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ORIGINAL PAPER

Circular Economy and the triple bottom line in Norway

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Abstract
A more circular economy aims to reduce global material consumption, make the most out of our resources, and create a more sustainable economic system. In this paper, we analyze how different circular economy actions in Norway affect indicators in the three pillars of sustainable development: economic prosperity (measured by value added), social equity (measured by employment opportunities), and environmental protection (measured by greenhouse gas emissions). Based on priorities of the EU's Circular Economy Action Plan and characteristics of the Norwegian economy, we have selected five value chains for analysis: electronics; textiles; construction and building; packaging and plastics; and metal efficiency. The results show that there is a substantial potential for increased value added and employment in Norway related to the circular transition, while at the same time mitigating greenhouse gas emissions. For increased material efficiency (plastic packaging, metals), employment gains can be substantial, while imports of metals and plastics decrease, resulting in lower upstream emissions, but higher Norwegian emissions. For consumer goods (textiles, electronics), the positive effects come about from shifting from a buy-and-discard model to a buy-repair/share/use longer model, resulting in increased employment in Norway

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and decreased imports, which potentially leads to lower emissions, but also lower employment globally. For re-use/re-purpose and recycling of building materials, emission-intense material extraction and processing activities are replaced by more labour intense activities, but has the largest potential of decreasing emissions within Norway.

Keywords Circular economy · Input-output analysis · Scenario analysis · Triple bottom line

Introduction

The implementation of a circular economy underlines the success of the 2030 Agenda for Sustainable Development [1] and has achieved a significant amount of attention in policy making in recent years, after the announcement of the European Green Deal [2], following long-term interests in the circular economy also in other parts of the world, as, e.g. the concept of ecological civilization in China [3, 4]. Although focused on enhancing environmental goals such as resource efficiency [5], circular economy can improve socio-economic outcomes through aspects such as innovation, value creation, and employment [6–8]. Thus, circular economy could help achieving simultaneously the three pillars—economic, social, and environmental—of sustainable development [9–11]. Despite being relevant for many of the global sustainable development goals (SDGs), circular economy concepts are central to achieving SDG 12, responsible consumption and production [1, 12]. The targets and indicators of SDG 12 look, in fact, at lowering material footprints (the final goal of the circular economy), reducing waste flows, and enhancing national recycling processes. All these are goals at the heart of circular economies, which aims at shifting away from linear economy processes by changing demand and supply systems. From a practical perspective, circular economy policies reflect the ones related to SDG 12 in their need for global multi-level partnerships involving the private sector and citizens-consumers are needed [13].

Despite the topic of a circular economy being high on the agenda of Nordic [14] and European [15–17] policy makers, and the concept of circular economy as described by the Ellen MacArthur Foundation [18, 19] requiring systems thinking, the number of studies considering the transition to a more circular economy as a systemic shift of the entire global economy is still low [8, 20–23]. In this context, system-wide encompasses not only individual industries or production systems but all links between raw material extraction and disposal, between producers via wholesale and retail trade to consumers, and the global interaction of humans with their natural environment. These links are not linear, but circular: by actively engaging consumers, and providing the right infrastructure, disposed products become raw materials that can be used in industrial production. In addition, materials should be kept in the circle as long as possible.

The 10 Rs of a circular economy (R0 refuse, R1 rethink, R2 reduce, R3 reuse, R4 repair, R5 refurbish, R6 remanufacture, R7 repurpose, R8 recycle, and R9 recover as energy) [24] conceptualize the circularity thinking, emphasizing that a circular economy can only be achieved through integrating consumer and producer actions along local and global supply chains.

Here, it is important to stress that the circular economy is not a goal in itself, it rather is a mean to the end goal of sustainable development. In this paper, we analyze how different circular economy actions in Norway, which have as their primary goal(s) one or more of the 10 Rs, affect the three pillars of sustainable development: economic prosperity (measured by value added), social equity (measured by employment opportunities), and environmental protection (measured by GHG emissions).

A characteristic of the Norwegian economy is a 'fragmented' value chain. Norway is very strong in the primary sector, i.e. mining and quarrying, oil and gas, and the process industry, that is closely linked to the mining industry, agriculture, hunting, fishing, forestry and, of course, in the tertiary sector, the services industries [25]. While there is some consumer goods manufacturing within Norway, most of these goods are imported [25]. This economic structure provides huge opportunities for Norway to adopt circular economy principles [26]. Mining and quarrying together with the process industry accounts for almost half of Norway's exports. Norway produces almost 3% of global aluminium, 4% of global silicon and ferro-silicon, and more than 3% of global ferro-manganese [27]. Emissions in the process industry subject to the European Emission Trading Scheme (ETS) are dominated by emissions from ferro-alloy and aluminium production [28]. Circularity strategies in the processing industry are manifold. First, replacing primary raw materials by urban mining, which is reclaiming raw materials from products, buildings, or waste [29], can decrease the demand and associated impacts of mining of primary raw materials, besides supporting a growing recycling industry, advancing recycling techniques, and creating a network for recovery and use of pre- and post-consumer scrap. In addition, the design and engineering of materials can contribute to circular economy by decreasing downstream material needs, increasing lifetime and performance, or increasing recyclability [30]. Norway is well positioned to be a relevant country on the forefront of this transformation as many of the process industry's company's research centres are located in Norway [28]. When it comes to manufactured products, such as electronics or textiles, it is mostly from the consumer side that Norway can adopt circular strategies. Norway has an advantageous position to provide a just transition towards a circular economy. The country has strong social system that serves as a support for decent job creation; skills training and adult learning is a common practice in Norway, including lower-skilled and unemployed people.

The circular economy is understood by the Norwegian industry as a possibility for higher value creation with more efficient resource use [31]. However, there are still some barriers to its effective implementation that can be overcome by enhancing industrial symbiosis with a harmonization of rules and regulations, increased dialogue between public authorities and industry, increased demand for environmentally friendly resource efficient products and increased R&D activities [32–34]. Even if we improved the production systems to minimize emissions and waste, and maximize reuse and recycling, the environmental benefits would be hampered if consumption trends remained equal and people continued buying and disposing of items in the same way [35, 36]. In addition, 'urban mining' requires a shift in the way consumers dispose of goods. While production processes can be directly influenced by taxation/stimuli, modifying consumption habits via direct instruments can often be counter-productive, and politically difficult. Furthermore, different policies may have synergistic, but also offsetting or rebound effects. Therefore, we believe both production and consumption must be seen in conjunction when designing policies for the future.

The EU Circular Economy Action Plan (CEAP) [17] is one the main blocks of the European Green Deal, and it has the aim to promote circular economy processes in the European industry, foster responsible consumption, and ensure that resources used are kept in the European economy for as long as possible. The transition towards a circular economy will affect the labor market structure. Both job creation and destruction will take place and it is therefore crucial for society to identify the labor and skills needed in a circular economy, so the job creation potential is maximized. CEAP is expected to boost both innovation and jobs, especially in relation with the re-use and recycling sectors.

The Action Plan identifies key product value chains for circularity, and these are: Electronics and ICT; Batteries and vehicles; Packaging; Plastics; Textiles; Construction and Buildings. In this study, we have selected to explore the following value chains further, in a Norwegian context: electronics; textiles; construction and building; packaging and plastics; and metal production and use. The selected value chains are also among the industries (incl. households) in Norway with high GHG-emissions, and large waste volume streams. They are also value chains with a large potential for emission reduction and potential job creation by implementing circular strategies, as defines by the 10 Rs. [24].

The paper is structured as follows: the next section introduces the underlying model, which is based on input-output economics, a methodology that brings together producer and consumer perspectives in a consistent quantitative framework. The 'Circular Economy Strategies: Scenario Design' section introduces relevant circularity strategies and value chains for Norway, the 'Results for the Selected Circular Economy Value Chains' section presents results, and the 'Discussion' section discusses policy implications, before giving a short conclusion in the 'Conclusion' section.

Modelling the triple bottom line

When zooming into the linear economy, it becomes immediately clear that manufacturing value chains by themselves are actually not linear, e.g. screws needed as inputs into machines that produce screws. Nobel laureate Wassily Leontief formulated these inter-industry dependencies and their interactions with the environment in a simple mathematical model in 1970 already [37]. Collecting the data for this type of model, i.e. input-output tables, has since become part of the system of national accounts [38, 39].

Today, economic models based on input-output data are state-of-the-art for macro-economic value chain and global value chain (GVC) analyses [40–43]. These data summarize consumer and producer actions in a consistent framework at the level of industries. These models are generally demand-driven and come with a large set of environmental and socio-economic extensions. This makes it possible to identify the link between consumer and producer action with the respective value chain effects. Computable general equilibrium (CGE) models in addition include behavioural equations, where different parts of the system change based on various elasticities. However, the sectoral structure is usually more aggregated and the integration of environmental indicators is not common. In the context of a circular economy, which affects all sectors of the economy, from mining, via manufacturing to services, and from producers to consumers to public administration, it is especially important to use macro-economic models with a detailed sector breakdown. The most comprehensive results can be achieved, when using dynamic models that are able to cover transitions of the entire economy, with high sector coverage and links between multiple regions [44].

[7] use a simple static input-output model for country-level macro-economic studies on the 'circular economy and benefits for society' for Finland, France, the Netherlands, Spain, and Sweden. Results of a global circular economy scenario, based on more detailed industry data and some dynamic considerations are available [45, 46], but not specifically tailored to Norway. We developed a dynamic input-output approach for implementing the economy wide changes pertaining to the circular economy transition in a dynamic model for the Norwegian economy, with high industry detail.

A dynamic input-output model for Norway

Here, we utilize a simple dynamic input-output model for Norway. The model is based on the 2018 structure of the Norwegian economy [47] representing 65 industries, and a time series of macro-economic aggregate indicators, including total value added and total final demand, distinguishing between household consumption expenditure, government consumption expenditure, gross fixed capital formation, and exports. The exogenous drivers of the model are population and the global economic development. Data for these are taken from the UNDESA population prospects [48] and the OECD's Longview [49], respectively. The model is going forward year by year, and is closed with respect to household consumption. Total household consumption and investments are endogenous to the model, depending on contemporaneous and past values of total value added. Using the demand-driven Leontief input-output model with $\mathbf{y}_t$ being the vector of total final demand by industry, and $\mathbf{A}$ being the intermediate coefficient matrix, output by industry, denoted by vector $\mathbf{x}$, is also endogenous:

$$\mathbf{x}_t = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{y}_t \tag{1}$$

From this, value added, employment, and GHG emissions by industry can be calculated. The model is described in more detail in Appendix A.

With total household consumption expenditures and investments being endogenous, the scenarios, where we change the structure of final demand and production technology as represented by matrix $\mathbf{A}$, will not only change output by industry, but also total output, and thus total value added. The latter, in turn, changes total household consumption expenditures and total investments, thus putting the entire economy on a new growth path.

Triple bottom line indicators

The triple bottom line refers to the three pillars of sustainable development: economy, society, and environment. For analyzing the impacts of the structural changes related to the transition to a more circular economy, we chose one indicator per each of these that was possible to adequately represent in the economic model and for which reliable historic data was available: value added (economy), employment (society), and GHG emissions (environment), three indicators that are established to be reliably linked to input-output based models [50]. Value added represents the production side calculation of GDP and is therefore the most conventional indicator for representing economic impacts. Employment could also be classified as a socio-economic indicator, not only representing societal but also economic impacts. One of the main links between economic activities and the society is employment, especially when considering gender and skill level of the work force. For the environment, the most natural indicator to analyze in the context of the circular economy would be material or resource use. In this context, the use of a material indicator has two drawbacks: first, the general assumptions in the scenarios refer to a reduction in material production and use. When using this indicator to quantify impacts, we would therefore present a reduction in material as an outcome of the structural changes, while actually these are assumptions underlying the changes implemented in the model. Second, even though it is possible to adequately represent physical material data in economic input-output models (see, e.g. [40, 51]), the economic data in our model is not detailed enough to be linked to the detailed physical material flow data. The same holds for waste flows, which can only be linked to the economic production data in a very limited manner as long as waste has not been given a value. Data on GHG emissions per economic activity are not only readily available and reliable, but the indicator GHG emissions also allows us to link the Circular Economy

Transition to the climate change mitigation discussion. The circular economy's potential for supporting the mitigation of climate change is getting more and more attention by policy makers and researchers [52–54].

Circular Economy Strategies: Scenario Design

In this section, we describe the value chains and scenarios that we analyze in this study. The value chains are selected based on the identified key value chains in the EU Circular Economy Action Plan (CEAP), a discussion with partners that financed part of the work (see the 'Funding' section in the end of the paper), and based on the role these value chains have in the Norwegian economy, both when it comes to value creation and environmental footprint, and also based on their potential for circular strategies. The selected value chains are electronics; textiles; construction and building; packaging and plastics; and metals. This study investigates effects on GHG emissions, value creation, and employment potentials in Norway for the selected value chains up to 2030 considering multiple transition scenarios.

Textiles and electronics are typical consumer goods, and consumption of such goods are responsible for a large share of households' material and emission footprints [55]. In [54] (Figure 2), we see for instance that the sector of wholesale and retail trade is the fifth largest when it comes to the total of direct and indirect emissions, and seventh largest when it comes to consumption based emissions. Figure 50 in the same study shows the largest volume of waste from both service sectors and households, a large part is mixed waste, but we assume consumer goods are responsible for a significant part. The wholesale is also the third larges industry in Norway when it comes to value added in 2020 [25]. Consumers play a significant role in the transition to a circular economy, and there are many relevant circular strategies in these value chains. Strategies available for consumers are mainly related to the first six of the ten Rs: from refuse to refurbish. The CEAP has a focus on sustainable products, right to repair, and empowering consumers, especially important for the textile and electronic value chains. Building and construction are among the industries with large environmental footprint within Norway. The construction industry is the third largest when it comes to the total of direct and indirect emissions, and second largest when it comes to consumption based emissions in Norway ([54], Figure 2). Also, a study by UNEP Resource efficiency estimates that 80% of emissions from material production were associated with material use in construction and manufactured goods [53]. The construction sector is the sixth largest industry measured in value added, 2020 [25], and there is a large potential for circular strategies related reuse and recycling. Plastics and packaging makes up a large amount of the Norwegian waste streams. Norwegian household use about 220kt plastic packaging such as food packaging every year [56], which makes up more than half of the plastic waste in Norway. In addition, waste from households and services produce large amounts of waste categorized as 'mixed waste' (see [54]), and much of this is unsorted plastic waste. Using minerals and metals more efficiently is also a key for circular economy, and these materials are important input factors into several of the key value chains identified in the CEAP, like electronics, batteries, vehicles and constructions. Mining and quarrying and the metal process industry are an important part of the Norwegian economy, and has a strong competitive advantage due to an abundance of cheap renewable energy. Norway produces almost 3% of global aluminium, 4% of global silicon and ferrosilicon, and more than 3% of global ferromanganese.

The primary industries agriculture, hunting, fishing makes up a rather small part of the Norwegian economy, 2% in 2020 [25]. Still, the bio-based industries are an important part of the circular economy and have large potentials for circular economy strategies, for instance when it comes to reduce food losses, and use of rest raw materials. However, the biobased side of the circular economy are outside the scope of this study. Oil and gas are the largest Norwegian industry when it comes to value added [25], but the petroleum products are mainly exported, and used as input, mainly energy in other industries. The main circular strategy of relevance is related to a shift to renewable energy sources. Because of these two issues, this sector is not analyzed in this study despite its size.

All the scenarios are summarized in Table 1. In the following subsections, we give some more details of each value chain and how they might change in the circular economy transition.

Textiles

The global textile industry has a high environmental impact and raw material consumption [57]. At the same time, less than 1% of the textiles are material recycled for new textiles [58]. Enhanced focus from policy and regulatory bodies, such as the European Commission, is expected to increase the awareness about the environmental impacts and issues, as well as addressing aspects such as *fast fashion* and barriers for increased reuse and material recycling [57, 58]. Another important innovation for establishing circularity in the textile sector is eliminating over-production. An estimated 30% of all fashion produced never gets sold [59]. Extending the life of 50% of clothes by an extra nine months of active use would reduce carbon, water and waste footprints by around 4–10% each. To increase durability producers need to use better quality materials and design and also increase consumer involved design initiatives. Life-cycle assessment studies, dealing with individual products, have found that a 10% increase in T-shirt lifetime globally results in 100000 t CO2e annually [60]. We have assumed increase in lifetime of textiles of about 10% resulting in a 10% decrease in spending on textiles per year[1]. At the same time either the demand for repair and share services increases, or spending on all consumption categories increases according the consumer demand model (see Appendix B).

Electronics

Electronic and electrical equipment (EEE) is one of the fastest growing waste streams in EU. Today, less than 40% of the materials are recovered, and scarce and valuable materials are being lost. However, there is an increasing amount of EU directives and guidelines for ensuring circularity of electronic goods (e.g. Eco Design, Circular Electronics Initiative, Right to Repair) [62]. Computer, electronic and optical products, and electrical equipment together account for about 2.2% of Norwegian household spending. Wholesale and retail trade has by far the largest share of value creation and employment in the Norwegian EEE value chain. Businesses selling, renting or repairing household electronics are spread over the entire country, thus providing a good base for an increasing sharing and repairing economy all over Norway [54]. We investigate two scenarios for EEE, related to changes in consumer behaviour and increased product lifetime. The first scenario assumes a twice-as-long lifetime, and will result in spending only half as usual on EEE per year. The savings

[1] The increase in lifetime of textiles was estimated based on dialogue with stakeholders involved in [61].

Table 1 Scenarios overview

Value chain	Scenario name	Scenario description
Textiles	All consumer goods: Increased quality, less purchase	10% lower spending on purchase, consumer savings allocated to several sectors
Textiles	Repair and share: Increased quality, more service sector	10% lower spending on purchase, focus on Norwegian products, consumer savings allocated for reparation (80%) and renting (20%), 10% reduction in imports (monetary)
Electronic and electric equipment	Increased quality, less purchase	50% lower spending on purchase, consumer savings allocated to several sectors
Electronic and electric equipment	Repair and share: Increased quality, more service sector	50% lower spending on purchase, focus on Norwegian products, consumer savings allocated for reparation (80%) and renting (20%)
Building materials	Reuse Repurpose	20% lower spending on mining and quarrying, wood products, fabricated metal products, and other non-metallic mineral products. 10% reallocated to re-purpose; 2.5% to each of wages, warehousing, information services, land transport
Building materials	Recycle	20% spending decrease in Mining and quarrying, wood products, fabricated metal products, other non-metallic mineral products, and rubber and plastic products. 10% reallocated to recycling; 2% reallocated to each of wages, warehousing, information services, land transport, R&D
Plastic packaging	Research and development	Increase on R&D in all industries to reduce plastic packaging by ≥ 15%
Plastic packaging	Net operating surplus	Higher capital earnings (net operating surplus) because of 15–30% lower spending on packaging materials

Table 1 (continued)

Value chain	Scenario name	Scenario description
Metals	Research and development	1% increase in efficiency, savings spent on R&D in basic metals, fabricated metal products, computer, electronic and optical products, electrical equipment, machinery and equipment, motor vehicles, and other transport equipment.
Metals	Net operating surplus	Higher capital earnings (net operating surplus) because of lower spending on materials (1% annual efficiency increase)

are used according to the 'average' use of surplus money in accordance with the description of the consumption model given in Appendix B. The second scenario assumes that the money saved by buying less is entirely used for repair and share services. The scenarios are presented in Table 1. The scenario assumptions are based on average numbers for savings potential from sharing and renting from a study for the EU [63] and adapting it to Norwegian expenditure shares.

Reusing and recycling building materials

The construction sector in Norway—which includes new buildings, refurbishment and demolition of buildings and infrastructure—is responsible around 14% of direct and indirect Norwegian emissions, almost two thirds of it for the production and transport of materials [64]. While recent developments and sector initiatives in the industry have increased the recycling of construction waste up to an 80%, these recycled materials do not often stay in the value chain, but rather go to other, non-circular chains [65]. In general, both in Norway and around the world, though, the construction value chains remain linear, with a 'take, make, dispose' approach which only recently has started to be rethought [66].

Circular economy measures can, nevertheless, be applied through the entire value chain of constructions activities, from the material production, building and materials design, construction phase, use of buildings, and end-of-life [67], with total savings on primary resource and energy use estimated in the hundreds of billions in Europe [68]. These measures should include both those aimed at the materials involved, and to the building itself [69], evidence from many other case studies in European countries can suggest circular business models with varying models of circular treatment which can indeed become profitable by themselves [70]. Statutory regulations, or lack thereof, and a widely supported product documentation system, are often cited by the relevant actors as main barriers [65, 71, 72], though behavioural and technical barriers have also been widely documented and assessed [73]

We have designed two scenarios for the reuse and recycling of building materials in Norway. Both scenarios assume that it is possible to reduce up to 20% the amount of virgin materials used, as explained in [65]. Virgin materials are replaced by repurposed materials (Reuse Re-purpose scenario), or by recycled materials (Recycle scenario.) As [54] assumes, usage of recycled or re-purposed materials requires additional documenting, tracking and certifying; these additional costs incurred in each scenario are allocated in the model as payments of labour, warehousing, IT services, transport and R%D services.

Plastic packaging

As a part of the EU's Circular Economy Action Plan, the Plastics Strategy [74] aims to design a new plastic economy based on circular strategies, focusing design and production towards reuse, repair and recycling. Packaging corresponds to around 40% of all plastic demand in Europe, and to almost 60% of all post-consumer plastic waste [75]. Furthermore, it is estimated that around 95% of the value of plastic packaging is lost after a short single-use cycle, i.e. single-use plastics—packaging and other consumer products such as straws, disposable cups, lids and cutlery—are rarely recycled, despite of their growing contribution to waste generation [76]. Although mostly focused on increasing collection and recycling of plastic waste, the Plastics Strategy also highlights the need for reducing the unnecessary generation of plastic waste, especially from single-use items and over-packaging, and encourage the reuse of packaging.

In our scenarios we reduce plastic packaging by 15%, 30%, or 65% until 2030, depending on the industry[2]. A 65% reduction in plastic packaging can be achieved in construction, trade, accommodation and food services, as well as for textiles. A 30% reduction is assumed achievable for the manufacturing industries, transport industries as well as public services such as health, social work, leisure activities and the like. All other industries are assumed to be able to reduce plastic packaging by 15% over the next decade. These reductions can either be achieved through increased spending on R&D activities, or simply by using less, so that the industry earns more (increase in net operating surplus).

Metals

Due to the abundance of cheap renewable energy, metal processing is an important industry in Norway. Norway is a major global supplier of aluminium and ferroalloys (silicon, ferrosilicon, and ferromanganese) [27, 77]. Emissions from ferroalloys and aluminium have the largest share in ETS quota emissions from the process industry in Norway [31]. Of these, most emissions are due to the use of fossil reduction agents, while emissions related to energy use the process industry are very low. The abundance of renewable energy sources such as hydropower and wind make Norway one of the countries where emissions per kilogram metal produced are lowest in the world [78]. Most of the research on circular economy in the metal industry focuses on recycling. However, given that some metals need to be produced from virgin ores, also in a more circular economy, Norway could be a natural source. Therefore, rather than analysing a recycling scenario, we chose the go higher up in the 10 R hierarchy and analyze the impacts of a reduction in metal use. A reduction in metal use can be achieved through higher metal efficiency. Here, we model an increase in efficiency by 1% per year between 2021 and 2030 in those industries that use a significant share of metal inputs: basic metals; fabricated metal products, except machinery and equipment; computer, electronic and optical products; electrical equipment; machinery and equipment n.e.c.; motor vehicles, trailers and semi-trailers; and other transport equipment, following the scenario modelling in, e.g. [46, 79, 80]. To achieve the reduction in metal use, we assume in a first scenario that the savings from purchasing less metal need to be spent

[2]The amount of reduction per industry was estimated based on dialogue with stakeholders involved in [61].

on R&D. In a second scenario we assume that efficiency increases were straight forward, so that the industry simply increases profits (net operating surplus). In a third scenario, R&D spending is increased only in the first years, while the industry can capitalize on improved efficiency in the latter half of the decade.

Results for the Selected Circular Economy Value Chains

Triple Bottom Line: Total Effect on Value Added, Employment, and GHG Emissions

Figures 1 to 3 show the development of value added, employment, and GHG emissions for all the scenarios relative to the baseline. We find distinct patterns across the scenario types, consumer behaviour (textiles, electronics), building materials, and industrial production (plastic, metals).

For the two scenarios focusing on changes in consumer behaviour, textiles and electronics, we find increased economic activity measured by value added, but also increased GHG emissions in Norway. However, emissions increase less than value added relative to baseline. The effect on employment depends on the reallocation of the consumer spending: if consumers simply spend the saved money on a general consumption bundle, employment increases approximately by the same percentage as value added. If consumers spent the saved money on repair and share services, employment increases twice as much as value added compared to baseline. In addition, in the ‘repair & share’ scenarios, GHG emissions increase less than in the other scenarios. These effects on employment and emissions can be explained by the relatively larger shift to services, with general higher employment intensity and lower GHG emission intensity in the ‘repair & share’ scenarios compared to the general consumer spending scenarios.

As for the building materials case, Fig. 2 shows that, while modest, the results we obtain point to the ‘right direction’ in both scenarios considered. Both reuse/repurpose and recycle scenarios see positive effects on value creation, and, while the recycle scenario is higher, the effects are overall comparable. Employment, likewise, is marginally positive, and similar for both scenarios. While small, these two combined indicators show that value added can indeed be created without employment losses. The GHG angle is, as shown in the graph, positive as well. There is a decrease in emissions for both scenarios, with reuse/repurpose of building materials being less energy and emission intense than recycling. The recycling scenario, thus, arises as a more conservative option in virtue of its relatively higher economic measures, though it is also easy to make a case for the reuse/repurpose scenario in virtue of its larger emission reduction and still positive value creation.

For the reduction in plastics packaging and the metal use/efficiency improvements, employment increases most when the savings are reallocated to R&D efforts. The increase in employment relative to the baseline is about 25% higher than the increase in value added compared to employment. When the savings from reducing plastic packaging or the use of metals is captured as additional capital earnings (net operating surplus), value added is increasing more than value added in the R&D scenario, but less than employment in the R&D scenario. Employment in the ‘Net Operating Surplus’ scenarios increases significantly less. Both a reduction in plastic packaging as well as an increase in metal efficiency require some R&D activities, before any capitalization is possible. For metals we have therefore also included the ‘Combined’ scenario (5 years of more R &D and then 5 years of increased capital earnings), which puts employment creation on a lower growth path after 2025, while value added increases faster compared to baseline after 2025 (grey lines in the

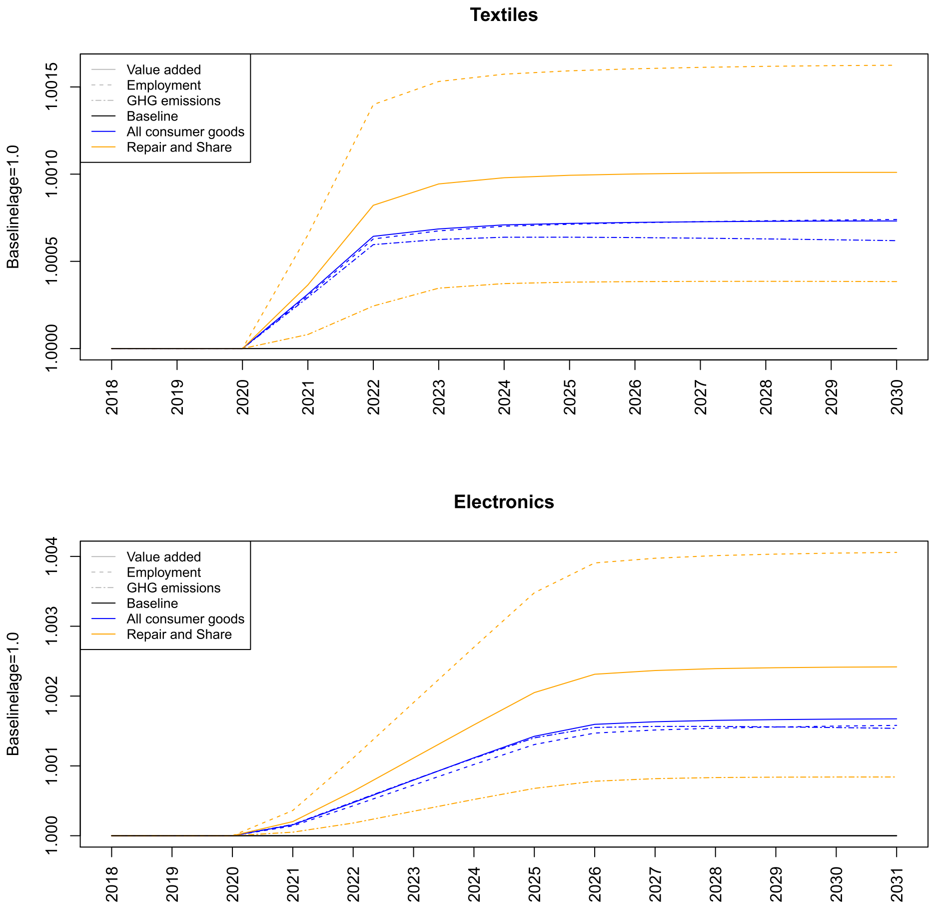

Fig. 1 Textiles and electronics scenarios—development of value added, employment and GHG emissions relative to baseline

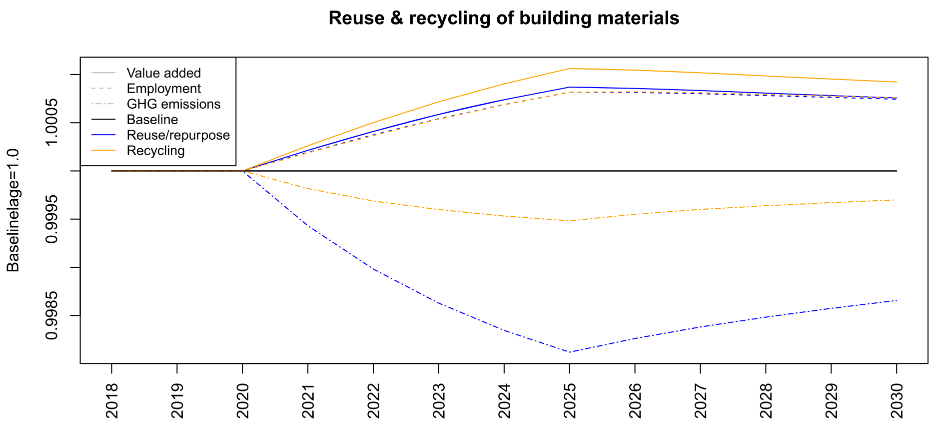

Fig. 2 Building material scenarios—development of value added, employment and GHG emissions relative to baseline

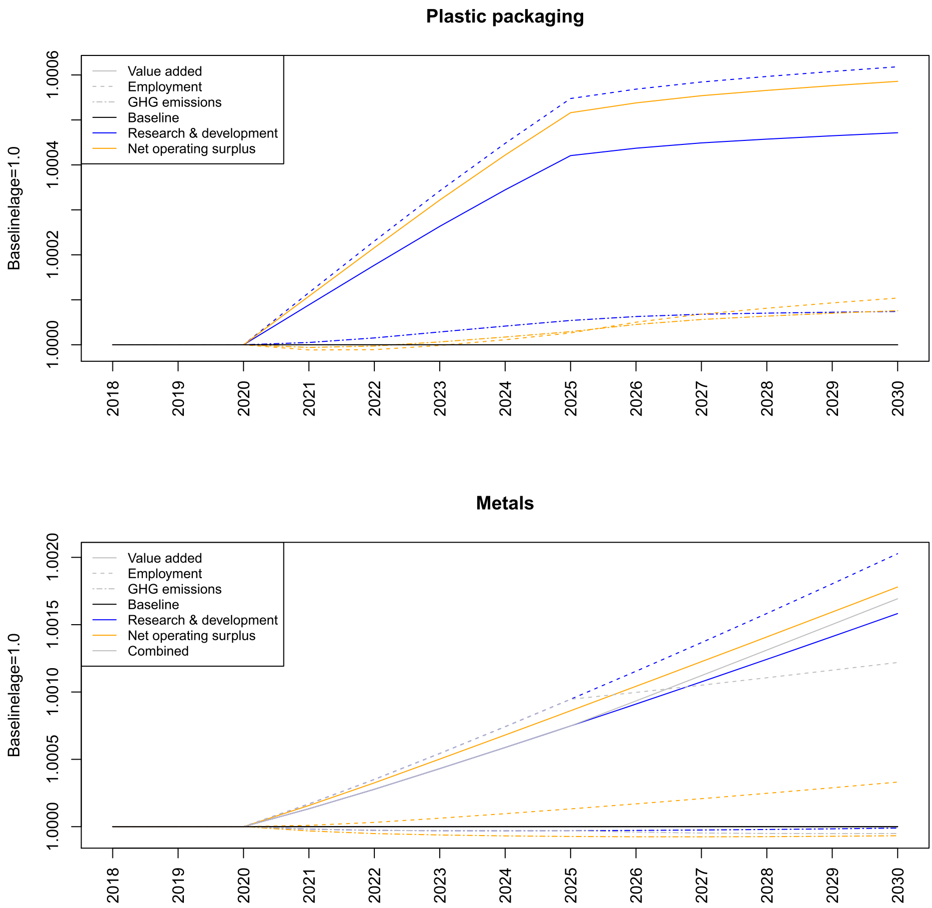

Fig. 3 Plastic packaging and metal scenarios—development of value added, employment and GHG emissions relative to baseline

figure). GHG emissions hardly change compared to baseline. While in the plastics packaging the increased economic activity may offset lower emissions from plastic production, for the 'increased metal efficiency' scenario, the decrease in emissions due to lower metal production may still be stronger than the emission increase due to increased economic activity. Here, the main factor is the emission intensity of plastics and metal production relative to the average emission intensity of all economic activities and the amount of plastics and metals imported to Norway. The share of plastics imported into Norway relative to all plastics used in Norway is relatively higher than for metals (66% for 'Rubber and plastics' compared to less than 40% for 'Basic metals' [47]). So that a reduction in plastics use in Norway is likely to reduce emissions relatively more abroad than a reduction in metal use.

Skills for a Circular Economy

Jobs needed for the circular economy or the green transition in general differ from those existing in the linear economy as they require higher analytical skills (creative problem solving) as well as higher intensity of human capital measured by formal education, work experience, and on the job training. For new green occupations on the job-training becomes a more distinctive trait which means that policies supporting skill training should be tailored even outside the formal educational system [81]. Thus, to maximize the potential of job creation during the transition, a high level of coordination between different institutional actors—labor unions, industry associations, businesses, the education sector, and the government—is required [82–84]. The active participation of these actors will provide a strong social system that allows those workers who lose their jobs to focus on acquiring new skills and reduces the re-allocation time to other jobs/sectors. As the effects differ by workers qualification, it is necessary to design policies that have a strong focus on low-paid low-skilled workers [85–87].

Among the possibilities for the Norwegian economy in terms of green job creation is the creation of jobs related to resource management in all industries, in relation with the management, use and treatment of materials and waste of production processes. Due to the circularity of a sustainable economic system, more jobs will be created in logistics and distribution of materials and products. High skill jobs for product development—in construction, design, and retail—are also necessary. Of particular importance are the jobs that connect the digital with the circular transformation of the economy; digitalization of production processes will assure a more efficient use of resources while data systems of material use and flows will help reducing the transaction costs for the re-use of materials within and between sectors.

Figures 4 and 5 show the number of additional jobs in the scenarios in 2030 compared to the baseline scenario by skill level. For more circular consumer behaviour regarding the

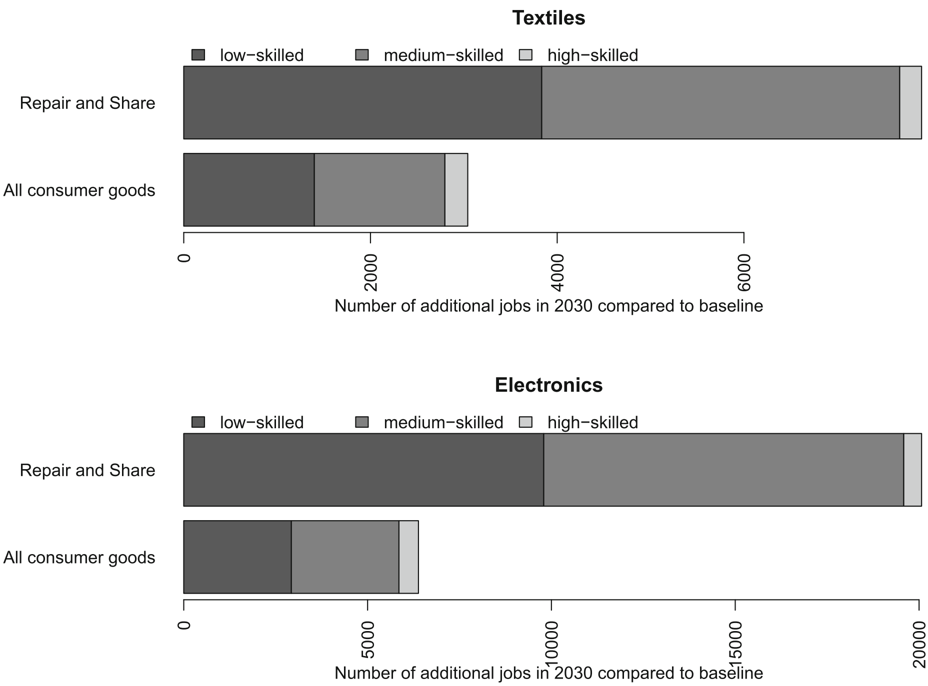

Fig. 4 Additional jobs compared to baseline, by skill, for circular consumer strategies

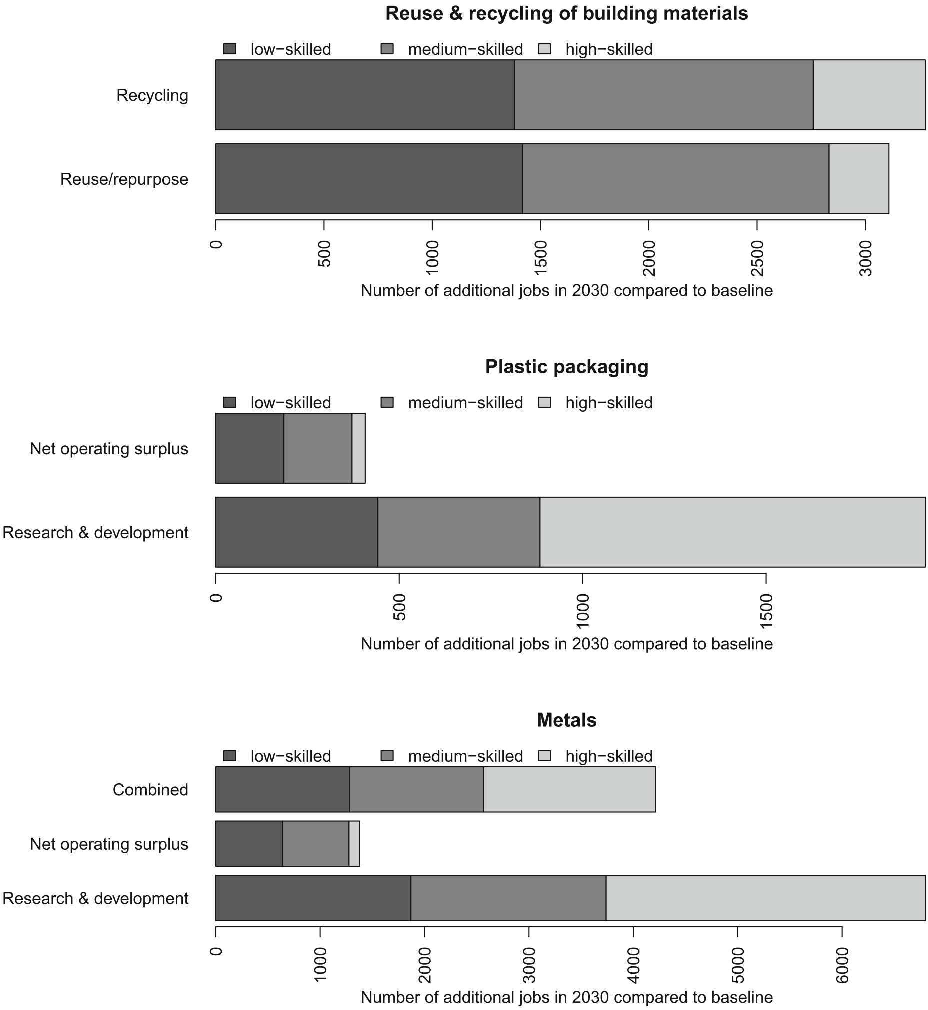

Fig. 5 Additional jobs compared to baseline, by skill, for circular producer strategies

consumption of textiles and electronics, we find that most of the new jobs created are low and medium skilled jobs in the repair and share services. The share of high-skilled jobs in the building material reuse/re-purpose and recycling scenarios is larger, but also here the new jobs are dominated by low and medium skill levels. For increasing materials recycling, additional jobs in R&D are necessary, thus leading to a twice as high number of additional high skilled jobs created.

For the plastic packaging and metal scenarios, the absolute number of jobs created differs largely due to the large difference in indirect and induced jobs created when additional earnings are absorbed as net-operating surplus (and only slowly reinvested into the economy) or spent on R&D services. For the metal efficiency value chain, we also included a combination of the two options. The results show that the effect is more than linear, especially in the number of high-skilled jobs created.

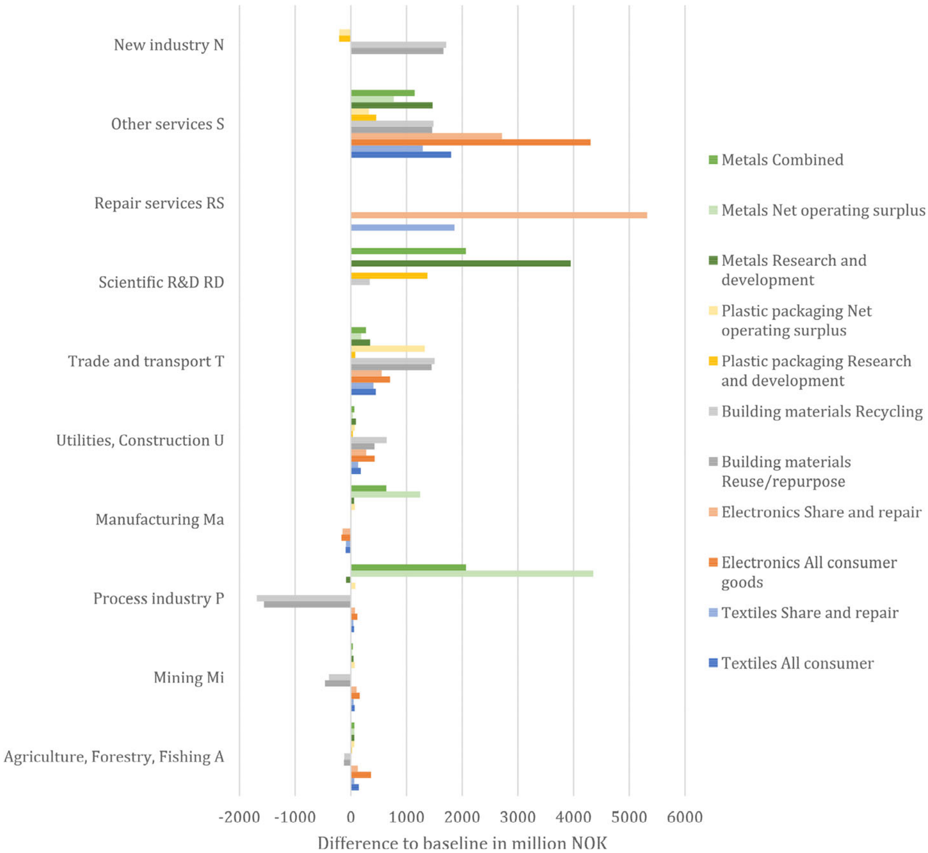

Fig. 6 Value creation potential compared to baseline, by aggregated industry

Here, we need to note that the findings regarding skill levels assume that the skill composition per industry remains the same. As the literature discussion in the beginning of this section showed, required skills may significantly change. The results here should therefore be considered in light of this discussion.

Effects by Industry

Figure 6 shows the value creation potential compared to baseline for all scenarios by aggregated industries (detailed results are displayed in Fig. 10 in the Appendix. The left column in the table indicates the industry aggregation from 64 detailed industries to the aggregated industries displayed here).

Common for most scenarios is a significant increase in value creation potential for the three industry groups Service industries, R&D, Trade and transport. Utilities, construction and manufacturing experience smaller, mainly positive impacts on value creation, while impacts in mining industries, and agriculture, forestry, fishing are very small, and both positive and negative. The aggregated industry, Process industry, shows particularly large variations of value creation impacts between the different scenarios. The metal scenarios have large positive impacts on value creation, while the scenarios related to circular strategies in building materials shows large negative potential impacts. This can be explained by the fact that circular strategies in building industries make use of already processed materials at the sacrifice of processing new materials, leading to a decline in the process industries. However, this is also based on the assumption that export from Process industries remains constant (equal to baseline) in these scenarios. For the metal scenarios, especially the ones with expenditures reallocated from spending on materials to spending on R&D, the direct, indirect, and induced effects increase economic activity in Norway.

The scenarios that focus on consumer goods, textiles and electronics, and behavioral changes do not not have any significant impacts on the process industries since their dependency on these industries is rather small. However, consumer goods as well as other intermediate inputs need to be designed in a way to make circularity possible, that is they need to be more durable, repairable, and recyclable. For this, a close cooperation between research, product design, product manufacturing, and the process industry is necessary. This increased collaboration across product value chains may bring additional business and value creation potentials that we have not considered here.

Discussion

Discussion of Results and Limitations in Model and Data

The analyses in this study are based on historical statistical data using the inter-industry and trade relations from 2018. Projection of the data for 2020–2030 will not capture the future changes in this general economic structure and trade between industries. In the scenarios we explicitly change this. Comparing the what-if-scenarios with the baseline scenario of economic growth but static inter-industry relations provides a basis for understanding potential implications of the circular economy transition compared to the non-circular world of today. In this study, we have analyzed a circular transition of five broad sectors/value chains: Textiles, electronics, building materials, plastic packaging, and metals. In a truly circular economy, however, producers and consumers are to change and use other circular production and consumption strategies in addition. The results relate only to the five selected sectors here and therefore do not give a complete picture of the total potential impacts of a circular economy transition in Norway. Employment increases in all scenarios, implying more people in work in full time positions. This increases the general income level, resulting in higher spending and additional positive economic effects. These effects, together with rebound effects of lower consumer spending due to longer life time of products are considered in the model. However, we do not model factor constraints or dynamic adjustments in the labour market. That is, the model assumes that a sufficient number of workers with the right qualifications are available to satisfy the labour demand for increased production in the growing industries. The results for employment should therefore be interpreted as showing the future need for workers and their skill levels across industries. Education policies and on-the-job training can then be targeted to secure a sufficiently qualified workforce in the future.

All circular strategies are aimed at reducing material use and waste, and therefore reducing related pressures on nature, be it on land-use due to extraction activities, air and soil emissions, or waste disposal. However, the economic input-output model, with the aggregated industry classification based on NACE 2, does not allow for a simple link of economic flow data with material flow data, be it primary or secondary materials. Hence, while we are able to model changes in the economic structures that come about with the circular transition, we are not able to quantify impacts on material flows, related extraction activities and their pressures on the natural environment. In addition, a lot of the environmental pressures may occur outside Norway, see next section. The representation of impacts on the environmental dimension of sustainable development is limited to GHG emissions for this analysis. A reduction in material extraction, however, is an underlying assumption for all scenarios. For more insights on how lower material extraction and processing around the world reduce pressures on nature, material flow and direct impact analysis could be used as a complement to the economic analysis at hand.

The International Context

In an increasingly connected world [88], changes in production and consumption systems in one country have immediate effects on other economies through global value chains. The famous ‘carbon leakage’ phenomenon is just one of many cross-border impacts of environmental policies, and studies like ‘The Material Footprint of Nations’ [89] have shown the significance of considering all supply chain effects in this context. In case of circular economy policies, trade structures may change significantly, given that raw materials may be replaced by recovered secondary materials, or the consumption of consumer goods is replaced by the use of consumer goods by sharing or repairing them. In fact, Norwegian imports of manufactured goods are reduced significantly in the consumer goods scenarios textiles and electronics (compare Fig. 7), while the reuse and recycling of building materials results in lower imports of materials from the process industry abroad (most significantly wood and non-metallic minerals, see Fig. 11 in the Appendix). The reduction in imports of construction services itself is artificial, as the industry was split into two, so that the reduction in imports from the original construction industry should be summed up with the increase in imports from the ‘New industry’ which are the recycling of building materials and the reuse of building materials industries, respectively. For the metal scenarios, we see a significant decrease in imports of basic metals.

The reduction in imports will reduce environmental impacts in raw material extracting and manufactured goods producing (textiles and electronics) countries, but, at the same time, have negative socio-economic consequences, if employment opportunities in the industries along the global value chains are lost. While a reduction in environmental pressures is generally positive, it is important to identify in which countries potential job losses may occur, so that policies can be put into place to ensure a Just Transition in the affected countries [90].

Given that Norway is a large exporter of raw and processed materials, a green transformation in other countries, especially away from oil, will have strong effects on the Norwegian economy. There is a need of quantitative assessments of the potential benefits and costs that will occur based on targeted interventions in the Norwegian economy. It is further important to understand the opportunities and risks facing the Norwegian economy regarding international competition as circular economy principles are adopted domestically and abroad.

While analyses of European or global circular economy transitions exist [8, 46, 91], no study has systematically assessed the effects on other countries of the circular economy transition in individual countries. However, the global studies suggest that in average environmental effects can be reduced, while employment opportunities can increase. These results are driven by the increasing importance of services in a circular economy as well as recycling activities being more labour intense than raw material mining activities.

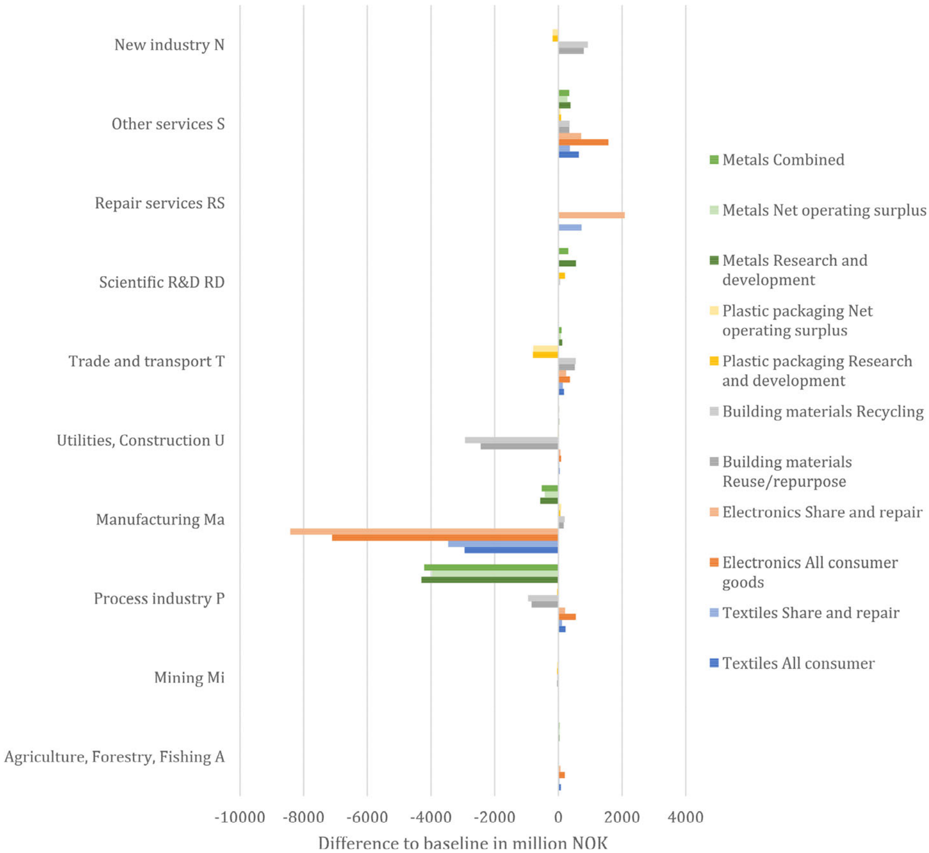

Fig. 7 Imports compared to compared to baseline, by aggregated industry

Policy Implications

The results from our analyses are not a forecasting of the future, but rather they give an overview of potential future effects on value added, employment, and GHG emissions of a circular economy transition. This also includes, which industries might need more or less workers, what kind of skills (educational level) are needed, and where in Norway the affected industries are located (see [61] for regionalized results). Therefore, these results identify for example jobs at risk of becoming stranded, and can be used by policy makers to design counter measures to minimize negative impacts (e.g. which other industries can be settled in affected regions). In the same way, the results identify in which industries and regions there is a potential for creating more values and jobs, and also at the same time minimize GHG emissions, and measures can be designed to stimulate these effects, e.g. supporting innovations in technologies and industries with large positive impacts. Even though the analysis of the circular economy transition in general shows positive potential impacts in Norway, several systemic barriers, tax and regulatory regimes exist, adapted for linear systems more than for circular economy. The successful implementation of the transition to a circular economy depends upon an innovative design of policies and implementation.

Achievement of the potential positive impacts of the circular strategies identified in this work requires and depends on advances in technologies, behavioural changes, and regulatory regimes, all dependent on innovative policies and guidelines. Some important factors crucial for realizing the potential are:

- Stricter requirements for waste sorting, including collection, reuse, and recycling.
- Stimulating creation of market places and designing rules (incl. transparency) for valorization and trade of waste and bi-products.
- Supporting long-term R&D investment in new circular innovations.
- Reform of tax system and regulations to support prolonging economic lifetime of goods, stimulate the repair and leasing service industry and stimulation of the markets for secondary materials and products, incl. regulations such as the "right to repair".
- Environmental taxes and labelling that also takes into account the entire supply chain of products, including abroad.
- Consumer education (schools, campaigns, news) and changing public attitudes, for example, towards waste minimization and intensified use of goods.

Norway's newly published circular economy and sustainability strategies [92, 93] have picked up some of these suggestions by [94] and [61], such as

- Longer life time of products to reduce the high Norwegian consumption.
- The government plans to present a holistic strategy for the buildings sector that will include measures to reduce the number of new buildings, the reuse/repurpose of building materials and the recycling and reduction of building material waste.
- Public procurement rules for ICT equipment will include demands related to waste prevention, lifetime extension, and increasing recycling.

Conclusion

A main goal of the circular economy transition is to contribute to reduced GHG emissions, reduced environmental impact, reduced resource use, and positive effects on employment and value added. Therefore, analysing simultaneously effects on these aspects are important when analysing different circular economy policies, strategies, and actions.

The results from the cases and scenarios analyzed in this study show that there is a substantial potential for increased value added and employment in Norway related to the circular transition. For the increased material efficiency (plastic packaging, metals), the scale of the overall effect depends on the way the efficiency increases are obtained: if these are obtained through increased R&D and design activities, employment gains are substantial, while they are more limited when the firms keeps the money as higher earnings. Emissions within Norway increase, while imports of metals and plastics decrease, resulting in lower upstream emissions. For consumer goods (textiles, electronics), the positive effects come about from shifting from a buy-and-discard model to a buy-repair/share/use longer-discard model, intensifying and prolonging the use of goods at the same time as requiring more workers for the maintenance. At the same time, GHG emissions within Norway may minimally increase due to generally higher domestic economic activity. However, imports of manufactured goods significantly decrease, allowing for the conclusion that emissions along upstream supply chains also decrease more than offsetting the increase in domestic emissions as imported manufactured goods have higher emissions per monetary unit than Norwegian services (see, e.g. data on CO2 emissions embodied in trade from OECD).

Similarly, for the re-use/re-purpose and recycling of building materials, emission-intense material extraction and processing activities are replaced by more labour intense activities, but less emission intense activities within Norway. We can therefore see a significant reduction in GHG emissions within Norway, making these scenarios an exemplary case for the positive triple bottom line effects of the circular economy. This study has analyzed the circular transition of five sectors in the Norwegian economy. However, in a full transition both producers and consumers behavioral patterns will change as so the structure of the underlying economic system. Our results relate only to the five industries and do not provide with a complete overview of the total impacts arriving from a complete circular economy. However, our results can serve as base for future research regarding labor mobility and sectoral policies needed for the shift of jobs and value from linear practices to circular ones.

Appendix A: A simple dynamic input-output model for Norway

The model is a combination of a dynamic macro-economic model depending on lagged and selected contemporaneous variables and an input-output model. We utilize the symmetric industry-by-industry input-output tables from the Norwegian statistical office [47]. The macro-economic relations are kept intentionally simple and are estimated based on time series data from 1970–2018 from the UN SNA Main Aggregates [48].

Household consumption expenditure per capita (Hpc) depends on contemporary and lagged value of value added per capita (Vpc), which serves as a proxy for income per capita.

$$Hpc_t = 0.379\,(0.5Vpc_t + 0.3Vpc_{t-1} + 0.2Vpc_{t-2}) + 32.127 \tag{2}$$

The weights for the lagged variables can be changed, but have no significant effects on the model results as per capita income in Norway is relatively stable. For this type of model, it is nonetheless important to include lagged variables for both model stability and also scenario path dependency. The latter ensures that income differences in 1 year due to changes specific to a scenario penetrate forward to the following years.

Total household consumption expenditures in year t (H_t) are then simply calculated by multiplying with the exogenous driver population (P_t).

$$H_t = Hpc_t P_t \tag{3}$$

Population projections are taken from UN World Population Perspectives [48].

Government consumption expenditures depend on population.

$$G_t = 109.331 P_t + 213530.321 \tag{4}$$

Gross fixed capital formation (investment I) grows with the value added growth rate, and exports (E) with the global economic growth rate (r) from the OECD Long View [49].

$$I_t = I_{t-1}\frac{V_t}{V_{t-1}} \tag{5}$$

$$E_t = (1 + r)E_{t-1} \tag{6}$$

This simple dynamic macro-economic projection (not forecasting) model is then used to drive the input-output model. The assumption is that the structure of final demand remains constant while the totals change. That is, each element in the vector of household demand y_t^H simply grows with the same growth rate, so that $\mathbf{y}_t^H = \mathbf{y}_{t-1}^H \frac{H_t}{H_{t-1}}$. The same holds for government consumption expenditures, gross fixed capital formation and exports.

Output by industry $\mathbf{x}_t$ is calculated using the Leontief model shown in Eq. (7) where $\mathbf{y}_t$ denote the total final demand by industry.

$$\mathbf{x}_t = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{y}_t \tag{7}$$

Output by industry is then used to calculate total value added, which is a driver for both contemporaneous household consumption expenditures and investments.

In the scenarios, the structure of household expenditure and investments and the production technology (the input coefficients) are changed exogenously, leading to alternative final demand vectors $\mathbf{y'}_t$ and input coefficient matrices $\mathbf{A'}_t$. This leads to new output by industry

$$\mathbf{x'}_t = \left(\mathbf{I} - \mathbf{A'}_t\right)^{-1}\mathbf{y'}_t, \tag{8}$$

which changes total value added, employment, and GHG emissions.

Total value added in year t is calculated from the value added coefficient vector $\mathbf{va}^T = \mathbf{1}^T - \mathbf{1}^T\mathbf{A}$ and the output vector as

$$V_t = \mathbf{va}^T\mathbf{x'}_t. \tag{9}$$

The employment per value added ratios are assumed to be constant, as are the GHG emissions per unit of 'emission relevant' inputs. For CO2, CH4, and N2O the relevant inputs are from industries 'Mining and quarrying', 'Coke and refined petroleum products' and 'Gas', which is part of the industry 'Electricity, gas, steam and air-conditioning'. In addition, for CH4 and N2O products from industries 'Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services', 'Products of forestry, logging and related services', and 'Agriculture' are relevant. HFK, PFK, and SF6 are assumed to have constant emissions per unit of output ratios across industries.

This model is not an economic forecasting model. Rather, it is a tool to inform about possible effects of 'what-if' scenarios on emissions and labour demand by industries, given that the remaining structure of the economy remains as is. The results should be assessed relative to the baseline scenario. They indicate the direction and possible size of the effects, but should not be taken exact estimates. The results show how changes in individual economic activities influence the economic structure. Direct, indirect, and induced effects of technological change and changes in household, government and investment structure are reflected.

The model is based on historic relation between economic activity, income and consumption and the production structure of the base year (currently 2018). To extrapolate data based on this until over the next decade will not necessarily give a complete picture, but it is a valuable starting point for assessing effects of policies through 'what-if' analyses.

Investments grow with the GDP (value added) growth rate, and the structure of the investment remains the same, with one exception: the exogenously given investment for individual scenarios, which comes in addition to the general investments. That means that additional investments in the scenarios are not crowding out other investments, but come as an additional economic stimulus. The results show which industries are likely to have an increased demand for labour, and which industries might contract. The actual labour market outcomes of course also depend on other factors as well as dynamic labour market adjustments such as wage adjustments, labour availability, and labour productivity changes that are not considered here. The current modelling of international trade is very simplified. Import shares by product are based on the supply table from the base year. Exports grow with global GDP projections from the IMF or OECD.

Once these limitations are well understood, they contribute to the main strength of the model: simplicity and transparency. These are reinforced by the other strengths: The model depends on very few types of data, which can be combined into one consistent framework with few equations. The model is data driven and very well reflects country-specific characteristics. Scenarios are implemented using one Excel sheet and the model runs only a few seconds, so that a large number of scenarios can be calculated for assessing the validity of different scenario assumptions. For every single result, we can find an explanation that is in the data or one of the few assumptions underlying the model.

Appendix B: Household consumption model for scenarios

Some of the scenarios includes an assumption that reparation services and/or extended product lifetimes will lead to decreased spending and subsequently savings for the consumers. The modelling must therefore consider what these savings will be utilized for, both such that value creation and total emission rates can be realistically accounted for. One fundamental aspect that must be accounted for when setting up the scenario assumptions are therefore how the population spends *surplus* cash. Consumer spending on various goods and services are investigated in several research fields, ranging from psychology of consumer behavior to macroeconomics. There are numerous factors believed to influence how people would spend extra disposable cash. Firstly, the origin of the cash and the amount will most likely impact how it is spent. After all, there is a large difference by receiving a one-time large lump sum, compared to indirectly receiving more mediocre sums from abstaining from buying new consumer products. The latter form is considered to be of most relevance for this paper's consumption scenarios. The motivation for this is that reparation services or longer lifetime of products will not entail a direct cash payment to the consumer, but will rather reduce the spending on re-purchasing of new appliances/items. We set up a simplified consumption model based on the principles of *Marginal propensity to consume*, commonly known as *extra dollar spending* [95].

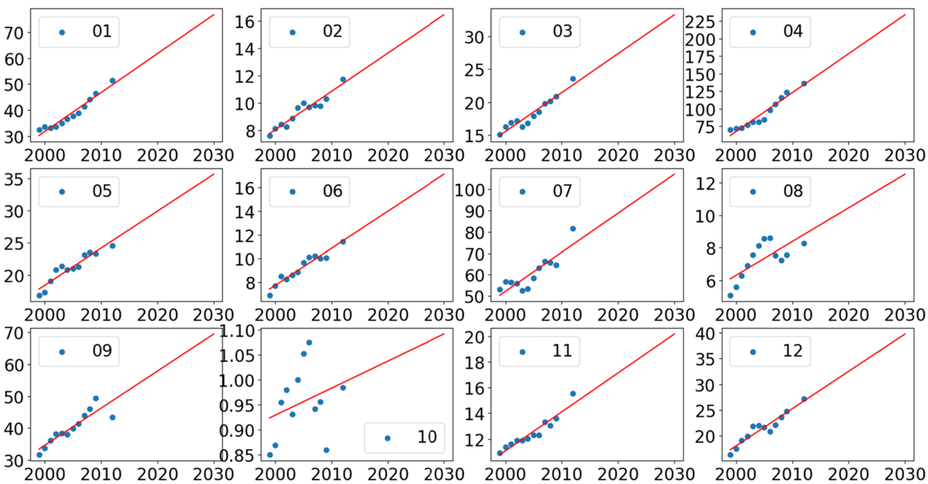

Fig. 8 OLS regression per spending category. The y-axis shows spending in 1000 Norwegian krone while the x-axis shows the year. The blue points are the data from the Norwegian Survey of Consumer Expenditure, and the red line is the regression line from the OLS. Spending categories labelled as in Table 2

Table 2 Overview of the categories in the Norwegian Survey of Consumer Expenditure

Number	Commodity and service group
01	Food and non-alcoholic beverages
02	Alcoholic beverages and tobacco
03	Clothing and footwear
04	Housing, water, electricity, gas and other fuels
05	Furnishings, household equipment and routine maintenance of the house
06	Health
07	Transport
08	Communication
09	Recreation and culture
10	Education
11	Restaurants and hotels
12	Miscellaneous goods and services

The model for the *marginal propensity to consume* is based on the *Survey of consumer expenditure in Norway* [96] with data collected annually from 1999 to 2009, and then again in 2012, for the categories shown in Table 2. The statistics has been since been discontinued, meaning that the last year of the series is from 2012.

The survey data were used to set up a linear regression model based on ordinary least square (OLS) per consumption category. All data points where given equal contribution in the *OLS*. This regression was then used to extrapolate the consumption per category for year 2030 as seen in Fig. 8. All the consumption categories had a positive coefficient, which indicates that spending per category was increasing despite some occasional occurrences of consumption declines in the time series. The different categories experienced different growth rates, and the shares per category are therefore different for 2030 than in the last year the survey was conducted. The regressions were used as estimators for how Norwegian spending will change over the coming decade.

Furthermore, this was used as a proxy to estimate how the Norwegian population's marginal propensity to consume was distributed among the main spending categories. The relative change in consumption spending per category, ΔS_c, is calculated as shown in Eq. (10). Here, S_c^{2030} and S_c^{2020} denotes the extrapolated spending based on the OLS per

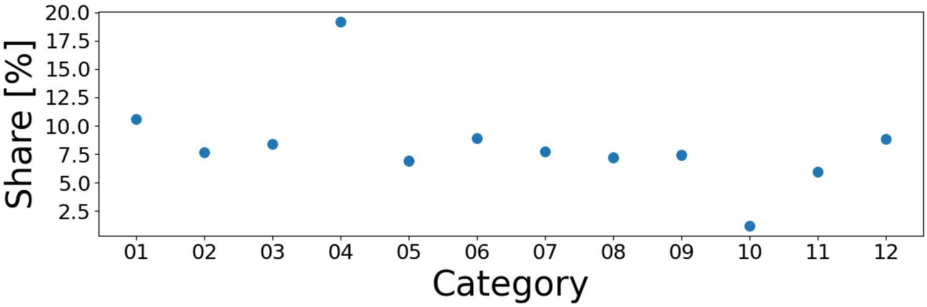

Fig. 9 Distribution of extra money for consumption spending per main category $\Delta \widetilde{S}_c$. Spending categories labelled as in Table 2

Table 3 Distribution of extra money for consumption spending per all 65 sectors

Sector	Share
Products of agriculture, hunting and related services	0.028578692
Products of forestry, logging and related services	0.001269686
Fish and other fishing products; aquaculture products; (...)	0.001965997
Mining and quarrying	0.000147733
Food products, beverages and tobacco products	0.150624802
Textiles, wearing apparel and leather products	0.083820192
Wood and of products of wood and cork, except furniture; (...)	0.000322615
Paper and paper products	0.002256463
Printing and recording services	6.45283E-05
Coke and refined petroleum products	0
Chemicals and chemical products	0
Basic pharmaceutical products and pharmaceutical preparations	0.044848317
Rubber and plastics products	0.001764771
Other non-metallic mineral products	0.001411667
Basic metals	1.81374E-05
Fabricated metal products, except machinery and equipment	0.003987648
Computer, electronic and optical products	0.019957138
Electrical equipment	0.013143002
Machinery and equipment n.e.c.	0.006142706
Motor vehicles, trailers and semi-trailers	0.021469272
Other transport equipment	0.002570405
Furniture; other manufactured goods	0.025131442
Repair and installation services of machinery and equipment	0.000561562
Electricity, gas, steam and air-conditioning	0.012286444
Natural water; water treatment and supply services	0.002107464
Sewerage; waste collection, treatment and disposal activities (...)	0.005570345
Constructions and construction works	0.001300803
Wholesale and retail trade and repair services of motor vehicles (...)	0.020879133
Wholesale trade services, except of motor vehicles and motorcycles	0.030129084
Retail trade services, except of motor vehicles and motorcycles	0.025365598
Land transport services and transport services via pipelines	0.011145477
Water transport services	0.004936291
Air transport services	0.006815791
Warehousing and support services for transportation	0.0087733
Postal and courier services	0.000453434
Accommodation and food services	0.065630075
Publishing services	0.00640427
Motion picture, video and television prog. production (...)	0.00586939
Telecommunications services	0.072038068
Computer programming, consultancy and related services; (...)	0.000592974
Financial services, except insurance and pension funding	0.027686415
Insurance, reinsurance and pension funding services, (...)	0.010137188
Services auxiliary to financial services and insurance services	0.00043308
Real estate services (excluding imputed rents)	0.021307781

Table 3 (continued)

Sector	Share
Imputed rents of owner-occupied dwellings	0.078502063
Legal and accounting services; services of head offices;(...)	0.001209886
Architectural and engineering services; technical testing (...)	0.000203757
Scientific research and development services	8.6138E-06
Advertising and market research services	6.14808E-07
Other professional, scientific and technical services; veterinary services	0.001085064
Rental and leasing services	0.005029954
Employment services	2.03559E-07
Travel agency, tour operator and other reservation services (...)	0.054645865
Security and investigation services; services to buildings (...)	0.000975092
Public administration and defence services; (...)	0.014597688
Education services	0.012454482
Human health services	0.044522887
Social work services	0.013961484
Creative, arts and entertainment services; library, archive, museum (...)	0.007276797
Sporting services and amusement and recreation services	0.005431153
Services furnished by membership organizations	0
Repair services of computers and personal and household goods	0.000366987
Other personal services	0.009676656
Services of households as employers; undifferentiated goods(...)	0.000131576
Services provided by extraterritorial organizations and bodies	0
Sum	**1.000**

category c. The sum of changes in consumption spending is different from 1, as seen in Eq. (11), and to ensure compatibility with the rest of the model this must be corrected for. A correction factor β is therefore calculated as seen in Eq. (12), and is thereafter used to adjust the changes in spending per category as shown in Eq. (13). The adjusted changes in spending per category is now given by $\Delta\widetilde{S_c}$ and will now sum to 1.00 as shown in Eq. (14). After performing the calculations in Eqs. (10)–(14), the relative change in consumption spending per category, ΔS_c, are shown in Fig. 9. This shows that if an average consumer saves 1 unit of money, this will be redistributed in accordance with the Fig. 9, and the largest spending will likely be on the category *04—housing, water, electricity, gas and other fuels*.

The spending on the twelve main categories were further disaggregated, and the final marginal propensity to consume vector per the 65 sectors in the IO-table can be found in Table 3. The concordance matrix used for this can be shared in Excel-format with interested readers.

$$\Delta S_c = \frac{S_c^{2030} - S_c^{2020}}{S_c^{2020}} \tag{10}$$

$$\sum_{c \in C} \Delta S_c \neq 1.00 \tag{11}$$

$$\beta = \left(\sum_{c \in C} \Delta S_c \right)^{-1} \tag{12}$$

$$\Delta\widetilde{S_c} = \Delta S_c \cdot \beta \tag{13}$$

$$\sum_{c \in C} \Delta \widetilde{S}_c \approx 1.00 \tag{14}$$

Appendix C: Detailed results by industry

		Textiles		Electronics		Building materials		Plastic packaging		Metals		
		All consumer	Share and repair	All consumer goods	Share and repair	Reuse/repurpose	Recycling	Research and development	Net operating surplus	Research and development	Net operating surplus	Combined
A	Agriculture	73	30	192	65	9	12	10	17	32	34	33
A	Forestry	6	3	14	7	-137	-137	1	10	3	2	3
A	Fishing	64	28	156	53	6	8	8	34	26	28	27
Mi	Mining	67	49	159	103	-465	-392	4	69	47	24	36
Ma	Food	172	76	427	145	14	21	22	429	72	77	75
Ma	Textiles	-157	-173	49	18	7	7	2	6	10	9	10
P	Wood	7	5	17	9	-756	-759	1	4	4	3	4
P	Paper	3	2	7	4	4	6	0	7	2	1	2
Ma	Printing	5	5	10	11	7	6	2	9	8	2	5
P	Coke, PP	0	0	0	0	0	0	0	0	0	0	0
P	Chemicals	0	0	0	0	0	0	0	0	0	0	0
P	Pharmaceuticals	31	18	75	38	9	7	0	36	16	13	15
P	Rubber and plastics	4	3	10	6	11	-113	-6	15	5	2	3
P	Non-metallic minerals	5	4	12	7	-636	-636	0	1	4	2	3
P	Basic metals	1	1	2	2	-8	-7	0	1	-118	3739	1756
P	Fabricated metals	8	14	-6	9	-184	-186	1	18	3	593	285
Ma	Electronics	7	10	-221	-216	0	0	2	1	8	30	19
Ma	Electrical equipment	4	23	-79	-25	0	2	1	19	3	421	206
Ma	Machinery	6	6	-28	-28	4	3	1	15	5	261	129
Ma	Motor vehicles	9	4	21	8	3	3	1	2	4	333	166
Ma	Transport equipment	3	3	6	7	-9	-10	0	0	2	174	86
Ma	Furniture and others	15	12	38	27	3	4	3	17	8	7	8
Ma	Repair and installation	15	21	34	51	-8	-18	0	2	10	6	8
U	Utilities	92	62	219	128	55	39	14	9	16	-2	6
U	Water	8	4	19	8	2	3	1	1	4	3	4
U	Waste	23	22	53	50	23	292	7	50	24	10	17
U	Construction	57	42	136	89	346	310	14	8	47	24	36
T	MV trade and repair	69	46	170	99	80	78	11	21	35	30	33
T	Wholesale trade	141	146	352	353	55	70	29	851	121	57	91
T	Retail trade	106	108	-139	-141	38	55	23	403	98	48	74
T	Land transport	66	54	162	123	708	699	7	44	45	26	36
T	Water transport	12	10	31	22	13	21	2	1	9	5	7
T	Air transport	20	12	50	24	6	6	4	3	12	9	10
T	Transport support	33	32	80	75	551	576	5	4	27	13	20
S	Post	12	18	26	42	33	30	10	3	30	5	18
S	Hotels and restaurants	45	26	109	51	13	13	9	25	30	20	25
S	Publishing services	39	35	90	76	69	68	21	13	64	17	42
S	Broadcasting	16	13	38	29	16	14	6	3	19	7	13
S	Telecommunications	228	117	560	230	103	109	41	36	125	99	114
S	Consultancy	46	53	103	121	369	350	29	7	89	18	56
S	Financial services	231	142	555	290	74	85	43	32	143	95	121
S	Insurance	57	35	137	73	26	31	10	8	32	24	28
S	Aux finance, insurance	17	11	40	23	8	8	4	3	15	7	11
S	Real estate services	161	217	349	493	129	196	55	23	197	73	140
S	Imputed rents	282	122	693	223	60	73	35	44	109	123	116
S	Legal, accounting	45	64	104	154	120	96	41	8	126	19	75
S	Architect, engineer	7	8	16	19	15	11	4	2	13	3	8
RD	Scientific R&D	1	1	3	2	1	338	1375	0	3949	0	2066
S	Marketing	9	16	19	38	17	14	5	2	17	4	11
S	Other services	8	9	20	20	14	11	4	2	13	4	9
S	Renting, leasing	27	34	64	55	47	45	11	3	38	12	26
S	Employment services	17	44	35	107	64	48	18	3	55	7	33
S	Travel services	50	22	124	41	11	13	7	8	20	22	21
S	Security, administration	35	65	80	159	109	85	30	5	97	15	59
S	Public administration	65	45	157	95	53	54	15	10	51	27	40
S	Education services	63	32	154	63	18	25	10	13	32	27	30
S	Health services	191	83	468	153	41	50	24	36	75	82	79
S	Social work	70	37	168	71	20	22	9	21	31	30	31
S	Cultural services	16	8	40	17	7	8	3	3	9	7	8
S	Sports	18	10	45	19	5	6	3	4	10	8	9
S	Organizations	3	5	8	14	5	5	3	1	11	1	6
RS	Repair services	2	1862	4	5321	1	2	1	1	2	1	1
S	Personal services	41	19	101	36	12	12	6	6	18	18	18
S	HH as employers	1	0	2	1	0	0	0	0	0	0	0
S	Extraterritorial	0	0	0	0	0	0	0	0	0	0	0
N	New industry	0	0	0	0	1663	1713	-211	-207	0	0	0
	Total	**2777**	**3835**	**6340**	**9165**	**2874**	**3504**	**1790**	**2224**	**6009**	**6758**	**6427**

Fig. 10 Value creation potential compared to baseline, by industry (in million NOK)

		Textiles		Electronics		Building materials		Plastic packaging		Metals		
		All consumer	Share and repair	All consumer goods	Share and repair	Reuse/repurpose	Recycling	Research and development	Net operating surplus	Research and development	Net operating surplus	Combined
A	Agriculture	67	28	170	56	12	15	8	12	28	31	29
A	Forestry	1	0	2	1	-8	-8	-6	-5	0	0	0
A	Fishing	11	5	27	9	1	1	-11	-10	4	5	5
Mi	Mining	6	5	15	9	-43	-36	-44	-43	4	2	3
Ma	Food	381	168	954	314	64	81	-222	-200	157	173	165
Ma	Textiles	-3375	-3696	1000	326	87	105	48	60	163	182	173
P	Wood	4	3	10	5	-413	-414	-1	-1	2	2	2
P	Paper	13	6	31	12	7	9	-3	-2	6	6	6
Ma	Printing	1	1	2	2	1	1	-5	-5	2	0	1
P	Coke, PP	0	0	0	0	0	0	0	0	0	0	0
P	Chemicals	0	0	0	0	0	0	0	0	0	0	0
P	Pharmaceuticals	166	78	413	149	38	42	-8	-2	71	75	73
P	Rubber and plastics	12	6	29	12	12	-104	-19	-18	7	5	6
P	Non-metallic minerals	8	4	20	8	-373	-373	0	0	4	4	4
P	Basic metals	1	1	5	5	-19	-18	0	0	-3982	-3672	-3902
P	Fabricated metals	21	15	40	19	-94	-94	-8	-8	-410	-389	-405
Ma	Electronics	96	46	-4344	-4519	19	24	12	14	23	27	24
Ma	Electrical equipment	67	55	-2964	-3021	13	18	-4	0	-354	-317	-344
Ma	Machinery	35	19	-1371	-1429	10	10	-6	-4	-185	-165	-180
Ma	Motor vehicles	96	42	241	79	21	26	12	15	-123	-76	-110
Ma	Transport equipment	14	8	35	16	-6	-6	1	2	-146	-131	-142
Ma	Furniture and others	109	51	273	96	23	28	5	9	45	50	47
Ma	Repair and installation	9	12	20	29	-5	-10	-1	-2	6	3	5
U	Utilities	6	4	14	7	3	2	1	1	1	0	1
U	Water	1	1	3	1	0	0	0	0	1	1	1
U	Waste	11	11	25	23	11	132	-28	-27	11	4	8
U	Construction	19	14	46	30	-2455	-3069	5	3	16	8	12
T	MV trade and repair	28	19	69	40	32	31	-2	-2	14	12	13
T	Wholesale trade	30	31	74	74	12	15	-536	-527	25	12	19
T	Retail trade	18	18	-24	-24	6	9	-249	-246	17	8	13
T	Land transport	12	10	30	23	130	128	-25	-24	8	5	7
T	Water transport	21	16	51	35	20	32	3	2	14	9	11
T	Air transport	49	27	120	52	13	14	8	7	26	22	24
T	Transport support	18	17	44	41	302	315	2	0	15	7	11
S	Post	3	4	6	9	7	6	1	0	6	1	4
S	Hotels and restaurants	282	124	706	232	61	74	25	33	116	129	123
S	Publishing services	11	8	27	16	12	13	0	-2	12	5	9
S	Broadcasting	13	8	32	17	8	8	3	2	10	6	8
S	Telecommunications	69	33	171	64	24	26	11	11	34	31	32
S	Consultancy	10	11	23	24	72	68	5	1	16	4	11
S	Financial services	12	6	28	13	3	4	2	2	6	5	6
S	Insurance	3	1	7	3	1	1	0	0	1	1	1
S	Aux finance, insurance	3	2	8	4	1	1	0	0	2	1	2
S	Real estate services	10	14	22	31	8	12	3	1	12	5	9
S	Imputed rents	11	5	26	9	2	3	1	2	4	5	4
S	Legal, accounting	11	15	23	32	29	23	8	1	22	3	15
S	Architect, engineer	2	2	5	5	4	3	1	0	4	1	2
RD	Scientific R&D	0	0	0	0	0	54	208	0	550	0	311
S	Marketing	7	12	15	30	14	11	4	1	13	3	8
S	Other services	3	3	7	7	5	4	1	0	4	1	3
S	Renting, leasing	8	10	20	17	14	14	3	0	12	4	8
S	Employment services	1	3	2	7	4	3	1	0	4	0	2
S	Travel services	121	54	301	100	26	32	16	19	49	54	52
S	Security, administration	10	18	24	44	30	23	7	0	27	4	16
S	Public administration	7	5	17	10	6	6	0	0	6	3	4
S	Education services	2	1	5	2	1	1	-2	-2	1	1	1
S	Health services	19	8	47	16	4	5	-2	-1	8	8	8
S	Social work	3	2	7	3	1	1	-6	-6	1	1	1
S	Cultural services	8	4	20	8	3	3	1	1	4	4	4
S	Sports	3	2	8	3	1	1	0	0	2	1	2
S	Organizations	1	1	2	3	1	1	0	-1	2	0	1
RS	Repair services	1	729	2	2085	1	1	0	0	1	0	0
S	Personal services	6	3	14	5	2	2	1	1	2	2	2
S	HH as employers	0	0	0	0	0	0	0	0	0	0	0
S	Extraterritorial	0	0	0	0	0	0	0	0	0	0	0
N	New industry	0	0	0	0	796	926	-182	-182	0	0	0
	Total	**-1403**	**-1889**	**-3368**	**-4721**	**-1434**	**-1760**	**-964**	**-1121**	**-3599**	**-3815**	**-3768**

Fig. 11 Changes in imports compared to baseline, by industry (in million NOK)

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Declarations

Competing Interests The authors declare no competing interests

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