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NATURE HAS LIMITS

HOW TO REDUCE NORWAY'S MATERIAL FOOTPRINT

ACKNOWLEDGEMENTS

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WWF

WWF is one of the world's largest and most experienced independent conservation organizations, with over 5 million supporters and a global network active in more than 100 countries. WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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This report has been commissioned by WWF Norway and produced by Ernst & Young AS.

FOREWORD

The global production and consumption of Earth's natural resources, humanity's footprint, is the main driver of the climate, nature and pollution crises. We will not be able to solve any of these crises or secure our long-term livelihood, without reducing our footprint.

The global footprint needs to be reduced to a level where the environmental impact of our production and consumption does not risk the stability of natural processes; we need to operate within the planetary boundaries. Norway has a clear responsibility as a country with one of the highest per capita consumptions of natural resources. WWF Norway has estimated that Norway's material footprint must be reduced by at least two thirds to align our economy with the limits of our planet.

The need for a circular revolution is one of the key transformations necessary for achieving a significant reduction in our material footprint. A true circular economy will require a significant shift across society.

The objective of this report — commissioned by WWF Norway and conducted by EY teams — is to enhance the understanding of Norway's material footprint and how it is distributed across our economy. The objective was also to help pinpoint sectors and circular measures to implement that will be particularly important in reducing Norway's material footprint.

This report is one of the first to study Norway's material footprint on an economic sector level. It gives a unique insight into the Norwegian material footprint and the sectors' pressure on the planetary boundaries. The report presents a wide range of circular economy measures for each sector — focusing both on policy measures and business strategies — as well as offering some cross-sector recommendations. It also provides a deep dive into the construction and transportation sectors, showing the potential of implementing a few high-impact circular economy measures.

The findings and policy measures presented in this publication are based on the analysis and findings of the authors and do not necessarily reflect WWF Norway's own policy recommendations. The main purpose for WWF Norway was to acquire new knowledge and insight needed to help us direct policies and prioritize high-impact actions to reach the goal of reducing Norway's material footprint and increasing the pace toward a circular transition of the economy. If we are not able to transition the economy in a manner that contributes to a significant reduction of our material footprint, Norway will not be able to reach its environmental goals.

We hope this report and its findings will be useful for both policymakers and industry actors and inspire them to set ambitious targets, but not least – actions.

Karoline Andaur,
CEO, WWF Norway

ABOUT THIS REPORT

According to the International Resource Panel, material use has more than tripled over the past 50 years. Increasing resource use is the main driver for climate change, pollution and loss of biodiversity. Extraction and processing of material resources accounts for over 90% of impacts on land use-related biodiversity loss and water stress, over 55% of greenhouse gas emissions and up to 40% of air pollution representing a potential health hazard. Moreover, the extraction of many raw materials raises serious social and human rights concerns. The root of the problem lies in our outdated, linear economic model that treats raw materials as expendable inputs to be used once and then discarded. Solving the crisis requires a fundamental shift to a circular economy that minimizes virgin resource extraction by effectively utilizing materials already in use.

This study outlines the material footprint of Norway by addressing the quantity of materials used by the Norwegian economy, divided into four main categories — metals, non-metallic minerals, fossil fuels and biomass. Additionally, it looks at material-related impacts on the environment and seeks to map out the potential to reduce and minimize identified impact. The findings suggest that there is an extensive challenge at hand, which cannot be addressed through a single solution. Multiple solutions, ideas and informed contributions are required to address the complexity of the issue in a manner that will minimize adverse impact on the planet and world population. Its focus is not on the consumption of individual consumers but rather on the system in which they operate. Thus, this report intends to inspire and build a circular toolbox for decision-makers in governments and businesses, to be drawn upon with an eye to reducing the national material footprint and enhancing circular action. This is rooted in quantitative data on current consumption and impacts at the sector level.

This report also identified the current material consumption of Norway at the national and sector levels based on input-output modeling for eight sectors (agriculture, forestry and fishing, transportation, construction, chemicals and materials, energy and utilities, other manufacturing and sales, public services and other services). Input-output modeling is also used to determine the sectors' relative impact upon the environment, presented through the lens of the planetary boundaries framework, which identifies nine safety boundaries for the earth's major ecosystems. Next, circularity measures and policies to reduce the material footprint are identified at the sector level based on a review of existing literature. In addition, two of the sectors with high circularity potential (construction and transportation) are assessed using a scenario-based analysis to quantify the potential of some of the most impactful circularity measures. Finally, impactful cross-sectoral circular policy instruments are mapped to address the circular economy's innate cross-sector nature.

The modeling and literature analysis have been supplemented by interviews with experts in relevant fields, peer reviews and a panel discussion with various potential stakeholders. Achieving a circular economy depends on the involvement of a broad range of stakeholders, therefore non-profit organizations, industry organizations, public authorities and governments were invited to review, provide their perspectives, and inform the report content to ensure that it would best serve its purpose. This report is intended to inspire and serve as a toolbox for the circular transition of Norwegian society, but it is not definitive. Supporting this essential transition will require further investigation across multiple areas.

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“The science is clear: The key question is no longer whether a transformation toward global sustainable resource consumption and production is necessary, but how to make it happen now.”

UNEP, International Resource Panel (IRP)

EXECUTIVE SUMMARY

Norway is among the countries with the highest levels of raw material consumption per capita, well above European and global averages. There is a strong correlation between a high material footprint and severe negative environmental impacts upon the planetary boundaries. The per capita material footprint must be reduced by a staggering 70% to stay within sustainable levels of consumption. Norway can substantially reduce its footprint through collective action on the part of politicians, businesses and consumers supported by a comprehensive package of circular measures and policy instruments.

The greatest circular potential lies in the construction, transportation, manufacturing and agriculture, forestry and fishing sectors. Within these sectors, some of the most impactful measures include optimizing use of space in offices and housing, reducing the use and number of personal vehicles, circular product design, and switching to a more plant-based diet. Enacting transformative circular policies and measures that avoid resource use is essential to harness this potential (i.e., by prioritizing measures based on the 9R-hierarchy, as presented in section 2 of this report). This requires a cultural paradigm shift in living, traveling and consumption habits, redefining prosperity away from material accumulation and toward valuing intangible assets such as time, community and wellbeing.

The quantitative analysis reveals that Norway can achieve a 10% reduction in its material footprint through transformative measures in the construction and transportation sectors alone. These measures form the transformative shift scenario described in section 3. The construction sector can curb raw material extraction by avoiding new building construction, increasing area efficiency, extending building lifetime and reusing building components where possible.
The transportation sector can increase the attractiveness of shared mobility and public transport, and encourage the use of smaller, more efficient personal vehicles. The 10% reduction can only be realized through radical, disruptive measures, such as limiting both car ownership and the construction of new buildings. Less ambitious measures were found to have a significantly lower impact, underlining the importance of systemic change.

A national target for material resource consumption supported by a comprehensive suite of policy levers is imperative if we are to achieve the transition to a circular economy. Accountability is essential for driving progress toward a circular economy and a top-down approach with a national target is critical for aligning all stakeholders. To advance the transition toward a circular economy, the five following overarching policy recommendations were identified:

1. **Restrict linearity** by taxing and restricting market access to non-circular products.
2. **Finance circular economy** solutions through circular procurement practices, subsidies and increased green investments.
3. **Enable circular economy** by standardizing design and supporting sharing platforms.
4. **Measure and inform** through standardized circularity indicators and targets, mandated reporting and the incorporation of digital tools.
5. **Awaken and educate** people and society on the circular economy by incorporating circular economy principles into all educational systems and implementing informational campaigns.

A cohesive and combined set of policy interventions across all five areas is instrumental to the achievement of national circularity. The necessary societal transition presents an opportunity to maintain a high quality of life, where values such as sense of community and an appreciation of access to quality goods and experiences take precedence over mass consumption.

The results leave no room for ambiguity — there is a significant gap between current policies and the actions required to align Norway's resource use with planetary boundaries and safeguard the environment for current and future generations.

1. RESOURCE USE AND THE ENVIRONMENTAL CRISIS

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1. RESOURCE USE AND THE ENVIRONMENTAL CRISIS

1.1 OVERCONSUMPTION DRIVING UNSUSTAINABLE RESOURCE USE

Today, prosperity is frequently equated with consumption. The focus on consumption has driven the development of a global economic model that relentlessly extracts, utilizes, and discards resources at an accelerating rate. **As seen in the figure below, increasing consumption habits and global population growth have caused the total amount of raw materials consumed (material footprint) per year to triple over the past 50 years. This is a greater growth rate than the growth of human wellbeing as measured by the Human Development Index.**[1]

The extraction and processing of materials are currently responsible for 55% of global greenhouse gas emissions. Addressing the climate crisis is thus impossible without reducing material consumption.[2] Resource extraction and processing are also extremely water and land-intensive and are responsible for 90% of both biodiversity loss and water stress. These activities are also the main driving forces behind the unfolding nature crisis.[3]

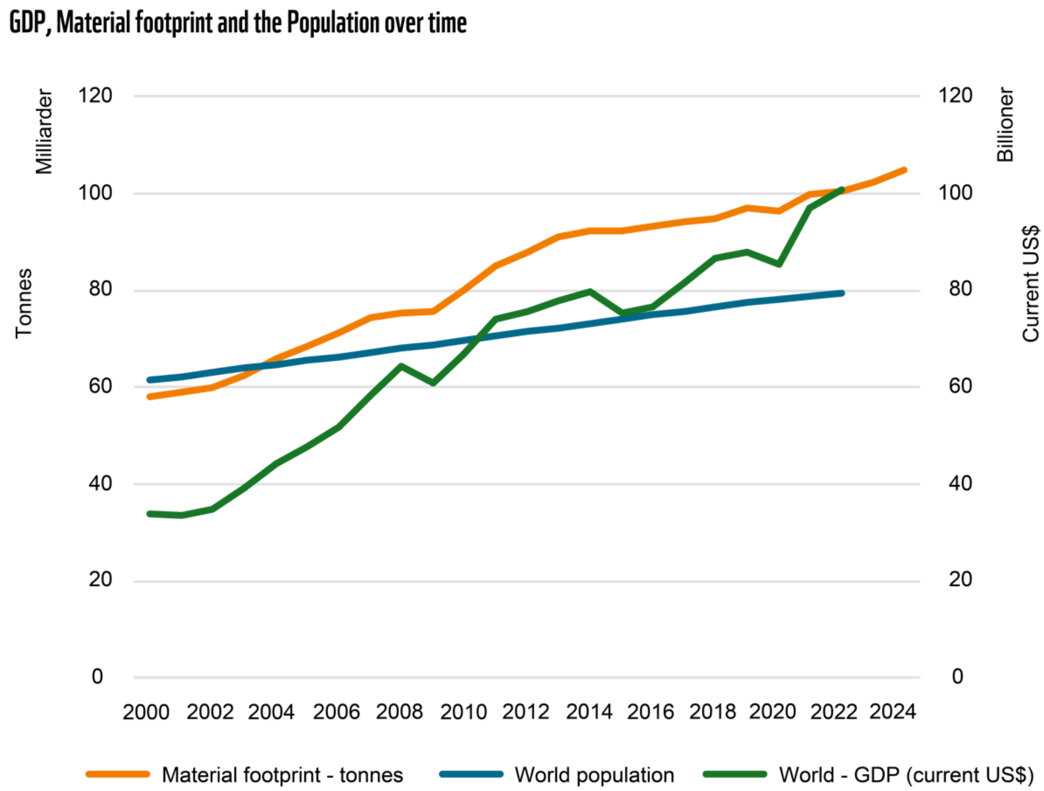

Figure 1: *Development of material footprint, gross domestic product (GDP) and population from 2001 to 2023. Data collected from International Resource Panel, the World Bank and SSB respectively.*

[1] (IRP; UNEP, 2024).
[2] (IRP; UNEP, 2024).
[3] (UNEP, 2019).

Current trends indicate continued unsustainable growth in use of resources

The Global Resources Outlook 2024 published by the UN's International Resource Panel predicts that the current level of material extraction will increase by 60% by 2060 at the current pace of development.[4] An extraction rate at this level will dramatically surpass the planet's capacity for resource regeneration, which has already exceeded safe levels.[5] In 2024, Earth Overshoot Day fell on August 1, four months earlier than it did in 1972.[6] As we approach a consumption rate that is double the replenishment rate, we are exhausting our resource base and access to fundamental necessities such as food and water.

1.2 CODE RED FOR EARTH'S LIFE SUPPORT SYSTEMS

Over billions of years, the Earth has developed many naturally self-regulating systems. These have maintained a state of relative stability, or equilibrium, that has allowed complex life and human civilization, to flourish. **Earth's self-regulating systems are a web of living and non-living systems, all of which are interconnected and mutually dependent. The failure of one system reduces the resilience of another.** These systems also help cycle resources such as carbon, nitrogen and water between living and non-living elements while keeping temperatures relatively constant. We are now disrupting many of these cycles. There are limits to the resilience of these systems, and when the resilience of a system is disrupted beyond these limits, recovery is rendered difficult, if not impossible.[7] **In essence, if humans continue with business as usual, a system collapse is inevitable.**

The planetary boundaries constitute a framework for assessment of multiple environmental limits

Since 2009, the Stockholm Resilience Centre has developed a framework called the planetary boundaries to calculate and visualize these limits. **The framework identifies thresholds for climate change, ocean acidification, stratospheric ozone depletion, biogeochemical flows (phosphorus and nitrogen), the rate of biodiversity loss, freshwater use, land-system change, aerosol loading and novel entities** (Figure 2). The thresholds mark the point beyond which there is a high risk of large-scale, abrupt, or irreversible environmental changes which can significantly damage ecosystems and threaten humanity.[8] Since 2009, there have been several revisions of the planetary boundaries, based on new studies filling key gaps in knowledge.
The most recent update of the framework found that the world has now crossed six out of nine planetary boundaries.

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[4] (IRP; UNEP, 2024).
[5] The point at which global resource consumption exceeds the Earth's ability to restore and renew its natural systems and resources.
[6] (Earth Overshoot Day, 2024).
[7] (Rockström, 2009).
[8] (Richardson, et al., 2023).

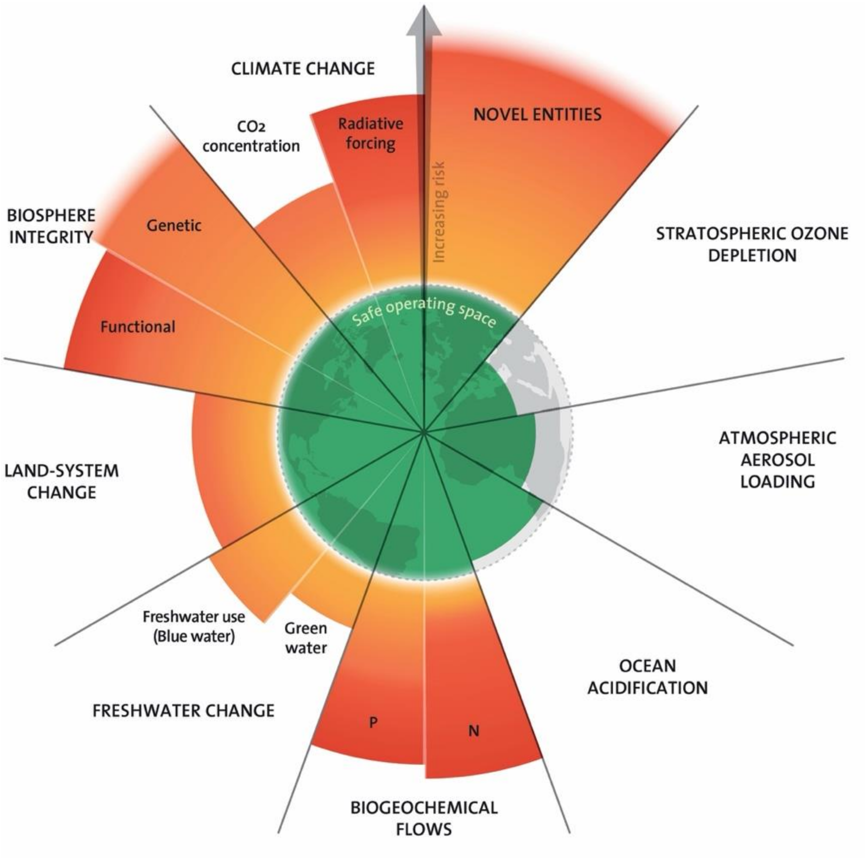

Figure 2: *The rose chart shows the nine planetary boundaries with today's level of activity and respective threshold. Credit: "Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023."*

Not only crossing the climate change boundary

The most well-known boundary is climate change. For millions of years, the concentration of carbon dioxide (CO_2) in the atmosphere has been relatively stable, as it is regulated by the carbon cycle, whereby carbon moves between the atmosphere, oceans, plants and soils. **Human actions are now disrupting this cycle by significantly increasing the levels of CO_2 in the atmosphere by burning fossil fuels, while simultaneously reducing the carbon capture capacity of natural systems through actions such as deforestation and degradation.**

The planetary boundaries show the other systems that are being destabilized by human activity. For example, the high level of CO_2 not only amplifies the greenhouse gas effect, but also contributes to ocean acidification and decreasing oceanic biodiversity. Humanity's consumption has led to a dramatically large degree of land-system change. **Of the 71% of land on Earth deemed "habitable," half is devoted to agriculture.** This comes at the expense of the local environment and biodiversity, while fertilizers and soil erosion disrupt biogeochemical flows.

(Esposito & Midgley, Bringing It Down To Earth: Nature Risk and Agriculture, 2021) (Rockström, 2009)

1.3 URGENT NEED FOR ACTION TO REDUCE THE MATERIAL FOOTPRINT

The current state of the planetary boundaries demonstrates that there is an urgent need to reduce human-made environmental impacts to restore the safe operating space of our planet. Lowering material consumption is an important means of reducing our impact on planetary boundaries. For instance, the consumption of meat requires production processes that contribute to land change, biodiversity loss, water use, increased use of fertilizers and the release of greenhouse gases. These affect the boundaries for biosphere integrity, land-system change, freshwater change, biogeochemical flows and climate change. The consumption of fossil fuels is directly tied to the climate change boundary, as the burning of fossil fuels releases CO_2 into the atmosphere.

The material footprint is a key metric of resource use

A common way of measuring material consumption is through the material footprint indicator, measured by raw material consumption (RMC). The measure accounts for all the material consumed in the entire value chain of goods and services up to the point of purchase by the final consumer. This metric links the final consumption in Norway to the amount of primary raw material extracted.

The material footprint is one of the indicators used by the European Union to track progress in the transition to a circular economy. The indicator was included in the revised EU monitoring framework for the circular economy adopted in 2023.[9] The same metric is used by the UN to measure progress against the Sustainable Development Goal 12 (Ensure sustainable consumption and production patterns).[10]

Urgent need for huge cuts in the material footprint in high-income countries

Globally, the material footprint is not evenly distributed among countries. High-income countries account for the majority of global consumption, with the average citizen in these nations consuming six times more material resources and representing 10 times the climate impact than a citizen of a low-income country.[11] This inequality can be seen in Figure 3, and therefore, high-income countries should take the lead in reducing their material footprint, as they have the greatest potential for significant reductions and the responsibility to contribute their fair share. This helps protect citizens of low-income countries, who may need to increase their material consumption to achieve an acceptable standard of living.

[9] (Dennis, 2023).
[10] (United Nations, 2023).
[11] (IRP; UNEP, 2024).

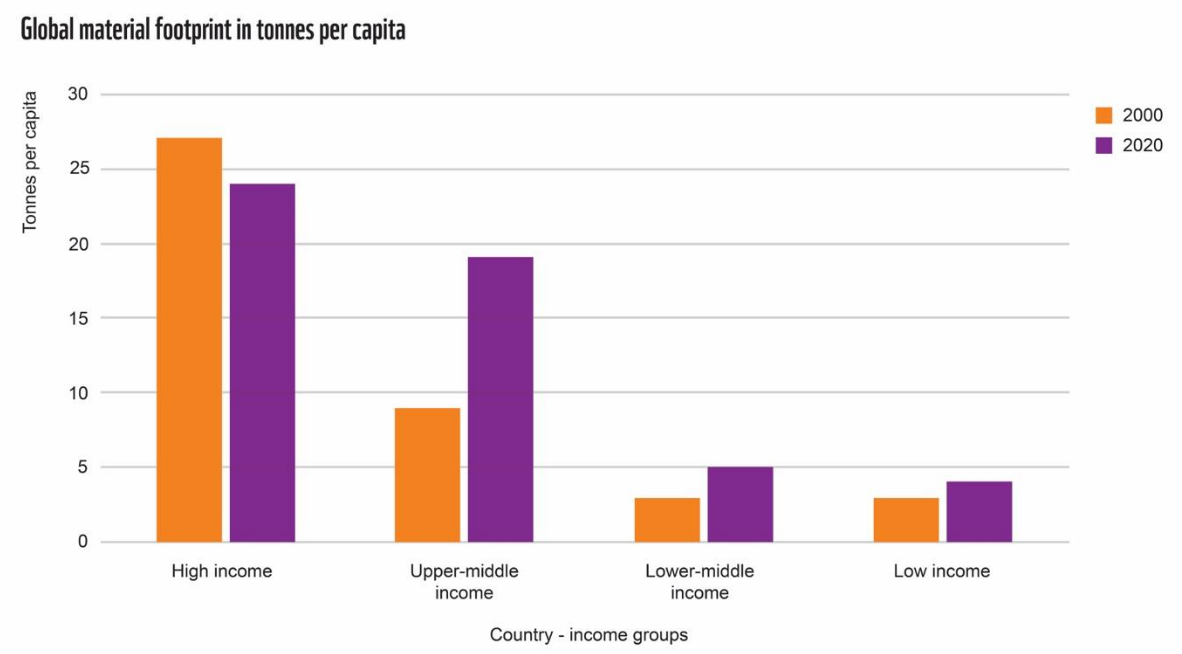

Figure 3: *The per capita material footprint per income country is sourced from Global Resource Outlook[12]. The tonnes per capita reflects the material footprint of the country divided by its population and not the average material footprint of individuals.*

1.4 A CIRCULAR ECONOMY – BALANCING ECONOMIC DEVELOPMENT WHILE LIMITING THE CONSUMPTION OF VIRGIN RESOURCES

Reducing the consumption of resources is crucial to alleviating the strain on the planet and enabling long-term societal prosperity. One way to achieve this, while securing societal wellbeing and the supply of goods and services, is to rethink how products are designed and used, and how needs can be satisfied through alternatives that go beyond buying and owning a product. Examples of such alternatives would be product sharing, extending product lifetime, and product repurposing at end of life. Such measures are called resource efficiency or circular economy measures.

A circular economy requires a transition away from the traditional linear economic model. This shift, which includes the adoption of circular economy measures and the reprioritization of needs, should not leave behind vulnerable members of society, such as low-income households. These members and their needs should be kept in mind in the adoption of policies.

It is also important to note that transitioning does not entail a reduction in quality of life; rather, it represents a new way to generate and access prosperity. The systemic changes required involve a decoupling of economic growth from excessive resource consumption. **The economy needs to shift away from the mass production of goods using raw materials and move toward the use of shared, quality goods.** Traditionally, national progress has been measured by GDP, but there is a growing global consensus that alternative measures should be considered. For instance, New Zealand has introduced a national measure of wellbeing.[13]

[12] (IRP; UNEP, 2024).
[13] (New Zeland Treasury, 2024).

Defining a circular economy – more than efficiency

The circular economy can be defined in many ways, but at its core, it is about more efficient resource use, a move from linear to circular consumption and a reduction in material consumption. WWF defines a sustainable circular economy as a regenerative system, driven by renewable energy that replaces the current linear “take-make-dispose” industrial model. Instead, materials are maintained in the economy and resources are shared, while waste and negative impacts are minimized. A sustainable circular economy, supported by an alternative growth and consumption narrative, should function within the planetary boundaries while creating environmental and society-wide benefits.

It is important to note that efficiency is only one part of the circular economy. A potential pitfall of overreliance on efficiency is what is known as the Jevon paradox, whereby increased efficiency leads to increased demand and consequently to increased consumption. It is, therefore, important to note that a true circular economy should reduce both overall material consumption, and the extraction of new virgin raw materials.

This concept is underpinned by a transition to renewable energy and materials, creating a more resilient system that is good for business, people and the environment.[14]

The 9R framework for resource efficiency

The circular economy encompasses a wide array of strategies and initiatives, resulting in a need for a structured framework to categorize and prioritize these approaches. As depicted in Figure 4, on the next page, **the 9R framework presents a clear hierarchical structure of circular strategies that minimize waste and effectively utilize resources throughout a product’s life cycle.**[15] The framework assigns a rank to these strategies, ranging from 0 to 9, with the highest priority assigned to lower numbered strategies, as these aim to avoid resource use altogether. **Simply put, decreasing the amount of product made or not making the product at all is more effective in reducing material and energy consumption than reforming existing products.** The framework is used internationally, including by the European Union, to standardize the classification of circularity measures and has also been incorporated into this report.[16]

[14] (WWF, 2020).
[15] (The European Commision, 2020).
[16] (European Comission, 2020a).

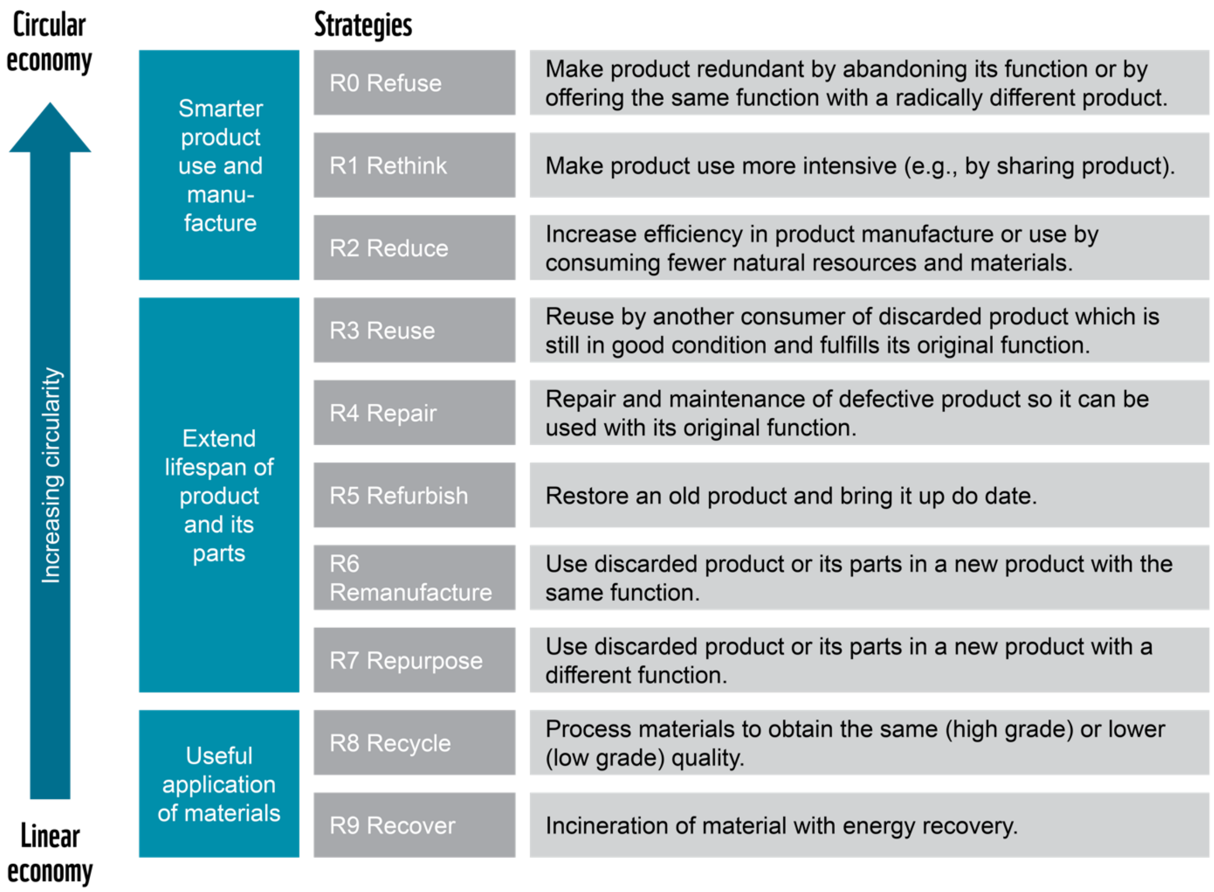

Figure 4: *Depiction of the 9R framework[17] and its circular strategies. The framework ranks strategies from 0 to 9, where low numbers indicate a high degree of circularity and circularity degree declines as one moves to higher numbered circular strategies.*

Smarter product use and manufacturing based on the R0-R2 strategies have the greatest potential to create a more circular economy. R0 Refuse focuses on abandoning certain products altogether or offering the same product in a radically different way, such as train travel as opposed to air travel. R1 Rethink is about using a product more intensively, for instance through the sharing of cars, clothes and other goods. R2 Reduce focuses on increasing efficiency when producing or consuming a product, such as by using refillable containers instead of single-use containers. Some of these changes are being facilitated by technological developments. For example, sharing models for businesses are being enabled by the widespread adoption of smartphones and the connectivity of the internet, allowing for more convenient tracking and the sharing of product availability.

The R3 to R7 strategies focus on keeping products and parts in use as long as possible. Following the logic of the hierarchy, the reuse of products and parts (R3) should be prioritized over repurposing (R7) where possible, since reuse does not involve any additional material consumption.

[17] (Kirchherr, Reike, & Hekkert, 2017).

Finally, the R8 and R9 strategies that focus on the end-of-life stage of products emphasize the effective processing and utilization of materials to reduce waste and conserve resources. By optimizing the life cycle of materials and redirecting them away from landfills, these strategies help reduce material demand and the overall environmental impact.

A circular economy offers a significant potential for reducing the material footprint

The Global Resource Outlook 2024 found that resource efficiency can reduce the world's dependence on virgin resources by more than 20%.[18] However, there is a major gap between circular potential and actual circular action. The global circularity rate currently stands at 7.2%, having decreased by 20% over the past six years.[19] The decrease can largely be attributed to growing material consumption coupled with a lag in the development toward circularity. Thus, action from all stakeholders is needed to shift the trend toward a society based on sustainable resource consumption.

A circular economy is a strategic response to resource scarcity

A circular economy is not only a societal model that would reduce impact on the planet, but also a way to ensure long-term access to resources. In recent years, decision-makers have recognized the urgency of addressing the finite nature of our planet's resources; as evidenced by fluctuating commodity prices and constrained material access. This is exemplified by the European Commission's Act on the critical raw materials, which was announced in 2022 as a measure toward meeting its 2030 climate and digital objectives.[19] The act aims to combat supply chain challenges and reduce the union's dependency on material imports.

To prioritize circular measures effectively, it is essential to understand the drivers behind the material footprint

The following sections contain the results from a series of analyses conducted to assess Norway's material footprint and related environmental impact at a sector level, thereby **identifying the most resource-intensive and environmentally harmful economic activities in Norway, enabling the assessment of effective circular measures.** Norway's material footprint and associated impacts on planetary boundaries are identified based on environmentally extended input-output modeling (EEIO). EEIO links material consumption and the associated impact on planetary boundaries to activities in the economy.

[18] (European Comission, 2022).
[19] (European Comission, 2022).

Input-output analysis using EXIOBASE

This study uses the environmentally extended multiregional input-output (EE-MRIO) database, EXIOBASE, to determine Norway's material footprint and its impact on the planetary boundaries at a national and sector level.

Environmentally extended input-output (EEIO) analysis is a method that combines economic input-output models with environmental data to assess the environmental impacts associated with economic activities and consumption patterns. EEIO analysis tracks the flow of goods, services and resources throughout the economy, and accounts for their associated environmental impacts throughout the value chain, up to the point of final consumption. EEIO models incorporate data on economic transactions between industry sectors along with information on the environmental impacts, such as energy use, water consumption and greenhouse gas emissions, linked to those transactions. This analysis makes it possible to use this data to track, describe and analyze the material consumption and environmental impacts of the different sectors.

The data EXIOBASE builds upon comes in large part from the "supply and use"

tables of individual countries, which contain economic data on the different goods and services that are produced, traded and consumed within each country. EXIOBASE disaggregates this data and links it to other countries, producing a global, multi-regional "supply-use table" which shows how goods and services move across borders, on a global scale.

Additionally, EXIOBASE relies on and builds upon data about the resources needed to produce and supply different goods and services. This includes resources such as the type and amount of raw materials, energy and water needed throughout each product and service's value chain. This data comes from life cycle inventory datasets and input-output tables.

EXIOBASE data may diverge from official national statistics, especially for trade-dependent small countries. Another limitation is the varying degree of detail within different economic sectors, which can make it difficult to determine which activities are found within a sector and to review a specific activity.

See Methodology for a more thorough description of the method, EXIOBASE and limitations.[21]

[20] (Kitzes, 2013).

2. NORWAY'S MATERIAL FOOTPRINT AND ENVIRONMENTAL IMPACT

Alamy

2. NORWAY'S MATERIAL FOOTPRINT AND ENVIRONMENTAL IMPACT

2.1 NORWAY'S MATERIAL CONSUMPTION AND ITS ENVIRONMENTAL IMPACT

Norway has one of the highest levels of material consumption per capita in the world, with a material footprint (Raw Material Consumption, RMC) estimated at 127 million tonnes annually.[21] With a population of approximately 5.4 million, this translates to an average material consumption per capita of 23.5 tonnes.[22] By comparison, in 2020, the EU's average consumption per capita stood at 14 tonnes,[23] which means that Norway's per capita consumption is almost 70% greater than that of the EU. In this report, "per capita" refers to the total value of a given measure within a country divided by its population, and therefore, does not necessarily represent each individual citizen's direct contribution to a given measure. For example, the material footprint per capita of Norway includes the material consumption from all sectors, including industry and the public sector, and not just private households.

Both Norway and the EU must still make significant strides in order to reach sustainable levels of consumption. In 2014, the International Resource Panel (IRP) recommended limiting raw material consumption to a range of six to eight tonnes per capita by 2050.[24] This range is supported by O'Neill et al.'s (2018) article, which identified a global sustainable limit for material footprint of 7.2 tonnes per capita.[25] **Considering Norway's current per capita consumption, this implies that a reduction of approximately 70% is necessary**, as seen in Figure 5, to achieve sustainability targets. A shift toward a more circular economy will be instrumental in making this transition.

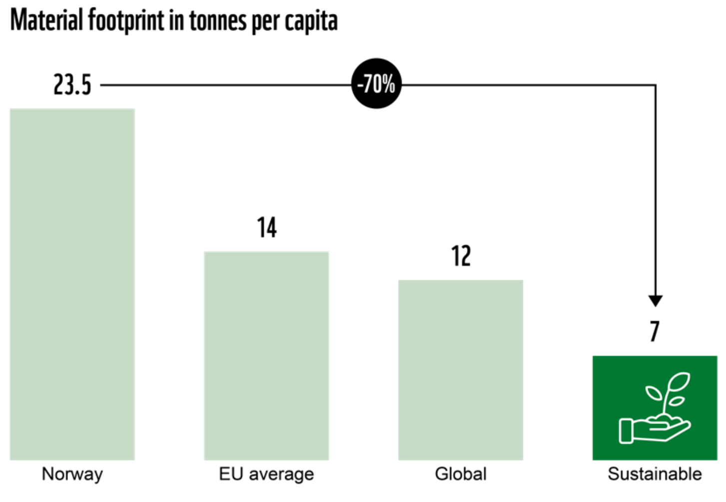

Figure 5: *The bar chart shows Norway's material footprint per capita compared to EU average, global and sustainable material footprint levels, raw material consumption (RMC) in tonnes.*

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[21] From the EEIO modeling, 2019-2022 average, RMC.
[22] RMC.
[23] (Eurostat, 2023b).
[24] (IRP; UNEP, 2014).
[25] (O'Neill, Fanning, Lamb, & Steinberger, 2018).

As illustrated in Figure 6, Norway's material footprint can be divided into four aggregated material categories: metals, non-metallic minerals, fossil fuels and biomass. Additionally, there are traditionally two ways of viewing material footprint: either accounting for used materials only or by including unused materials displaced during extraction. The used material footprint refers to extracted materials directly utilized to produce a product or supply a service, thereby entering the economic system. Unused materials include any resources displaced or disturbed during production that do not enter the economic system, such as agricultural harvesting losses, by-catch from fishing and overburden materials from mining.

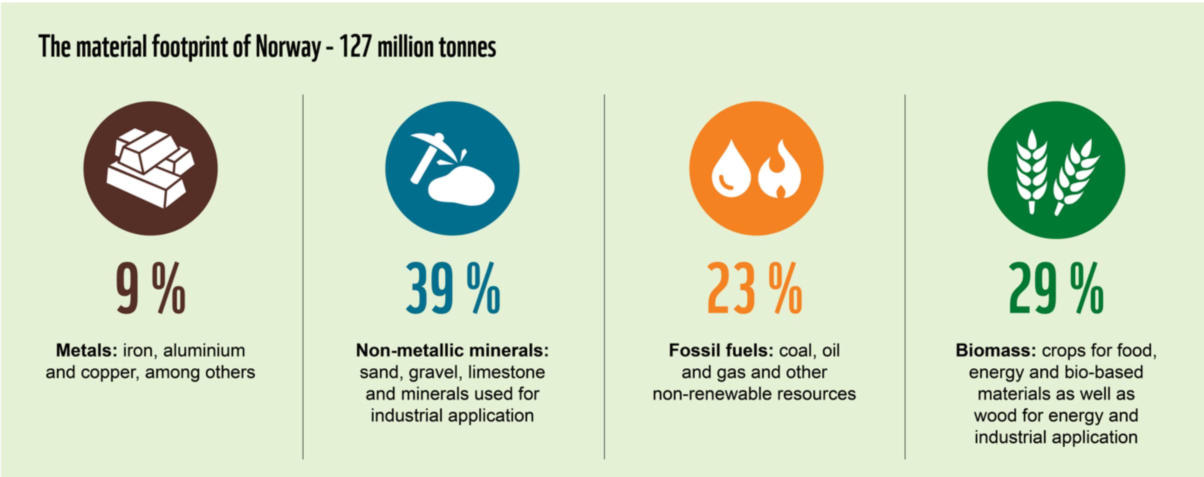

***Figure 6:** This shows the material footprint of Norway distributed by material group, (RMC).*

RMC accounts for used material extraction, while total material consumption (TMC) includes both used and unused extractions. TMC provides a more comprehensive picture of overall environmental impact and better reflects how material extraction influences planetary boundaries. For this study, RMC has been deemed to be a more appropriate measure of resource usage for two key reasons.[26] Firstly, data on unused material extraction is often either poorly recorded or omitted, meaning unused material extraction estimates carry a great deal of uncertainty,[27] which would lessen the certainty of any analysis. Secondly, by including unused extractions in its calculations, TMC complicates the issue of comparing materials with varying degrees of environmental impact. See the Methodology and Appendices for more information about the material footprint indicator and unused material footprint data.

[26] (Kovanda, 2020).
[27] (Stadler K. W.-J., 2018).

As shown in Figure 7, the material footprint reflects the quantity of materials needed to produce goods and services demanded by end users in Norway, irrespective of where the material extraction and production occur. This way of calculating impact represents the consumption-based approach*.* As opposed to the traditional official inventory, which only includes emissions occurring within Norway's territory, the consumption-based approach, provides a more comprehensive understanding of the environmental impact for which Norwegian consumers are responsible. It is important to note that goods and services that are exported from Norway and consumed abroad are not accounted for in Norway's material footprint. This means that most of the raw materials and associated environmental impact from the Norwegian petroleum sector are not accounted for in Norway's material footprint, given that most fossil fuels are exported and consumed abroad.

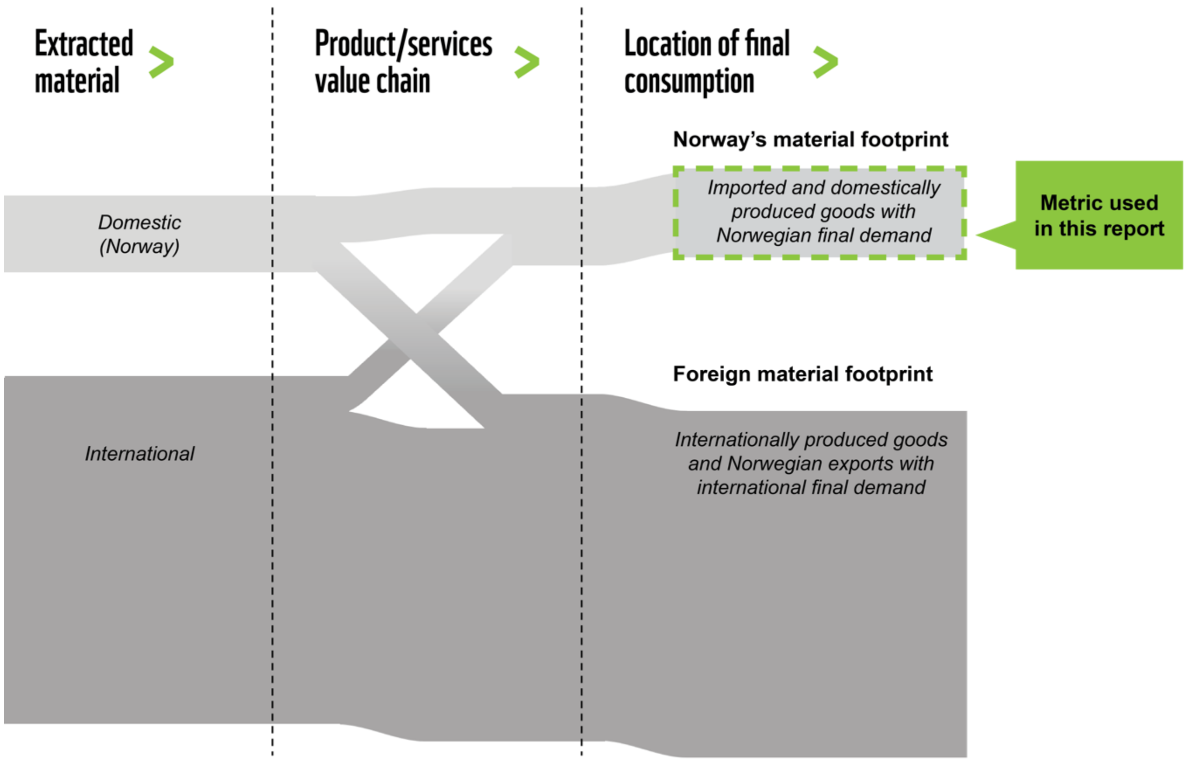

Figure 7: *This figure illustrates the factors that determine the goods and services accounted for in Norway's material footprint. The crossing of domestic and international material flows represents the various ways in which the value chains of goods and services move in and out of Norway. This includes exports (part of the flow from domestic to international markets) and imports (part of the flow from international to domestic markets). Note that the width of the flows is not to scale for illustrative purposes; Norway's consumption is approximately 0.1% of the world's raw material consumption.* [28]

[28] Calculations based on Norway's (WWF, 2022) and global (Eurostat, 2024) material consumption for 2021.

2.2 THE ECONOMIC SECTORS' MATERIAL FOOTPRINTS AND IMPACTS ON PLANETARY BOUNDARIES

Looking at each sector individually can offer a better understanding of the key drivers of material consumption and their impact on planetary boundaries, thereby enabling more focused actions and better cross-sectoral strategies. **This report has identified the material footprint and associated environmental impacts based on environmentally extended input-output modeling (EEIO) from EXIOBASE.** To provide a meaningful sector analysis, EXIOBASE's hundreds of sector activities have been aggregated into eight high-level sectors, through a sector classification. Table1 provides a short description of each of the eight sectors. EXIOBASE also has a high number of available environmental impact categories. Nine of these were chosen to assess Norway's impact on planetary boundaries. For more detailed information about the sector classification process, the activities included in the aggregated sectors, the translation of environmental impact categories into planetary boundaries and limitations, see Methodology and Appendix A and B.

	DESCRIPTION OF THE SECTORS
	Agriculture, forestry and fishing: The agriculture, forestry and fishing sector involves the production, processing, marketing and distribution of plant and animal-based products for human consumption and use. This sector also extends to the production of food and beverages.
	Construction: The construction sector is responsible for the planning, designing and building of physical structures such as homes, commercial buildings, roads and bridges.
	Other services: The other services sector comprises a wide array of non-manufacturing industries such as retail, hospitality, finance and entertainment. These industries provide services rather than tangible goods, and they play a vital role in growing the economy and creating employment opportunities.
	Transportation: The transportation sector encompasses all types of vehicles and services used to transport people and goods from one location to another. This includes airlines, railways, shipping companies, lorry firms, logistics providers and public transit. This sector does not account for the construction of transportation infrastructure. This is included in the construction sector.
	Energy and utilities: The energy and utilities sector includes companies that produce, distribute and sell energy products like oil, gas, electric power and water.
	Other manufacturing and sales: The other manufacturing and sales sector involves the production of goods on a large-scale using machinery and the subsequent selling of these goods to consumers and businesses. This sector encompasses a broad range of industries, from electronics to clothing.
	Chemicals and materials: The chemicals and materials sector encompasses the production and distribution of a wide range of substances, including plastics, metals, rubber and various chemical compounds. This sector also extends to the mining of coal, metal ores and other minerals.
	Public services: The public services sector encompasses government-operated services, institutions and agencies, providing a wide range of services to the public, such as health care, education, defense and social welfare. This sector is funded through public money, including taxes and government loans, and plays a crucial role in the administration and regulation of a country's infrastructure and resources.

Table 1: *The eight sectors assessed in this study.*

Norway's material footprint and its related impact on planetary boundaries varies across the different sectors of the economy, as demonstrated in Figure 8 and Figure 9. EEIO links material consumption and associated environmental impact to different economic activities, which opens for an analysis at the sector level.

Material footprint is an important metric to consider when assessing Norway's environmental impact; however, it is not without its limitations. The material footprint aggregates the various materials used in the economy, distinguishing between only four main material categories: metals, non-metallic minerals, fossil fuels and biomass. Hence, it does not distinguish between various subcategories, in which different materials used could have a larger or lesser planetary impact. For example, although the contributions of a tonne of grass and a tonne of meat to planetary boundaries are different and unique, the two would fall under the same category and add the same amount of material consumption. Similarly, the metric does not distinguish between the renewable and the non-renewable, biotic and abiotic, or scarce and abundant resources.

However, the material footprint is still an invaluable tool for the transition toward a circular economy, particularly when one understands how best to use it. The benefits of the material footprint include its standardized measurement methods and the relative ease of data recording, and the metric has been widely used by international actors such as the International Resources Panel (IRP) and the European Union when measuring resource efficiency. Additionally, there is a strong correlation between humanity's consumption of goods and the amount of resources extracted, which is closely linked to humanity's environmental impact.[29] **As the demand for new products increases, more materials must be extracted, leading to greater human activity and environmental disturbance (straining the planetary boundaries).**[30]

Material footprint and planetary boundaries

The role each sector plays within Norway's pressure on the planetary boundaries adds a valuable dimension to the analysis. This is why this report looks at both material footprint and the planetary boundaries jointly. The report aims to provide insight into the environmental impacts caused by material consumption within the different sectors. By identifying which sectors place the greatest strain on specific planetary boundaries, more targeted solutions and policies can be developed for the shift toward an economy within the planetary boundaries.

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[29] (Steinmann, et al., 2017).
[30] (IRP; UNEP, 2019).

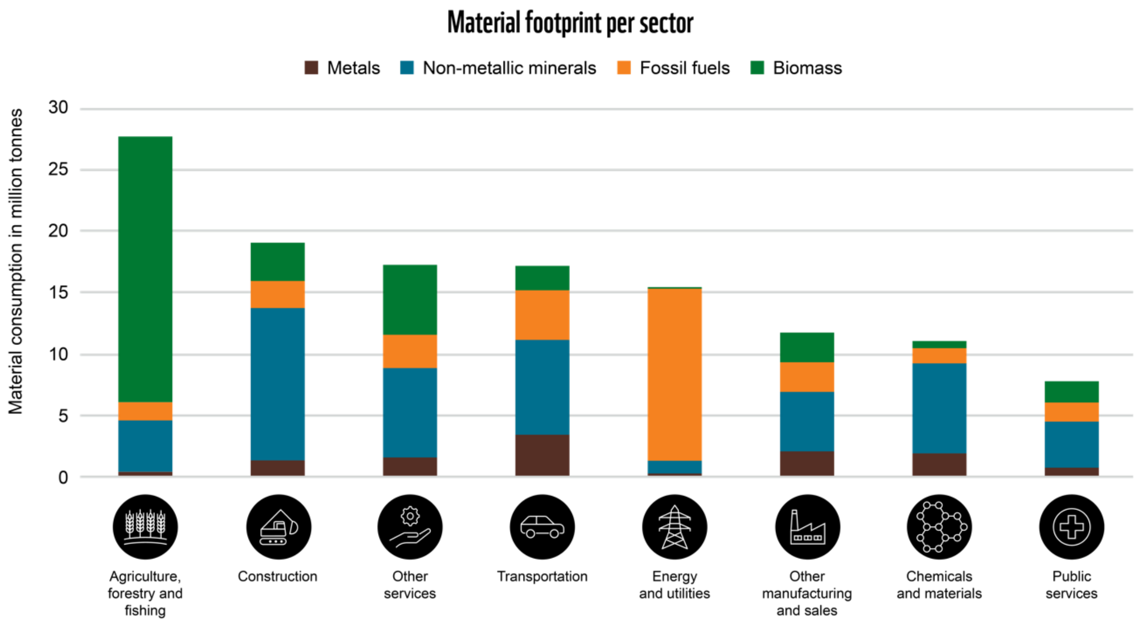

Figure 8: *The bar chart depicts Norway's material footprint (RMC), per sector and material category, in million tonnes. This accounts for Norway's total 127 million tonnes RMC.*

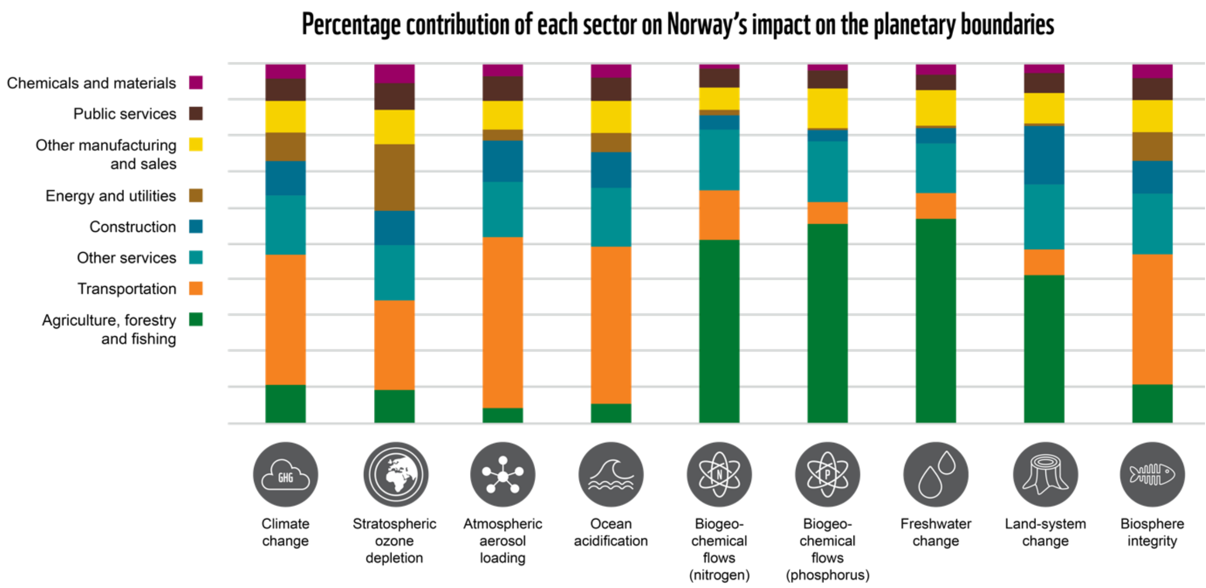

Figure 9: *The bar chart depicts each sector's respective proportion of Norway's total impact on the different planetary boundaries.*

Figure 8 shows the distribution of material consumption across sectors. The agriculture, forestry and fishing sector has the largest material footprint and is the largest consumer of biomass. Similarly, the transportation sector is the largest consumer of metal, the construction sector of non-metallic minerals and the energy and utilities sector of fossil fuels. The agriculture, forestry and fishing sector's large biomass consumption is reflected in its high impact on the planetary boundaries, particularly on biogeochemical flows, freshwater change and land-system change, as seen in Figure 9. While the transportation sector also places a significant strain on the environment, it does so via completely different planetary boundaries, reflecting the distinct material consumption patterns of each sector.

How to interpret the planetary boundary charts

The above graph illustrates the proportion of Norway's total impact that each sector has on the different planetary boundaries. The pressure of each sector on the different planetary boundaries is presented as a percentage; Norway's total impact on each of the planetary boundaries is the sum of all sectoral impacts.

The graph provides insights, for each of the boundaries, on which sectors exert the largest impact, and therefore which should be prioritized to reduce Norway's overall impact most effectively. For example, the agriculture, forestry and fishing sector bears the largest responsibility for Norway's impact on the boundaries of biochemical flows. Additionally, the planetary boundary chart complements the material footprint metrics by providing more context for how each sector impacts the environment.

While assessing the findings, it is important to note that this report does not quantify specific planetary boundary thresholds for each sector. The assessment regarding how much Norway, or the world, should reduce its impact on the various boundaries is beyond the scope of this report. Moreover, due to the nature of the boundaries representing distinct environmental limits, neither this graph nor this report aims to rank or compare the planetary boundaries. While material consumption results in impacts on the planetary boundaries, a reduction in the material consumption for a sector will not necessarily result in a proportional reduction in impact on the planetary boundaries.

Notably, the planetary boundary of novel entities has not been included in the graph, as this study found there to be a lack of sufficient data to accurately account for the numerous different novel entities and their diverse impacts. However, this report recognizes its importance and has attempted to address the matter where applicable. More detailed information about how the relative impacts were calculated and which impact categories were used to represent each planetary boundary are included in the Methodology and Appendix A.

Sector analysis

In the remainder of this section, the material footprint and impact on planetary boundaries are broken down and discussed for all sectors. This is done to fully elucidate the drivers, opportunities and potential for reducing the footprint. In addition, the circular potential is assessed by evaluating the availability of effective circular measures within the sector and assessing the extent to which the environmental footprint occurs abroad during the extraction or production of a product or service. The recommended policy measures were identified by focusing on subcategories representing significant contributions to the sectors' material footprints. It should be noted that policy tables are not exhaustive, and while some specific policies may be applicable, their main purpose is to show the realm of possibilities when it comes to enacting change. Next, literature reviews on circular economy within each sector and subsector were used to identify policies that would increase circularity and reduce material consumption. Reviews and input from subject matter experts and relevant stakeholders were used to ensure that the policy recommendations address the most critical areas and barriers to circular action within each sector. The analysis is meant to inform policymakers and industry when evaluating which measures and policies can contribute to a more circular economy. In Section 3, the impact of promising circular measures in the construction and transportation sectors is quantified. These sectors were chosen based on a combination of the sectors' material footprint, relative impact on the planetary boundaries and a qualitative assessment of their circular potential.

The sectors analyzed in this report vary in terms of maturity, data availability and prevalence in the literature. This variation is reflected in the level of depth and standardization of the information provided at the sector level.

Figure 10: *Sector classification; subsectors included in the sector.*

AGRICULTURE, FORESTRY AND FISHING

– Sector impact and high-level circular potential

Sector activities

The agriculture, forestry and fishing sector involves activities such as crop cultivation, pastoral farming, forest management, aquaculture, and the harvesting of fish and other aquatic organisms. This sector includes products sold to end users from producers within agriculture, forestry and fishing, including food and beverages. For example, in forestry, this includes wood for private use, but not wood used as construction material, as this is covered in the construction sector.

Material footprint – largest consumer of biomass

The agriculture, forestry and fishing sector has a significant material footprint as it requires various inputs to grow, feed, and harvest produce, as well as for processing the latter into final products. This sector's material footprint **accounts for one-fifth of the national footprint, with biomass making up the majority of the sector's material footprint.** The large share of biomass is primarily linked to the consumption of food and beverages. **The material footprint** encompasses **the entire value chain,** from farming to sales, necessitating a variety of materials such as metals for machinery, fossil fuels and non-metallic minerals for fertilizers.

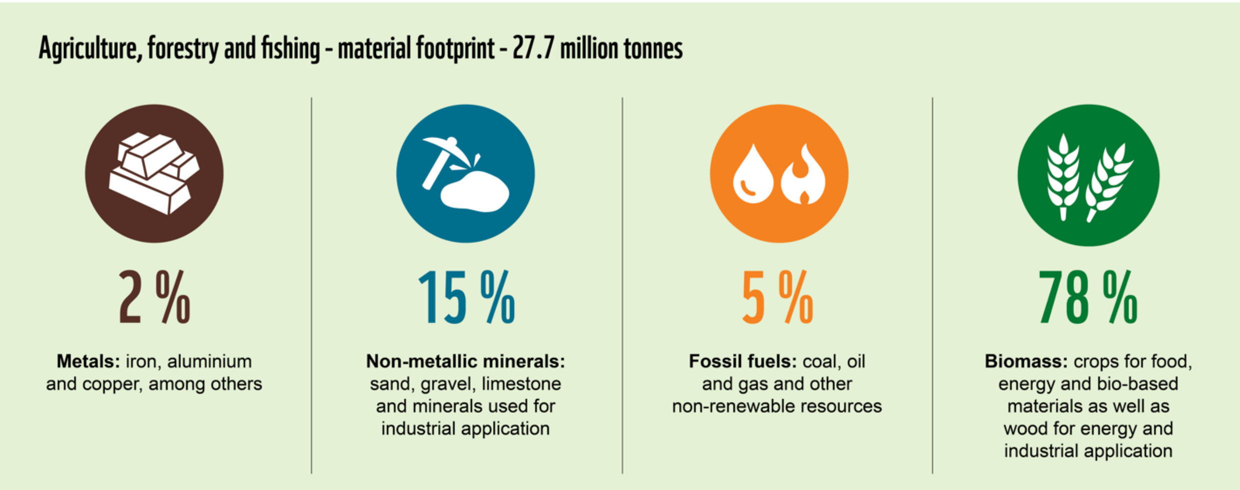

Figure 11: *This table shows the distribution of the sector's material footprint (RMC).*

Planetary boundary – biggest impact of any sector upon land-system change, freshwater and biogeochemical flows

The production, harvesting and consumption of biomass have significant planetary impacts, making agriculture **one of the largest contributors to biodiversity loss on a global scale.**[31] Most of the world's productive land is now dedicated to food production, with agricultural land area of 4.79 billion hectares exceeding that of the world's forests at 4.05 billion hectares.[32] In Norway, approximately 3.5% of the total land area is used for agriculture. Of Norway's agricultural land, 33% is used for arable farming and 67% for grazing and animal feed.[33]

[31] (UNEP, 2024)
[32] (Breakdown of habitable land area, World, 2019, 2019)
[33] (NIBIO, 2024).

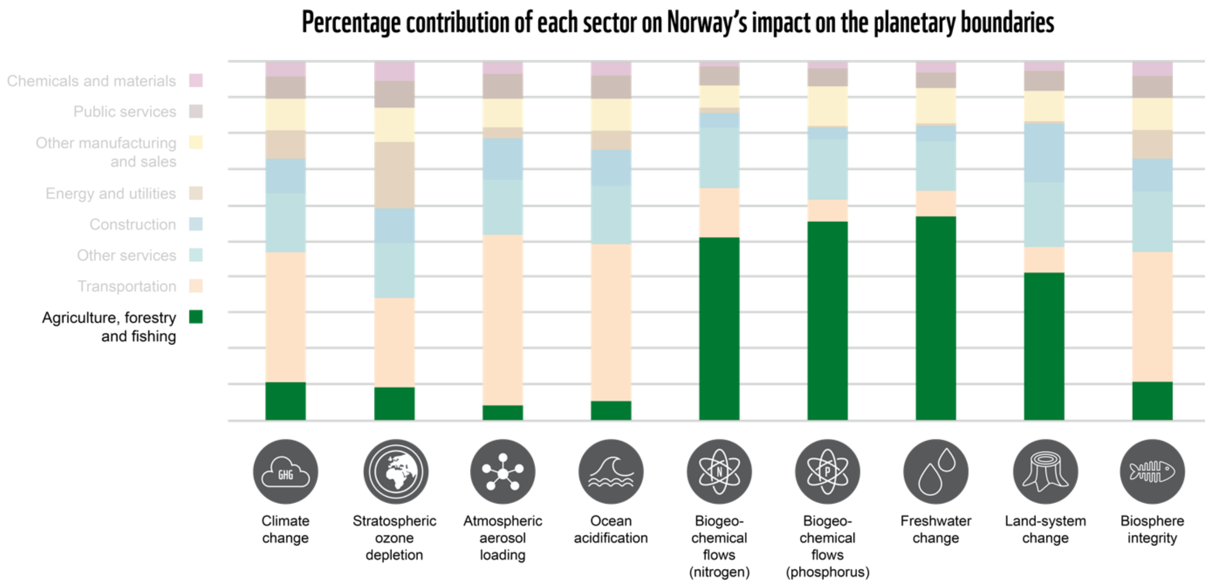

Figure 12: *The bar chart shows the percentage of Norway's total impact each sector has on the different planetary boundaries.*

Fertilizers are widely used to enhance plant growth in most agricultural systems. However, overuse of synthetic fertilizers and spreading of animal manure are the key drivers of eutrophication and degraded water quality, impacting nitrogen and phosphorus biogeochemical flows.

The irrigation and processing of food and fiber products also require significant volumes of water, making this sector **the largest consumer of freshwater.** In some instances, this can potentially contribute to local water stress or impact river systems.[34] Ammonia pollution can create dead zones in aquatic habitats.[35]

Domestic and international influence – Norway's self-sufficiency is at 46%, and with a large export category within the sector, it can impact the footprint outside its borders

The material footprint and its relative impact on the planetary boundaries suggest a significant opportunity for action on the part of businesses and politicians. However, it is crucial to identify where Norway can exert the greatest influence on transition to a circular economy. As of today, **Norway is approximately 46% self-sufficient in food,** slightly lower when accounting for animal feed (i.e., soy and corn).[36] Thus, consumption in this sector stems from both domestic production and imports.

The largest food import category, measured in monetary value, includes animal feed and food products like fruits, nuts and flour.[37] Notably, the sector is the second most significant export category in Norway, primarily consisting of fish and other aquaculture products.[38] The impact on Norwegian ecosystems originating from the production and harvesting of exported fish and other

[34] (Oldertrøen, 2022).
[35] (ESA, 2023).
[36] (Svennerud, Smedshaug, Rustad, & Finci, 2023).
[37] (SSB, 2024d).
[38] (SSB, 2024d).

aquaculture products, as well as from imported feed for the aquaculture sector, is not included in Figure 11, because exported fish is consumed outside Norway and thus not part of Norway's material footprint. **The extensive export volume means that the sector can significantly impact material footprints beyond Norway's borders.**

In Norway, 32.3% of the area is covered by forests.[39] Norway is an exporter of timber; of the 11.5 million cubic meters of timber cut down in 2022, more than 4 million cubic meters were exported.[40] Most of the production forests are intensively managed, consisting primarily of planted monocultures of spruce or pine, with clear cutting as the main harvesting method. This intensive forestry practice is a major threat to the forest-dwelling species listed as endangered in Norway.[41] There is considerable potential for Norway to implement effective nature protection initiatives, set standards, and control excessive material consumption within its forest sector.

Circularity potential – Significant circularity potential for the agriculture, forestry, and fishing sector by eliminating food waste throughout the value chain

The consumption of food and beverages is identified as the most significant contributor to the sector's material footprint and impact on planetary boundaries. Therefore, measures aimed at reducing the material footprint in this area should be prioritized. In 2021, **Norway's food waste was measured at 450,000 tonnes,** equivalent to around 900 million meals, enough to feed the country's population for six months. It is estimated that **this food waste could potentially be reduced by 75%.**[42] This estimate includes both food waste (occurring at the end of the supply chain, such as with consumers or retailers) and food loss (happening earlier in the chain, such as during production or transportation). The agriculture industry experiences significant food loss throughout the supply chain, from harvesting to transportation and storage.

The national diet can also be a key factor in reducing the use of fertilizer, pesticides and land use. For example, producing 100 grams of beef requires on average more than 150 m^2 of farmland a year, while producing the same amount of protein with peas requires on average less than 4 m^2.[43] Similarly, the climate footprint of protein from plants (e.g., legumes and nuts) is roughly one-tenth of that of red meat (e.g., beef and lamb).[44] According to Nordic Nutrition Recommendations, Norwegians currently consume 55% more meat than recommended.[45]

Targeting agricultural practices can also potentially reduce the industry's impact. This includes tools, machinery and vehicles used throughout the value chain, which could reduce their material consumption through electrification. In addition, selecting what is grown, what fertilizers are used and how raw materials are processed can contribute to further reductions in material consumption, although these can be highly context dependent.

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[39] (NIBIO, 2024).
[40] (SSB, 2022b) (SSB, 2023b).
[41] (Svensson, 2021)
[42] (Matsvinnutvalget, 2023).
[43] (Poore & Namecek, 2018).
[44] (Miljødirektoratet, 2020).
[45] (Klimautvalget 2050, 2023), (WWF, 2024).

	EXAMPLE POLICY MEASURES	BUSINESS STRATEGIES
SMARTER PRODUCT USE AND MANUFACTURE (R0-2)	• Encourage reduced production and consumption of red meat (e.g., tax red meat and remove the tax-free status on red meat). • Stimulate plant-based production (e.g., set up a fund for vegetables and fruit production). • Revise dietary advice taking planetary boundaries into consideration. • Stimulate regenerative farming (e.g., organic fertilizer, crop rotation and variation). • Remove VAT on donated food and vegetables. • Eliminate food waste (e.g., forbid supermarkets from discarding unsold food). • Promote local and seasonal food systems. • Review and, where relevant, update current practices on food date stamps. • Require companies to have food waste plans.	• Increase attractiveness of planetary health diet (e.g., plant- and microbial-based nutrition). • Increase utilization of produce (e.g., alternative use of "ugly fruits and vegetables" that might otherwise be discarded). • Increase resource efficiency in agriculture through precision agriculture (e.g., sensors, drones). • Donate and reduce prices on soon-to-expire products. • Create other food products out of nearly expired food (e.g., fishcakes out of raw fish). • Reduce food waste at retailer (e.g., improve food demand forecasting). • Minimize food loss in supply chain (e.g., better harvesting techniques, transportation solutions). • Enable consumers to reduce food waste at home (e.g., smaller sizes). • Avoid sales strategies that encourage overstocking. • Implement predictive inventory management systems to help minimize waste.
EXTEND LIFESPAN OF PRODUCT AND ITS PARTS (R3-7)		• Reduce food loss through improved storage capacity and quality to extend lifespan of products. • Use all parts of animals and plants (e.g., excess fish byproducts in nutrients supplements and pharmaceutical applications, fertilizers).
USEFUL APPLICATION OF MATERIAL (R8-9)	• Stimulate restoration of organic agricultural soil. • Promote composting, including broader anerobic digesters, by implementing and improving on necessary infrastructure and collection systems. • Provide guidance on how to reduce waste and how best to sort biowaste.	• Excess byproducts of food waste, agriculture, forestry and fishing can serve as feedstock for other industries (e.g., bioenergy).

Table 2: *Circular economy strategies presented according to their place in the R strategies framework. The policy examples are not exhaustive but considered important levers for increasing the circularity of the sector.*[46]

[46] (WWF, 2023) (Willett, et al., 2019) (Miljødirektoratet, 2024a) (Matsvinnutvalget, 2023) (Ellen MacArthur Foundation, 2024b) (Klima- og miljødepartemantet, 2020) (European Comission, 2020b) (WWF, 2023) (Shephard, 2021) (Ellen MacArthur Foundation, 2021c) (Jahren, Nørstebøe, Simas, & Wiebe , 2020).

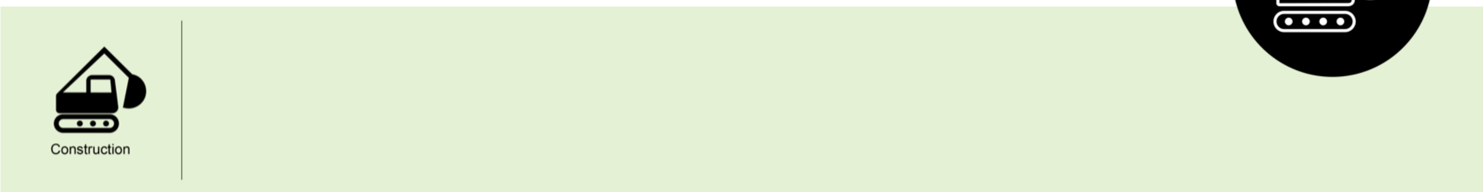

Figure 13: *Sector classification; subsectors included in the sector.*

CONSTRUCTION

– Sector impact and high-level circular potential

Sector activities

The construction sector encompasses the planning, designing and building of physical structures, such as homes, commercial buildings, roads and civil engineering projects.

EXIOBASE data looks at construction as an end-user product. This means that construction activities involved at an earlier stage in a product or service's value chain may not be classified under this sector and are instead accounted for in the sector for the final end-user product.

Material footprint — the second largest material consumption sector in Norway

The construction sector has **the second greatest material footprint in Norway** due to its heavy dependence on raw material extraction to supply materials for the construction of buildings and infrastructure. **Non-metallic minerals comprise a significant portion of the material footprint of the sector.** Non-metallic minerals are mostly composed of aggregates, such as sand, gravel and crushed stone, utilized in a range of activities, such as road building or as the main components of concrete. This analysis does not account for unused materials, such as excess from digging and construction, meaning the material footprint is even larger. This is particularly relevant for civil engineering projects, such as tunnels and roads, which often require the displacement of large quantities of minerals.

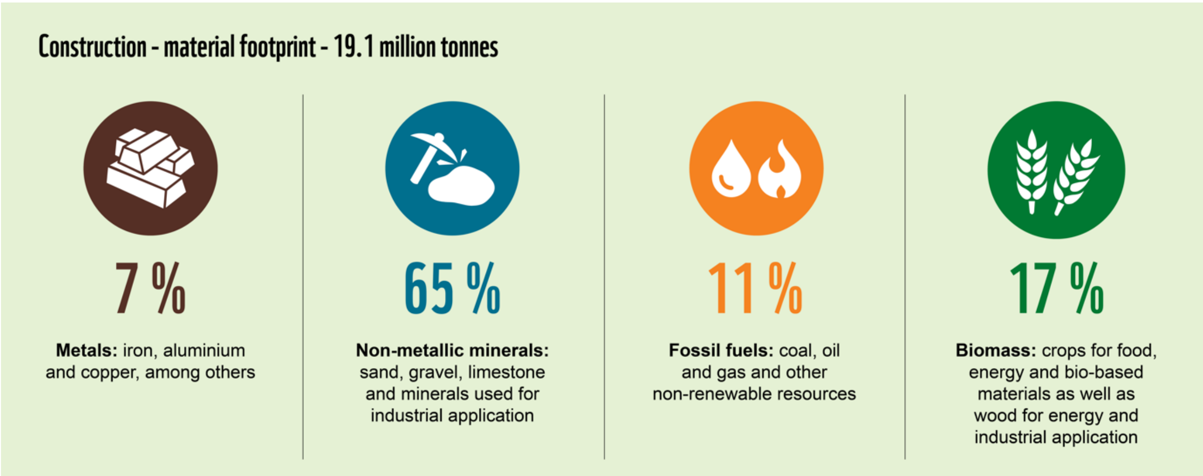

Figure 14: *This table shows the distribution of the sector's material footprint (RMC).*

Planetary boundary — most notable impact on land-system change, an inherent aspect of all construction activities

Compared to the significant size of material consumption, the sector's relative impact on planetary boundaries is smaller. However, the sector's most substantial influence, as seen in Figure 15, is on **land-system change, ocean acidification and atmospheric aerosol loading.** Land-system change is an inherent aspect of all construction activities, as any project typically involves altering land masses. This impact is particularly pronounced in new construction projects. In Norway, housing construction represented 40% of all the land converted between 2008 and 2019, a quarter of which was for recreational purposes, such as cottages and cabins.[47] The changes in the landscape and environment can have severe impacts on sensitive natural habitats, such as when marshlands are drained for development. **Land use change and habitat loss are the biggest threats to biodiversity in Norway,** and this impact is compounded by the release of large volumes of greenhouse gases.

[47] (SSB, 2022a).

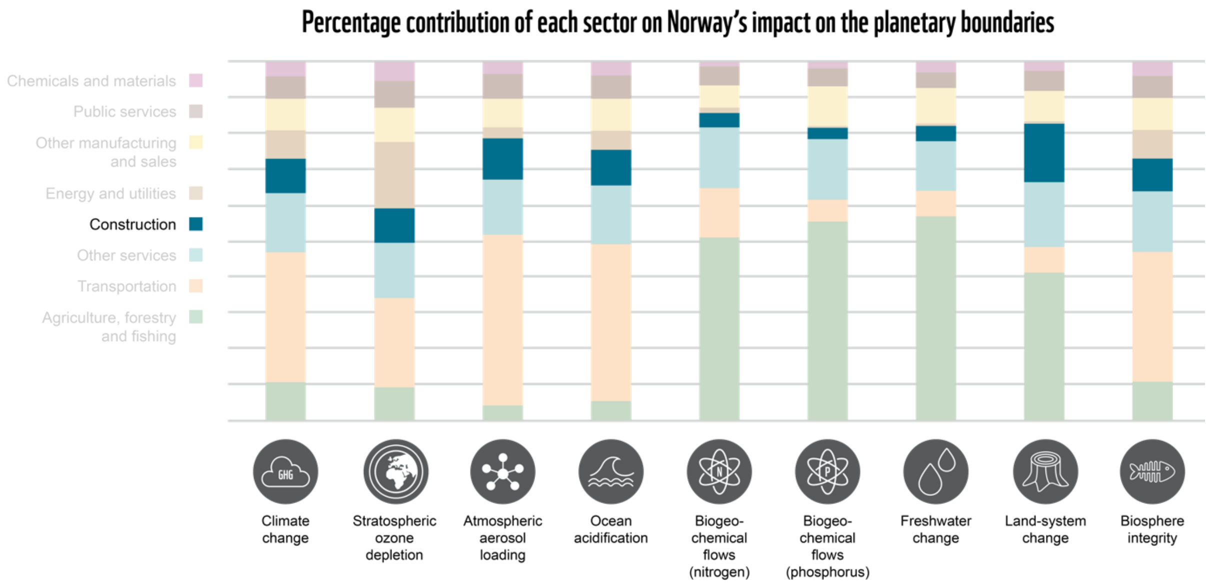

Figure 15: *The bar chart shows the percentage of Norway's total impact each sector has on the different planetary boundaries.*

Domestic and international influence — domestic control is limited to the planning and execution phase

Norway relies on many imported materials for construction purposes, resulting in a substantial portion of sector-related emissions originating from abroad. Concrete represents roughly one-third of Norway's material usage in construction and is a significant import category.[48] [49] Globally, one-half of steel production is consumed by the construction sector, and metal represents one of the largest import categories in Norway.[50] Norway can introduce restrictions on new construction projects and on construction on undeveloped land. One measure could involve establishing strict restrictions on the conversion of nature, such as area neutrality, within each municipality. Furthering the cooperation and communication between municipalities and construction companies is essential to align a shared understanding of transition goals and strategies.[51] This would **promote area-efficient construction and building management.**

Circularity potential — rethinking use of building area would significantly impact the material footprint of the sector

The construction sector has significant potential for increasing circularity, both by improving the efficiency of building area to reduce the demand for new construction and by adopting circularity measures in construction processes. The latter can be achieved by advancing sustainable design practices.

Building placement and design are crucial. Using building-information-modeling (BIM), which integrates sustainability factors, can be impactful. Building area efficiency rates, the amount of space used for an activity, can be improved by adopting circular business models, such as sharing models. Another means of increasing the efficiency of building space is through

[48] (Byggevareindustrien, u.d.).
[49] (SSB, 2024d).
[50] (Distribution of steel end-usage worldwide in 2022, 2024).
[51] (Byggenæringens Landsforening, 2022).

designing for multipurpose use. One example of this is using office canteens as restaurants at night. There are several potential solutions and relevant initiatives, which can be specific to the type of building and the activities within it.

Beyond the efficiency of buildings, measures that prolong the lifespan of buildings would reduce the required frequency of new construction, which in turn would reduce the material footprint. This can be achieved through material choices, renovation and refurbishment of aged buildings.

While as outlined above, the number of construction projects can be decreased to reduce material consumption, there is also strong potential for improving how such construction is carried out. One-quarter of total waste generated in Norway in 2021 came from construction, making it the largest single source of waste. At the construction site, key circular strategies include **reusing components, recycling cement and minimizing structural cement usage**. There is potential for improvement via logistical solutions, material planning and the design of components and buildings. Cooperation between architects, construction companies and their suppliers can yield customized, efficient material solutions and reduce waste stemming from misunderstandings and logistical errors. To facilitate tracking of waste generation and alignment with goals and regulations, one initiative is to increase the level of detail and impose stricter standardization and digitalization requirements in waste plans for new construction projects.[52] Construction companies can be incentivized to reduce their waste through fines targeting excess material consumption and waste generation. Improved planning can increase recycled material rates, which can serve as feedstocks for new buildings. Some of the policies related to construction presented in Table 3 are explored in greater detail within the deep dive section (Section 3.3.1).

[52] (Multiconsult, 2023).

	EXAMPLE POLICY MEASURES	BUSINESS STRATEGIES
SMARTER PRODUCT USE AND MANUFACTURE (R0-2)	• Encourage nature protection through tax incentives (e.g., a nature tax on land use and nature degradation). • Stimulate circular collaboration across value chain (e.g., with architects, engineers, contractors, suppliers, etc.). • Facilitate circular business models such as digital rental platforms (e.g., rental of private recreational residences). • Incentivize landscaping and urban planning to support local ecosystems. • Set requirements for the percentage of recycled materials used in new construction projects. • Stimulate material efficiency (e.g., material-efficient structural forms and techniques) through material-specific price incentives. • Encourage sustainable design practices (e.g., BIM). • Cap construction on undeveloped land by setting limits on the total area that can be developed per year in municipalities. • Base taxation rates partially on area efficiency.	• Adapt the use of buildings to meet demand (e.g., less demand for office space, increased demand for housing). • Increase area efficiency by designing co-living spaces, such as shared accommodations. • Improve utilization of building areas by transforming existing spaces into multipurpose areas. • Avoid building in sensitive areas. • Increase building utilization by creating multi-use spaces (e.g., versatile/ flexible/movable internal walls). • Provide shared space solutions (e.g., office space, terraces). • Design for disassembly to ease reuse of components (e.g., modular design, material record of a building). • Design for longevity (e.g., future climate adaptability and resilience). • Use a new generation of materials (e.g., 3D printing, biomimicry). • Increase use of recycled materials.
EXTEND LIFESPAN OF PRODUCT AND ITS PARTS (R3-7)	• Incentivize the use of long-lasting building materials and products. • Expand waste plan for construction processes to further prioritize reduction, reuse and recycling. • Incentivize and increase the competitiveness of marketplace for used materials. • Encourage sustainable procurement through the support of digital platforms for material passports and databases, as well as tariff rate systems.	• Extend the lifetime of buildings by post-phoning demolition through structural maintenance practices (e.g., design for durability, perform regular maintenance, monitor and assess condition). • Use life cycle assessment and digital tools to track material usage and life cycle management of buildings.
USEFUL APPLICATION OF MATERIAL (R8-9)	• Establish an extended producer responsibility scheme. • Stimulate the recycling of materials and increased recycled content in new products. • Review and, where relevant, set penalties for excessive construction waste.	• Incinerate material for energy generation. • Implement recycling practices for cement.

Table 3: *Circular economy strategies presented according to their place in the R strategies framework. The policy examples are not exhaustive but considered important levers for increasing circularity of the sector.*[53]

[53] (Høibye & Sand , 2018) (EEA, 2022a) (Miljødirektoratet, 2024a) (WWF, 2023) (Klimautvalget 2050, 2023) (ARUP; Ellen MacArthur Foundation, 2022).

Figure 16: *Sector classification; subsectors included in the sector.*

OTHER SERVICES

– Sector impact and high-level circular potential

Sector activities

The other services sector includes a wide range of non-manufacturing industries, such as hospitality, financial services, recreational activities and entertainment. These industries commonly provide services rather than tangible goods, yet they consume a significant quantity of materials in supplying these services. For example, the sector includes restaurants, and their consumption of food, biomass and other materials contributes to the sector's footprint.

Material consumption — hotels and restaurants consume large amounts of biomass

The other services sector has the third largest material footprint in Norway, after the agriculture, forestry and fishing sector, and the construction sector, with hotels and restaurants being the largest contributors to material consumption. **Most of the footprint in these subsectors comes from their high consumption of food and beverages,** with food waste posing a challenge for both restaurants and hotels. Other subsectors that contribute significantly to material consumption include the real estate services, the recreational services and the cultural and sporting services. Real estate activities, often linked to the material-intensive maintenance and refurbishment of buildings, also add to the sector's overall material footprint.

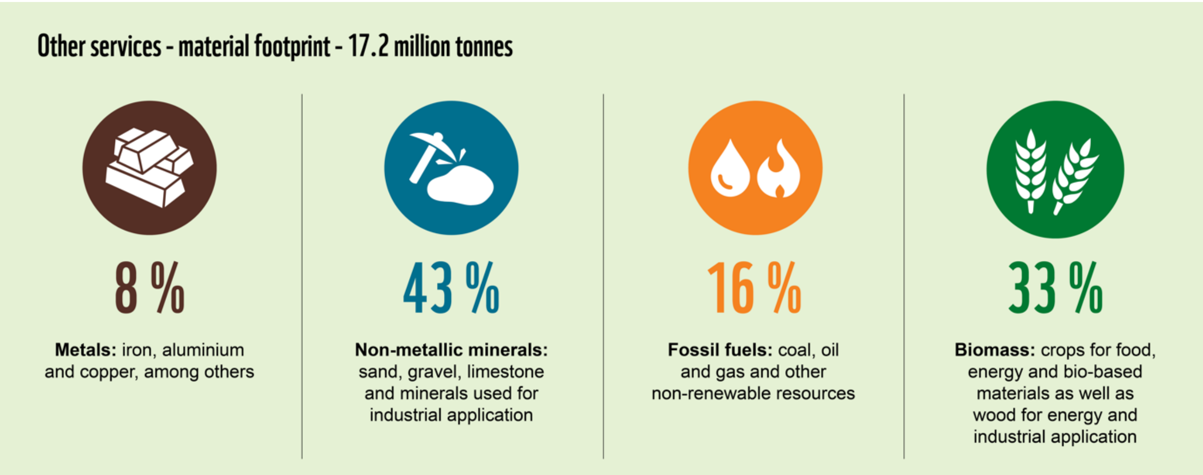

Figure 17: *This table shows the distribution of the sector's material footprint (RMC).*

Planetary boundaries — other services exert a substantial impact on multiple planetary boundaries

Overall, the other services sector **significantly impacts all planetary boundary dimensions** (Figure 18). The sector's relative impact is evident when considering the various subsectors and the wide array of service deliveries. An important aspect of the other services sector is its significant influence on both economic activity and employment. The hospitality sub-sector emerges as a notable contributor to both employment and planetary boundary impacts, driven by substantial resource consumption, including land and food, as well as associated emissions. Other important sub-sectors, such as recreational, cultural and sporting services contribute to the overall impact, particularly in key areas like ecosystem damage caused by land use and the production of necessary equipment and products.

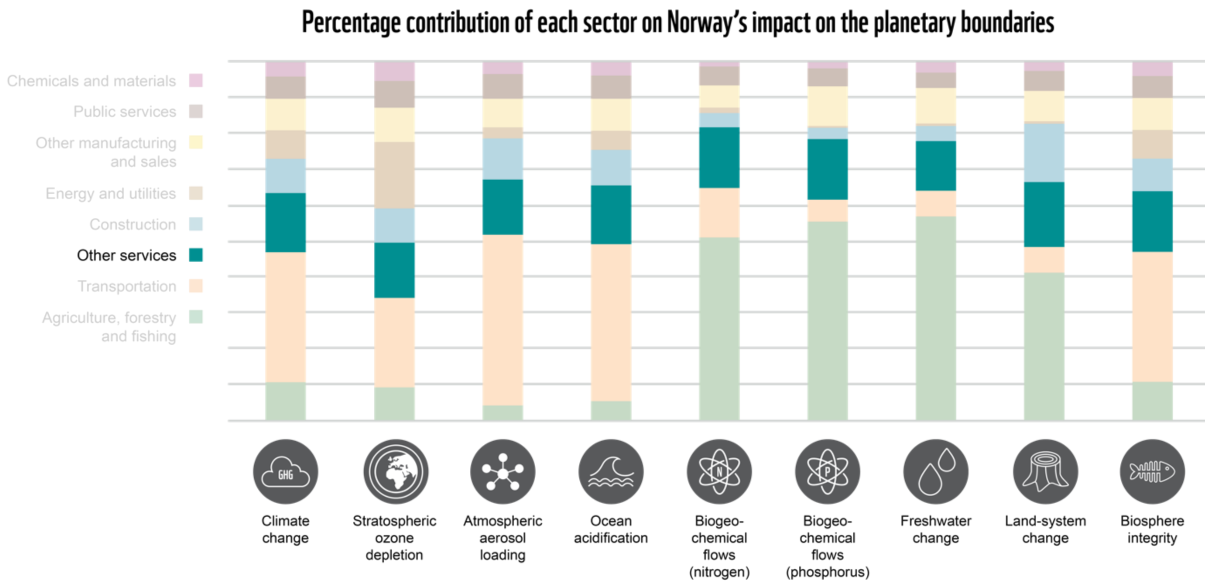

Figure 18: *The bar chart shows the percentage of Norway's total impact each sector has on the different planetary boundaries.*

Domestic and international influence — all services provided are subject to domestic control; however, the supply chain is mainly international

The sector exhibits a **strong level of domestic regulation on the activities** provided by the service segment. Hotel overnight stays and restaurant dining happen domestically; however, the materials used to provide these services may not be subject to the same control mechanisms as those found in other sectors, such as manufacturing and sales.

Circular potential — the circular potential of the sector lies in improving waste streams and adopting circular purchasing strategies

As a non-manufacturing sector, the key circularity potential lies in unrealized opportunities within emerging business models, adopting circular purchasing strategies and improving waste streams. The hospitality sector could greatly benefit from waste elimination through reduction, reuse and recycling initiatives. As mentioned earlier, the other services sector exerts significant influence on GDP and employment and can serve as a circular accelerator. For instance, circular business models, such as "product as service," can increase the utilization of products while creating jobs and revenue. An important lever to facilitate these business models is financial services. The role of financial services in transitioning society toward circularity is widely recognized, although the sector itself has a relatively small material footprint. Circularity can play a critical role in financial services by hedging risks (i.e., material price volatility) and leveraging new business opportunities. Loans with circular criteria or circular economy bonds are some of the means by which financial services can advance circularity in society.

	EXAMPLE POLICY MEASURES	BUSINESS STRATEGIES
SMARTER PRODUCT USE AND MANUFACTURE (R0-2)	• Restrict the use of single-use products. • Create educational programs and campaigns that encourage sustainable purchasing habits. • Limit new construction projects (e.g., nature tax to limit conversion of nature and land degradation). • Encourage the financial services sector to provide financing for circular economy (CE) (e.g., loans with CE criteria) initiatives. • Stimulate the adoption of circular business models, product-as-service models and digital solutions to reduce or regulate waste (e.g., retain product ownership, product life extension, design for circularity). • Review legislation on food donations to ease restrictions. • Set circular criteria for public procurement and third-party suppliers (e.g., incorporate circular design in construction). • Stimulate the market for high-quality secondary materials.	• Eliminate unnecessary product use in hospitality services (e.g., reduce single-use products and provide refill options). • Utilize non-polluting cleaning materials. • Encourage financial services to adopt circularity in risk assessments (e.g., hedge the risk of future commodity supply and material price volatility). • Adopt regenerative practices in unused areas (e.g., install bird houses, establish beehives). • Promote plant based, local and seasonal food sourcing for hospitality services. • Implement circular procurement practices (e.g., refurbishing of buildings). • Increase efficiency of buildings (see. construction and energy sector). • Avoid the use of single-use products.
EXTEND LIFESPAN OF PRODUCT AND ITS PARTS (R3-7)	• Review, and where relevant, update regulations to advance reuse, repair and remanufacturing services.	• Reduce food waste in the hospitality sector. • Nudge hotel guests to make less resource-intensive choices (e.g., reuse towels). • Repurpose organic food waste to create new products (e.g., turn fruits into jam).
USEFUL APPLICATION OF MATERIAL (R8-9)	• Stimulate the recycling infrastructure.	• Improve material recycling rates.

Table 4: *Circular economy strategies presented according to their place in the R strategies framework. The policy examples are not exhaustive but considered important levers for increasing circularity of the sector.*[54]

[54] (Ellen MacArthur Foundation, 2023a) (UNEP, 2020) (Jahren, Nørstebøe, Simas, & Wiebe , 2020) (ARUP; Ellen MacArthur Foundation, 2020) (Bittner, Bakker, & Long, 2024) (WWF, 2023).

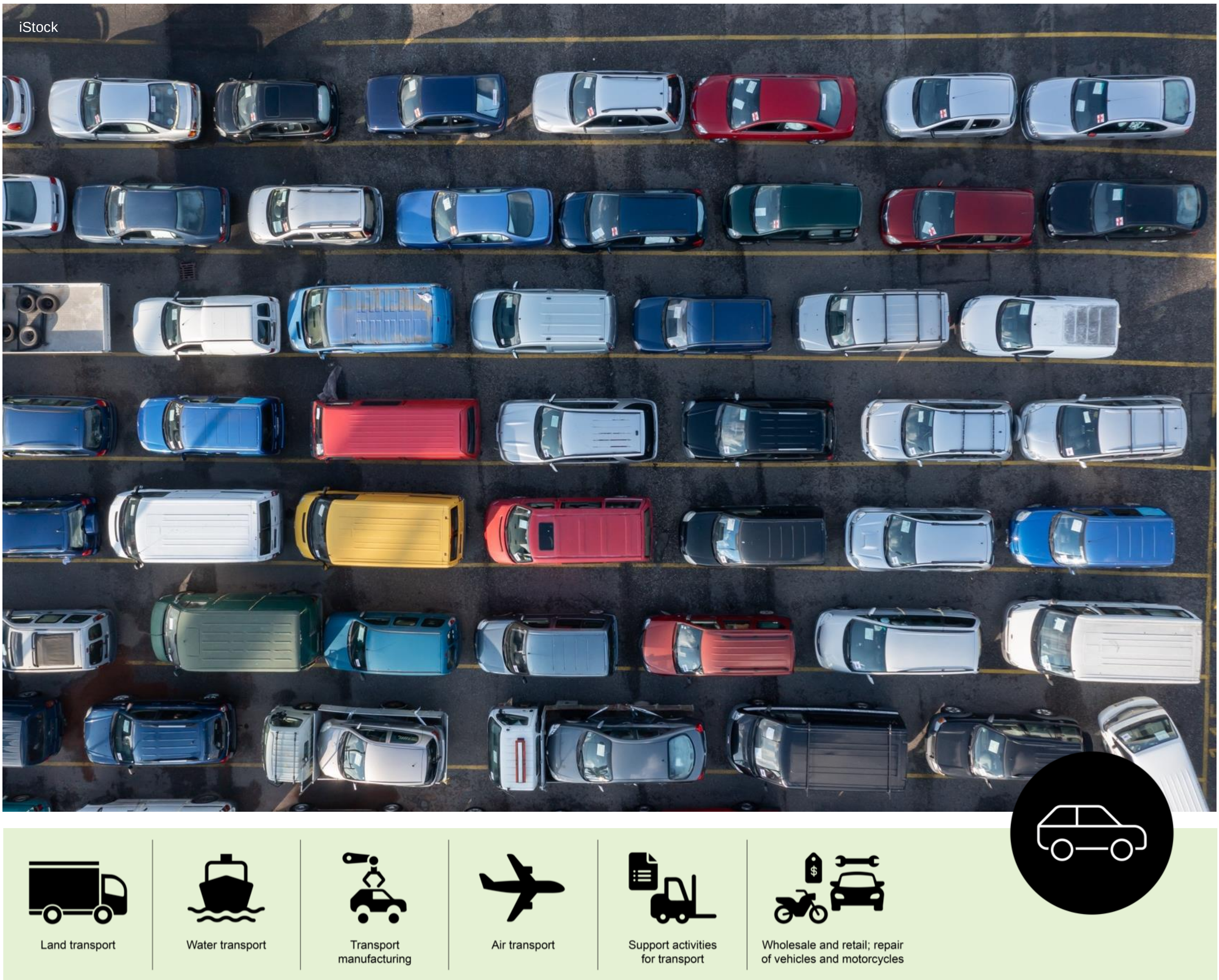

Figure 19: *Sector classification; subsectors included in the sector.*

TRANSPORTATION

– Sector impact and high-level circular potential

Sector activities

The transportation sector encompasses all vehicles and services used to transport people and goods as end products. This includes airlines, railways, shipping companies, trucking firms, logistics providers and public transit. The construction of transportation infrastructure, such as roads and railways, is not included, as this is covered in the construction sector.

Material footprint — a sector responsible for a major share of metal consumption in Norway

Approximately one-third of Norway's overall metal consumption can be attributed to the transportation sector (Figure 8). This is directly linked to the manufacture of transportation vehicles such as cars, trains and ships. The production process also requires large amounts of non-metallic minerals.

Cars have a strong position in Norwegian households, constituting 76% of the total transportation of people in 2022, measured in passenger-kilometers.[55] However, the length of trips varies across different means of transportation. Looking at the number of trips, cars make up approximately 50%, while walking is the second largest contributor at 23%.[56]

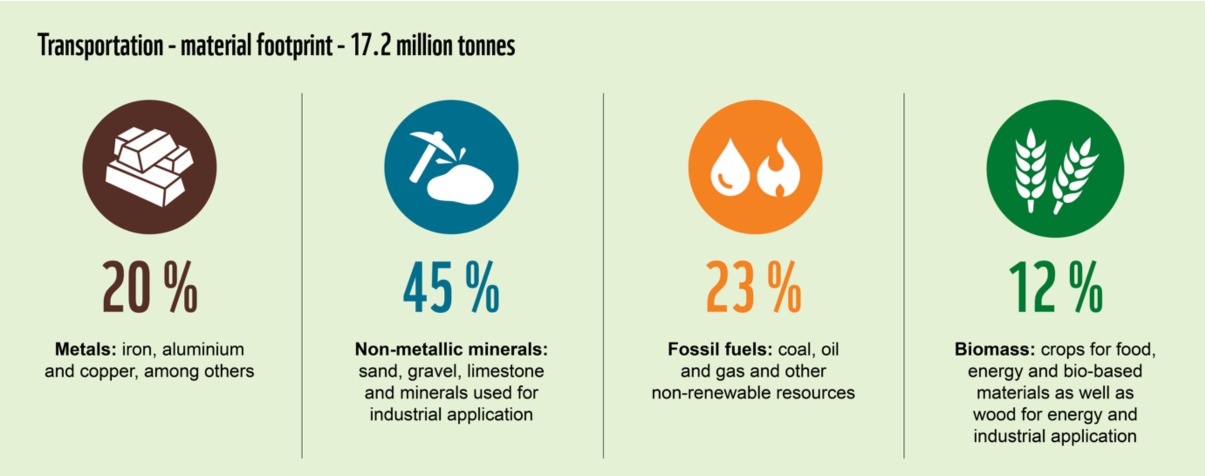

Figure 20: *This table shows the distribution of the sector's material footprint (RMC).*

Large volumes of fossil fuels are consumed within the sector, both in industrial processes for vehicle production and in the operation of vehicles and services. Electrifying Norway's transportation sector would reduce overall fossil fuel consumption associated with vehicle operation. However, the production process for electric vehicles is material-intensive and generally requires materials with more challenging supply chains, such as cobalt, nickel, lithium and manganese.

Planetary boundaries — one of the sectors with the largest impact across many planetary boundaries

The transportation sector has one of the most significant impacts on planetary boundaries among all sectors. Climate change, biosphere integrity, ocean acidification, stratospheric ozone depletion and atmospheric aerosol loading are the most notable planetary boundary impacts (Figure 21). A significant portion of the sector's impact is due to the operation of transport

[55] (SSB, 2023c).
[56] (Opinion, 2023).

vehicles and Norway's significant shipping activity. For example, air travel emits high levels of greenhouse gases, road transportation releases pollutants such as road salt and microplastics and ships can spread invasive species that affect marine ecosystems. Notably, within shipping, GHG emissions from cruise travel have tripled in the last 10 years[57] and are on track to overtake air travel by 2024.

Furthermore, the extraction and processing of materials, as well as the manufacture of transportation vehicles, are resource-intensive processes that impact multiple planetary boundary dimensions.

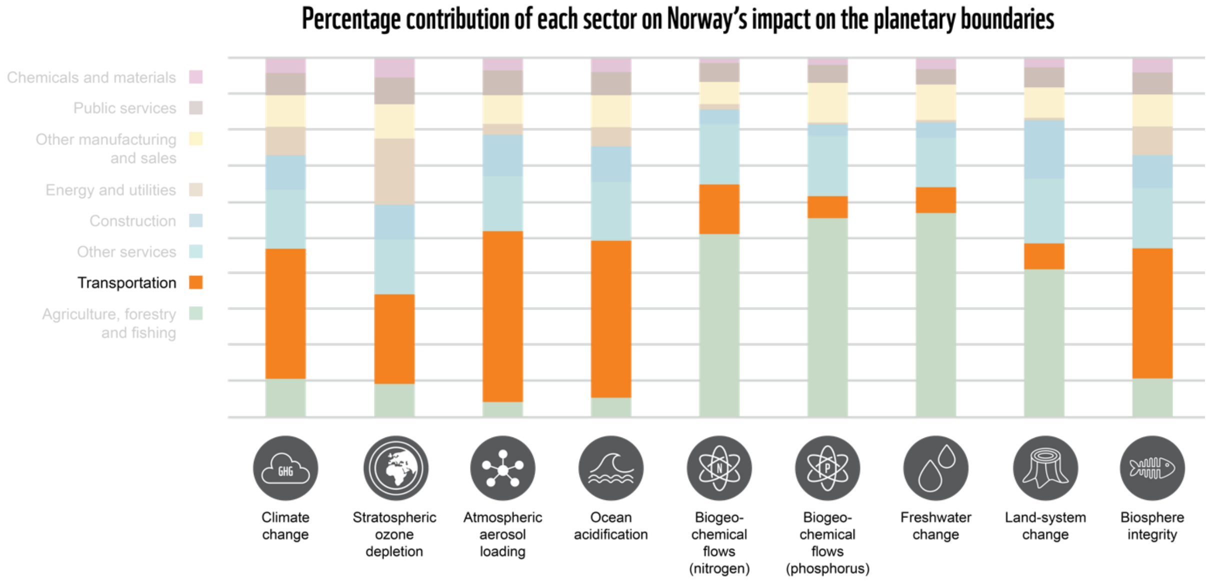

Figure 21: *The bar chart shows the percentage of Norway's total impact each sector has on the different planetary boundaries.*

Domestic and international influence — a sector with significant import volumes

The domestic and foreign influences on the material footprint and emissions of the transportation sector is mixed. A substantial portion of the footprint associated with the operation of transport vehicles occurs domestically. However, the vehicles that facilitate these tasks, especially on land and at sea, are predominantly manufactured abroad. **Transportation vehicles are one of the largest import categories in Norway.**[58]

Circularity potential — strong potential for change where Norway has the greatest influence

The circularity potential is strongest where Norway has the greatest influence and can implement policies with a tangible impact. As mentioned above, this largely pertains to the domestic operation of transport vehicles, including personal cars, lorry-based freight carriage and vehicles within shipping and aviation. Changes with potential significant impact could involve reducing overall transportation, gradually banning certain types of transport, transitioning to more sustainable transportation forms and adopting greener technologies.[59]

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[57] (Aftenposten, 2024).
[58] (SSB, 2024d).
[59] (Miljødirektoratet, 2023a).

The transportation sector can be encouraged, through incentives and/or taxes, to adopt more sustainable practices and purchasing decisions. **The electrification of heavy transportation vehicles is necessary to reduce Norway's climate impact** in compliance with national emission targets, and this transition to electrification can be further stimulated through governmental initiatives. Other efficiency measures, such as reducing the weight and wind resistance of lorries, could decrease the overall energy requirements of the lorry fleet, while logistical solutions could reduce the number of lorries needed on the road. Promoting proper repair, reuse and recycling of vehicles should be strongly emphasized.

Implementing **sustainable urban planning practices** can reduce both the distances required to travel, as well as the overall need for transportation. This includes optimizing urban areas for easier mobility and creating effective transport systems. The policies related to personal transportation in Table 5 are further detailed in the deep dive section (Section 3.3.2) on transportation that explores the circularity potential within the sector.

	EXAMPLE POLICY MEASURES	BUSINESS STRATEGIES
SMARTER PRODUCT USE AND MANUFACTURE (R0-2)	• Stimulate the use of alternative transportation to private cars (e.g., public transportation, tax on private car ownership). • Improve mobility in urban areas through better planning (e.g., 15-minute cities). • Stimulate the adoption of electric vehicles (EVs), alternative fuels and development of related infrastructure (e.g., heavy land-based transportation, marine vessels). • Encourage more intensive use of the existing fleet of privately owned vehicles (e.g., carsharing, carpooling). • Stimulate logistical efficiency within shipping and cargo transportation by enabling the sharing of transport routes, or penalizing low efficiency. • Review and, where relevant, reform vehicle taxation according to weight and size to reduce material consumption and infrastructure wear and tear.	• Prioritize electric and alternative fuel types for heavy transport vehicles and marine vessels. • Reduce long-distance travel (e.g., by active use of digital meetings). • Enable the easy use of public transport, walking and biking. • Retain product ownership (e.g., provide leasing or rental alternatives to customers). • Optimize freight capacity through shared solutions and distribution centers. • Provide car-sharing alternatives. • Impose lorry fill rate requirements (e.g., logistical efficiency for lorries that travel with low fill rates). • Design for circularity (e.g., making cars durable and lighter, design for reuse and remanufacturing). • Implement smart mobility solutions (e.g., use big data for route optimization). • Promote logistical efficiency by incorporating hub-and-spoke models and embedding reverse logistics into routing.
EXTEND LIFESPAN OF PRODUCT AND ITS PARTS (R3-7)	• Review and, where relevant, implement tax and procurement policies that incentivize reuse, repair, resale and remanufacturing of vehicles and vehicle parts. • Stimulate increased reuse of car parts (e.g., mainstream quality standards for used car parts).	• Reuse components that are still functional. • Repair vehicles and their components (avoid write-offs). • Upgrade old vehicles and components to meet the latest standards. • Reuse defective vehicles or parts into new products (e.g., EV batteries for energy storage).
USEFUL APPLICATION OF MATERIAL (R8-9)	• Establish an extended producer responsibility scheme.	• Recycle metals and materials to be used as feedstock into new cars.

Table 5: *Table shows the circularity measures and policies according to the R framework for the transportation sector. The recommendations are not exhaustive; they are nonetheless important measures for increasing the circularity of the sector.*[60]

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[60] (ARUP; Ellen MacArthur Foundation, 2019) (Fremtind, 2022) (Miljødirektoratet, 2024a) (WWF, 2023) (Klimautvalget 2050, 2023).

Figure 22: *Sector classification; subsectors included in the sector.*

ENERGY AND UTILITIES

– Sector impact and high-level circular potential

Sector activities

The energy and utilities sector includes companies that produce, distribute and sell energy products such as oil, gas, electric power and water. The material footprint also includes all technical installations and services related to this sector.

Material footprint — accounts for half of Norway's fossil fuel consumption

The petroleum industry represents the majority of the sector's material footprint with 96% of the total consumption. Norway's renewable natural resources have provided the energy sector with a sustainable source of electricity that has a relatively low material footprint. This green electricity is distributed to other sectors, with 27% going to households and buildings for heating and other private consumption.[61] Industry is the largest consumer of electricity in Norway at 34.5%, while the electricity consumption of the transportation sector is steadily rising as more vehicles transition away from fossil fuels.[62]

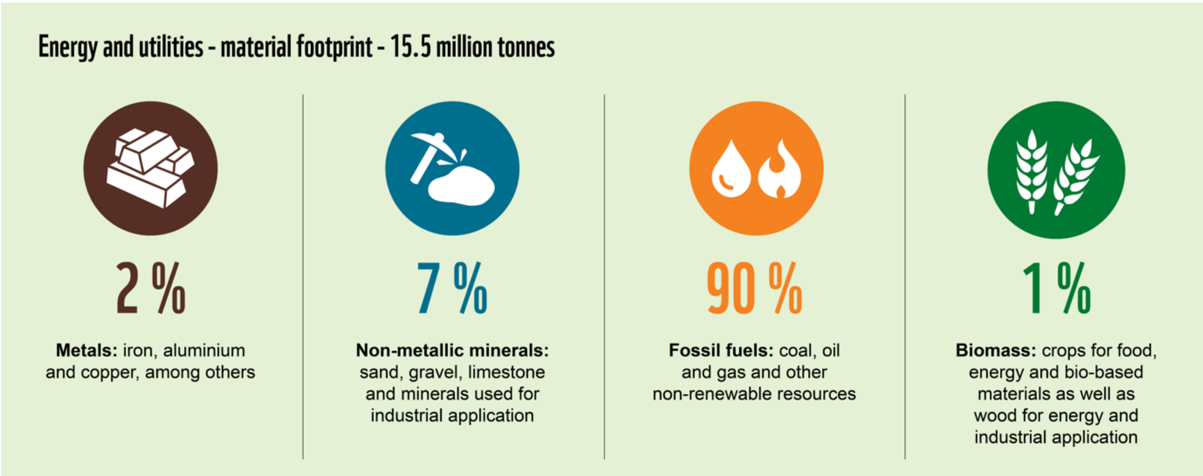

Figure 23: *This table shows the distribution of the sector's material footprint (RMC).*

Although much of Norway's industry and private transportation relies on green electricity, fossil fuels are still a very important energy source for both. This is why the **energy and utilities sector is responsible for half of Norway's material consumption of fossil fuels.** The high material consumption is primarily driven by the energy-intensive processes involved in the extraction and processing of oil and gas. For example, enhanced oil recovery from aging oil fields requires large amounts of energy to pump water into oil reservoirs, while refining oil products demands a large heat load for distillation and other processes. Fuel for private transportation, such as for personal vehicles, also falls within the scope of this sector.

Planetary boundaries — fossil fuels have a large impact on climate change and ocean acidification

Climate change, ocean acidification and stratospheric ozone depletion are the planetary boundaries on which the sector exerts the greatest impact. The sector's impact on planetary boundaries is closely tied to the extensive use of fossil fuel. Fossil fuels are commonly burned for energy, releasing various GHGs. This includes CO_2, which contributes to climate change and ocean acidification, as well as nitrogen oxides which contribute to stratospheric ozone depletion.

[61] (NVE, 2023b).
[62] (NVE, 2023b).

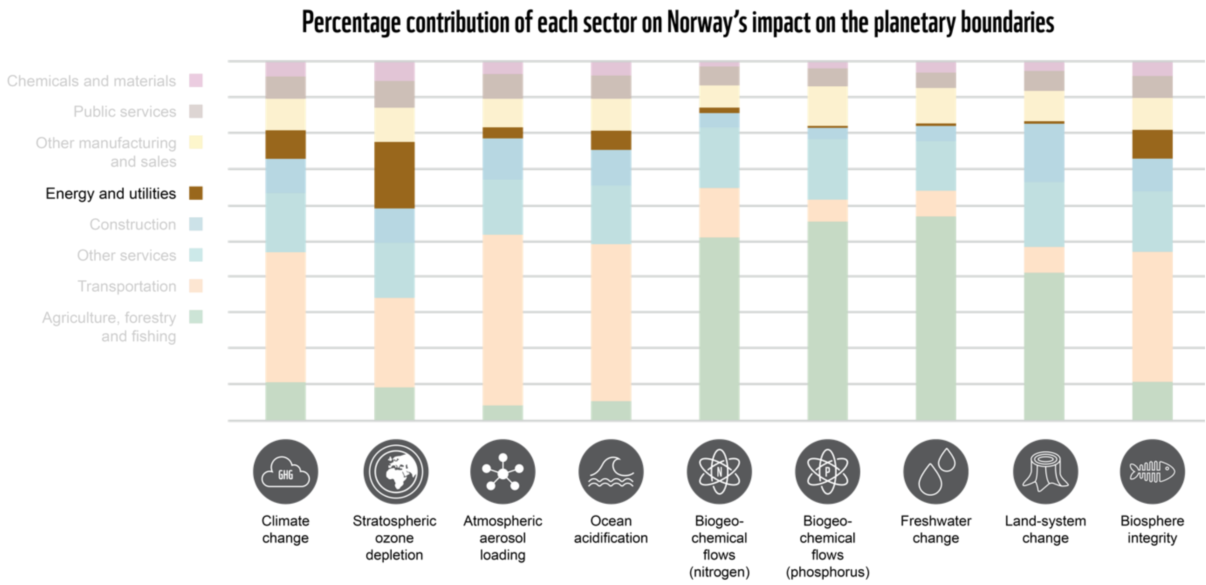

Figure 24: *The bar chart shows the percentage of Norway's total impact each sector has on the different planetary boundaries.*

Domestic and international influence — Norway can influence the global material footprint as a major exporter of oil

Norway exercises significant domestic control over material consumption and emissions within the energy and utilities sector. The country is predominantly self-sufficient in electricity production. In 2022, Norway was a net exporter of electricity.[63] Furthermore, much of the sector's infrastructure, including the electrical grid, is overseen by domestic government authorities. The sector encompasses Norway's largest export category: oil and gas, which made up 26% of the country's GDP in 2022.[64]

Circular potential — further electrification will lower the material footprint, but this will come at a cost

The energy and utilities sector's material footprint is **dominated by fossil fuels, accounting for 96% of the sector's material consumption.** Electrification of offshore platforms can reduce fossil fuel usage. However, while this shift would reduce reliance on fossil fuels, it is important to note that the initiative would increase electricity demand in Norway. **Norway is already a leading consumer of energy, using almost 97,000 kwh per capita, compared to Europe's average of 38,300 kWh.**[65] This increase will strain Norway's current hydroelectric production.
If the added demand is not met by renewable energy sources, the circular benefits of electrification remain uncertain,[66] as Norway would have to import more electricity at times of low production from less renewable energy sources. Norway would benefit from reducing overall energy demand and increasing energy efficiency.

[63] (Statnett, 2022).
[64] (Borgås, 2023).
[65] (Our World in Data, 2024).
[66] (Kirkerud, et al., 2023).

Both for its energy needs and for its current economy, Norway is still reliant on fossil fuels. The most impactful changes are those that shift Norway away from fossil fuels. While Norway's oil production does not directly add to its material footprint, **it contributes heavily to the global material footprint.**[67] Several actors, including Klimatutvalget 2050, are urging Norway to reduce this contribution by ceasing or limiting its oil production, requesting an end of further oil exploration.[68] According to the Intergovernmental Panel on Climate Change (IPCC), such action is essential to reaching the Paris Agreement goal of limiting global warming to 1.5°C above pre-industrial levels, which requires net-zero CO2 emissions globally by around 2025.[69]

Within its own borders, Norway can take measures to reduce its reliance on fossil fuels. This includes further electrification across sectors, but also building more renewable energy facilities to meet Norway's electricity demands. In the short term, this will increase material consumption for all the required turbines, solar panels, etc. It also includes promoting tailored solutions that increase energy efficiency, such as heat pumps in buildings to reduce energy consumption for heating or more efficient server cooling solutions to meet energy demand.

Renewable energy projects of the future will impact the environment. They will, at least initially, require added material consumption to create and set up the new energy systems and technologies. Renewable energy will also impact the planetary boundaries; for example, the implementation of solar panels and wind turbines will, in many cases, result in land-system changes. Increased electrification will also require expanding and upgrading the electricity network, adding to material consumption in the short term. However, this is the case for all transition projects requiring new infrastructure, and both material consumption and planetary impacts are expected to taper off or plateau over time. Unlike fossil fuels, renewable energy does not require the continuous extraction of new materials. **Investment in renewable energy is a short-term cost for long-term benefits.**

[67] (IEA, 2022).
[68] (Klimautvalget 2050, 2023).
[69] (IPCC, 2019).

	EXAMPLE POLICY MEASURES	BUSINESS STRATEGIES
SMARTER PRODUCT USE AND MANUFACTURE (R0-2)	• Revise current legislation on oil and gas financial incentives and disincentives to align with a circular system. • Stimulate energy efficiency (e.g., utilization of excess energy such as heat from industry and data centers). • Support renewable energy production to be in line with circular economy (e.g., plan for circularity in project inception). • Stimulate electrification of heavy transportation, construction, etc. • Promote data collection and exchange among stakeholders for all renewables (e.g., product passport). • Run information campaigns that set clear guidelines toward green practices and sustainable energy consumption.	• Electrify business activities (e.g., transportation and industry). • Utilize excess energy to facilitate new ventures (e.g., excess heat from industry operations can serve as heating for surrounding buildings). • Build for energy efficiency in buildings (e.g., smaller buildings, cooling/heating systems in buildings). • Design for longevity (e.g., energy-effective consumer products). • Design for disassembly (e.g., wind turbines and solar panels). • Improve data collection and tracking for industrial energy consumption. • Optimize IT solutions to reduce the number of servers needed. • Reduce energy consumption by implementing more energy-efficient air-conditioning technology.
EXTEND LIFESPAN OF PRODUCT AND ITS PARTS (R3-7)	• Stimulate energy efficiency measures in buildings (e.g., heat pumps, insulation, LED lighting, sensor technologies). • Reduce energy consumption by limiting energy price subsidies to reflect actual energy prices.	• Increase the efficiency of current energy infrastructure. • Bioeconomy – use excess biomass as an energy source for industries that are difficult to electrify. • Establish industry standards for secondhand renewables (e.g., photovoltaic panels, lithium-ion batteries, wind turbine components). • Reduce electricity grid peak loads by adopting new technologies.
USEFUL APPLICATION OF MATERIAL (R8-9)	• Establish an extended producer responsibility scheme. • Stimulate the recycling infrastructure for renewable energy (e.g., recycling of photovoltaic panels and wind turbine components).	• Implement carbon capture and storage (CCS) at waste incineration plants.

Table 6: *Circular economy strategies presented according to their place in the R strategies framework. The policy examples are not exhaustive but considered important levers for increasing the circularity of the sector.*[70]

[70] (Spilde, Krekling Lien, & Magnussen, 2018) (NVE, 2024) (European Parliament, 2024) (OECD, 2023) (IEA, 2023a) (United Nations Economic Commission for Europe, 2015) (Klimautvalget 2050, 2023) (Gate C, 2023) (Miljødirektoratet, 2024a).

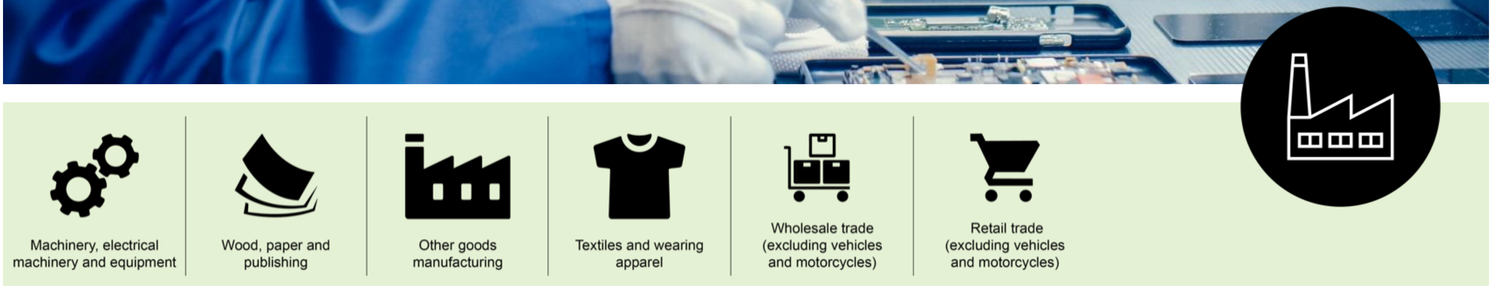

Figure 25: *Sector classification; subsectors included in the sector.*

OTHER MANUFACTURING AND SALES

– Sector impact and high-level circular potential

Sector activities

The manufacturing and sales sector involves the large-scale production of goods using machinery, followed by the sale of these goods to consumers and businesses. This sector encompasses a broad range of industries that provide products purchased by end users such as electronics and clothing.

Material footprint — electronic equipment and machinery constitute half of the sector's footprint

The other manufacturing and sales sector's material footprint is primarily attributed to the production of electronic equipment and machinery, which has **high-associated metal consumption.** This high material footprint from electronic consumption is reflected in **Norway's electronic waste generation, which stands at 27 kg per capita annually, the highest in the world.**[71] The manufacturing of textiles and apparel also contributes to the material footprint of the sector, which heavily depends on the extraction of primary raw materials such as cotton.

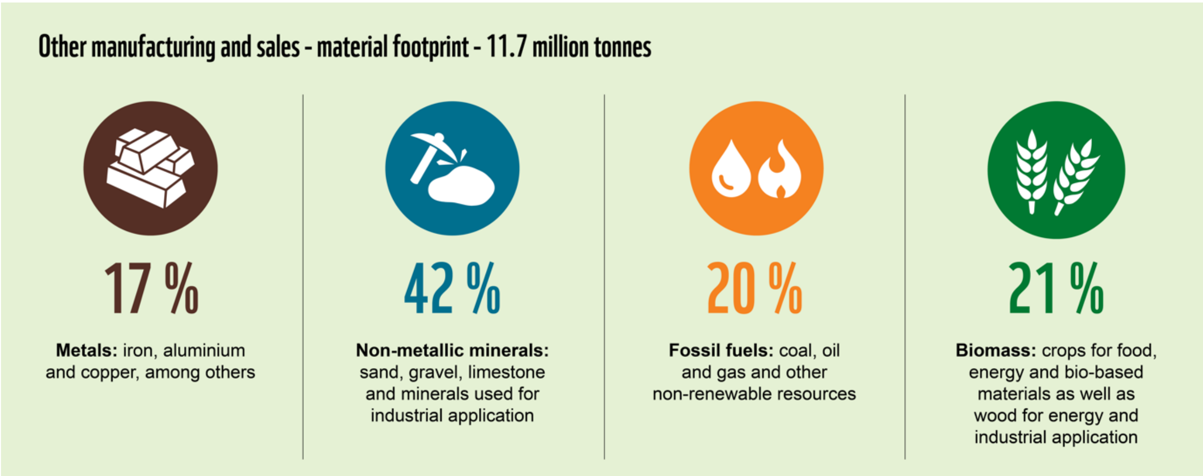

Figure 26: *This table shows the distribution of the sector's material footprint (RMC).*

Planetary boundaries — high impact on the planetary boundaries relative to material footprint size

The other manufacturing and sales sector has a significant impact on the planetary boundaries throughout its value chain, as it often involves multiple inputs and supply tiers from a product's cradle-to-grave life cycle**. Sub-sectors such as the textile industry and electronic equipment depend on large quantities of freshwater throughout the manufacturing stage.** At the manufacturing level, the material footprint is often influenced by **chemical spills that** leak into local ecosystems and negatively impact biosphere integrity. The release of ecotoxic chemicals is also seen at the end-of-life stage, where waste streams from both industries are finding their way both legally and illegally into developing countries. These countries often have limited infrastructure to handle the waste volumes.[72]

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[71] (Baldé, et al., 2024).
[72] (EEA, 2023c).

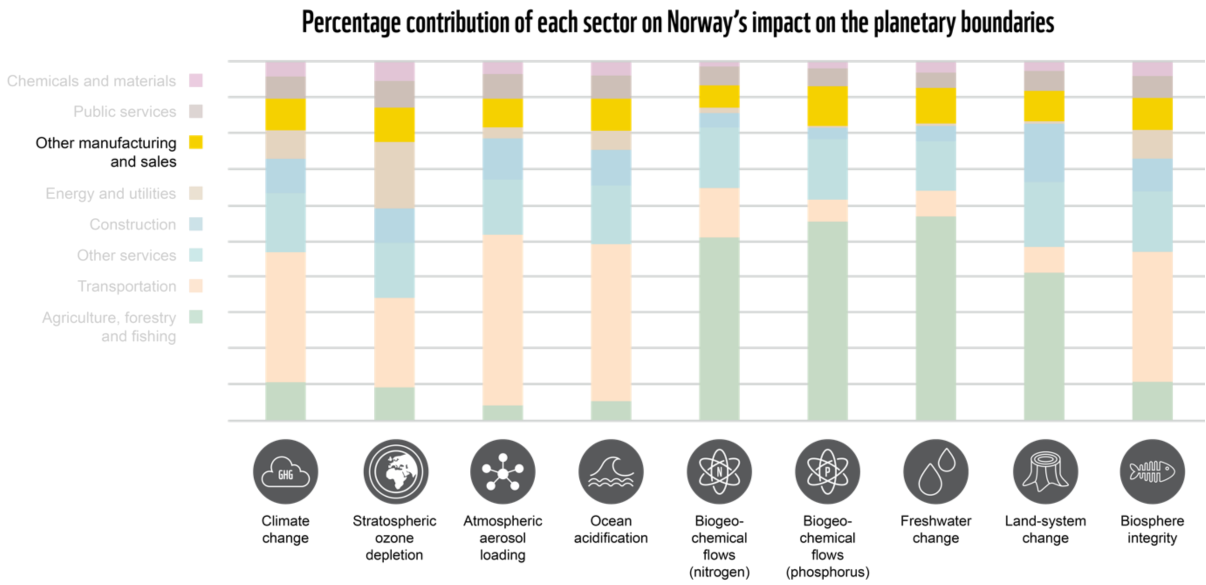


Figure 27: *The bar chart shows the percentage of Norway's total impact each sector has on the different planetary boundaries.*

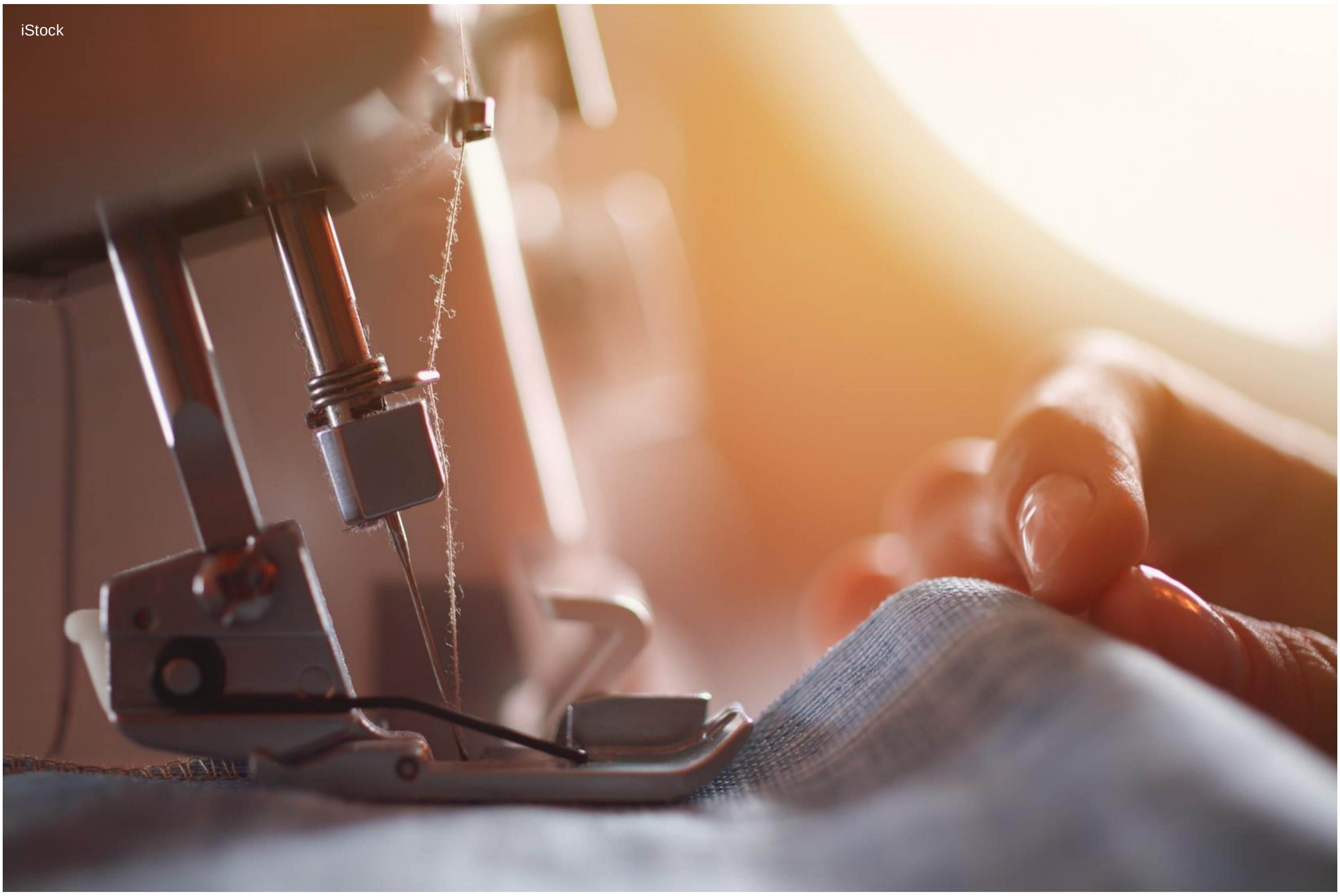
Domestic and international influence — Norway exerts little domestic control on production today

The domestic regulation of manufacturing activities is low. Controlling the material footprint and emissions from input factors proves challenging, as the sector is heavily reliant on the import of raw materials and products for production and sale. Furthermore, these industries often involve multiple layers of suppliers and subcontractors, making traceability an ongoing challenge. However, **there are control levers related to the procedures and processes involved in delivering a product or service to the end consumer and the end-of-life procedures for products.** Control levers for the actual consumption of products also exist, such as **end-of-life requirements.**

Circularity potential — leveraging the tax system by favoring more durable and circular alternatives can have ripple effects throughout the manufacturing sector

In Norway, there is unrealized potential in e-waste recycling, with **79% of e-waste currently being recycled.**[73] Metals can be recycled indefinitely, and recycling is several times less energy intensive than mining and refining new metals.[74] Hence, incentivizing material recycling can substantially reduce GHG emissions and mining demand while preventing waste from ending up in landfills. The circularity of metals can be achieved through enhanced recycling schemes and take-back programs. In addition, there is an opportunity to **incentivize circular behavior** among retailers and consumers by reforming the tax systems to support product longevity, repair services and secondary material markets.[75] Implementing **stricter waste sorting regulations and efficient collection, reuse and recycling processes** can further improve resource recovery and reduce environmental impact.[76]

[73] (Miljodirektoratet, 2024).
[74] (EuRIC).
[75] (Wiebe, 2022).
[76] (Wiebe, 2022).



One important policy measure to make the above mentioned possible is through **extended producer responsibility (EPR), which assigns the responsibility for a product's end of life to the producer rather than the consumer.** This could include ensuring products are repairable and have a reasonable lifetime. Alternatively, inspiration for policies can be drawn from France, the first country to introduce a mandatory repairability index on electronics and to ban the destruction of unsold non-food products.[77] These policies could be supported by working toward the digital product passes already planned for the EU Green Deal as a means of tracking products, and informing users.[78]

[77] (Ellen Macarthur Foundation, 2022).
[78] (GS1 Norway, 2020).

	EXAMPLE POLICY MEASURES	BUSINESS STRATEGIES
SMARTER PRODUCT USE AND MANUFACTURE (R0-2)	• Tax or restrict poor-quality products with short lifespans (e.g., anti-fast fashion bill). • Encourage reduced manufacturing demand (e.g., streamline product standards for chargers). • Support sharing and rental models through incentive programs and long-term capital (e.g., product-as-service). • Stimulate the use of recycled content (e.g., tax benefits for producing/ sourcing recycled fibers). • Implement externality fees for virgin raw materials (e.g., non-renewable virgin fiber). • Support ecolabelling to enable consumers to make informed purchases (e.g., phase out PFAS and microplastic).	• Increase the efficiency of hardware (e.g., cloud migration to centralize hardware and increase utilization). • Provide platforms for the sharing of products (e.g., rental and sharing of clothes, tools and equipment). • Provide alternative services to consumers (e.g., rental options -product-as-service). • Limit packaging (e.g., refill options). • Promote ecolabelling to raise consumer awareness. • Design for longevity (e.g., durable and easy-to-repair products). • Design for disassembly (e.g., mono-material in apparel, modular design in electronic equipment). • Increase the efficiency of textile resources and use renewable inputs. • Gain access to training and platforms that help shift business strategy in alignment with the circular economy, gaining the needed competency to remanufacture/refurbish goods and products.
EXTEND LIFESPAN OF PRODUCT AND ITS PARTS (R3-7)	• Stimulate secondhand market platforms. • Ban destruction of unsold and returned textiles. • Review and, where relevant, implement tax and procurement policies that incentivize reuse, repair, resale and remanufacturing of textiles and electronic equipment (e.g., remove VAT on repair services). • Establish the right to repair — enable consumers to choose cost-effective repairs as opposed to replacing goods. • Leverage digital product passports (DPPs) to enable and help provide control for circular initiatives such as “multi-life” or “service of any goods.”	• Provide repair services. • Provide repaired or upcycled products for resale (e.g., furniture, apparel, electronics). • Implement take back-programs to create feedstock of parts and products for resale and ensure appropriate end-of-life treatment of products that cannot be repurposed.
USEFUL APPLICATION OF MATERIAL (R8-9)	• Establish extended producer responsibility schemes. • Stimulate collection, sorting and recycling infrastructure (e.g., R&D for recycling processes).	• Increase the efficiency of recycling (e.g., automation in disassembly and refurbishment processes).

Table 7: *Circular economy strategies presented according to their place in the R strategies framework. The policy examples are not exhaustive but considered important levers for increasing circularity of the sector.*[79]

[79] (Meloni, Souchet, & Sturges, 2017) (Ellen MacArthur Foundation, 2017) (Zengerle , Prunel, Lozano, & Wang, 2021) (Lisca, Feeley, Lozano, & Wang, 2021) (Departementenes sikkerhets- og serviceorganisasjon, 2022) (European Comission, 2023) (Reuters, 2024) (Miljødirektoratet, 2024a) (WWF, 2023).

Figure 28: *Sector classification; subsectors included in the sector.*

CHEMICALS AND MATERIALS

– Sector impact and high-level circular potential

Sector activities

The chemicals and materials sector encompasses the production and distribution of a wide range of substances, including plastics, metals, rubber and various chemical compounds.

This sector also extends to the mining of coal, metal ores and other minerals. It does not encompass metals used in construction materials or rubber in tires, as these substances fall under the construction and transportation sectors.

Material consumption — much of the sector's material footprint is tied to plastics, ceramics and building materials for personal use

One-tenth of Norway's overall material footprint is attributed to the chemicals and materials sector. The large amount of non-metallic mineral consumption is primarily due to the use of plastics, ceramics and personal building materials. Metal consumption is largely linked to the mining sector, given the high metal content of mining equipment. The fertilizer industry also exerts a significant influence on the sector's material footprint.

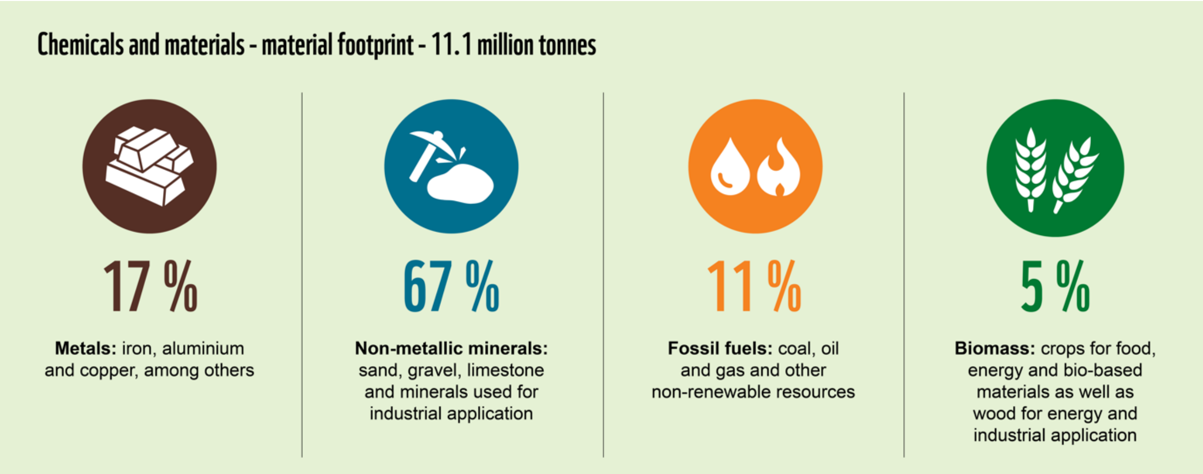


Figure 29: *This table shows the distribution of the sector's material footprint (RMC).*

Planetary boundaries — plastic's dependency on fossil fuel and resistance to decomposition strains planetary boundaries.

The chemicals and materials sector has its most significant impacts on freshwater systems and biogeochemical flows, as illustrated in Figure 30. However, it is important to note that this study does not cover the planetary boundary dimension for novel entities. This is significant because Norway consumes large amounts of plastic, a novel entity. Therefore, this sector has a substantial impact on this dimension.[80, 81] Plastics pose numerous environmental challenges, as they are made from fossil fuels and are non-biodegradable. In the case of microplastics, these concerns also extend to public health. Beyond plastics, the sector's impact on biogeochemical flows is directly linked to products from the fertilizer industry. The sector also includes building materials for personal use, where improper disposal of products like cement, plaster, asphalt and rock wool contributes to aerosol emissions, land-system changes and freshwater contamination.

[80] (SSB, 2023d).
[81] (Stockholm Resilience Centre, 2022).

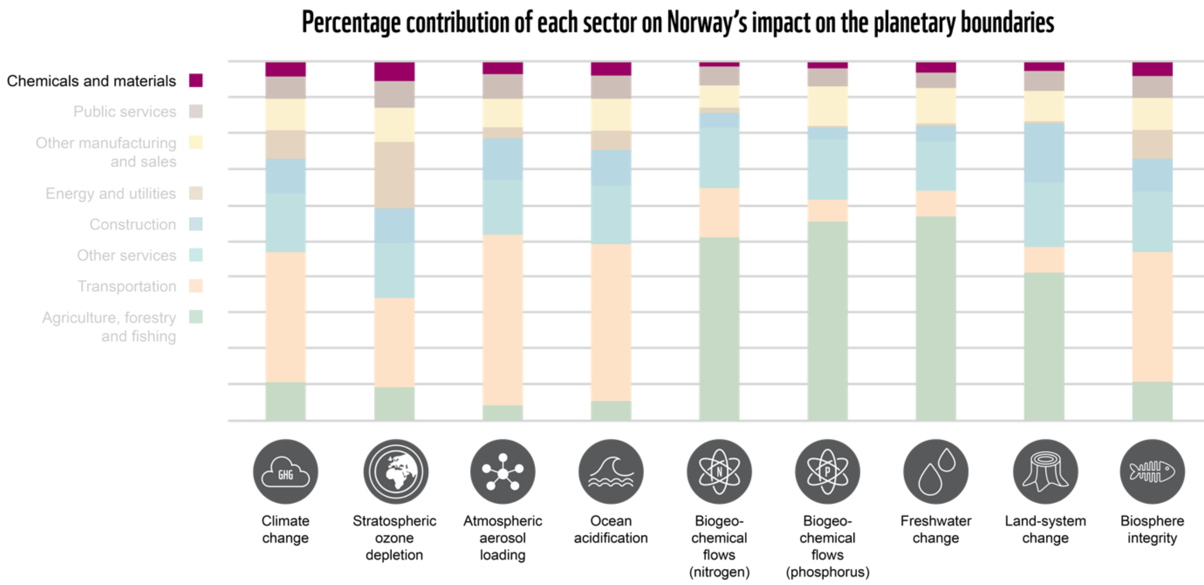


Figure 30: *The bar chart shows the percentage of Norway's total impact each sector has on the different planetary boundaries.*

Domestic and international influence — control lever for the production of chemical and materials sector is mainly set abroad

The level of domestic regulation in Norway's chemicals and materials sector is highly dependent on what materials are consumed, where and for what purpose. Norway exercises greater control over domestic activities and natural resources, particularly in the mining and production of materials like cement, tiles and plaster. Fertilizers have minimal impact on Norway's national material footprint, as the total mass and materials required for their production are relatively low compared to other products. However, Norway is the home of the largest fertilizer factory in Europe, and therefore, has material influence over the global material footprint.

The plastic industry is an example of an industry in which much of the production takes place abroad. In 2021, Norway imported 1,140,000 tonnes of plastics, including semi-finished and finished products, compared to 605,000 tonnes produced domestically.[82] Therefore, since most of the material consumption, particularly of finished and semi-finished plastic products, occurs in the latter subsector, there are generally low levels of domestic control over the manufacture of products within the sector.

Circular potential — the chemicals and materials sector holds a substantial circular potential, particularly in plastics and construction articles

The chemicals and materials sector holds a significant circular potential, despite having a smaller material footprint and impact on planetary boundaries compared to other sectors. It is particularly important to improve circularity for plastics, which the EU considers a priority material. Plastics have been given high priority due to the durability of the material, the pollution risk plastics

[82] (SSB, 2023d).

represent and the fossil fuels required for their production. Metals are also of critical significance to the economy and are at risk of becoming scarce[83]. Coupled with a high environmental impact, metals are considered a priority area for circularity. The recycling rate[84] for many metals, such as aluminum in Norway, is high. However, this is not the case for plastics and building materials, where increased recycling could reduce the demand for virgin resources. Alternative materials and technologies for plastics and construction articles are of great interest, partly due to their low circularity.[85] Mining activities can increase circularity by promoting resource efficiency, ensuring a longer product life and increasing the use of recycled materials. Furthermore, there is a high potential to reduce chemical fertilizer usage in the sector by replacing it with alternative nutrients derived from food waste and sewage.[86]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[83] (European Commission & Directorate-General for Environment, 2014).
[84] (SSB, 2023a).
[85] (SSB, 2023a).
[86] (European Commission & Directorate-General for Environment, 2014).

	EXAMPLE POLICY MEASURES	BUSINESS STRATEGIES
SMARTER PRODUCT USE AND MANUFACTURE (R0-2)	• Stimulate the adoption of products that avoid the use of unnecessary chemicals and materials. • Encourage the adoption of products that avoid packaging. • Support business models that reduce packaging (e.g., refill or no packaging). • Restrict the wasteful use of packaging. • Standardize plastic crates and pallets used for transportation to enable shared packing system. • Require companies to assess the potential to reduce chemical and material use and create a plan to reduce or refuse it. • Implement fees or bans on single-use plastic products/applications. • Encourage take-back schemes (e.g., increase current scope beyond bottles).	• Provide natural products that avoid chemical use. • Provide products that avoid packaging (e.g., non-liquid soaps and shampoos). • Develop shared packaging systems (e.g., pooled packaging). • Design for high-performing products that can be reused. • Provide refill models (e.g., at-home refills of washing liquids, juice, milk, shampoo). • Create smarter plastic packaging. • Redesign products containing plastic. • Design for dismantling of ceramics. • Incentivize return of packaging from businesses/consumers.
EXTEND LIFESPAN OF PRODUCT AND ITS PARTS (R3-7)	• Set minimum recycled content for products (e.g., packaging, automotive, construction, electronics), particularly for plastics, and track material flows with digital product passports. • Establish requirements on reusable, repairable and durable products. • Improve secondary plastics market.	• Promote circular mining/urban mining to reduce pressure on raw material extraction through.
USEFUL APPLICATION OF MATERIAL (R8-9)	• Establish extended producer responsibility scheme (e.g., deposit refund scheme). • Launch initiatives to increase recyclability of plastics, plastic waste sorting, and convince society to improve waste sorting practices.	• Improve plastic separation in collection processes. • Increase sorting and recycling capacity of plastics.

Table 8: *Circular economy strategies presented according to their place in the R strategies framework. The policy examples are not exhaustive but considered important levers for increasing circularity of the sector.*[87]

[87] (Jahren, Nørstebøe, Simas, & Wiebe , 2020)[87] (Miljødirektoratet, 2023b) (Verstraeten-Jochemsen, Baars, Faber, & de Wit, 2023) (EEA, 2023d) (Plastics Europe AISBL, 2022) (Ellen MacArthur Foundation, 2023b).

Figure 31: *Sector classification; subsectors included in the sector.*

PUBLIC SERVICES

– Sector impact and high-level circular potential

Sector activities

The public sector encompasses government-operated services, institutions and agencies that provide a wide range of services to the public, such as health care, education, defense and social welfare. The sector's footprint includes all materials and products consumed and used in these subsectors. This sector is funded through public financing, including taxes and government borrowing, and plays a crucial role in the administration and regulation of infrastructure and resources.

Material consumption — public administration exerts the smallest material footprint of all the sectors

With the smallest material footprint of all sectors, the public services sector represents 6% of Norway's total material footprint. Public administration and defense are responsible for around half of the sector's footprint. The footprint from defense is expected to increase, as Norway intends to boost spending on military equipment.[88] **Health is the second largest contributor, followed by education.** A common factor across all activities within the sector is the public procurement of goods and services, as well as the ownership of properties requiring regular upkeep and maintenance.

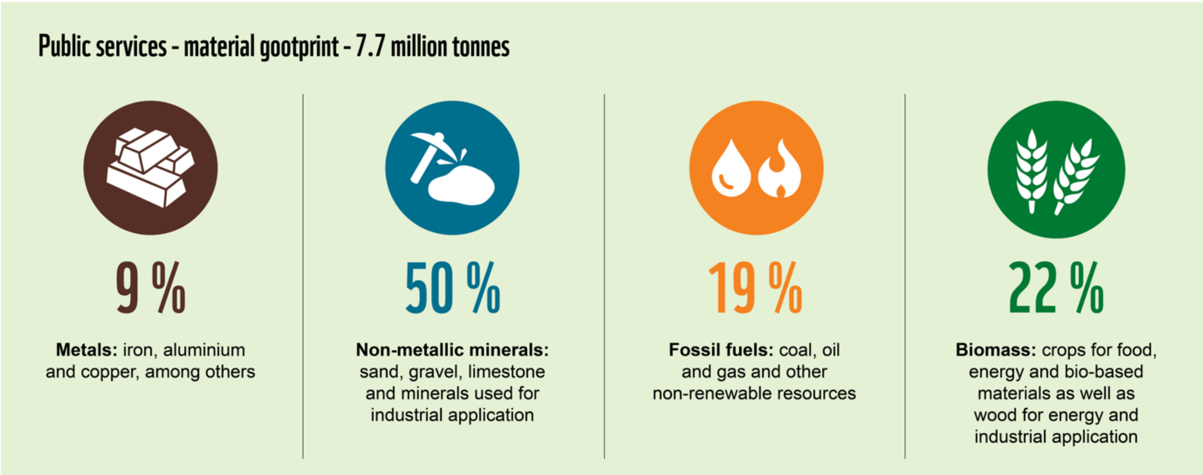

Figure 32: *This table shows the distribution of the sector's material footprint (RMC).*

Planetary boundaries — high impact across multiple planetary boundaries relative to material footprint size

The public services sector has a significant impact on planetary boundaries relative to its material footprint. This impact is similar to that of the other services sector. Like the other services sector, the public services sector covers a broad set of activities, from health care to education, which can explain the distribution of its impact. The public services sector's **extensive procurement practices, necessary to deliver its many services,** exert **significant influence throughout its value chain due to the wide array of goods purchased.** In addition to procurement, the public sector owns much of its real estate and infrastructure, which affects land--system change. **The relative size of this impact should be seen in combination with the sector's high employment rates and its contribution to GDP.**

[88] (Åshild Langved, 2024).

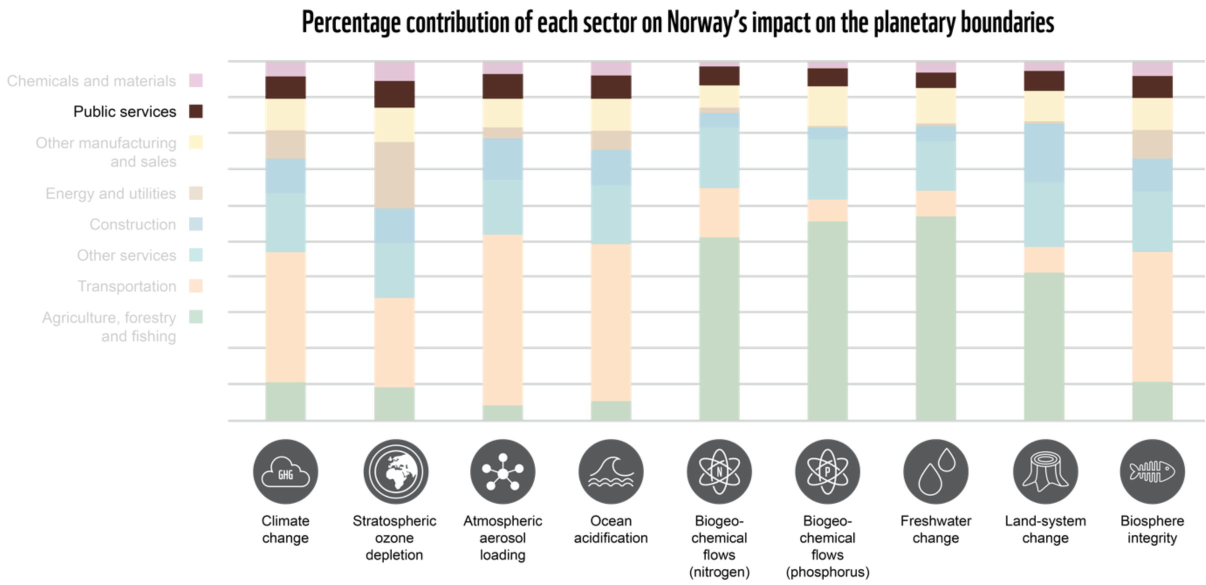

Figure 33: *The bar chart shows the percentage of Norway's total impact each sector has on the different planetary boundaries.*

Domestic and international influence — leveraging the public sector's robust procurement processes can potentially reduce material usage

The public services sector exhibits a high level of domestic control since all service activities take place within Norway. Equipment needed to facilitate the health and defense industries is supplied through a combination of domestic supply and imports.[89] Influencing the material use and emissions related to the production of imported goods presents more challenges from a Norwegian perspective. In considering the potential to influence the sector domestically, it's important to consider the role of public procurement. Due to the sector's substantial public presence, **procurement processes allow for direct influence on material usage and emissions, even for imported goods.**

Circular potential — public procurement holds significant circularity potential, even beyond its own material footprint and impact on planetary boundaries

Public sector purchasing power in Norway is significant, with public spending accounting for 45.8% of GDP.[90] Certain local authorities have already demonstrated leadership in setting environmental requirements that have directly led to green innovation. For example, Oslo Municipality's initiatives to promote emission-free building sites.[91]

Thus, public authorities have considerable opportunities to enhance circularity throughout the economy when planning and purchasing. Given the differences between them, **solutions and initiatives may require tailoring to each subsector while still aligning with Norway's overall goals and needs.** The health sector has a particularly high consumption rate of single-use products.[92] While the use of some single-use products might be necessary to meet safety

[89] (SSB, 2024d).
[90] (SSB, 2024b).
[91] (Omland & Gelting Andresen, 2022).
[92] (Health Care Without Harm, 2021).

standards, there is potential to replace some with reusable alternatives to reduce unnecessary waste accumulation and increase recycling. Within public administration and the defense services, purchasing decisions should take material consumption into account. Across the public sector in Norway, it is **vital that authorities and management set and understand the importance of material consumption goals.**

For instance, increasing circularity through the development of urban infrastructure can only be achieved through long-term planning. All subsectors should aim to reduce the material footprint of their internal operations.

	EXAMPLE POLICY MEASURES	BUSINESS STRATEGIES
SMARTER PRODUCT USE AND MANUFACTURE (R0-2)	• Stimulate the adoption of circular business models, product-as-service models and digital solutions to reduce or regulate waste (e.g., retain product ownership, product life extension, design for circularity). • Develop sector-specific guidelines and set circular criteria for public procurement and third-party suppliers (e.g., circular design in construction). Train staff to ensure successful implementation. • Support alternatives to single-use items in the health sector (e.g., sterilization using UV).	• Adopt digital solutions to minimize transport (e.g., online doctor consultations). • Circulate uniforms throughout the service industry (e.g., health workers, military). • Increase the adoption of service contracts (e.g., rent equipment for the health sector). • Adopt a circular procurement strategy across subsectors and set circular criteria. • Reduce energy and raw material use (e.g., increased use of simulations in defense).
EXTEND LIFESPAN OF PRODUCT AND ITS PARTS (R3-7)	• Review and, where possible, implement tax and procurement policies to integrate circularity (e.g., repair, sharing, resale and remanufacturing).	• Create a coherent circular service market across all public entities (e.g., repairs, redistribution, refurbishment). • Extend the lifetime of buildings by postponing demolition through structural repairs.
USEFUL APPLICATION OF MATERIAL (R8-9)	• Develop and harmonize collection and sorting procedures.	• Establish recycling collection.

Table 9: *Circular economy strategies presented according to their place in the R strategies framework. The policy examples are not exhaustive but considered important levers for increasing circularity of the sector.*[93]

[93] (Ellen MacArthur Foundation, 2021b) (Zengerle , Prunel, Lozano, & Wang, 2021) (Robinson & Alsius, 2024) (Forsvaret, 2023).

3. SCENARIOS FOR THE CONSTRUCTION AND TRANSPORTATION SECTORS

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3. SCENARIOS FOR THE CONSTRUCTION AND TRANSPORTATION SECTORS

There is great potential for reducing the material footprint and impact on planetary boundaries in Norway. This section further explores the potential of key circular measures within two critical sectors: construction and transportation. These sectors were chosen for their significant material footprint and impact on planetary boundaries, as well as the potential for targeted policy interventions to reduce these impacts. It is important to note that Norway will have to implement a much broader circular transition to reduce its material footprint to a level well within planetary limits. The potential for action is also significant in other sectors, such as agriculture, forestry and fishing sector and the other services.

In assessing the impact of circular measures on the construction and transportation sectors, two scenarios were considered:

- **Current estimated trajectory scenario:** accounts for potential reductions based on existing systems and habits
- **Transformative shift scenario:** envisions a world where car ownership and new building construction are tightly regulated and restricted

The two scenarios look at the potential reduction of Norway's yearly material consumption. In the construction sector, three key circular measures were found to have the potential to lower the material footprint from housing, office and cabin construction in Norway by 28% to 72%. This reduction equates to 2% to 6% of Norway's total material footprint. In the transportation sector, four key circular measures were found to have the potential to lower the material footprint from personal vehicles in Norway by 34% to 76%, representing a reduction of 2% to 4% of Norway's total material footprint. In the transformative shift scenario, the combined contribution of the construction and transportation sectors could reduce Norway's total material footprint by up to 10%.

The scenarios follow a bottom-up approach and show potential areas of significant raw material consumption (RMC) reduction within Norway's economy. Due to the lack of data and the complexity of the analysis, this assessment neither investigates nor presents specific policies for reaching these targets. In choosing key measures for the scenario analysis, several sources informed the decision. Subsectors with a high material footprint were given priority and the most impactful measures from similar reports, such as a related study by WWF Germany, were used. A literature review of other relevant studies was also conducted to confirm the selection of measures.[94] These estimates show the importance of implementing key circular policies high in the R-hierarchy to transition to a sustainable consumption level. See the Methodology for a more detailed description of the estimates and assumptions involved in the calculations.

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[94] (WWF, 2023) (Metabolic, 2022) (Hertwich, et al., 2019).

This report has not accounted for diminishing returns in the effectiveness of the measures within its calculations. In actual application, when multiple measures are implemented simultaneously to address the same issue, the effectiveness of each measure may be diminished because their impacts overlap. As a result, the cumulative benefit is less than the sum of the individual effects, leading to a reduction in overall effectiveness. For example, if opening new public transportation systems is on its own expected to reduce personal vehicle use by 27% and the increased use of car sharing has the potential to reduce personal vehicle use by 16%, it is unlikely that implementing both measures together would result in a 43% reduction. Some individuals who would have used public transportation may instead choose car sharing, and vice versa. However, this report assumes no diminishing returns within its scenarios due to the complexity of these calculations and the lack of available data.

3.1 SCENARIO: THE CONSTRUCTION SECTOR – THE SECOND LARGEST CONTRIBUTOR TO NORWAY'S MATERIAL FOOTPRINT

As shown in Section 2, the construction sector consumes an alarmingly high proportion of society's material resources, leading to the rapid depletion of finite resources.[95] For example, several materials, including metals and even seemingly abundant natural resources such as sand for concrete production, are nearing exhaustion.[96] The resource-intensive activities of the sector are further compounded by its massive environmental impact due to land use, water pollution, landfill waste and energy consumption.[97] Concrete constitutes the majority of the weight of buildings, followed by steel, wood and brick, depending on the type of building.[98] Concrete is a manufactured composite of cement (produced from limestone and clay), sand or gravel aggregates and water.[99] The extraction of these raw materials and the production of cement require huge amounts of energy and release significant amounts of CO_2, making the concrete industry responsible for approximately 8% of global CO_2 emissions.[100]

One of the most impactful activities is the construction of buildings, which accounts for approximately 85% of the sector's material footprint in Norway[101]. **This report has identified three key circular strategies based on their potential to avoid unnecessary building construction: increasing area efficiency, extending the building lifetime, reusing building components for construction, and renovating housing, office spaces and cabins.** Table 10 and Figure 34 demonstrate the effect of these three key circular strategies.

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95 (Solgaard, Bramslev, & Hope, 2019).
96 (Solgaard, Bramslev, & Hope, 2019).
97 (Still, 2021).
98 (EEA, 2022b).
99 (Uvex, 2022).
100 (Lehne & Preston, 2018).
101 (SSB, 2024c).

	Reduction in raw material consumption (RMC)			
Scenario	Current estimated trajectory		Transformative shift	
Metric	Kilotonnes	Contribution (%)	Kilotonnes	Contribution (%)
Increase area efficiency	1,801	17%	3,827	36%
Extend building lifetime	819	8%	2,551	24%
Reuse building components	362	3%	1,232	12%
Sum reduction in building type housing, offices and cabins (of ~11,000 kt)	2,982	28%	7,611	72%
Sum reduction construction sector (of ~19,000 kt)	2,982	16%	7,611	40%

Table 10: *Reduction in kilotonnes and percentage reduction as a share of the total estimated material footprint from building construction in Norway, (RMC). Minor calculation discrepancies could arise.*

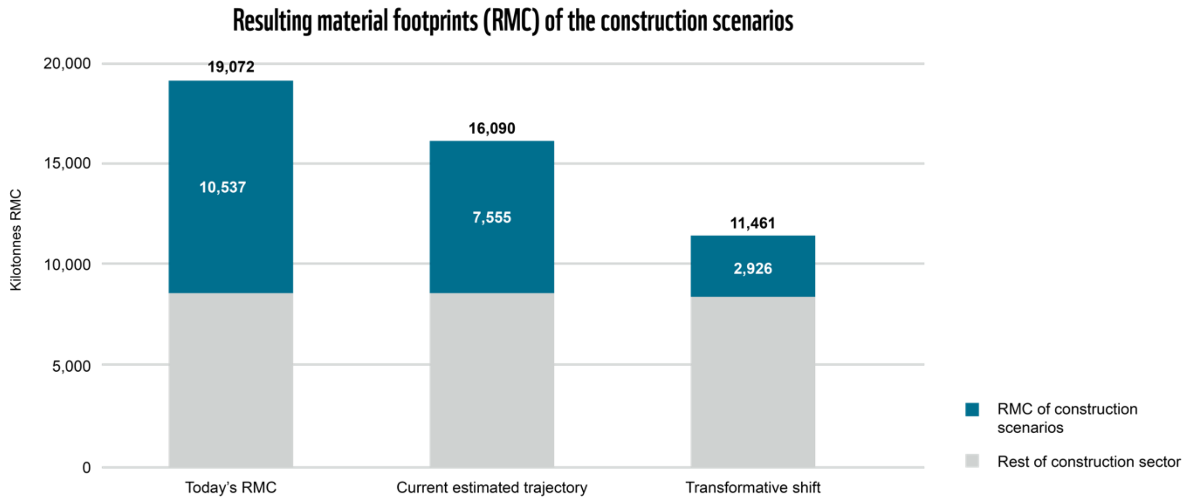

Figure 34: *Stacked bar chart displays the potential reduction in RMC within the construction sector through targeted measures within housing, office and cabin construction.*

Targeted strategies hold the potential to significantly reduce the sector's material footprint and impact on planetary boundaries

Increasing area efficiency, extending building lifetime, and increasing the reuse of building materials could lower the building construction footprint by 28% to 72%, depending on the scenario. **Of the proposed measures, increasing area efficiency is estimated to have the greatest potential for reducing material footprint, with a possible 36% reduction in the transformative shift scenario.** Extending the lifetime of buildings contributes a further reduction of 24% and increasing the reuse of building components adds another 12% reduction in the same scenario.

While the exact effects on planetary boundary metrics have not been quantified, the anticipated decrease in the material footprint is likely to produce corresponding positive impacts across those dimensions. The mitigation effect will be especially high for GHG emissions and land use, with the greatest effect stemming from the area efficiency measure.

The construction sector's emissions account for more than 9 million tonnes of CO_2e, making it the largest contributor to Norway's GHG emissions from the material footprint.[102] Since the construction of housing, offices and cabins amounts to more than half of Norway's building construction, this study suggests that increasing area efficiency, as an example, could potentially decrease the sector's GHG emissions by approximately 25%.

The estimated reductions are based on untapped potential related to our building, living and working patterns

Norway's per capita floor area is one of the highest in the world.

As nations experience economic growth over time, the average living space per person tends to increase. However, even among countries with similar GDP per capita of around US$50,000 annually, there is wide variation in average housing floor area per person.[103] This ranges from 30 m^2 to as high as 70 m^2 per person, with **Norway ranking among the top countries, with an average of 70 m^2 housing space per capita, even when excluding additional residencies, such as cabins.**[104]

Globally, it is estimated that 42% of commercial office space is underutilized,[105] and according to the 2022 Living Conditions Survey on working environment, 42% of employed individuals have the option to work remotely from home.[106] **Increasing area efficiency in both existing and new building construction constitutes the most efficient measure for reducing material demand.**[107]

Reducing per capita floor area could significantly free up energy resources, as residential buildings account for about one-third of the final energy demand in Norway.[108]

More than 22,000 buildings are demolished each year

Many of the buildings that are demolished today are still in good condition.[109]

Extending the lifespan of existing buildings through renovation and adaptive reuse is seen as an effective strategy for reducing embedded emissions and material consumption by delaying the demand for new buildings.[110] Research in Norway has revealed a wide variation in building lifespans, spanning from as little as four decades to as much as three centuries, with an average of 125 years.[111] **Consequently, making the extension of building lifespans the new norm holds huge potential.** New building construction demands approximately 17 times more material than renovation.[112] However, it is important to assess when renovation is appropriate, and avoid renovation motivated solely by trends. An outcome of renovation is often the disposal of building components and interiors as waste, long before their technical lifespan is over. Norwegians spent NOK 88 billion on housing renovations in 2020.[113]

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[102] (Miljødirektoratet, 2024b).
[103] (Hertwich, et al., 2019).
[104] (Amundsen, 2023).
[105] (Irisys, 2021).
[106] (SSB, 2024a).
[107] (Pauliuk, Sjöstrand, & Müller, 2013).
[108] (Pauliuk, Sjöstrand, & Müller, 2013).
[109] (Hagenes, 2021) + (Solgaard, Bramslev, & Hope, 2019).
[110] (EEA, 2023a).
[111] (Brattebø & Bohne, 2006).
[112] (Bouillon-Duparc, 2022).
[113] (Elnan, 2021).

A large portion of building materials ends up in landfills

The construction industry accounts for 25% of Norway's total waste volume.[114] Today, most construction sites produce approximately 40 kg to 60 kg of waste per m^2.[115] Norway places a strong emphasis on recycling construction and demolition waste (C&DW), and recycling accounts for approximately 57% of total C&DW treatment.[116] However, a significant portion — over 30% — of C&DW in Norway still ends up in landfilling, which is considered the least desirable alternative in the waste management hierarchy.[117] **Compared to other European nations, Norway has one of the highest landfilling rates** for **construction and demolition waste.**[118] A recent study found that the Norwegian construction sector was only 7% circular in 2023.[119] This indicates untapped potential for greater reuse of building materials. **Significant obstacles include the lack of suitably specified components available for reuse, concerns related to quality assurance and risk management, as well as the financial costs involved.**[120]

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114 (DFØ, 2024).
115 (DFØ, 2024).
116 (Marchuk, 2020).
117 (Marchuk, 2020).
118 (EEA, 2023b).
119 (SINTEF, 2024).
120 (Hertwich, et al., 2019).


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3.2 SCENARIO: THE TRANSPORTATION SECTOR – ONE OF THE LARGEST CONTRIBUTORS TO NORWAY'S MATERIAL FOOTPRINT

As mentioned in Section 2, the transportation sector consists of multiple subcategories. Various activities contribute to the environmental footprint of these subcategories. One of the most impactful is the ownership and use of personal vehicles (cars), which stands out as potentially the largest single contributor to material consumption within the sector in Norway.

Cars affect the environment in multiple ways. The manufacture of new vehicles requires large volumes of materials. Metals constitute the majority of the weight of personal vehicles, with other materials such as plastics, glass and textiles making up the remainder. The consumption of metals exerts a significant impact on planetary boundaries due to the resource-intensive nature of their extraction and production processes. Electric vehicles, which are increasingly common in Norway, require a greater quantity of metallic minerals for their production than traditional combustion-engine vehicles; they also utilize other finite resources. Figure 35 shows the metallic mineral use in electric vehicles.

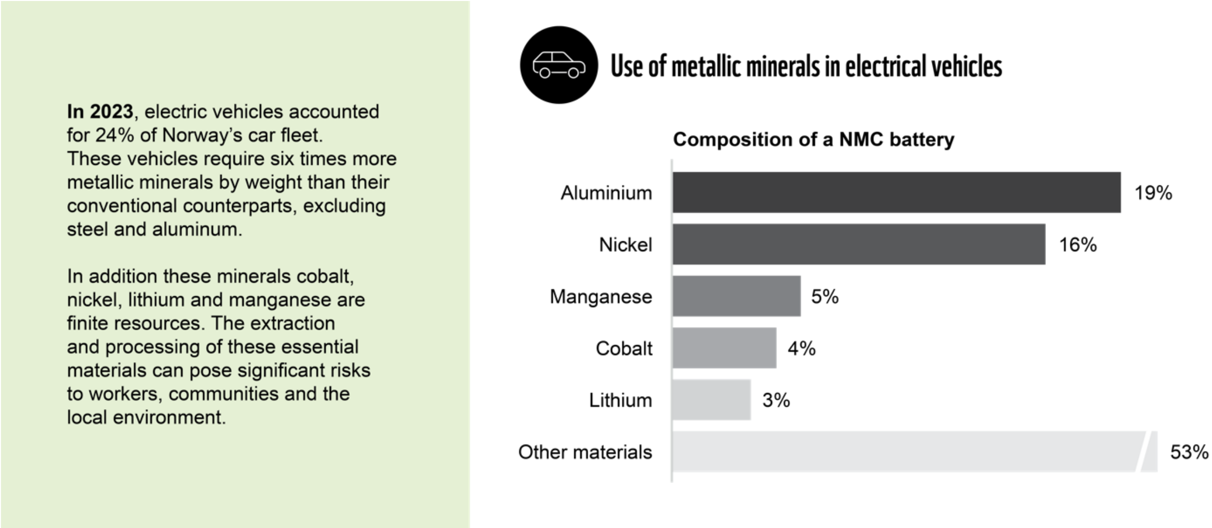

Figure 35: *The figure shows a bar chart of the metals used and their respective percentage share in nickel, manganese cobalt, NMC batteries. The NMC battery is a common battery in EVs today, though the use of lithium iron phosphate batteries is experiencing rapid growth.*[121]

In addition, the widespread use of personal cars strains transportation infrastructure and necessitates additional materials to maintain, improve, and expand capacity. Since there are no high-volume vehicle producers in Norway, all vehicles are imported via complex supply chains that stretch across the world, with global ramifications.

This section of the report focuses on personal transport and aims to quantify the potential impact of four key circular strategies: **increasing car sharing, increasing carpooling, promoting smaller cars and increasing the use of alternative transportation (such as public transport, biking and walking).** The primary focus of these strategies is to reduce the need for private passenger car ownership and use, thereby reducing the transportation sector's footprint. These measures have been adjusted to the Norwegian context, considering factors such as population density and areas of high potential impact, such as large urban areas. Table 11 and Figure 36 show the potential effect of these strategies on the material footprint.

[121] (Abuelsamid, 2023).

	Reduction in raw material consumption (RMC)			
Scenario	**Current estimated trajectory**		**Transformative shift**	
Metric	Kilotonnes	Contribution (%)	Kilotonnes	Contribution (%)
Increase car sharing	285	4%	1,030	16%
Increase carpooling	383	6%	916	14%
Smaller cars	1,000	15%	1,319	20%
Increase use of other transportation	577	9%	1,732	27%
Sum reduction in addressable personal vehicle use (of ~6,500 kt)	**2,245**	**34%**	**4,997**	**76%**
Sum reduction in transportation sector (~17,000 kt)	**2,245**	**13%**	**4,997**	**29%**

Table 11: *Reduction in kilotonnes and percentage reduction as a share of the total estimated material footprint from personal vehicles in Norway, (RMC). Minor calculation discrepancies could arise.*

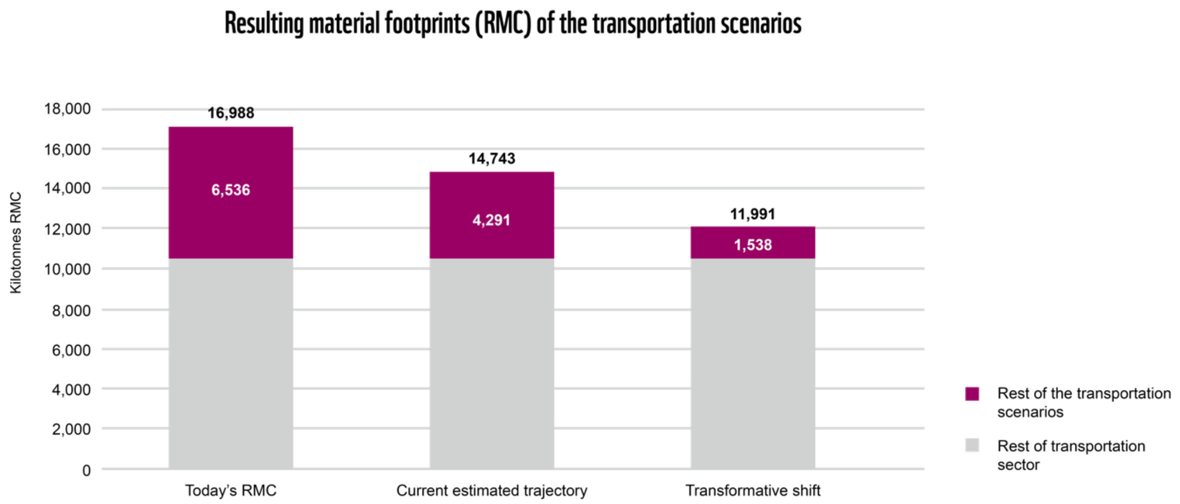

Figure 36: *Stacked bar chart displays the potential reduction in RMC within the transportation sector through targeted measures within personal transportation.*

Targeted strategies can significantly reduce the sector's material footprint and impact on planetary boundaries

Increased car sharing, carpooling and the use of other transportation have the potential to lower the total demand for personal vehicles by 126,000 to 770,000 compared to today, depending on the measure and the scenario. Of the proposed measures, increased use of other transportation is estimated to have the greatest potential, with a potential to reduce vehicle usage by up to 27% or approximately 770,000 vehicles in the transformative shift scenario. Reducing vehicle weight and size, while not affecting the number of personal vehicles on the road, is estimated to have a great potential for reducing the footprint, with a possible reduction of 20% in the transformative shift scenario.

Similar to the construction sector, although the precise impact of these strategies on planetary boundary dimensions hasn't been quantified, they are expected to closely align with the associated reduction in material footprint. See the exploration of the impact of the transportation sector's material footprint on the planetary boundaries in Section 2.2. Reducing the average size of personal vehicles may have an effect on planetary boundaries that differs from that of other measures. For example, a focus on weight may drive a transition to lighter materials, but these may have a different impact per unit. Therefore, **it is important to consider solutions with a total reduction in environmental impact.**

Road traffic accounts for approximately 18% of GHG emissions in Norway.[122] Since personal vehicles account for the majority of traffic, this study suggests that car sharing could potentially decrease Norway's total GHG emissions by approximately 3% if the number of personal vehicles is reduced by 16%. However**, it is important to recognize that the impact of these strategies on the sector's GHG emission will diminish over time as Norway's car fleet continues to transition to predominantly zero-emission vehicles.** In 2023, one-fourth of the cars registered in Norway were electric, compared to less than 4% in 2016.[123]

Similarly, reducing the number of personal vehicles could significantly affect other key planetary boundary dimensions. Ocean acidification, driven by higher CO_2 concentrations in the atmosphere, is heavily influenced by emissions from personal vehicles. Fewer cars on the road would also likely improve biosphere integrity by reducing pollution and minimizing the need for road construction projects that interfere with natural habitats.

The estimated reductions are based on untapped potential related to our travel patterns

Norwegians are buying larger and heavier cars than before.

In recent years, **there has been a growing preference for larger and heavier cars.** Apart from plug-in hybrid cars, the average weight of all types of personal vehicles has increased over the past five years.[124] The most significant increase has been observed in electric vehicles, which experienced an average weight increase of approximately 15% between 2020 and 2022. This trend is not limited to Norway. In Europe and the USA, a similar trend is evident, showing a 1 cm increase in car width every two years over the last two decades. This has implications for both direct material consumption and infrastructure requirements[125], increasing both the material and energy needs for cars and accelerating road abrasion. **In 2023, the Norwegian government introduced a weight fee for personal vehicles. As of 1 July, the tax was at NOK 12.50 per kg for personal vehicles exceeding 500 kg, regardless of the type of personal vehicle.**[126]

98% of the time, cars are found in a parking lot or garage

In 2023, there were approximately 2.9 million personal vehicles registered in Norway.[127] This results in approximately one car per person for 65% of the population aged 17 and older. Most of the time, these cars are found in a parking lot or garage. In fact, it has been estimated that, on an

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122 (SSB, 2024g).
123 (SSB, 2024e).
124 (OFV, 2022).
125 (T&E, 2024).
126 (Finansdepartementet, 2023).
127 (SSB, 2024f).

average, **cars in Norway are not in use 98% of the time.**[128] **The low utilization rate comes from Norwegian travel habits, which include ownership of a second or third car in many households, which is used only during holidays and weekend trips.**[129]

About 85% of office commutes involve no passengers beyond the driver

The average car occupancy rate in Norway per trip has been estimated at around 1.5 passengers.[130] However, the number of passengers varies based on the purpose of the trip. Longer journeys, such as weekend getaways, typically accommodate more passengers per trip. Conversely, shorter, routine trips tend to have fewer passengers. Office commutes typically have one of the lowest passenger counts per trip, with an estimated average of 1.14 passengers. This suggests that 85% of office commutes are solitary trips, involving only the driver.

Public transport accounts for only 10% of passenger transportation in Norway

Public transportation accounts for approximately 10% of all personal transportation in Norway.[131] However, there has been a decline in usage of public transport compared to 2018, largely influenced by changes in travel patterns due to the Covid-19 pandemic.[132] Increased remote work and the growing number of personal vehicles have contributed to this trend. **Consequently, the proportion of public transportation in total trips is lower now than it was before the pandemic.** This development is reflected in the capacity utilization for public transportation, which was estimated at 25% in 2022, down nine percentage points from 2019.[133] The usage of public transportation varies by region and trip purpose. Higher-density areas exhibit more frequent use. Public transportation is most commonly used for shorter trips. There are also some limitations to public transport adoption in Norway outside of urban areas, due to relatively low population density. However, **there is substantial potential to reduce car dependency in Norway by promoting cycling and walking, as approximately 70% of daily trips made by Norwegians are relatively short, lasting less than 30 minutes.**[134]

Car sharing in Norway

Currently, there are 11 car sharing providers in Norway (Helle, 2024). Car sharing can be divided into two main categories: business-to-consumer (B2C) and peer-to-peer (P2P). The B2C model can either be a membership model or a business that organizes the fleet. Examples of the B2C business model include companies like Hertz Bilpool, Hyre, MoveAbout and Vybil. The P2P model is platform-based rental system between private individuals. An example of the P2P business model is Getaraound (formerly known as Nabobil).

In Oslo, 600 parking spaces are currently reserved for car sharing (Oslo kommune, u.d.).

[128] (Transportøkonomisk Institutt, 2022).
[129] (Opinion, 2023).
[130] (Vågane, 2009).
[131] Estimated based on public transport share of total PMK in 2022 (SSB, 2023c).
[132] (Andersen, 2023).
[133] (Andersen, 2023).
[134] (Opinion, 2023).

3.3 ACHIEVING THE ESTIMATED MATERIAL FOOTPRINT REDUCTIONS OF THE SCENARIOS REQUIRES ACTION BEYOND THE SECTOR ITSELF

Social and cultural norms are significant barriers to success for both the construction and transportation sectors

Several of the measures introduced in the scenario analysis, along with others, have been evaluated in previous studies. Results from previous assessments indicate that there are no simple fixes for reducing the material footprint within these sectors, as many of our traveling and living patterns are deeply ingrained in our daily lives. For instance, a project by the Norwegian Public Roads Administration aimed at promoting carpooling in 2015 yielded limited results, highlighting the challenge of altering established habits.[135] **These findings suggest that policies alone may not suffice to realize the full circular potential for the sectors. New policies must be complemented by a shift in social norms and a review of existing policies.** For example, increasing second home ownership, decentralization policies and construction of new road infrastructure leading to induced demand are all potential drivers of increased car ownership.[136] Similarly, the Planning and Building Act and the regulations on technical requirements for construction works do not sufficiently incentivize area efficiency and renovation, nor do they facilitate circular value chains.[137] **The primary barriers to change include a lack of opportunities, a lack of awareness, ingrained old habits and misconceptions about the costliness of environmental considerations.[138] These barriers, in turn, limit the creation of effective policies.**

In other words, to achieve material reduction, one needs to act in multiple arenas to increase understanding throughout society and induce individuals, businesses and policymakers to take action. The following section (Section 4) will elaborate on cross-sector action to identify the synergies and actions required to bring about a shift in material consumption.

[135] (Meland, Lervåg, & Roche-Cerasi, 2015).
[136] (NRK, 2014) (Bloomberg, 2018).
[137] (kbnn, 2022).
[138] (Grønn Byggallianse, u.d.).

4. CROSS SECTOR RECOMMENDATIONS AND CIRCULAR POLICIES TO REDUCE MATERIAL CONSUMPTION

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4. CROSS-SECTOR RECOMMENDATIONS AND CIRCULAR POLICIES TO REDUCE MATERIAL CONSUMPTION

This report has examined the material footprint of various industry sectors in Norway, the impacts on planetary boundaries and sector-specific actions and strategies to reduce material footprint and increase circularity. However, a circular system, much like nature, does not function in silos; it requires fundamental changes across industry sectors.

Transitioning to a circular economy is a multifaceted process that encompasses socio-economic, political and cultural shifts. It requires a comprehensive and holistic policy mix, a clear strategy with targets, indicators and measures, as well as clearly defined responsibilities and effective monitoring mechanisms.[139]

4.1 KEY BUILDING BLOCKS FOR A CIRCULAR ECONOMY

Policy actions can generate a set of societal effects, such as guiding consumer purchases or creating a new market. Moreover, the government can influence supply chains through circular procurement strategies, as identified in Section 2 of the report.

Norway's national circular economy strategy and action plan falls short of its potential

Developing and incorporating circularity fundamentally relies on national circular economy strategies that utilize policies across the nine R categories introduced.[140] Norway's government presented their circular strategy in 2021 and followed up with an action plan in 2024. However, the action points in this plan largely use wording such as *assessment*, *investigation* and *development*, and do not go beyond what is required of Norway as a member of the EEA.[141] **The current regulatory** framework **fails to eliminate the barriers that prevent a holistic implementation of circular measures.**[142]

A national material resource target should be the next milestone for Norway

To transition toward a circular economy in Norway, a comprehensive top-down approach with a national reduction target for resource consumption is imperative. Establishing a measurable, time-bound target is essential for enhancing circularity and reducing the overall material footprint, thereby ensuring alignment with planetary boundaries. The target's ambition should reflect the gap of 70% between Norway's material footprint and sustainable levels. **If Norway commits to a circular economy mission, a comprehensive national material flow analysis will be crucial.**[143] Such an analysis will reveal the complexities of material flows in the economy, uncovering opportunities and synergies across sectors and guiding effective policy interventions to accelerate the transition toward circularity.[144]

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[139] (Brusselaers & Gillabel, 2022).
[140] (JASPERS, 2022).
[141] (Norwegian Center of Circular Economy, 2024).
[142] (Miljødirektoratet, 2024a).
[143] (Regjeringen, 2024b).
[144] (IRP; UNEP, u.d.).

The European Parliament stresses the importance of setting binding targets for resource consumption within 2030 in its revised Circular Economy Action Plan from 2021.[145] These targets and indicators should provide a solid foundation for effective planning and investment decisions. To make the targets binding, it would be beneficial to enshrine the targets in a resource conservation law.[146] The Netherlands is considered a frontrunner in the circular economy and has set the target of a 50% reduction in the use of abiotic raw materials by 2030.[147]

The government must take responsibility and lead by example

Public procurement accounted for about 35% of all public spending in 2022.[148] As a result, the government constitutes a significant market force. In Norway's circular action plan, the government posits that public procurement of circular goods and services will be a key component of a transitioning society.[149] **Procurement decisions should be grounded in data and evidence about material footprints and the planetary boundaries.** To enable staff to make informed decisions, it is crucial that they receive the necessary training and support and control tools.

Moving beyond recycling and higher up in the R hierarchy

As mentioned in the first section of this report, policies aligned with R strategies, such as refuse, reduce and reuse are more impactful than those lower down the hierarchy. **However, current national policies are focused primarily on the lower end of the R hierarchy, namely recycling and recovery measures.[150]** For instance, most policies concerning products lack clauses that address material resource efficiency.[151] Furthermore, there are few policies aimed at reducing consumption or extending product lifetimes, which contributes to the continued linearity of today's economy. **All in all, "narrowing the loop" through absolute reduction in resource consumption should be the guiding principle.**

Create a level playing field

Companies depend on the government to remove financial and regulatory barriers, create fair competition, ensure reliable planning for circular innovation and enable circular business models to thrive. Companies may construct durable products due to mandated eco-friendly designs or opt for recyclable packaging if the law prescribes it. **Currently, linear practices are often more economically viable for companies.** Market incentives founded on "the polluter pays" principle can help establish the business case for circular goods and services. Externalities need to be factored into pricing to discourage harmful practices and stimulate circular innovation. The EU has recognized that a circular economy is key to increasing competitiveness and reducing dependency on other markets,[152] and more circularities will also decrease businesses' climate and nature risks.

[145] (European Parliament, 2023).
[146] (WWF, 2023).
[147] (Rijksoverheid, 2016).
[148] (SSB, 2022c).
[149] (Regjeringen, 2024a).
[150] (Brusselaers & Gillabel, 2022).
[151] (Milios, 2018).
[152] (European Comission, u.d.).

Signaling the path to circular consumption

The government has a responsibility to guide the people in the right direction, ensuring that people understand the reasoning behind policies and feel empowered to take the right actions. One emerging policy requirement to facilitate this is the **Eco-design for Sustainable Products Directive,** introduced in the EU as part of the implementation of the circular economy action plan. The regulation will set requirements for both information and performance. One aspect of the informational requirements is **digital product passports (DPPs)**, which will facilitate product transparency, and allow consumers to make purchasing decisions based on factors beyond just cost. DPP was identified in Section 2 as an efficient tool for increasing circularity on a sector level.

Ultimately, a combination of regulatory, economic and informational instruments will be needed to fully transform consumer behavior and align it with Norway's environmental goals. Consumer choices, such as opting for public transport over private vehicles, can be influenced through legislation. Likewise, monetary incentives can motivate individuals to repair, instead of replacing, faulty electrical appliances. Such small yet significant behavioral changes can gradually become embedded in daily routines, establishing a new societal norm.[153]

[153] (Miljødirektoratet, 2024a).

4.2 FIVE OVERARCHING POLICY RECOMMENDATIONS FOR THE CIRCULAR ECONOMY

The following five overarching policy recommendations describe measures designed to advance the adoption of a circular economy in Norway. These recommendations have been identified based on a literature review,[154] and emerging national and EU policies. In addition, policy measures that appeared across multiple sectors also have inspired the identification of these overarching categories. Lastly, subject matter interviews with experts and a panel discussion have informed the overarching policy categories presented below.

1. Restrict linearity

Circular practices must become the default solution and an easier option for businesses and consumers. Thus, it is critical to introduce policies that increase the cost of non-circular practices or restrict the opportunities to operate within a make-use-waste system. Some proposed policies include:

- **Tax non-circular practices:** Implement taxes that reflect the true cost of extracting and wasting valuable virgin resources. The tax revenue can be allocated toward environmental restoration and /or preventing the effects associated with the practices being taxed. In Section 2, different tax options were identified as critical levers for circularity. A nature tax and a tax on virgin material products were identified as examples of taxes under consideration in Norway.[155] Tax relief is covered in the next circular economy policy category.

- **Restrict market access:** Limit the market entry of products or materials that are at odds with closing the loop. One possible measure is to ban non-circular products from market entry, similar to the EU's ban on single-use plastic products and the Styrofoam ban in several states in the USA. In Section 2, restrictions related to packaging and single-use products were identified as a policy measure on a sectoral level.

- **Extended producer responsibility** (EPR) schemes: EPR schemes hold producers and distributors responsible for the end-of-life of their products and services, shifting the economic burden of waste disposal from municipalities and consumers to producers. In essence, the schemes are a set of policies that facilitate appropriate collection, recycling and disposal of products. The cost of putting the infrastructure in place is thus removed from governments, municipalities and consumers. This will also increase the competitiveness of circular products. EPR schemes are suggested by several sectors in Section 2 of this report. An example of a candidate for EPR schemes is the textile industry, which currently lacks an infrastructure for end-of-life handling, such as collection, sorting and recycling facilities. EPR schemes could facilitate this process by reducing dependency on virgin feedstocks and limiting the amount of waste sent to landfills.

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[154] (Hartley, Schülzchen, Bakker, & Julian, 2023) (Ellen MacArthur Foundation, 2015) (WWF, 2023).
[155] (Departementenes sikkerhets- og serviceorganisasjon, 2022).

2. Finance circular economy solutions

Financial instruments can help create a market for a circular economy and make new business ventures viable and attractive. Circular businesses often require a higher initial investment, and securing a down payment takes longer than in a linear business model. Below are policy measures that can accelerate the adoption of circular practices.

- **Circular procurement practices: Circular procurement** practices have been emphasized as an important policy lever throughout Section 2. Implementing mandatory circular public procurement, establishing sector-specific circular procurement guidelines and setting circular procurement targets are effective ways for governments and businesses to strengthen their influence.

- **Subsidies: Subsidies** can influence the decisions of businesses and consumers. Adopting subsidies that support circular practices and eliminating existing environmentally harmful subsidies that serve as barriers can help reduce pressure on virgin resources.

- **Green investment funds and loans: Green investment funds, green loans with circular conditions and circular economy bonds** can provide much-needed stability for circular business ventures, particularly those facing new regulatory challenges and a maturing consumer market.

- **Governmental financial incentives:** The EU has recommended using VAT as a tool to stimulate circular activity. For example, removing VAT on second-hand products, products with recycled content and repair services can increase repairs and reduce the purchase of new products.[156] These measures are also on the political agenda in Norway. However, the current tax system can hinder circular activity; for example, if gifts are taxed while the destruction of goods is written off. Thus, a review of the current tax systems and their effect on material consumption is necessary. Tax relief measures can be found on a sectoral level in Section 2.

[156] (Departementenes sikkerhets- og serviceorganisasjon, 2022).

3. Enable the circular economy

Enabling the circular economy involves a set of policy measures that ease the adoption of circular businesses and practices, thereby building a foundation for new practices to flourish. Designing and creating a society that operates and creates co-existing goods and services is essential to reduce overproduction and minimize redundancies.

- **Standardizing the design** for multiuse products will reduce pressure on the overproduction of goods. Charging cables for electrical equipment are an example of goods that can be standardized to minimize the need for multiple cables. This approach has already been successfully implemented throughout the EU and can be extended to more products.

- **Companies should be required** to produce goods and deliver services with minimal environmental impact by setting standards or requiring, for example, longer warranty terms. The EU has already adopted a directive on eco-design for sustainable products.[157] Product requirements such as product life expectancy, repairability, chemical use, energy consumption and the use of recycled materials will all limit products' environmental impact and increase consumer awareness.

- **Making circular solutions and alternatives** more attractive can ensure wider adoption across society. For instance, the attractiveness of public transport can be achieved through increased ease of access and reduced cost, which has a correlated effect on increased usage by citizens.

- **Supporting sharing platforms** is highlighted throughout the report as an effective measure to increase utilization of products. Community-based initiatives, such as sharing tools and products, is an example of a small-scale sharing platform. The Toronto tool library is such a service, through which a subscription grants access to more than 700,000 tools to perform small household improvements and chores.[158]

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[157] (European Council, 2024).
[158] (Ellen MacArthur Foundation, 2021a).

4. Measure and inform

Stakeholders today recognize that data gaps are a significant barrier to the adoption of a circular economy at both national and company levels. Accurate data is essential to identifying surplus materials and creating synergies across different sectors. Moreover, data plays a crucial role in tracking progress toward smart and sustainable resource management. It enables policymakers to refine policies and promote circular procurement practices. For businesses, robust data supports informed decision-making in manufacturing processes and material selection. Ultimately, comprehensive data empowers consumers to make environmentally conscious purchasing decisions. Policies to increase data gathering and sharing can be seen below.

- **Circular economy indicators and targets** :Standardize circular economy indicators and targets both nationally and for businesses. A more detailed explanation of the significance of national material resource targets is explained in Section 4.1.

- **Circularity reporting:** Mandatory circularity reporting at both company and national levels is essential to identifying information gaps and increasing awareness. The existing policy, the Corporate Sustainability Reporting Directive (CSRD), requires companies to report on their resource consumption. This includes the European Sustainability Reporting Standards (ESRS) E5, which provides a good starting point. However, ESRS E5 is currently only mandatory for companies that have classified or understood resource dependency as "material," in other words, critical to their business.

- **Digital tools:** Digital tools, such as the **Digital Product Passport (DPP)**, are a solution that allows consumers to access life cycle data at the product level. Blockchain is one way to facilitate DPPs and can enable data gathering and sharing on a larger scale to inform all stakeholders.

5. Awaken and educate

A circular society is only possible if all parts of society work together to identify synergies of material use and knowledge sharing. This is best achieved by educating individuals, businesses and decision-makers in schools or through informational campaigns. Collaborative efforts within communities, businesses and governments are essential to accelerating the adoption of circular practices and improving resource efficiency. On the whole, this can help consumers make environmentally friendly purchases.

- **Informational campaigns:** Run informational campaigns to educate consumers on how to make conscious choices that will enhance circularity in society. For instance, the EU has launched a circular consumer footprint calculator to increase awareness and provide guidance on how to reduce individual material consumption.[159]

- **Circular economy in the curriculum:** Incorporate the circular economy in the curriculum in schools, professional degrees and higher education. This is important to increase the application of circular economy thinking in all sectors of society from small businesses to larger organizations.

4.3 TIME TO ACT

The world is currently at a pivotal juncture. The global economy's reliance on extensive resource extraction is pushing our planet to its tipping point. **Norway's raw material consumption per capita is among the highest globally,** significantly surpassing both European and global averages. **Embracing a circular economy can help shift human prosperity away from exploiting the Earth and toward fostering societal and planetary wellbeing.**

This report highlights substantial opportunities for circular practices in the construction, transportation, manufacturing and agriculture, forestry and fishing sectors. **Our quantitative analysis indicates that Norway could reduce its material footprint by 10% through transformative actions in the construction and transportation sectors alone.** The urgency of integrating circular principles into governance is a critical call to action, with species extinction, ecosystem collapse and climate instability all on the rise.

A wide array of policy levers must be pulled to transition to a circular economy. To achieve the latter, decision-makers need to restrict linearity, finance circular economy solutions, enable a circular economy, measure, inform, and educate. This report outlines a comprehensive toolbox of policies and strategies, at both sectoral and international levels, designed to "close the loop" and ensure enduring prosperity.

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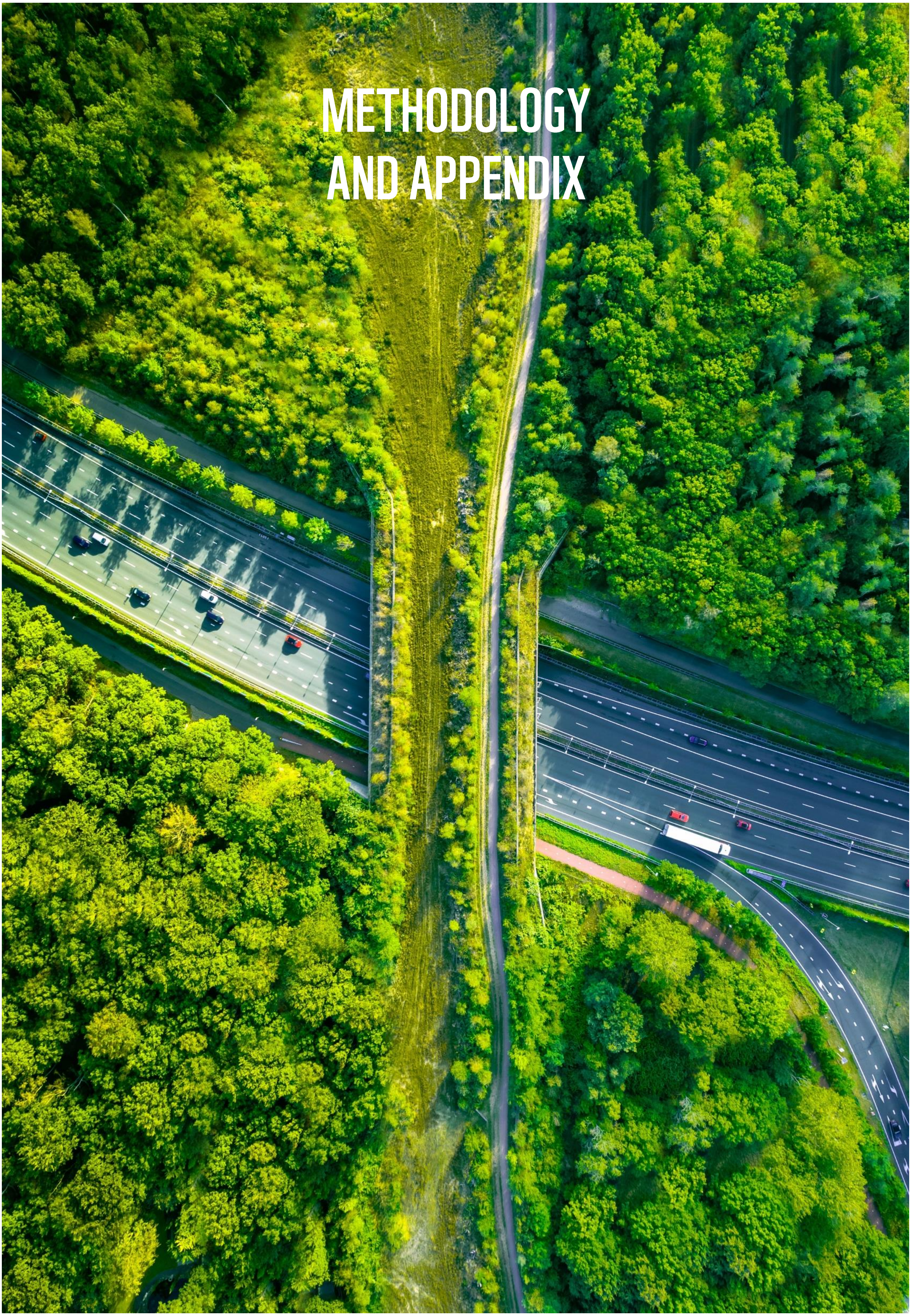
[159] Footnote is missing


METHODOLOGY
AND APPENDIX

METHODOLOGY

This section describes the methodological background, data extraction and analysis, and outlines limitations associated with the method and dataset used.

Our analysis utilized the environmentally extended multiregional input-output (EE-MRIO) database EXIOBASE (version 3.8.2). The economy was broken down into eight economic sectors to facilitate comparison and in-depth analysis of selected sectors. The material footprint and environmental impact of activities within the Norwegian economy were assessed using a consumption-based approach, assigning resource use and environmental impact to the sector where final consumption occurred. Multiple data sources from relevant reports and scientific literature were used to include key circular measures from the construction and transportation sectors in the scenario analysis.

About the underlying data

EXIOBASE was developed by a consortium of research institutions throughout Europe and funded by European research framework programs. It features detailed data on 44 countries and the 5 'rest of the world regions' (*Asia and Pacific, America, Europe, Africa and the Middle East*) and provides information on 163 industrial sectors. The construction of EXIOBASE relies on the disaggregation and linkage of country-specific supply and use tables, which come together to form a comprehensive global multi-regional supply-use table. Disaggregation procedures are informed by a compilation of auxiliary data on production volumes - for example, material database data from Food and Agriculture Organization Statistics (FAOSTAT) and International Energy Agency (IEA), and detailed trading data from the BACI. Additionally, the database includes coefficient data for production processes, detailing input requirements per production unit, primarily sourced from life cycle inventory data and input-output tables. For more information about the compilation process of EXIOBASE, see Stadler et al.'s (2018) publication about the development of EXIOBASE 3 at https://doi.org/10.1111/jiec.12715.

One of the advantages of using EXIOBASE is the high number of available environmental impact categories. Nine categories were chosen to assess Norway's impact on the planetary boundaries. See Appendix A and Table 12 for more detailed information about each impact category and their link to the planetary boundaries' framework. The link between each planetary boundary and impact category, as well as the relative comparisons between sectors drawn out in this report, was discussed with researchers at the Stockholm Resilience Centre to ensure the scientific integrity and consistency of the calculations. However, the Stockholm Resilience Centre bears no responsibility for the report's conclusions or outcomes, as the responsibility for the content remains solely with the authors.

The Norwegian material footprint has been assessed by a division based on the standard four aggregated material categories, namely: metals, non-metallic minerals, fossil fuels and biomass, and amounts to a total of 127 million tonnes.

Traditionally, there are two ways of viewing material footprint: either by only accounting for used materials, or by including unused material displaced during extraction. Used material footprint refers to extracted materials that are directly utilized to produce a product or supply a service, thereby entering the economic system. Unused material is any material that has been moved, displaced, or otherwise disturbed during the production of a product without entering the economic system, such as agricultural harvesting losses, by-catch from fishing, and overburden materials from mining. The material footprint that only accounts for used material is known as raw material consumption (RMC), while accounting for both used and unused material would give the total material consumption (TMC).

TMC provides a more comprehensive picture of the overall environmental impact and better reflects material extraction's influence on planetary boundaries. For this study, RMC has been deemed to be a more appropriate measure of resource usage for two key reasons.[160] Firstly, data on unused material extraction is often either poorly recorded or omitted, meaning unused material extraction estimates are burdened with a great deal of uncertainty,[161] which would lessen the certainty of any analysis. Secondly, by including unused extractions in its calculations, TMC exacerbates the issue of comparing materials with varying degrees of environmental impact.

Variations in data choices and parameters can lead to differing material footprint calculations across reports. This report's use of RMC means it will present lower footprints than reports that use TMC. Furthermore, when calculating the material footprint using EXIOBASE data, two different data sets could be used: either a product-by-product (pop) matrix or an industry-by-industry (ixia) matrix. This report based its calculations on the pop matrix, as it provided more data points. The differences between these matrices can be illustrated by calculating Norway's total material footprint, where using pop yields a total of 127 million tonnes, while ixi results in 138.5 million tonnes.

Additionally, due to the lack of up-to-date data on cycled materials in EXIOBASE, the 127 million tonnes presented in this report do not account for cycled materials. However, this has been calculated by other reports, such as Norway's Circular Gap Report for 2020. They estimated that Norway cycled 5 million tonnes of materials in 2020[162]. If our report had a reliable estimate of Norway's annual cycled material, this estimate would have been added to Norway's total material footprint. The above choices and omissions within the methodology may lead to discrepancies between the results presented in this report and those of other studies on material footprint.

Data extraction and processing

Data from EXIOBASE was extracted from zip files downloaded from EXIOBASE's website using a Python tool called Pymrio. The results are averaged for the period 2019-2022.
The data was extracted to an Excel file for further processing and visualization.
Additional information on the Python code setup can be found at
https://pymrio.readthedocs.io/en/latest/notebooks/working_with_exiobase.html.

[160] (Kovanda, 2020).
[161] (Stadler K. W.-J., 2018).
[162] (Circle Economy Foundation; Circular Norway, 2020)

	Planetary boundary	EXIOBASE metrics
	Land-system change	Land use
	Biogeochemical flows	Nitrogen and phosphorus
	Climate change	Greenhouse gas (GHG) emissions
	Biosphere integrity	Climate change endpoint, ecosystems
	Ocean acidification	CO_2
	Stratospheric ozone depletion	Ozone layer depletion
	Freshwater change	Water consumption
	Atmospheric aerosol loading	Particulate matter 2.5 ($PM_{2.5}$)
	Novel entities	No available data

Table 12: *The table shows which metrics from EXIOBASE are used to map environmental impact by using the planetary boundary framework.*

The EXIOBASE database has inherent limitations, as recent data points are extrapolated. Real data ends in 2019 for CO_2 emissions, 2017 for GHG emissions, 2015 for energy data, 2013 for materials, and 2011 for most other data points.[163] Moreover, developing EE-MRIO-models involves data harmonization because countries report data differently. Accordingly, a small trade-exposed country like Norway can experience diverse results with different models because the MRIO models handle the reconciliation of
data differently. For more information about limitations in the data, see Stadler et al. (2018).

The consumption-based approach

The consumption-based approach accounts for the impacts originating from domestically produced and imported goods where the final product is "consumed" in Norway. This means it excludes the impacts of exported goods and services (see Figure 7). This allows the assessment of cumulated upstream impacts in any economic sector without the risk of double counting.[164] It gives insight into the impact from Norwegian economic activities regardless of whether the impacts occur domestically or abroad, providing a more precise picture of the impacts that Norway can influence.

The consumption-based impacts can stem from three sources:

- Goods and services produced in Norway and with Norwegian final consumption.
- Goods and services imported to be used in intermediate production in the Norwegian economy and with Norwegian final demand.
- Goods and services imported directly to Norwegian final consumers.

Sector classification and prioritization

Eight sectors were assessed in the modeling: agriculture, forestry and fishing, construction, other services, transportation, energy and utilities, other manufacturing and sales, chemicals and materials and public services (Table 13). These are aggregates of the 199 sub-sectors included in EXIOBASE. The classification and aggregation of these sub-sectors were partially guided by concordance tables from EXIOBASE's website. Where possible, this report has aimed to align its sector classification with EXIOBASE's, allowing us to make use of their in-depth analysis on the sub-sectors. This includes the link between EXIOBASE's (and in turn, our) sectors and the NACE codes, providing more information about the activities that fall under the respective sectors. EXIOBASE's work has guided most of our decisions within sector allocation.

It is challenging to perform a sector classification based on EXIOBASE's detailed sectors that produces eight aggregated sectors and is intuitive, mutually exclusive and collectively exhaustive due to the inherent complexity and overlaps in economic activities. Additionally, there are limitations in the available information about how different products and material flows are allocated across economic activities in EXIOBASE, introducing uncertainties into the aggregation process. The uncertainties have been addressed by consulting experts to verify sector methodology, resulting in sector classification that best represents the economic activities and material flow.

[163] (Stadler & al., 2021).
[164] (Stadler K. W.-J., 2018).

Despite EXIOBASE's detailed sectoral breakdown, some sectors lacked granularity. For example, "construction" was represented by only one sector. Additionally, differences in sector names between raw data and concordance tables required manual mapping to ensure inclusion of all data. Furthermore, some EXIOBASE sectors overlapped with many NACE codes. In those cases, all the NACE codes had to be assigned to the same EXIOBASE sector, even though the grouping seemed inappropriate. For example, "post and telecommunication services" is one sector in EXIOBASE, while it would be preferrable to split post and telecommunication services, assigning post to the transportation sector.

See Appendix B for the complete sector classification and Table 13 for more information about sub-sector allocation. The concordance tables are available on EXIOBASE's website https://ntnu.app.box.com/v/EXIOBASEconcordances.

Table 13: *Subsector classification.*

Scenario analysis calculations

When evaluating the effects of circular measures in the construction and transportation sectors, the study examined two scenarios: the **current estimated trajectory and a transformative shift scenario**.

- The current estimated trajectory scenario estimates reductions using current practices and behaviors, such as survey data about current mobility preferences.
- In the transformative shift scenario, most of the potential comes from utilizing existing building stock and, to a larger extent, avoiding the construction of new buildings. Similarly, in the transportation sector, car ownership is envisioned as very limited, drawing inspiration from Singapore's car ownership rate of 20%.[165] However, this figure has been adjusted for the Norwegian context by considering population density of different areas in Norway and population distribution, particularly in larger cities.

Each scenario projected annual material footprint (RMC) reduction potential. Key measures for the scenario analysis were chosen from various sources. Initially, subsectors with significant material footprints were emphasized, and the most effective measures identified in comparable reports, including a relevant study by WWF Germany, were incorporated. Additionally, a literature review of other relevant research was conducted to validate the chosen measures.[166]

The calculations were done as a bottom-up exercise, using multiple sources to identify low and high potentials for reduction within the various measures. To illustrate, different estimates were identified for how much one can extend the lifespan of a building,[167] the theoretical reuse percentage of building materials,[168] and how large an increase in public transportation use is achievable.[169] Below follows a more detailed description of the estimates and assumptions used to calculate the potential reduction in material footprint.

Estimates and assumptions used in the construction scenario calculations

According to Statistics Norway (SSB), 43.3% of annual building construction (measured in square meters) is attributed to housing, 4.7% to offices, and 7.4% to cabins, averaging at 56.4% of the overall construction from 2011 to 2023.

[165] (Oi, 2023).
[166] (WWF, 2023) (Metabolic, 2022) (Hertwich, et al., 2019).
[167] (Hertwich, et al., 2019).
[168] (Metabolic, 2022).
[169] (Gregersen, Liland Hartveit, & Christiansen, 2002/2003).

Measure 1: Increased Area Efficiency

A. The calculation for this measure consists of two contributing parts:
B. The contribution from constructing new buildings with increased area efficiency – fitting more people per square meter, thereby lowering material demand.

- Current estimated trajectory scenario: (A) 20% reduction in total area of new housing, office and cabin construction projects from increased area efficiency.[170] This change is led by developing construction practices and policy recommendations under review.[171] (B) No contribution.
- Transformative shift scenario: (A) 40% reduction in the total area of new housing, office and cabin construction projects from significantly increasing area efficiency.[172] This estimate partly based on previous studies focused on achieving circularity within the construction sector and research into ideal living area standards. (B) An additional 10% reduction from avoiding new housing, office and cabin construction projects by increasing area efficiency in existing building mass.

Measure 2: Extend building lifetime:

Extending the lifetimes of buildings through maintenance and refurbishment would decrease the need and number of new construction projects.

- Current estimated trajectory scenario: assumes a 10% increase in building lifespan, leading to a 5% reduction in housing, office and cabin construction each year.[173]
- Transformative shift scenario: assumes a 50% increase in building lifespan, leading to a 19% reduction in housing, office and cabin construction each year.[174]

[170] (Fishman, et al., 2021).
[171] (Grønn byggallianse, 2016).
[172] (Fishman, et al., 2021).
[173] (Fishman, et al., 2021).
[174] (Fishman, et al., 2021).

Measure 3: Reuse building components

The average material composition by mass of housing, offices and cabins is 75% concrete, 6% wood, 7% steel, 6% brick, 1% glass, and 5% other waste.[175] Current standard secondary material use (recovered material reintroduced into the economy, part of R3-R7) is only 3% for concrete, 95% for steel, 15% for wood, 0% for brick, and 8% for glass. Based on a report by Metabolic, the technical maximum secondary material use rate is 30% for concrete, 95% for steel, 30% for wood, 25% for brick, and 100% for glass.[176] Apart from steel, there is significant improvement potential for secondary material use of construction materials.

- Current estimated trajectory scenario: assumes the secondary use rate can improve to 8% for concrete, 18% for wood, 5% for brick, and 28% for glass.
- Transformative shift scenario: assumes that the secondary use rate can improve to 21% for concrete, 25% for wood, 20% for brick, and 88% for glass.

Estimates and assumptions used in the transportation scenario calculations

According to Statistics Norway (SSB), there were 2.9 million cars in Norway in 2022. The breakdown of car types was 39% diesel, 28% petrol, 20% electric, and 12% hybrid. The share of electric vehicles was less than 4% in 2016 and has been increasing rapidly over the past few years.[177] Annual new car sales were 174,000 in 2022 and 123,000 in 2023. The scenario calculations use the average between these two years.

Measure 1: Car sharing

The analysis distinguishes between the inhabitants of Norway's 10 most populous cities and the rest of the country. This distinction accounts for the fact that people in more densely populated areas are more likely to use car sharing. It is estimated that a car that is part of a car-sharing program can serve 15 people.[178] However, a rise in car sharing does not directly correspond to an equivalent decrease in privately owned vehicles, as some individuals may supplement car sharing with personal car ownership. The replacement rate is set at 75%, based on a 2022 study of car sharing in Bergen.[179]

- Current estimated trajectory scenario: 15% of the population over 17 in the 10 largest cities in Norway uses car sharing, and 5% of the population over 17 outside these cities uses car sharing.
- Transformative shift scenario: 40% of the population over 17 in the 10 largest cities uses car sharing, and 15% of the population over 17 outside these cities uses car sharing.

[175] (SSB, 2024h).
[176] (Metabolic, 2022).
[177] (SSB, 2024e).
[178] (Vågane, 2009).
[179] (Nenseth & Ellis, 2022).

Measure 2: Carpooling

The estimates are based on work-related journeys, which generally have fewer passengers per journey and thus offer higher improvement potential. Non-work-related journeys, such as trips to cabins, often have more passengers, offering less potential for increased carpooling. The calculations recognize that a rise in carpooling does not directly correspond to an equivalent decrease in privately owned vehicles, as some individuals may opt to supplement carpooling with personal car ownership. The replacement rate is set at 75%, as in the car-sharing calculations.[180]

- Current estimated trajectory scenario: For work-related journeys, this assessment assumes that one in five work-related journeys with only one passenger is replaced by carpooling. For other journeys, one in 10 journeys with only one passenger is replaced by carpooling.
- Transformative shift: For work-related journeys, this assessment assumes that one in three work-related journeys with only one passenger is replaced by carpooling. For other journeys, one in five journeys with only one passenger is replaced by carpooling.

Measure 3: Smaller cars

For smaller cars, it is estimated that the total weight of Norway's cars could be significantly reduced by decreasing the proportion of SUV-type vehicles. In 2022, SUVs accounted for 63% of new car sales.[181] Promoting the purchase of lighter vehicle alternatives would reduce the material footprint of the sector.

- Current estimated trajectory scenario: The average weight of new vehicles sold is reduced by approximately 15% compared to the average weight per vehicle in 2020, by lowering the share of SUVs in new car sales to approximately 30%.
- Transformative shift: The average weight of new vehicles sold is reduced by approximately 20% by lowering the share of SUVs in new car sales to approximately 20%.

Measure 4: Increased use of other transportation

Other transportation includes the use of public transportation, biking and walking. For public transportation, the total number of kilometers traveled by land-based public transportation modes is used as the basis for the scenario calculations. These alternatives are often preferred for more frequent, shorter journeys.[182] Recognizing their substantial potential to supplant private car ownership, the scenarios assume a complete 100% replacement rate.

- Current estimated trajectory scenario: The use of other transportation is increased by 40%.
- Transformative shift scenario: The use of other transportation is increased by 120%.

[180] (Nenseth & Ellis, 2022).
[181] (OFV, 2022).
[182] (Opinion, 2023).

APPENDIX A: LIST OF IMPACT INDICATORS AND ASSOCIATED UNITS ASSESSED IN THE REPORT

Impact category	Unit
Land use	km^2
Nitrogen	kg
Phosphorus	kg
GHG emissions	tonnes of CO_2- equivalents (t CO_2-eq)
Climate change endpoint, ecosystems	PDF
Carbon dioxide (CO_2)	kg
Ozone layer depletion	kg CFC-11 eq.
Water consumption	m^3
Particulate matter 2.5 ($PM_{2.5}$)	kg

APPENDIX B: MAPPING OF EXIOBASE SECTORS TO 8 AGGREGATED SECTORS

EXIOBASE sectors	Aggregated sectors
Animal products nec	Agriculture, forestry and fishing
Cattle	Agriculture, forestry and fishing
Cereal grains nec	Agriculture, forestry and fishing
Crops nec	Agriculture, forestry and fishing
Manure (biogas treatment)	Agriculture, forestry and fishing
Manure (conventional treatment)	Agriculture, forestry and fishing
Meat animals nec	Agriculture, forestry and fishing
Oil seeds	Agriculture, forestry and fishing
Paddy rice	Agriculture, forestry and fishing
Pigs	Agriculture, forestry and fishing
Plant-based fibers	Agriculture, forestry and fishing
Poultry	Agriculture, forestry and fishing
Raw milk	Agriculture, forestry and fishing
Sugar cane, sugar beet	Agriculture, forestry and fishing
Vegetables, fruit, nuts	Agriculture, forestry and fishing
Wheat	Agriculture, forestry and fishing
Wool, silkworm cocoons	Agriculture, forestry and fishing
Fish and other fishing products; services incidental of fishing (05)	Agriculture, forestry and fishing
Beverages	Agriculture, forestry and fishing
Dairy products	Agriculture, forestry and fishing
Fish products	Agriculture, forestry and fishing
Food products nec	Agriculture, forestry and fishing
Meat products nec	Agriculture, forestry and fishing
Processed rice	Agriculture, forestry and fishing
Products of meat cattle	Agriculture, forestry and fishing
Products of meat pigs	Agriculture, forestry and fishing
Products of meat poultry	Agriculture, forestry and fishing
Products of vegetable oils and fats	Agriculture, forestry and fishing
Sugar	Agriculture, forestry and fishing
Products of forestry, logging and related services (02)	Agriculture, forestry and fishing
Additives/blending components	Chemicals and materials
Biodiesels	Chemicals and materials
Biogasoline	Chemicals and materials
Charcoal	Chemicals and materials
Chemicals nec	Chemicals and materials
N-fertilizer	Chemicals and materials
Other liquid biofuels	Chemicals and materials
P- and other fertilizer	Chemicals and materials
Aluminum ores and concentrates	Chemicals and materials
Anthracite	Chemicals and materials
Chemical and fertilizer minerals, salt and other mining and quarrying products n.e.c.	Chemicals and materials
Coking coal	Chemicals and materials
Copper ores and concentrates	Chemicals and materials
Iron ores	Chemicals and materials
Lead, zinc and tin ores and concentrates	Chemicals and materials
Lignite/brown coal	Chemicals and materials
Nickel ores and concentrates	Chemicals and materials
Other bituminous coal	Chemicals and materials
Other non-ferrous metal ores and concentrates	Chemicals and materials
Patent fuel	Chemicals and materials
Peat	Chemicals and materials
Plastics, basic	Chemicals and materials
Precious metal ores and concentrates	Chemicals and materials

EXIOBASE sectors	Aggregated sectors
Rubber and plastic products (25)	Chemicals and materials
Sand and clay	Chemicals and materials
Secondary plastic for treatment, re-processing of secondary plastic into new plastic	Chemicals and materials
Stone	Chemicals and materials
Subbituminous coal	Chemicals and materials
Uranium and thorium ores (12)	Chemicals and materials
Aluminum and aluminum products	Chemicals and materials
Basic iron and steel and of ferro-alloys and first products thereof	Chemicals and materials
Copper products	Chemicals and materials
Fabricated metal products, except machinery and equipment (28)	Chemicals and materials
Foundry work services	Chemicals and materials
Lead, zinc and tin and products thereof	Chemicals and materials
Nuclear fuel	Chemicals and materials
Other non-ferrous metal products	Chemicals and materials
Precious metals	Chemicals and materials
Secondary aluminum for treatment, re-processing of secondary aluminum into new aluminum	Chemicals and materials
Secondary copper for treatment, re-processing of secondary copper into new copper	Chemicals and materials
Secondary lead for treatment, re-processing of secondary lead into new lead	Chemicals and materials
Secondary other non-ferrous metals for treatment, re-processing of secondary other non-ferrous metals into new other non-ferrous metals	Chemicals and materials
Secondary precious metals for treatment, re-processing of secondary precious metals into new precious metals	Chemicals and materials
Secondary steel for treatment, re-processing of secondary steel into new steel	Chemicals and materials
Ash for treatment, re-processing of ash into clinker	Chemicals and materials
Bottles for treatment, recycling of bottles by direct reuse	Chemicals and materials
Bricks, tiles and construction products, in baked clay	Chemicals and materials
Cement, lime and plaster	Chemicals and materials
Ceramic goods	Chemicals and materials
Glass and glass products	Chemicals and materials
Other non-metallic mineral products	Chemicals and materials
Secondary glass for treatment, re-processing of secondary glass into new glass	Chemicals and materials
Construction work (45)	Construction
Secondary construction material for treatment, re-processing of secondary construction material into aggregates	Construction
Aviation gasoline	Energy and utilities
Biogas	Energy and utilities
Bitumen	Energy and utilities
BKB/peat briquettes	Energy and utilities
Blast furnace gas	Energy and utilities
Coal tar	Energy and utilities
Coke oven coke	Energy and utilities
Coke oven gas	Energy and utilities
Crude petroleum and services related to crude oil extraction, excluding surveying	Energy and utilities
Distribution and trade services of electricity	Energy and utilities
Distribution services of gaseous fuels through mains	Energy and utilities
Electricity by biomass and waste	Energy and utilities
Electricity by coal	Energy and utilities
Electricity by gas	Energy and utilities
Electricity by geothermal	Energy and utilities
Electricity by hydro	Energy and utilities
Electricity by nuclear	Energy and utilities
Electricity by petroleum and other oil derivatives	Energy and utilities
Electricity by solar photovoltaic	Energy and utilities
Electricity by solar thermal	Energy and utilities
Electricity by tide, wave, ocean	Energy and utilities
Electricity by wind	Energy and utilities
Electricity nec	Energy and utilities
Ethane	Energy and utilities
Gas coke	Energy and utilities

EXIOBASE sectors	Aggregated sectors
Gas works gas	Energy and utilities
Gas/diesel oil	Energy and utilities
Gasoline type jet fuel	Energy and utilities
Heavy fuel oil	Energy and utilities
Kerosene	Energy and utilities
Kerosene type jet fuel	Energy and utilities
Liquefied petroleum gases (LPG)	Energy and utilities
Lubricants	Energy and utilities
Motor gasoline	Energy and utilities
Naphtha	Energy and utilities
Natural gas and services related to natural gas extraction, excluding surveying	Energy and utilities
Natural gas liquids	Energy and utilities
Non-specified petroleum products	Energy and utilities
Other hydrocarbons	Energy and utilities
Oxygen steel furnace gas	Energy and utilities
Paraffin waxes	Energy and utilities
Petroleum coke	Energy and utilities
Refinery feedstocks	Energy and utilities
Refinery gas	Energy and utilities
Steam and hot water supply services	Energy and utilities
Transmission services of electricity	Energy and utilities
Transportation services via pipelines	Energy and utilities
White spirit and SBP	Energy and utilities
Collected and purified water, distribution services of water (41)	Energy and utilities
Food waste for treatment: bio gasification and land application	Energy and utilities
Food waste for treatment: composting and land application	Energy and utilities
Food waste for treatment: incineration	Energy and utilities
Food waste for treatment: landfill	Energy and utilities
Food waste for treatment: wastewater treatment	Energy and utilities
Food waste to incineration	Energy and utilities
Food waste to wastewater treatment	Energy and utilities
Inert/metal/hazardous waste for treatment: landfill	Energy and utilities
Inert/metal waste for treatment: incineration	Energy and utilities
Oil/hazardous waste for treatment: incineration	Energy and utilities
Other waste for treatment: wastewater treatment	Energy and utilities
Paper and wood waste for treatment: composting and land application	Energy and utilities
Paper for treatment: landfill	Energy and utilities
Paper waste for treatment: bio gasification and land application	Energy and utilities
Paper waste for treatment: incineration	Energy and utilities
Plastic waste for treatment: incineration	Energy and utilities
Plastic waste for treatment: landfill	Energy and utilities
Secondary raw materials	Energy and utilities
Sewage sludge for treatment: bio gasification and land application	Energy and utilities
Textiles waste for treatment: incineration	Energy and utilities
Textiles waste for treatment: landfill	Energy and utilities
Wood waste for treatment: incineration	Energy and utilities
Wood waste for treatment: landfill	Energy and utilities
Electrical machinery and apparatus n.e.c. (31)	Other manufacturing and sales
Machinery and equipment n.e.c. (29)	Other manufacturing and sales
Office machinery and computers (30)	Other manufacturing and sales
Radio, television and communication equipment and apparatus (32)	Other manufacturing and sales
Furniture; other manufactured goods n.e.c. (36)	Other manufacturing and sales
Medical, precision and optical instruments, watches and clocks (33)	Other manufacturing and sales
Tobacco products (16)	Other manufacturing and sales
Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods (52)	Other manufacturing and sales
Leather and leather products (19)	Other manufacturing and sales
Textiles (17)	Other manufacturing and sales

EXIOBASE sectors	Aggregated sectors
Wearing apparel; furs (18)	Other manufacturing and sales
Wholesale trade and commission trade services, except of motor vehicles and motorcycles (51)	Other manufacturing and sales
Paper and paper products	Other manufacturing and sales
Printed matter and recorded media (22)	Other manufacturing and sales
Pulp	Other manufacturing and sales
Secondary paper for treatment, re-processing of secondary paper into new pulp	Other manufacturing and sales
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials (20)	Other manufacturing and sales
Wood material for treatment, re-processing of secondary wood material into new wood material	Other manufacturing and sales
Computer and related services (72)	Other services
Financial intermediation services, except insurance and pension funding services (65)	Other services
Hotel and restaurant services (55)	Other services
Insurance and pension funding services, except compulsory social security services (66)	Other services
Other business services (74)	Other services
Other services (93)	Other services
Post and telecommunication services (64)	Other services
Real estate services (70)	Other services
Renting services of machinery and equipment without operator and of personal and household goods (71)	Other services
Research and development services (73)	Other services
Services auxiliary to financial intermediation (67)	Other services
Extra-territorial organizations and bodies	Other services
Membership organization services n.e.c. (91)	Other services
Private households with employed persons (95)	Other services
Recreational, cultural and sporting services (92)	Other services
Education services (80)	Public services
Health and social work services (85)	Public services
Public administration and defence services; compulsory social security services (75)	Public services
Retail trade services of motor fuel	Transportation
Supporting and auxiliary transport services; travel agency services (63)	Transportation
Motor vehicles, trailers and semi-trailers (34)	Transportation
Other transport equipment (35)	Transportation
Air transport services (62)	Transportation
Inland water transportation services	Transportation
Other land transportation services	Transportation
Railway transportation services	Transportation
Sea and coastal water transportation services	Transportation
Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motorcycles parts and accessories	Transportation

APPENDIX C: MATERIAL CATEGORIZATION BREAKDOWN

The material categorization encompasses the domestic extraction of 221 materials subdivided into four main categories for the consumption-based accounting (CBA) in the EXIOBASE analysis. This categorization accounts for the materials according to their respective sectors of final use, reflecting the material footprint attributed to consumption activities.

Metal
Bauxite and aluminum ores
Copper ores
Gold ores
Iron ores
Lead ores
Nickel ores
Other non-ferrous metal ores
PGM ores
Silver ores
Tin ores
Uranium and thorium ores
Zinc ores

Non-metallic minerals
Building stones
Chemical and fertilizer minerals
Clays and kaolin
Gravel and sand
Limestone, gypsum, chalk, dolomite
Other minerals
Salt
Slate

Fossil fuels
Coking coal
Crude oil
Lignite/brown coal
Natural gas
Natural gas liquids
Other bituminous coal
Peat
Subbituminous coal

Biomass (used)
Crop residues - Feed
Crop residues - Straw
Fishery - Aquatic plants
Fishery - Inland waters fish catch
Fishery - Marine fish catch
Fishery - Other (e.g., aquatic mammals)
Fodder crops - Alfalfa for forage and silage
Fodder crops - Beets for fodder
Fodder crops - Cabbage for fodder
Fodder crops - Carrots for fodder
Fodder crops - Clover for forage and silage
Fodder crops - Forage products nec
Fodder crops - Grasses nec for forage and silage
Fodder crops - Green oilseeds for fodder
Fodder crops - Leguminous nec for forage and silage
Fodder crops - Maize for forage and silage
Fodder crops - Other grasses
Fodder crops - Rye grass, forage and silage
Fodder crops - Sorghum for forage and silage
Fodder crops - Swedes for fodder
Fodder crops - Turnips for fodder
Fodder crops - Vegetables and roots, fodder
Forestry - Coniferous wood - Industrial roundwood
Forestry - Coniferous wood - Wood fuel
Forestry - Kapok fruit
Forestry - Natural gums
Forestry - Non-coniferous wood - Industrial roundwood
Forestry - Non-coniferous wood - Wood fuel
Forestry - Raw materials other than wood grazing
Primary crops - Kapokseed in shell
Primary crops - Honey
Primary crops - Beeswax
Primary crops - Abaca
Primary crops - Agave fibers nes
Primary crops - Almonds
Primary crops - Anise, badian, fennel
Primary crops - Apples
Primary crops - Apricots
Primary crops - Arecanuts
Primary crops - Artichokes
Primary crops - Asparagus
Primary crops - Avocados
Primary crops - Bambara beans
Primary crops - Bananas
Primary crops - Barley
Primary crops - Beans, dry
Primary crops - Beans, green
Primary crops - Berries nec
Primary crops - Blueberries
Primary crops - Brazil nuts, with shell
Primary crops - Broad beans, horse beans, dry
Primary crops - Buckwheat
Primary crops - Cabbages
Primary crops - Canary seed
Primary crops - Carobs
Primary crops - Carrots
Primary crops - Cashew nuts, with shell
Primary crops – Cashew apple
Primary crops - Cassava
Primary crops - Cassava leaves
Primary crops - Castor oil seed
Primary crops - Cauliflower
Primary crops - Cereals nec
Primary crops - Cherries
Primary crops - Chestnuts
Primary crops - Chick peas
Primary crops - Chicory roots
Primary crops - Chillies and peppers, dry
Primary crops - Chillies and peppers, green
Biomass (used)
Primary crops - Cinnamon

Biomass (Used)

Primary crops - Citrus fruit nec
Primary crops - Cloves
Primary crops - Cocoa beans
Primary crops - Coconuts
Primary crops - Coffee, green
Primary crops - Coir
Primary crops - Cotton lint
Primary crops - Cottonseed
Primary crops - Cow peas, dry
Primary crops - Cranberries
Primary crops - Cucumbers and gherkins
Primary crops - Currants
Primary crops - Dates
Primary crops - Eggplants
Primary crops - Fiber crops nes
Primary crops - Figs
Primary crops - Flax fiber and tow
Primary crops - Fonio
Primary crops - Fruit fresh nes
Primary crops - Fruit, tropical fresh nes
Primary crops - Garlic
Primary crops - Ginger
Primary crops - Gooseberries
Primary crops - Grapefruit and pomelos
Primary crops - Grapes
Primary crops - Groundnuts in shell
Primary crops - Hazelnuts
Primary crops - Hemp fiber and tow
Primary crops - Hempseed
Primary crops - Hops
Primary crops - Jojoba seeds
Primary crops - Jute and jute-like fibers
Primary crops - Kapok fiber
Primary crops - Karite nuts
Primary crops - Kiwi fruit
Primary crops - Kolanuts
Primary crops - Leeks and other alias. veg.
Primary crops - Leguminous vegetables, nes
Primary crops - Lemons and limes
Primary crops - Lentils
Primary crops - Lettuce
Primary crops - Linseed
Primary crops - Lupins
Primary crops - Maize
Primary crops - Maize, green
Primary crops - Mangoes, mangosteens, guavas
Primary crops - Mate
Primary crops - Melonseed
Primary crops - Millet
Primary crops - Mixed grain
Primary crops - Mushrooms
Primary crops - Mustard seed
Primary crops - Natural rubber
Primary crops - Nutmeg, mace and cardamoms
Primary crops - Nuts, nes
Primary crops - Oats
Primary crops - Oil palm fruit
Primary crops - Oilseeds nec
Primary crops - Okra
Primary crops - Olives
Primary crops - Onions
Primary crops - Onions, dry
Primary crops - Oranges
Primary crops - Other bastfibers
Primary crops - Other melons (Cantaloupe, etc.)
Primary crops - Papayas
Primary crops - Peaches and nectarines
Primary crops - Pears
Primary crops - Peas, green
Primary crops - Peas, dry
Primary crops - Pepper
Primary crops - Peppermint
Primary crops - Persimmons
Primary crops - Pigeon peas
Primary crops - Pineapples
Primary crops - Pistachios
Primary crops - Plantains
Primary crops - Plums
Primary crops - Pome fruit, nes
Primary crops - Poppy seed
Primary crops - Potatoes
Primary crops - Pulses nec
Primary crops - Pumpkins, squash, gourds
Primary crops - Pyrethrum, dried flowers
Primary crops - Quinces
Primary crops - Quinoa
Primary crops - Ramie
Primary crops - Rapeseed
Primary crops - Raspberries
Primary crops - Rice
Primary crops - Roots and tubers, nes
Primary crops - Rye
Primary crops - Safflower seed
Primary crops - Sesame seed
Primary crops - Sisal
Primary crops - Sorghum
Primary crops - Sour cherries
Primary crops - Soybeans
Primary crops - Spices nec
Primary crops - Spinach
Primary crops - Stone fruit nec
Primary crops - Strawberries
Primary crops - String beans
Primary crops - Sugar beets
Primary crops - Sugar cane
Primary crops - Sugar crops nes
Primary crops - Sunflower seed
Primary crops - Sweet potatoes
Primary crops – Tallow tree seeds
Primary crops - Tang. mand clement. satsma
Primary crops - Taro
Primary crops - Tea
Primary crops - Tea nes
Primary crops - Tobacco leaves
Primary crops - Tomatoes
Primary crops - Triticale
Primary crops - Tung nuts
Primary crops - Vanilla
Primary crops - Vegetables fresh nec
Primary crops - Vetches
Primary crops - Walnuts
Primary crops - Watermelons
Primary crops - Wheat
Primary crops - Yams
Primary crops – Yautia

GLOSSARY

Term	Explanation
Circular potential	Circular potential refers to the capacity of a system, sector, or economy to implement circular economy principles, such as reducing waste, extending product life cycles, and recycling materials, to transition toward more sustainable practices. It indicates the extent to which an entity can shift from a linear "take-make-dispose" model to a regenerative model that maximizes resource efficiency and minimizes environmental impact.
Cultural paradigm shift	A cultural paradigm shift is a fundamental change in the underlying beliefs, values and practices of a society, often leading to a new way of thinking and behaving. It involves redefining societal norms and priorities, such as moving from a focus on material wealth to valuing sustainability, community and wellbeing.
Decoupling	Decoupling, in a systems context, refers to the separation of components or subsystems to reduce their interdependencies, allowing them to operate, change and fail independently without affecting the whole system. In this report, it refers to the separation of resource consumption from economic growth. This approach enhances modularity and facilitates easier maintenance, scalability and resilience of the system.
Equilibrium	Equilibrium, in an environmental context, refers to a state of balance within a natural system where dynamic processes occur at rates that allow the system to remain stable over time. It is characterized by the absence of large-scale, abrupt changes, enabling the coexistence and sustained functioning of diverse life forms, including human civilization.
Extended producer responsibility (EPR)	Extended producer responsibility (EPR) is an environmental policy approach where producers are given a significant responsibility, financial and/or physical, for the treatment or disposal of post-consumer products. Assigning such responsibility incentivizes producers to incorporate environmental considerations into the design of their products and packaging to minimize waste and encourage recycling.

Term	Explanation
Linear business models	Linear business models are based on a straightforward, one-way flow of resources and products, starting with the extraction of raw materials, moving through manufacturing and consumption, and ending with the disposal of waste. This traditional model operates on a “take-make-dispose” principle, which often leads to inefficiencies and environmental degradation due to the lack of recycling and reuse of resources.
Material footprint	The material footprint is a measure of the total amount of raw materials extracted and used to produce the goods and services consumed by a particular population or economy. It serves as an indicator of the environmental impact and resource intensity of consumption patterns, reflecting the pressure placed on natural resources.
Planetary boundary	A planetary boundary is a scientific concept defining the environmental limits within which humanity can safely operate. Beyond these limits, the stability of Earth’s life-supporting systems could be at risk. These boundaries encompass critical thresholds in Earth system processes, such as climate change, biodiversity loss and nutrient cycles, which, if crossed, could lead to irreversible environmental changes.
Product-as-a-Service (PaaS)	Product-as-a-Service (PaaS) is a business model in which, instead of selling physical products, companies offer the benefits and functionalities of a product through a service subscription or lease agreement. This model encourages manufacturers to create durable and maintainable products, as they retain ownership and are responsible for the product’s performance and life cycle management. This often leads to more sustainable practices and closer customer relationships.
Raw material consumption (RMC)	Raw material consumption (RMC) refers to the total amount of raw materials extracted and used to produce goods and services within an economy over a specific period. It is a measure of the environmental impact and resource efficiency of production processes, reflecting the sustainability challenges associated with the depletion of natural resources and the need for more circular economic practices.

Term	Explanation
Recycled material	Recycled material refers to any substance or product that has been recovered or diverted from the waste stream and reprocessed into a new product, reducing the need for virgin raw materials.
Remanufacturing	Remanufacturing is a comprehensive and rigorous industrial process through which used products, often considered at the end of their life, are restored to like-new condition with equivalent or better performance and warranty. This process involves disassembly, cleaning, repairing, replacing worn parts, reassembly and testing, which not only extends the lifespan of products but also significantly reduces environmental impact by conserving materials and energy.
Resilience	Resilience, in a system or organization, refers to the ability to withstand, adapt to, and recover from disruptions, stresses, or changes while maintaining core functions and structures. It involves the capacity to anticipate risks, absorb impacts, and transform or evolve in response to challenges, ensuring long-term sustainability and stability.
(9)R-strategies	R-strategies refer to nine circular economy strategies that are structured in a hierarchical order from most to least circular. The nine circular strategies are (0) Refuse, (1) Rethink, (2) Reduce, (3) Reuse, (4) Repair, (5) Refurbish, (6) Re-manufacture, (7) Repurpose, (8) Recycle, (9) Recover.
Sharing economy	The sharing economy is an economic model defined by the peer-to-peer-based sharing of access to goods and services, often facilitated by community-based online platforms. This model maximizes the utilization of assets by enabling individuals to rent or borrow goods rather than own them outright, promoting sustainability, reducing consumption, and fostering a sense of community.
Sustainability-linked loan	A sustainability-linked loan is a financial instrument and type of loan that incentivizes borrowers to achieve predetermined sustainability performance targets. The terms of the loan, such as the interest rate, can be tied to the borrower's achievement of these targets, which typically focus on environmental, social and governance (ESG) criteria, encouraging businesses to operate more sustainably.

Term	Explanation
Systemic change	Systemic change refers to a profound transformation in the structures, relationships and dynamics of a system, leading to a significant shift in its behavior and outcomes. It goes beyond superficial or incremental adjustments, targeting the root causes of issues to bring about enduring and comprehensive change across an entire system.
Total material consumption (TMC)	Total material consumption (TMC) is a metric that quantifies the aggregate amount of raw materials directly used by an economy, including both domestically extracted resources and the raw material equivalents of imported goods. It includes both used and unused extracted materials and provides a comprehensive view of the material footprint of economic activities, reflecting the total environmental pressure exerted through the consumption of resources.
Virgin resources	Virgin resources are raw materials that have been extracted from the natural environment for the first time and have not been previously used or processed. These resources, such as minerals, metals, oil, gas and timber, are finite, and their extraction often has significant environmental impacts, including habitat destruction and pollution.

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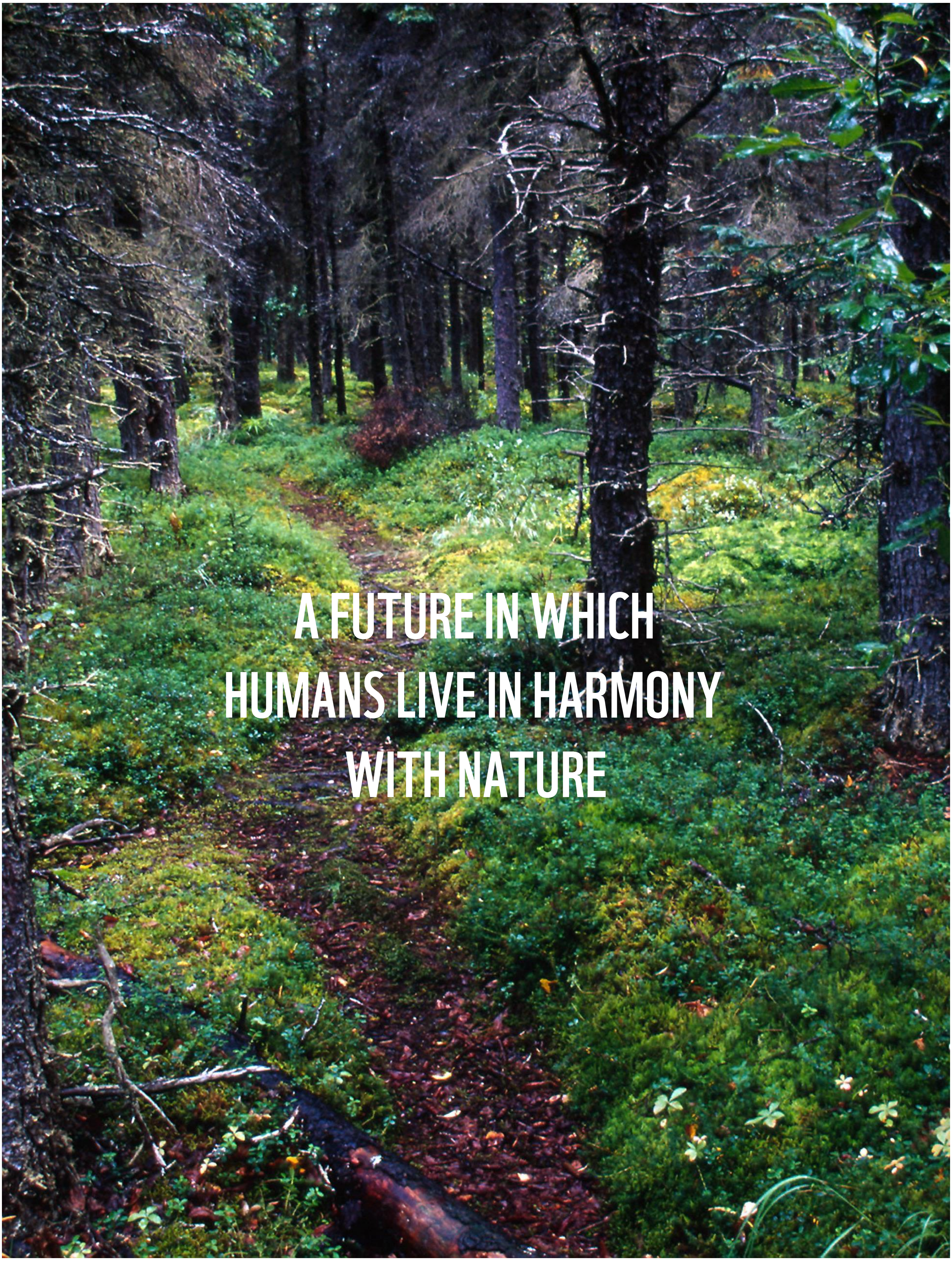

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