given complex value chains.

Norway's plastic system is at a critical inflection point. The country can decide either to continue under Business-As-Usual and preserve a mostly linear system with only a 25% recycling rate (a future in which an estimated 97,000 tonnes would be recycled by 2040 compared to nearly 270,000 tonnes incinerated with energy recovery) or embrace an ambitious yet credible zero-waste circular plastic economy pathway where circular solutions account for an estimated 69% of plastic waste.

EXHIBIT 8

Plastic fate in the System Change Scenario: a wedges analysis

THE SYSTEM CHANGE SCENARIO HAS A 69% CIRCULARITY RATE



Waste generated in Norway excluding imports; includes waste that is treated in Norway and exported.

This "wedges" shows the share of treatment options for the plastic that enters the system over time under the System Change Scenario. Any plastic that enters the system has a single fate, or a single "wedge." The Reduce wedge represents plastic utility that has been fulfilled without using physical plastic. The Substitute wedge reflects plastic utility that has been fulfilled by alternative materials such as paper or compostable materials. The Recycle wedge accounts for the plastic that is recycled in the system, either mechanically or chemically. The Dispose wedge includes plastic that cannot be reduced, substituted, or recycled but is managed in a way that ensures that it does not leak into the environment. All other plastic is considered Mismanaged.

"it is not the lack of technical solutions that is preventing a zero-waste circular plastic economy in Norway, but rather insufficiently ambitious regulatory frameworks, business models, incentives, and funding mechanisms"

The System Change Scenario offers multiple environmental, economic, and social benefits, including: (a) a more efficient use of resources with a significant reduction of fossil-based virgin plastic; (b) a contribution to the fight against climate change; (c) a reduction in mismanaged plastic waste, reducing the impact on Norwegian ecosystems; and (d) a shift away from waste-to-energy incineration.

More efficient use of resources with a significant reduction of fossil-based virgin plastic

Our analysis estimates that 289,000 tonnes of plastic material entered the Norwegian market in 2019; this could increase to 376,000 tonnes by 2040 under Business-As-Usual. The share of virgin plastic demand is conservatively estimated at 259,000 tonnes in 2019, and only marginally decreases, to 245,000 tonnes by 2040, in the Business-As-Usual scenario, due to the increasing use of recycled content and bio-based feedstock, as shown in Exhibit 9. In the System Change Scenario, virgin plastic can be reduced further to 176,000 tonnes by 2040, a 28% reduction - essentially decoupling economic activity from the growth of virgin plastics. Note that, in both the System Change Scenario and Business-As-Usual we assume a similar share of recycled content and bio-based content to replace demand for virgin material. The share of virgin plastic in the System Change Scenario is further decreased due to the combined impact of reduction and substitution levers.

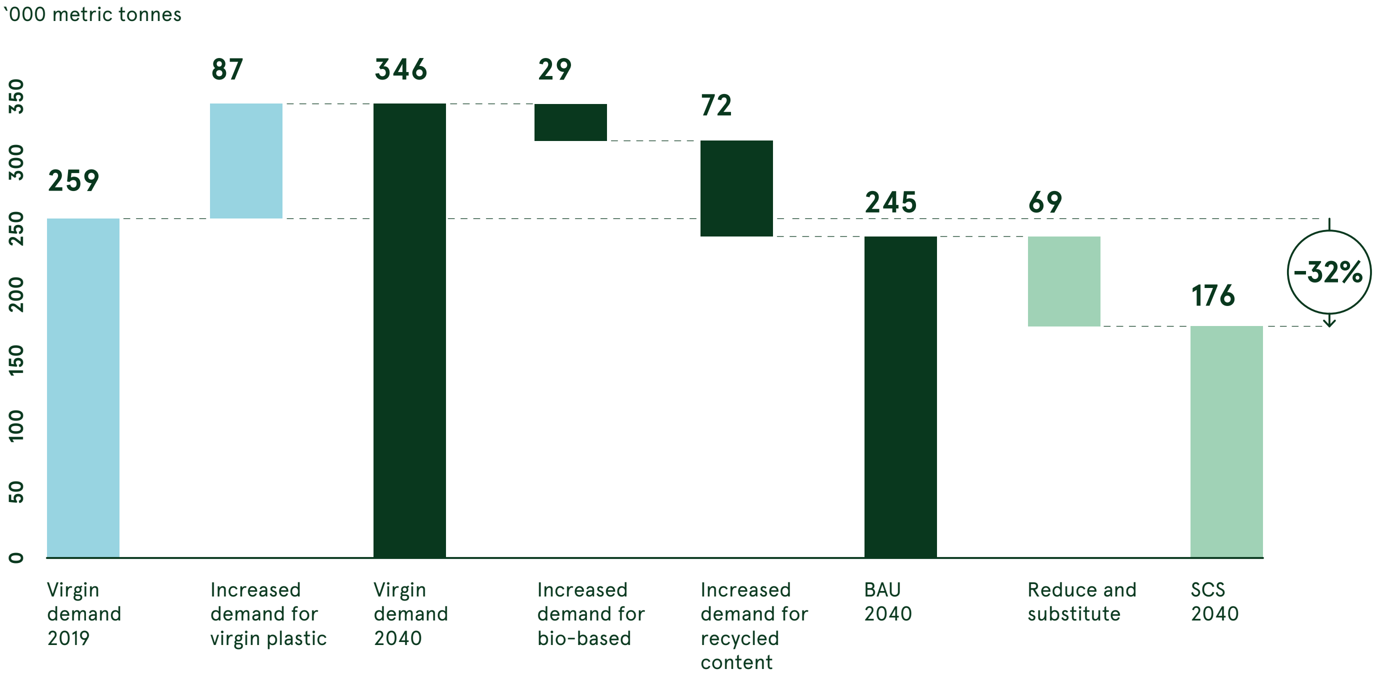
Contribution to the fight against climate change

Under Business-As-Usual, it is estimated that Norway's plastic industry (from production to fate) will emit over 2 million tonnes of CO_{2eq} annually by 2040. Under the System Change Scenario, this could be reduced to 1.5 million tonnes of CO_{2eq}, a 25% reduction, achievable via the reduction of plastic in the system and a shift from virgin to recycled plastic. While this is a significant reduction for a "hard to abate" sector, it is not nearly enough to be aligned with the Paris Agreement, or with Norway's net-zero carbon by 2050 target. Achieving these more ambitious goals will require further decarbonisation efforts outside the scope of our analysis (including shifting

EXHIBIT 9

Virgin plastic demand under Business-As-Usual and the System Change Scenario

BY 2040, VIRGIN PLASTIC DEMAND COULD FALL BY 32% RELATIVE TO 2019 LEVELS UNDER THE SYSTEM CHANGE SCENARIO



This figure shows virgin plastic demand in 2019, 2040, and in 2040 after the Reduce and Substitute levers are applied.

to renewable energy, electrifying plastic production, shifting to bio-based feedstock, decarbonising waste-to-energy incineration, and more). And yet, a 25% reduction in GHG emissions as a result of dematerialisation and recycling is still an important contribution to the fight against climate change. At a social cost of carbon of US$ 50/tonne28 of CO_2e, this is equivalent to a net financial benefit of US$ 259 million to society between 2020 and 2040, which is excluded from the tangible financial outcomes covered in the rest of our analysis.

Reduction in plastic pollution

Norway is among the countries best positioned to reach near-zero plastic pollution; an ambitious target not yet achieved by any country. The System Change Scenario shows that this target is achievable through two main levers: (1) a better control of exports and (2) actions taken because of an increased understanding of littering and associated behaviour. In the Business-As-Usual scenario, we estimate that up to 8,000 -12,000 'tonnes of plastic (3-4% of Norway's total plastic waste) could end up with an unwanted fate every year by 2040, of which 5,000 tonnes end up in landfills in Europe, 1,000 - 2,000 tonnes end up either in mismanaged landfills or being burnt openly in the Global South, and the remaining 2,000 – 5,000 tonnes are littered in Norway. The System Change Scenario shows that the unwanted fate of plastic could be significantly decreased – to an estimated 1,000 – 3,000 tonnes (0.5-1% of plastic waste) – of which the lion's share is expected to stem from littering in Norway.

These estimates rely on the best available data, but it is important to acknowledge the high degree of uncertainty in littering and export data (see the technical appendix for further details on the assumptions used for this analysis).

Nonetheless, it is safe to assume that the System Change Scenario would have a significant impact on littering given the reduction of plastic in the system and improvements to sorting and recycling, even if the precise figure is difficult to quantify.

Moving away from waste-to-energy incineration in Norway and abroad

The System Change Scenario provides a compelling pathway for Norway to significantly reduce its reliance on waste-to-energy incineration by 2040. Under Business-As-Usual, the share of waste-to-energy incineration will remain over 72% of plastic by 2040, while the proposed 10 system interventions in the System Change Scenario could reduce this to 29% by 2040.

Under Business-As-Usual, we estimate that Norway would export up to 47% (104,000 tonnes) of its unsorted mixed plastic waste for waste-to-energy incineration by 2040, mostly to Sweden. In contrast, in the System Change Scenario, Norway can become self-sufficient in terms of waste-to-energy incineration capacity by 2040 with current 2019 capacity (at least for its plastic waste stream). While market dynamics mean that it is possible some exports will continue even under the System Change Scenario, their pace are expected to reduce greatly. Additionally, if plastic waste imports (which are excluded from all the other figures in this chapter) were taken into consideration in the System Change Scenario, by 2040, 41% of the plastic waste incinerated with energy recovery in Norway would come from imports (assuming Norway continues to import waste at current rates and excluding waste exported for waste-to-energy incineration).

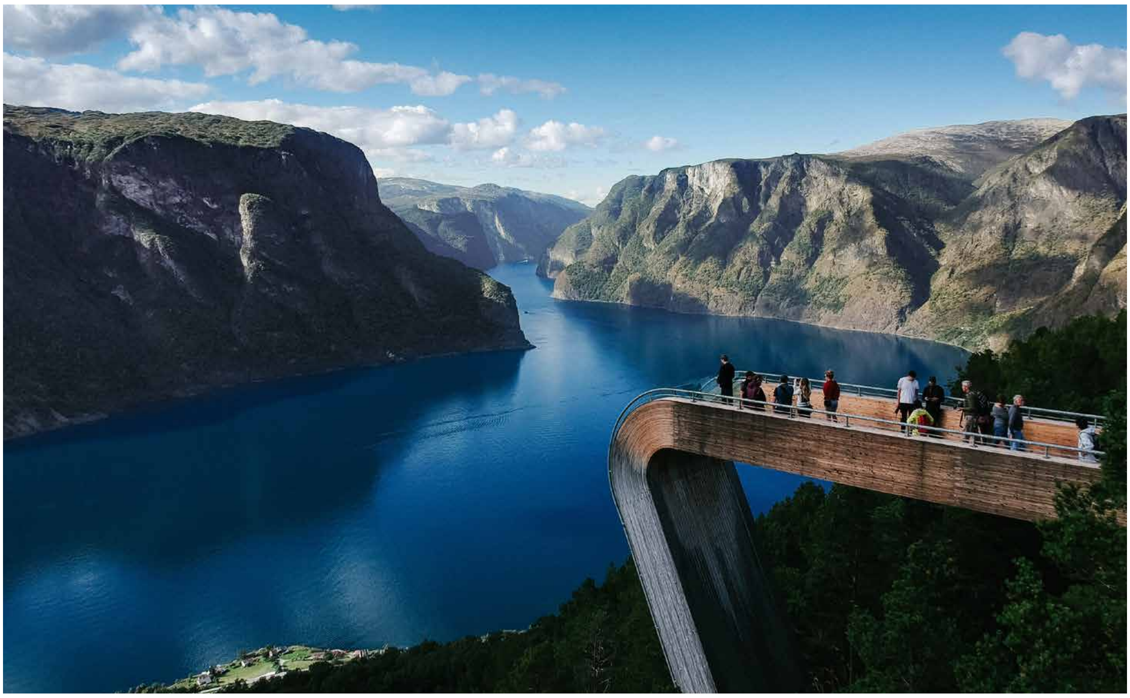


Photo by Robert Bye on Unsplash

28 Report of the High-Level Commission on Carbon Prices, 2017.

Crucially, the System Change Scenario delivers these considerable benefits without additional costs to the system[29] and without reducing employment. Our analysis shows that the cumulative net cost for society of managing waste in Norway between 2021 and 2040 is comparable between the Business-As-Usual and the System Change Scenarios, at NOK 349 billion and NOK 342 billion, respectively. Similarly, the number of direct jobs supported by the industry is estimated at 5,500 for Business-As-Usual and 5,700 under the System Change Scenario by 2040 (including jobs both in and outside Norway). Overall, given the uncertainty attached to this analysis (e.g. regarding the price of oil), we can conservatively say that shifting to a zero-waste circular plastic economy can be done at no additional cost and will not reduce net employment (although jobs may shift from production to "green" jobs in recycling and service sectors). In addition, while we have only accounted for direct jobs, if indirect jobs were included, it is likely that the System Change Scenario would have a net positive impact on employment because the circular economy relies on services (as opposed to the linear economy that relies on manufacturing products), driving a shift from capital-intensive to labour-intensive industries.

Comparing scenarios and understanding trade-offs

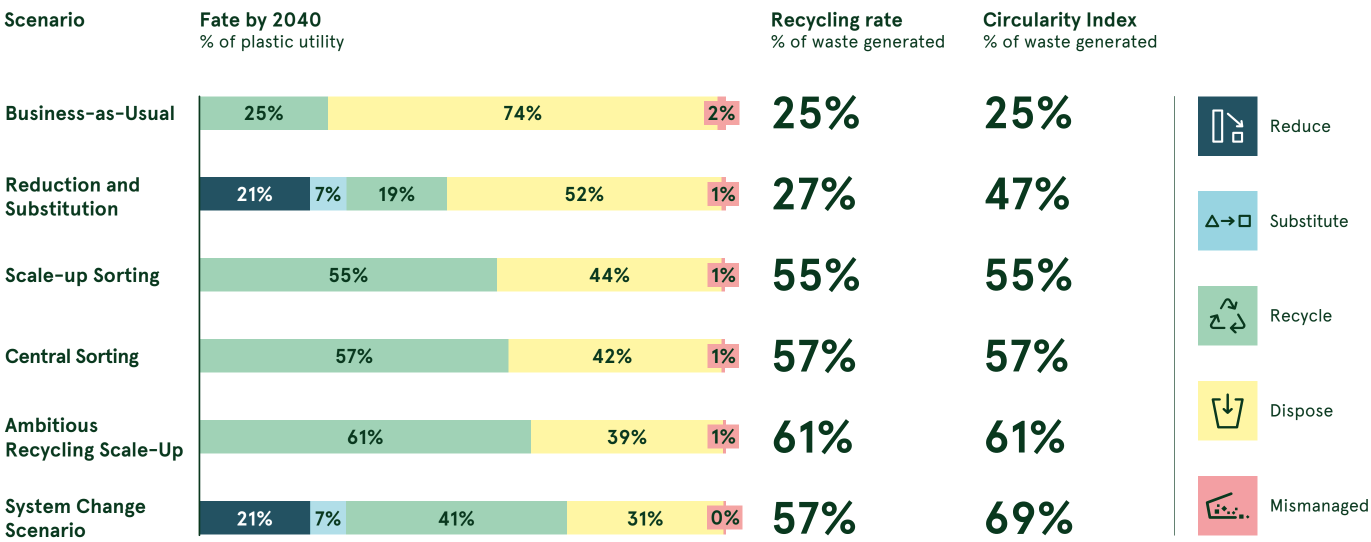
Exhibit 10 compares the fate of plastic under the different scenarios modelled, as well as the recycling rate and circularity index for each scenario. As the exhibit shows, the System Change Scenario has the highest potential to achieve a zero-waste circular plastic economy.

The System Change Scenario is not only more likely to achieve a zero-waste circular plastic economy, but it is also more desirable from a socio-economic and environmental perspective. When analysing trade-offs by comparing scenarios across key economic, environmental and social indicators, the System Change Scenario has the highest performance in three out of four indicators and is superior to the Business-As-Usual scenario in all four indicators, as shown in Exhibit 11.

EXHIBIT 10

Plastic waste fate, recycling rates, and circularity index under different scenarios

THE SYSTEM CHANGE SCENARIO HAS THE HIGHEST CIRCULARITY INDEX



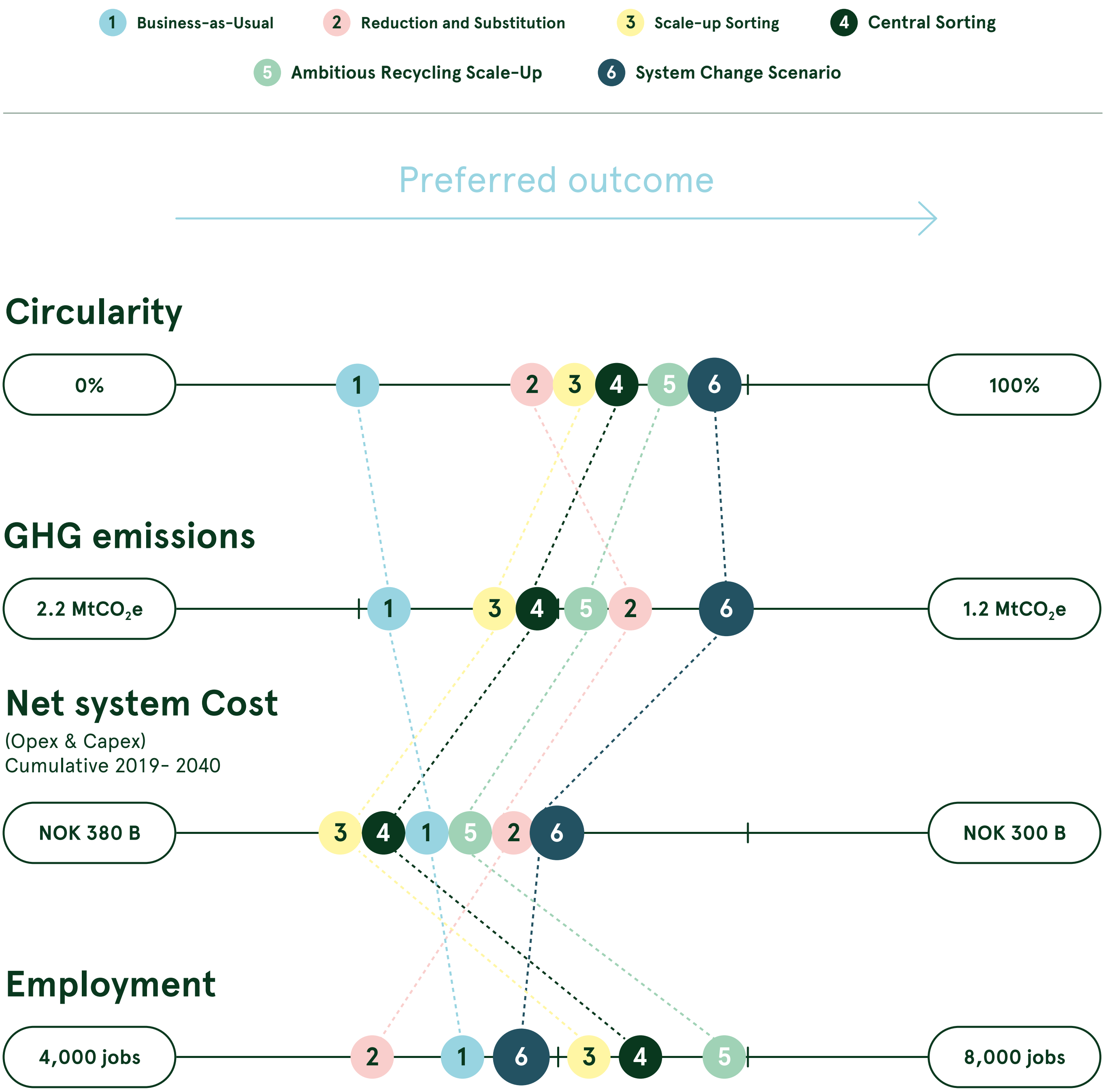
Recycling rates are defined as actually recycled material excluding processing losses. Circularity index is defined as the sum of the reduce, substitute and recycling lever.

29 present value of net costs incurred between 2021 and 2040 (capex and opex) incurred by all waste generated in Norway (including revenue streams) and covers the entire plastic value chain (i.e., plastic production, packaging conversion, collection, sorting, recycling and disposal including export cost, as well as the same cost for substitute materials, and estimated cost for the new business models).

EXHIBIT 11

Financial, environmental, and social indicators under different

THE SYSTEM CHANGE SCENARIO OUTPERORMS OTHER SCENARIOS IN MOST DIMENSIONS THAT MATTER



An approach that works

Dramatically reducing the share of incinerated waste with energy recovery is a complex system-level challenge, but one that is achievable in Norway using existing solutions. Achieving this outcome requires implementing all 10 synergetic system interventions outlined in Exhibit 12 concurrently, ambitiously, and starting immediately.

Importantly, as the system interventions have multiplier effects, implementing them simultaneously yields the greatest impact. Plus, while innovation and new solutions across every part of the value chain can make the transition better, easier, and faster, the System Change Scenario can achieve all the systemic outcomes outlined in the previous section with existing solutions.

EXHIBIT 12

Ten system interventions are critically needed to achieve the System Change Scenario by 2040

DIFFERENT SYSTEM INTERVENTIONS ARE APPLICABLE TO DIFFERENT PLASTIC CATEGORIES AND DIFFERENT STAKEHOLDER GROUPS

■ Highly applicable ■ Somewhat applicable ■ Not applicable

	System intervention	Most relevant plastic categories: Bottle	Rigid	Flex	Multi	Main responsible stakeholder
1	Reduce growth in plastic consumption	Somewhat applicable	Highly applicable	Highly applicable	Highly applicable	Consumer goods brands; retailer
2	Substitute plastic with suitable alternative materials when beneficial	Not applicable	Somewhat applicable	Highly applicable	Somewhat applicable	Consumer goods brands; retailer
3	Re-design products for recycling	Somewhat applicable	Highly applicable	Somewhat applicable	Highly applicable	Consumer goods brands
4	Create new market for different types of recyclates	Somewhat applicable	Highly applicable	Highly applicable	Not applicable	Waste management companies; packaging converters ; consumer goods brands
5	Increase sorting capacity in Norway	Highly applicable	Highly applicable	Highly applicable	Not applicable	Municipal government
6	Scale up mechanical recycling capacity	Highly applicable	Highly applicable	Highly applicable	Not applicable	Waste management companies
7	Invest in innovation to improve current existing technology	Somewhat applicable	Highly applicable	Highly applicable	Not applicable	Financial sector; national government; waste management companies
8	Scale up chemical recycling	Not applicable	Not applicable	Highly applicable	Highly applicable	Petro-chemical industry; waste management companies
9	Control export fate	Not applicable	Somewhat applicable	Highly applicable	Somewhat applicable	National government
10	Innovation fund	Somewhat applicable	Somewhat applicable	Highly applicable	Highly applicable	National government together with industry

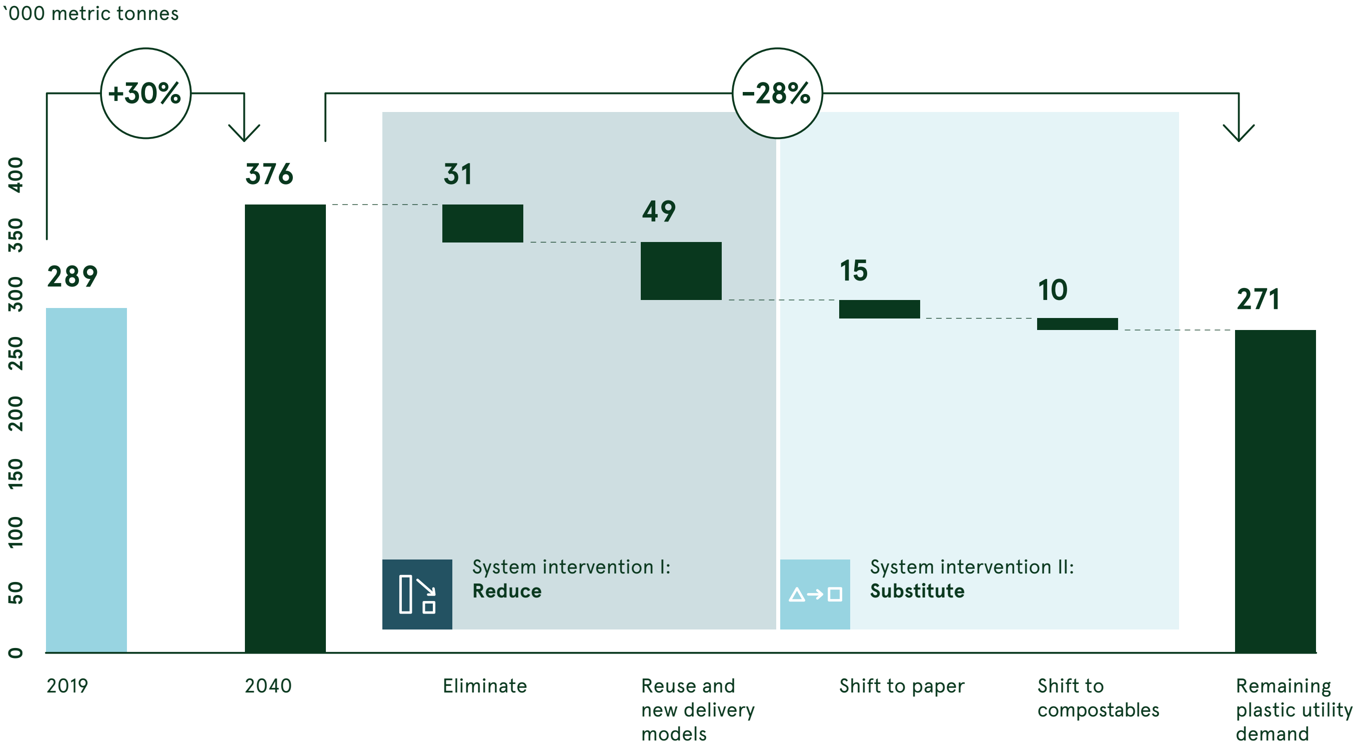
A better plastic system in Norway means relying on more responsible plastic consumption and more responsible plastic waste management. More responsible plastic consumption primarily requires the implementation of upstream solutions, while more responsible plastic waste management requires the implementation of downstream solutions.

Unleashing the upstream: achieving a zero-waste circular plastic economy first requires reducing plastic consumption, substituting materials where it is beneficial, and ensuring all remaining plastic products are designed for recycling

EXHIBIT 13

Opportunity to reduce and substitute plastic under the System Change Scenario

THE CURRENT GROWTH PATTERNS IN PLASTIC CONSUMPTION CAN BE REVERSED THROUGH REDUCTION AND SUBSTITUTION LEVERS



This figure shows plastic utility demand (in other words, plastic waste generated under BAU) in 2019, 2040, and in 2040 after the Reduce and Substitute levers are applied. The respective per cent of plastic waste in 2040 that is reduced by each lever is 8 per cent, 13 per cent, 4 per cent and 3 per cent for a total reduction of 106,000 tonnes or 28 per cent of projected 2040 utility demand.

System Intervention #1: Reduce plastic consumption to avoid over 20% of projected plastic waste generation by 2040

An increased focus on reduction strategies is necessary to limit the growth of plastic consumption over the next 20 years. In a Business-As-Usual scenario, plastic consumption in Norway could grow from 289,000 tonnes in 2019 to 376,000 tonnes in 2040, increasing pressure on our waste management systems, climate and ecosystems, both in Norway and beyond. Limiting the growth of avoidable plastic consumption is feasible if it provides society with the most attractive alternative solution from environmental, economic, and social perspectives. Reduction offers net savings to society by cutting the need for waste management and provides the highest mitigation opportunity in GHG emissions compared to any other lever. But it requires consolidated action, mostly from consumer goods companies and retailers, to ensure that, (1) avoidable plastic is systematically eliminated at source and, (2) new delivery models (including reuse systems) are developed and deployed at scale.

To calculate the reduction potential in Norway, we applied the peer-reviewed framework developed in "Breaking the Plastic Wave", which scores dozens of known solutions for each plastic application based on four dimensions: performance, technology, affordability and convenience. The full details of this assessment can be seen in the technical report. Our analysis found that up to 31,000 tonnes of plastic waste (8%) – mostly packaging – can be eliminated at source while 49,000 tonnes (13%) can be reduced through new delivery models – without reducing utility to consumers. Flexible packaging - especially carrier bags and films (both post-consumer and B2B) - are the applications with the largest reduction potential (48,000 tonnes), followed by rigid packaging (14,000 tonnes including mostly pots, tubs and trays) and beverage bottles (13,000 tonnes). On a per capita basis, this system intervention reflects a reduction from 65 kg (under Business-As-Usual) to 51 kg of plastic per person per year by 2040 (compared to 54 kg today). For more information on this analysis and the relevant assumptions, please consult the technical report.

Examples of applications with the highest potential for reduction are:

- Use of concentrated capsules for household cleaners, soaps or even toothpaste
- Moving from liquid to solid cosmetics
- Packing reusable water bottle and bags
- Drinking off-premises coffee or tea from a reusable cup
- Scaling up the use of soda and/or sparkling water dispensers
- Trialling edible packaging alternatives for food and drinks
- Ordering online shopping, groceries, or meals in re-usable boxes and containers
- Shopping from in store displaying bulk dispensers and plastic-free aisles
- Shifting from disposable to reusable diapers
- Encouraging business-to-business development of closed loop and/or re-use systems for secondary and tertiary packaging (e.g. crates).

While this system intervention requires that consumers shift their behaviour, the role of consumer goods companies and governments is even more important.

- Consumer goods companies and retailers have the most prominent role in ensuring that:
  - They adopt regulatory or standard requirements for plastic packaging that focus on the elimination of avoidable packaging.
  - They scale-up supply chain innovation, such as the use of seasonal food, local suppliers, digital trackers, and choice editing (reducing the need for packaging to differentiate products).
  - Consumers are offered the choice to consume differently. R&D programmes and pilots must be implemented to identify which existing solutions could be culturally accepted in Norway and the impact of each one on a product-by-product basis.
- The central government can also play a role by shifting the burden of the cost of waste management towards producers through different policies, such as legally binding extended producer responsibility (EPR), and legally binding taxes on single-use plastic and waste-to-energy incineration. New policies will need to meet the requirements set out in the relevant EU legislation.

System Intervention #2: Substitute plastic wherever feasible and beneficial to prevent an additional 7% of plastic generation by 2040

In parallel to reduction, Norway should harvest the potential for the substitution of plastic wherever it can be undertaken at no cost to society or the environment. Material substitution is a complex topic that requires careful examination at the product level to understand performance, convenience and cost, as well as unintended consequences. In this report, only two material substitution strategies were considered: paper and compostable materials. These two materials were selected because they are the most prevalent for replacing single-use packaging. This system intervention refers only to substituting single-use plastics with other single-use materials; using metal or glass as multi-use substitutes can be legitimate but is included under System Intervention #1. It is important to note that our analysis on substitution should not be considered predictions of change or recommendations, but indicative of the future scaling of existing materials assuming no unintended consequences. Therefore, a key enabling condition is for the feedstock for these two materials to be sustainably sourced (including sound land and water management) and recycling rates to remain high.

In a globalised system of food production and consumption, the GHG emission savings offered by lightweight plastic materials are important. However, if supply chains are shortened, transport is decarbonised, or reuse and recycling rates are high, other substitute materials – such as glass and metals – can perform well. Life cycle analysis on a product-by-product basis should remain the standard for science-based decision-making processes when it comes to substitution.

For our analysis, compostables are defined as materials capable of disintegrating into natural elements in a home or industrial composting environment within a specified number of weeks, leaving no toxicity in the soil according to credible international standards. Compostables are most relevant where food waste processing infrastructure exists or will be built, and for substituting thin plastic films and small formats. Substitution with compostable materials is most appropriate for products with low plastic recycling rates and high rates of food contamination, making co-processing with organic waste a viable option. Given the specificity of the Norwegian context – such as high food-waste sorting at source, cold weather leading to low potential for home composting, and a heavy reliance on anaerobic digestion for food-waste processing – the potential of compostable materials has been adjusted to exclude target materials and applications that typically take longer to degrade (e.g. thicker products and poly(lactic acid)).

Our analysis found that up to 15,000 tonnes (mostly of packaging), can be substituted with paper and up to 10,000 tonnes with compostables. Non-food contact applications, and dry food applications where water barrier properties are not necessary, including post-consumer films, have one of the highest substitution potentials (10,000 tonnes), followed by rigid packaging (10,000 tonnes) mostly comprised of pots, tubs and trays, and B2B films and carrier bags (2,000 tonnes). For more information on this analysis, please see the technical report.

Overall, it is worth noting that the substitute materials in this category come at a higher cost (up to 2 times more when including production and packaging conversion).

Ensuring the development of substitute materials at scale in Norway relies on several enabling conditions:

- The central government supporting the development of research and innovation in the field of alternative materials for single-use plastic packaging and problematic materials or formats (see System Intervention #10).
- The central government, as well as other EU governments:
  - Supporting the development of standards which clearly define acceptable composting materials according to locally available management system and providing clarity around the word "biodegradable".
  - Promoting certification schemes for the sustainable sourcing of biomass and the adoption of strict criteria by brands and producers to ensure

that substitutes contain recycled content and are sourced responsibly.

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

- The financial sector recognising the space as financially viable with economic opportunities.

In accordance with the Circular Economy Action Plan, the European Commission is currently assessing applications where using biodegradable and compostable plastics can be beneficial to the environment, and the criteria for their use. Further policy development in this area is expected.

System Intervention #3: Implement ambitious design for recycling standards for all plastic products and packaging put on the market

Design for recycling interventions have multiple benefits, including increasing the share of plastic that is recyclable, increasing the value of recycled plastic, and reducing losses in the sorting and recycling process. Taken together, these can significantly boost recycling economics and support the scaling of the recycling industry. According to the Ellen MacArthur Foundation, design for recycling has the potential to raise US$120 per tonne of recycled plastic[30], virtually doubling profitability across the value chain (which can be captured by material recovery facilities, recyclers or a combination of the two).

"Breaking the Plastic Wave" identifies four main design for recycling principles that are highly applicable in Norway:

1. **Switch from multimaterials to monomaterials**
Multimaterial products often exist to meet the toughest packaging requirements but are not mechanically recycled due to poor economics. While there is currently no pathway for mechanical recycling for multimaterials in the EU today, our analysis shows that about 30% of multimaterials (especially multilayers packaging) can be redesigned in the next 20 years to allow monomaterial alternatives. Examples of this in practice are multimaterial food pouches that have switched to monomaterial polypropylene.

2. **Redesign (or remove) dyes, plastic pigments, and additives**
One of the biggest barriers currently preventing recyclers from creating recycled plastic of a quality that can compete with virgin output is the presence of dyes, pigments, and/or additives. Colour is typically used for marketing purposes, but it makes recycling extremely challenging. To create a circular loop between plastic and products, many more items need to be made from unpigmented plastic and new marketing approaches need to be developed, such as using recyclable inks and labels. Coca-Cola, for example, has shifted the Sprite bottle to a transparent colour to enhance its recyclability.

3. **Remove problematic polymers**
There are currently thousands of different plastic types and multiple formats, which inhibits the quality guarantee of the recyclate. By eliminating hard-to-recycle polymers that would otherwise contaminate the rest of the plastic waste stream (such as PVC) and reducing the number of polymers used, both the sorting and recycling of plastic will be improved. These changes will decrease the complexity of sorting (for both consumers and sorters) and simplify recycling processes, ultimately increasing recycling yields and reducing costs.

4. **Improve labelling and design for source separation**
As sorting at source is often considered the missing link, better labelling could help both the consumer and the sorter to place products into the correct recycling stream. Labelling should therefore conform to clear national or international standards that take the practical recyclability of different materials into account. The packaging industry should also ensure that "labelling for recycling" is intuitive, especially when multiple polymers are used, to maximise recycling efforts from consumers, pickers, and sorters, as well as from recyclers themselves. For example, a box made of high-density polyethylene (HDPE) with a lid made of low-density polyethylene (LDPE) should have each component labelled separately, as opposed to the current practice in which, for the sake of aesthetics, HDPE and LDPE are both mentioned on the bottom of the box. By improving labelling practices, the complexity of sorting and recycling processes will decrease, thereby increasing the share of waste collected for recycling, increasing recycling yields, and reducing costs during sorting and recycling.

30 Ellen MacArthur Foundation, The New Plastics Economy, Catalysing Action, 2017 (Page 39)

Achieving this at scale in Norway depends on a few enabling conditions:

- Policy interventions to accelerate the adoption of design for recycling measures. Examples include: fee modulated EPR schemes; design for recycling standards; recycling targets; minimum recycled content targets; taxes on the use of virgin plastic feedstock; regulatory mandates on certain pigments, polymers and additives; disclosure mandates; and the regulation of recycling labelling practices.
- Greater industry collaboration to accelerate this transition by developing new polymer and packaging designs in coordination with recycling and sorting technology companies and harmonising materials and packaging formats across companies. Increased investment in R&D (by both public and private players) can also boost design for recycling.
- Voluntary commitments by producers and retailers to increase recyclability and integrate recycled content in plastic products.
- Shifting consumer preferences to drive higher demand for recycled content and higher recyclability of plastic products.

Scaling the downstream: sorting and recycling capacity are the backbone of any national recycling strategy and ultimately ensure plastic waste is not sent straight to waste-to-energy incineration

System Intervention #4: Create new markets for different types of recycled content to enable the full potential of sorting and recycling technologies

Stimulating market demand for recycled plastic is a critical factor to ensure a zero-waste circular plastic economy is achievable. At the moment, the demand for certain plastic recyclates fluctuates due to insufficient commitment to use post-consumer recycled content, but our analysis indicates that new markets with an annual turnover of NOK 1.4 billion could be created by 2040. While sorting and recycling infrastructure makes recycling technically feasible, greater and more reliable demand for recycled content will make recycling economically viable and de-risk investments. In 2019, the two material recovery facilities (MRFs) in Norway reported that the main limitation for increasing their output was insufficient demand for high quality recycled content, not technical limitations or feedstock supply challenges. While an increasing number of global brands have committed to using at least 25% recycled content in packaging through Ellen MacArthur's Foundation Global Commitment, it is important to ensure an exponential domestic growth in demand for recycled content for all types of polymers.

Design for recycling (System Intervention #3) naturally increases demand for recycled content due to improved quality and stability, but it is important to continue incentivising this demand. This can be achieved in a number of ways:

- Packaging converters can diversify their R&D portfolio to include as many recyclate types as possible and demonstrate that the incorporation of recycled content is technically feasible and economically viable.
- Consumer goods companies (and potentially retailers) can commit to increasingly higher use of recycled content in their products to drive demand, and sign long-term purchasing agreements (similar to those that supported the growth of renewable energy) to de-risk investment for recyclers.
- The central government can set a national target for recycled content use in accordance with EU legislation and provide financial incentives for companies/products with a high share of recycled content, similar to the new practices in other European countries. The EU is currently working on developing mandatory requirements for recycled content in areas such as packaging, construction materials, and vehicles, that can provide a framework for such legislation at the national level in Norway.

System Intervention #5: Increase sorting capacity 16-fold to over 220,000 tonnes to enable a zero-waste circular plastic strategy

By far the main bottleneck to achieve any recycling target in Norway is the lack of sorting infrastructure. Massively increasing sorting capacity must therefore be the cornerstone of any strategy to achieve a zero-waste circular plastic economy. Today, just 16,000 tonnes of plastic (6% of the plastic waste collected) is sorted and brought to the only two MRFs or central sorting plants in Norway, which only accept mixed waste. Of the 99,000 tonnes (34%) of plastic waste sorted at source by consumers, businesses or industries (including beverage bottles from the deposit scheme), most is exported. The majority (60%) of the plastic waste collected from the 85% of the population which has access to source sortation but do not separate their plastic waste is incinerated with energy recovery – a total of 170,000 tonnes a year.

Our analysis shows that the development of a domestic sorting infrastructure is the most impactful lever to enable a zero-waste circular plastic system as it is the most effective way to divert plastic waste from waste-to-energy incineration to recycling. Under the System Change Scenario, up to 220,000 tonnes of plastic waste per year would need to be sorted. This corresponds to a 16-fold increase compared to 2019 levels. While ambitious, we believe that this increase is feasible as it meets economic, technical, logistical, and climate constraints. About half of this, an estimated 110,000 tonnes, could come from plastic waste sorted at source by consumers, businesses, or industries (including beverage bottles from the deposit scheme) and only require fine sorting. An additional 111,000 tonnes would be collected as mixed waste, either from parts of the country that do not have access to sortation at source or as waste that is not properly sorted, and would require both rough and fine sorting and thus different facilities.

Sorting at source is more efficient in theory as it eliminates a sorting step, but, source separation rates have been increasing very slowly, if at all.[31] While source separation from business will be regulated in the near future and therefore is expected to increase, achieving significantly higher rates of source separation from consumers is unlikely. As such, our System Change Scenario assumes only a moderate increase in source sortation (from 34% in 2019 to 40% in 2040), mostly driven by businesses. It is also important to consider that an inefficient source sortation system may lead to an inefficient hauling system and therefore a potentially higher cost burden. It also requires different types of MRF able to sort mixed waste and sorted waste. In addition, it is the prerogative of municipalities to decide waste management practices, potentially making it complex to make nationwide changes without top-down regulation. In a report recently published by Mepex, Norner, and Handelens Miljofond29, a switch to mixed waste collection is recommended, with the goal to centralise and harmonise sorting practices nationwide while offering reduced collection cost.

Achieving this ambitious target depends on two key enabling conditions:

- National and local governments incentivising the implementation of EU policies that support the development of sorting infrastructure to boost recycling, through financial incentives or mechanisms (e.g. virgin plastic tax or carbon tax), as well as potentially through new regulations that comply with EU legislation. Other forms of financial support, such as direct investment or low-rate loans, can also incentivise the growth of this sector.

Industry continuing to support the financing of such schemes through EPR regulations and committing to the higher use of recycled plastic content in their products to increase demand for recyclates and ensure MRFs have a proper market and profitable business models.

System Intervention #6: Scaling up mechanical recycling capacity by 10 times to over 100,000 tonnes to ensure resilience and traceability

Increasing Norway's mechanical recycling capacity will not necessarily lead to net economic, social or environmental benefits to the system. In fact, we assume that plastic that is not recycled in Norway is likely to find a recycling market overseas. However, our analysis shows the potential to increase the recycling capacity in Norway by up to 104,000 tonnes per year by 2040, and this development would provide with greater resilience and traceability.

In an environment where increasing regulatory pressure is pushing national governments around Europe to increase their recycling rates, the recycling industry will require significant scaling over the next years to be able to absorb additional supplies. Given the historically low profitability of mechanical recycling, these developments will probably not mobilise sufficient funding quickly enough, exposing Europe to the risk of a highly competitive recycling market. Building a domestic recycling industry would help Norway to mitigate this risk and create intrinsic resilience to ensure its recycling targets are met (and potentially increased). Technological limitations might exacerbate pressures for certain applications, especially when it comes to food grade recycling which is notoriously hard to achieve, particularly when it comes to post-consumer waste. But low hanging fruits exist, and the presence of a best-in-class deposit system for beverage bottles in Norway provides a great starting point.

Additionally, increasing domestic processing capacity will make traceability easier and reduce the risk of Norwegian waste being exposed to mismanaged, un-sound recycling practices abroad. The creation of a local recycling industry could also foster stronger collaboration between local players and result in higher levels of recycled plastic content being used in Norway.

However, the development of recycling capacity requires scale, which for some applications may require collaboration with neighbouring countries. As such, the creation of a recycling industry could be explored by Nordic countries as a joint strategy to efficiently secure their recycling commitments.

This system intervention will need the right enabling conditions to encourage private waste management companies to invest in Norway, for example:

- The national government needs to ensure more economic recycling to attract private sector investment. This could be achieved through benefit schemes for recycling plants; financial incentives for the use of recycled content and/or disincentives for the use of virgin materials; financial disincentives for plastic to be sent to waste-to-energy incineration (e.g. a waste-to-energy incineration tax or carbon tax); and ensuring that EPR fees contribute fairly to recycling operational expenditures.
- Industry and the financial sector need to map out the waste system to identify recycling stream opportunities and invest in missing technologies locally.

The successful implementation of this system intervention requires the implementation of System intervention #5 – increase sorting capacity.

31 Vi må gjenvinne mer plast. Slik skal vi få det til. - HMF (handelensmiljofond.no), 2021.

System Intervention #7: Invest in sorting and recycling innovation to burst through technological ceilings and unlock higher recycling rates

Current technologies are among the key limiting factors to increasing recycling rates above 50%. Specifically, the significant loss rates in the process (estimated at 35-55% depending on material and technology), limitations to feedstock tolerance (both in terms of polymer variety and contamination levels), and high processing costs all significantly limit the scale of recycling. Our analysis shows that any ambitious recycling target relies on technology improvements to push the boundaries of current manufacturing processes. Breaking the technological ceiling requires investing in and supporting innovations in both sorting and recycling processes, particularly those that improve the yields of sorting technologies (both rough and fine sorting) and the yields of recycling technologies (both mechanical recycling though washing and grinding and chemical conversion).

Promising innovations include using advanced spectroscopy, machine learning, digital markers for better traceability, advanced robots, and deep learning or artificial intelligence to better recognise polymers and products. In parallel, recyclers should invest in R&D to ensure constant improvements in their processes and decrease losses at each processing step.

Supporting this transition will require collaboration between all value chain actors from fast-moving consumer goods companies to waste management companies, from regulators to financial institutions, including:

- Strong investment support through grants to research programmes and technology entrepreneurs in the field to stimulate innovation.
- Private public partnerships to de-risk and accelerate the commercialisation and transfer of new technologies.
- Close collaboration with neighbouring European countries to leverage existing programmes and innovations, potentially through the creation of joint initiatives.

Photo by Masha Kotliarenko on Unsplash

System Intervention #8: Develop plastic-to-plastic chemical conversion locally to unlock recycling opportunities for materials that cannot be recycled mechanically and provide feedstock for food grade applications

Chemical conversion refers to any process which breaks down plastic into its chemical constituents (as opposed to mechanical recycling which does not alter the chemical structure of plastic during processing). Our analysis indicates the viable potential to build up a chemical conversion industry in Norway focused on naphtha production for plastic-to-plastic. Such an industry could emerge by 2025 and potentially process up to 36,000 tonnes of plastic raw material input by 2040, producing22,000 tonnes of feedstock for the plastic industry. Alternatively, Norway could collaborate with existing chemical conversion technology providers in neighbouring countries to support the development of these technologies.

Our analysis shows an economic opportunity for chemical conversion given its technically feasibility and economic potential, particularly for recycling food-contaminated products and in providing virgin-quality feedstock. Chemical conversion is synergetic, not competitive, with mechanical recycling as they use different feedstock. However, chemical conversion has significant downsides, including high energy consumption (impacting its overall life cycle analysis profile) and unproven product yields for different feedstock types and conditions. For these reasons, chemical conversion should not be treated as a "silver bullet" and should be scaled very cautiously. Mechanical recycling should be prioritised over chemical conversion as it has better economic and environmental impacts and is a more mature technology. However, there is a role for chemical conversion in a zero-waste circular plastic industry due to its potential to raise the technical recycling ceiling, especially with regards to food-grade plastic, and avoid the technical limitations of mechanical recycling due to inherent degradation process after several loops.

Overall, developing chemical conversion technologies would position Norway at the forefront of innovation. Conditions that could support this development include:

- Increasing financial flows toward mid- to industrial-scale pilots to de-risk the technology and create proof of concept.
- Ensuring the development of mass balance certification mechanism to verify claims of recycled content use given the complex chemical process.
- Reaching a sufficient scale to penetrate the naphtha market, which requires very large volumes to guarantee a steady supply of crackers.

This system intervention refers strictly to plastic-to-plastic chemical conversion. In our analysis, plastic-to-fuel chemical conversion is considered "disposal" not "recycling" as it merely increases the use of the material by one "loop" before it is burned as fuel.

System Intervention #9: Control the fate of plastic waste exported outside Norway to achieve a near-zero plastic pollution footprint.

While developing a plastic recycling trade is important to ensure that the use of recycled content becomes mainstream, the exports of plastic scraps both within and outside of the EU needs to be closely monitored. The Basel Convention, including the amendment signed in May 2019 that entered into force in 2021, classifies plastic as a hazardous waste when contaminated with other materials and not destined to be recycled in an environmentally sound manner, can be used as the basis of regulation in Norway. This will further reduce the risk of Norwegian plastic waste ending up in landfills in the EU or being mismanaged and leaked to the environment in the Global South.

System Intervention #10: Create an innovation fund to encourage, support and enhance innovation across the plastic value system

Taken together, the nine system interventions described above can have a massive impact on the Norwegian plastic system. And yet, achieving the vision of a zero-waste circular plastic economy in Norway will require technological advances, new business models, significant spending, and – most crucially – accelerated upstream innovation. This massive innovation scale-up requires a focused and well-funded R&D agenda, including moon-shot ambitions.

Innovation can unleash the System Change Scenario by making solutions more affordable, more scalable, and more convenient for consumers, while further reducing environmental and health impacts. The key areas that urgently require innovation include packaging-free alternatives, improved barrier properties for monomaterials or new materials that are bio-benign, design for recycling solutions for multimaterials, advanced/automated sorting (including digital watermarks), improved process efficiency and feedstock tolerance for mechanical recycling, and improved yields/lower energy requirements for chemical recycling.

.These advancements are unlikely to materialise without a significant, plastic-dedicated innovation fund(s) to encourage, support and enhance innovation – in Norway and beyond. This fund can channel investors towards the "valley of death" stage (the gap between developing innovations and their commercial application in the marketplace) by helping to rapidly transfer technologies out of labs and universities to achieve early commercialisation/implementation. This can be funded through philanthropy, impact investing, government grants, patient capital, non-diluted financing (e.g. grant and impact investing), and blended finance.

Raising ambitions: Even the System Change Scenario is not enough to create a decarbonised, Paris-aligned plastic system by mid-century

The System Change Scenario proposes a pathway to a circular plastic economy in Norway. But, while it reduces GHG emission by 25% by 2040 through dematerialisation and shifts from virgin to recycled content, this strategy is far from being aligned with the Paris Agreement, which Norway is a signatory of. Achieving the full decarbonisation of the Norwegian plastic system requires pulling levers well beyond the scope of our analysis, such as decarbonising Norway's electrical grid, decarbonising production and end of life processes through electrification and/or a shift to hydrogen, electrifying transportation, shifting to bio-based feedstocks, carbon capture and storage for flue gas, and more.

The Energy Transition Commission (ETC) estimates that the plastic sector can achieve up to 56% emission reductions by 2050 globally, and probably even more in developed economies such as Norway. According to the ETC, while energy efficiency can provide a moderate contribution, the decarbonisation of production processes is likely to contribute the majority of this emissions abatement through zero-carbon energy sources for high heat production (e.g. hydrogen, direct electrification, or biomass). The price of renewable energy and the technical feasibility of carbon capture storage technology are also going to be important factors in determining this pathway.

Decoupling the plastic industry from fossil-based feedstock is one of the key strategies, but requires ambitious target settings which are yet to be developed

There are three major types of feedstock for the plastic industry: (1) fossil-based feedstock (commonly referred to as virgin plastic); (2) bio-based feedstock; and (3) recycled-based feedstock, which can be derived from mechanical recycling or chemical conversion. As of today, it is estimated that about 3% of the feedstock in Norway comes from bio-based sources[32] and 5-10% comes from recycled content[33]. That means the vast majority of plastic (87-92%) is derived from fossil-based, virgin feedstock.

In our analysis, we have decoupled recycling rates from the use of recycled content in Norway because recycled content could have been recycled abroad and plastic recycled in Norway can be used abroad. In practice, this means that, while 41,000 tonnes of recyclates produced from Norwegian waste through closed loop recycling are available as recycled content, we estimate that only 15,000 – 30,000 tonnes are actually used as recycled content in Norway. The net difference can be attributed to activities overseas.

Exhibit 14 shows different possible feedstock pathways for the System Change Scenario. These pathways have been generated based on realistic targets but are not actual projections. Instead, they should be viewed as a sensitivity analysis or a nuanced view of feedstock under different future scenarios. It presents four future feedstock worlds (not to be confused with the scenarios analysed in Chapter 2):

- The "baseline" feedstock pathway assumes that bio-based feedstock and recycled-content increase to 10% and 25%, respectively, by 2040 (up from 3% and 5-10% today).
- The "bio-based world" feedstock pathway assumes that bio-based content will increase to 20% while recycled content increases to 25%.
- The "recycling world" feedstock pathway assumes that recycled content increases to 50% (40% from mechanical closed loop recycling and 10% from plastic-to-plastic chemical conversion) while bio-based content increases to 10%.

32 The Norwegian Environment Agency, Bio-based and Biodegradable Plastics (2018)
33 Estimated amount by Mepex expert team.

- The "new feedstock world" feedstock pathway – the most ambitious of all – assumes that recycled content increases to 50% and bio-based bio-based content increases to 20%.
- All six scenarios analysed in Chapter 2, including the System Change Scenario, assume the "baseline" feedstock pathways; they could all have a considerably greater reduction in GHG emissions if more ambitious changes to feedstock were made.
- While the System Change Scenario allows a reduction of GHG of 26% by 2040 (from 2 million tonnes of CO_{2eq} by 2040 under Business-As-Usual to 1.5 million tonnes of CO_{2eq} under the System Change Scenario), a deep change in feedstock to restrict virgin plastic to only 30% of the feedstock mix could deliver an additional 15% reduction (or 37% total reduction from Business-As-Usual), bringing the total GHG emissions from Norway's plastic industry down to 1.27 million tonnes of CO2eq by 2040. This analysis highlights the need for Norway to track and scale the use of bio-based and recycled content and integrate it into its national plan to support efforts across emissions mitigation, climate action, and advance a zero-waste circular plastic economy. The reduction of the use of virgin material in the feedstock mix is an important target for any Paris Agreement-aligned strategy.

EXHIBIT 14

Feedstock pathways for the System Change Scenario and associated GHG emissions by 2040

VIRGIN PLASTIC COULD REPRESENT ONLY 30% OF THE FEEDSTOCK IN A CIRCULAR SYSTEM BY 2040

Conclusion

The "Achieving Circularity" study highlights the fact that no silver bullet solution can create a zero-waste circular plastic economy in Norway, but rather a combination of interventions across the full plastics value chain. It also shows that, while all 10 system interventions under the System Change Scenario are important, reducing avoidable plastic consumption and scaling sorting capacity are the backbone of any circular plastic economy strategy. Similarly, our analysis confirms that recycling alone – no matter how ambitiously it is implemented – will not achieve Norway's economic, environmental and social goals given the objective technical limitations of this technology and the fact that many materials are not technically or economically recyclable. Our central message is that combining upstream interventions, such as reduction and design for recycling, with downstream interventions, such as enhancing sorting and recycling, is critical for success. A better plastic system in Norway relies on both more responsible plastic consumption and more responsible plastic waste management.

All stakeholders have a role to play. Achieving the ambitious changes envisioned under the System Change Scenario requires the government to incentivise more sustainable business models based on the reuse of materials and realign incentives that currently give virgin plastic feedstock an advantage over recycled secondary materials. They also need to enact ambitious policy measures across the plastics value chain to foster innovation. Industry needs to remove avoidable, single-use and hard-to-recycle plastic from the market, invest in material and business model innovation, and join with governments to help finance improved waste collection and sorting. Public-private collaborations are required to set standards on materials, formats, reuse, and recyclability. And the effective management of every step of this progress is essential.

While this study presents a diverse set of pathways representing different potential strategies for Norway's plastic system, we recognise that there are dozens of possible levers and system variables across this highly complex system. We therefore invite all stakeholders to test the open-access, dynamic scenario analysis tool that we developed in order to bring our model and wealth of data to your fingertips. Please try our Plastsimulator.

The goal of this study is to accelerate the transition to a **zero-waste circular plastic economy in Norway** by providing a first-of-its-kind, full-system model of the Norwegian plastic system that helps guide policymakers, industry executives, investors, and civil society representatives through the highly complex plastic landscape as they advance in their quest to achieve circularity in Norway.

Our hope is to help strengthen the dialogue between industry and the public sector, and ground it on scientific evidence and analytical rigour.

Complementing this study is an open access, online simulator tool **'Plastsimulator'** that enables stakeholders to create and test their own science-based scenarios and understand the economic, environmental and social impacts of different pathways, **try now**.

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