

Nordic Working Paper

Low-Carbon Circular Transition in the Nordics

Part II: Potential impacts of circular economy in
selected areas

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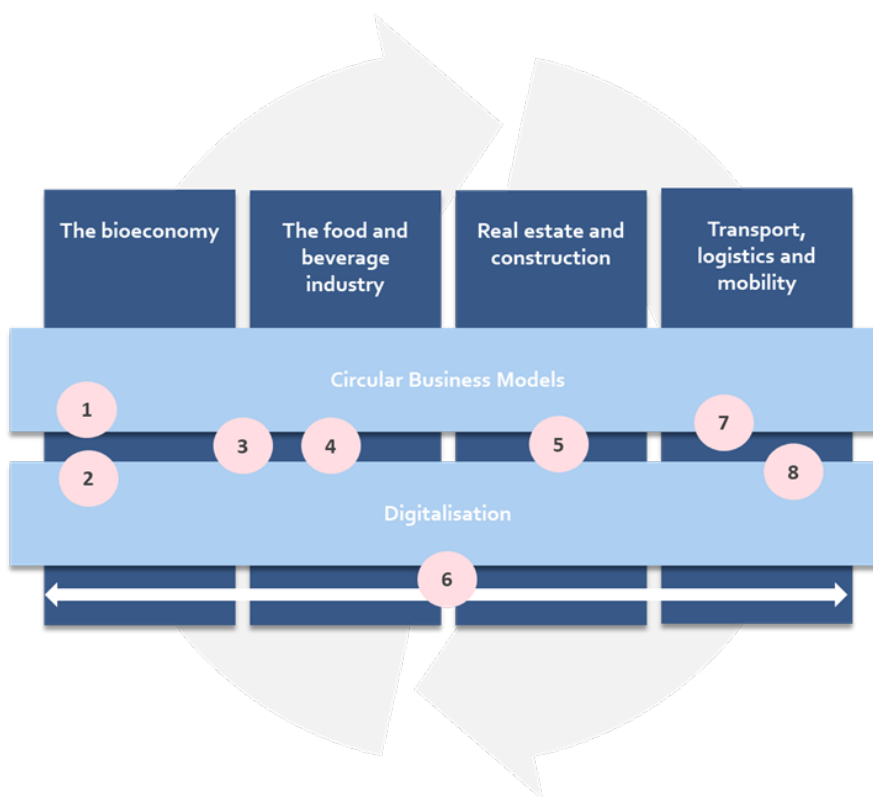
Executive Summary

The objectives for the study titled 'Low-Carbon Circular Transition in the Nordics' are to generate insight pertaining to the potential of circular economy in the Nordic region and to provide recommendations for unlocking this potential. This report covers the second part of the study. It focuses on **identifying, describing, and assessing impacts of circular transition, alongside barriers to development.**

This second portion of the study took its point of departure from the potential areas of circular economy that had been identified in the first part of the study. These include the following areas of industry: the bioeconomy; the food and beverage industry; the building and construction industry; and the mobility, transport, and logistics sector. Also among the areas of potential identified were two significant drivers of circular transition: digitalisation and new circular business models.

Our hypothesis was that potential that is of interest with specific regard to circular transition can be cultivated at the nexus of these areas by releasing circular mechanisms that will have broader impacts within and across the relevant sectors. Therefore, we chose an approach of building strong cases that provide an illustrative sample of these mechanisms and of their potential impacts on the areas of industry highlighted via part I, which formed the foundation for this study.

The circular economy (CE) opportunities chosen as topics for the case studies showcase a range of mechanisms that drive the circular transition within the chosen areas of industry. The case studies are meant to give inspiration related to mechanisms that the Nordic countries could support in aims of harnessing the potential for circular transition in a sustainable and integrated Nordic region.



The following circular economy opportunities were selected for focus: 1) closed-loop wood-based textile solutions, 2) new applications for ocean biomass, 3) predictive management supporting circular food-chain solutions, 4) new business models and digital platforms for the minimisation of

food loss, 5) models for increased (re)utilisation of buildings, 6) digital platforms supporting circular economy, 7) smart mobility solutions, and 8) circular transport logistics.

For each of the case studies, the current state of affairs in the Nordics was described, future potential identified, and impacts assessed: 1) impacts on business development and growth; 2) impacts on climate and the environment, including biodiversity; and 3) socio-economic impacts, inclusive of possible variations between Nordic locations, along with barriers to unleashing the potential represented by the circular opportunities.

The cases show that there are multiple areas of demand for CE solutions and numerous benefits, over the full life cycle of the industrial processes described. There is a clear need to obtain greater value from resource use and develop more sustainable production and consumption patterns by transforming linear resource flows into loops. In the big picture, CE solutions prove their immense potential to facilitate business development and innovation, reduce greenhouse gas emissions, have positive biodiversity effects, and support a cleaner environment (air, water, and soil). In addition, the solutions have various socio-economic implications. Importantly, these differ greatly across Nordic locations, which must be considered as CE becomes a key tool in a process of green and just transition.

The case studies of CE opportunities highlight the following general trends as the main drivers manifesting future potential:

- The core trend is that of increased demand for resource-efficiency, decoupling, and waste prevention, for which CE provides solutions.
- Market demand for CE solutions is rising as prices of virgin materials increase in tandem with those of waste-handling. Hence, CE solutions will become more business-viable.
- Regulatory actions in various sectors and branches of industry are boosting the circular transition. An important example is the EU ban on landfill disposal of residual waste from 2025 onward.
- Technological development enables new solutions and makes new business models viable. Digitalisation is a major driver in this development.

The bioeconomy: The key reason for studying the bioeconomy was the assumption that exploring different solutions for a more sustainable and circular Nordic bioeconomy is necessary for preparing for the future and for ensuring that the Nordic countries can preserve their competitive advantage at the forefront of circularity development. Significant business potential was found in the expansion and up-scaling of circular processes and technologies, along with development of new material streams, opportunities, and markets. On the other hand, a risk of competition, duplication of effort, and diseconomy of scale was identified too. Key climate and environmental impacts were found in the potential to reduce CO₂ emissions, reduce the need for non-renewable resources and virgin materials, and increase carbon sinks. Simultaneously, however, potential for biodiversity loss and for negative impacts on ecosystems was identified. The main socio-economic impacts were pinpointed in relation to the possibility of strengthening regional innovation networks and of diversifying the employment base. Finally, indirect impacts on Nordic societies' health and welfare were identified also.

The food and beverage industry: We examined the food and beverage industry mainly in response to the need to create more sustainable consumption and production patterns, from primary production to food waste, by applying CE principles. The industries engaged in food and beverage activities provide good conditions for circular business development and for new business activities along all the value chains, with the use of data and digital tools being key to many of the associated opportunities. Potential for business impacts was found in cost savings enabled via predictive management and logistics throughout the value chain, new business opportunities related to data and digital solutions, and better management of

logistics chains leading to less food loss and waste. Among the climate and environmental impacts identified were significant potential for reduced nutrient emissions to the air, water, and soil; better soil quality, reduced water consumption and phosphorus-mining; reductions in food waste through greater end-of-life use of the food produced; and significant potential for reduced emissions and a lower environmental burden from food production by means of decreased production and waste. Possible socio-economic impacts are related to indirect impacts on health and welfare in Nordic societies, changes in employment structure, and potential better access to affordable produce.

The building and construction sector: Building and construction accounts for a significant proportion of materials' consumption, energy use, and waste generation. The sector also accounts for a considerable proportion of the economic activity in the Nordic countries. Transforming this sector, therefore, is a central component of CE efforts. Circularity opportunities require rethinking the entire life cycle of a building, from reducing the need for virgin resources and increasing energy- and resource-efficiency (by means of good design, choices of materials, project management, and logistics) – to optimising the use, reuse, and shared use of buildings for different purposes, as well as improving construction waste's management. One key issue is to ensure that reparation and rebuilding is made possible through circular thinking already in the planning and construction phase. Business potential was identified in circularity requirements for building materials and design, possible cost savings, increased markets for material streams, and new business models and business growth connected to marketplaces and logistics. Key climate and environmental impacts of the sector's circular transition were linked to emission reductions through less material production, increased reuse and recycling, decreased need for extraction of virgin materials (by means of reuse), material substitution and waste reduction, and decreased landfilling of the materials. Potential risks were identified in the handling of hazardous waste. Key socio-economic impacts were visible in relation to developing housing, jobs, and business activities in various areas by means of adaptive (re)utilisation of buildings, skills development in the building and construction sector, new employment opportunities related to digital platforms, and safety and health impacts stemming from buildings and their use.

The mobility, transport, and logistics sector: The reason for studying the final sector in our survey was that transport and logistics operations constitute a prerequisite for circular economy and for its resource flows. At the same time, domestic transport in the Nordic countries accounts for a significant share of emissions, and all countries in the region have set targets for reducing emissions from transport. A clear need exists to lower emissions, develop efficient transport systems and logistics, and support innovative transport services. The ongoing desire to reduce environmental burdens from the transport sector means that there is huge potential and need for mobility-as-a-service (MaaS) solutions. It is expected that MaaS will accelerate R&D activities in the manufacturing sector and thus bring business opportunities for transport and associated activities. Growth in business volume for the non-personal-transport sector as a whole is an obvious expected impact of MaaS, with expected rises in efficiency and economy of scale sector-wide. The likely shift in emphasis away from physical assets and toward information management can be expected to open new avenues for innovation. Digitalised services are also scalable, thereby bringing potential to share the best practices across the Nordic region and thus encourage greater effectiveness. Among the key business impacts are increased efficiency and economy of scale, cost savings in logistics, reduction in idle/underutilised assets, and new digital-solution- and platform-economy-based business concepts. The expected climate and environmental impacts include reductions to emissions (in CO₂-eq. terms) and to air pollution through reduced need for travel and through shifting the favoured modes of transport away from fossil-based solutions, CO₂ emission reductions brought by more efficient logistics operations, reduced use of natural resources connected with the manufacture of private vehicles, and better utilisation of space as less land is needed for mobility. The socio-economic impacts include

increased focus on skilled labour, more skilled workers, possible reductions in total employment, lower costs of transport for individuals, and unequal opportunities for people living in different regions.

Also, important **barriers to releasing the circularity potential** were identified, in four categories: technology barriers, regulatory barriers, market barriers, and cultural barriers.

Among the technology-related barriers are hurdles connected with new value-chain structures and new ways of collaborating, especially with regard to the critical steps in getting CE solutions based on new technologies to work at industrial scale after their piloting and demonstration phase. Digitalisation is one of the main drivers for CE, while the key challenges in this regard are related to such factors as continuing lack of harmonised data standards, low quality of existing data, and limited access to data.

Regulatory barriers are visible in lack of regulation, prevailing standards and regulation that prohibit or complicate CE solutions, and shortcomings such as conflicting/counterproductive policies and regulation. Regulatory barriers act at multiple levels, and the growing role of EU regulation may exert an especially strong effect on the ways in which Nordic co-operation can influence policy development and regulation.

Market barriers arise mainly in relation to underdeveloped markets for CE solutions – solutions that, for reason of low market volumes, business-as-usual solutions' low cost relative to the new solutions, and absence of the necessary infrastructure, are not yet business-viable. Also, low costs of virgin materials and issues of waste-handling are blocking the implementation of CE solutions. As the CE transition requires new models for co-operation and restructuring of existing value networks, business turbulence and higher risks are expected over an extended time, with some of the barriers linked to modern industries' low readiness to change their structures and business models accordingly.

The cultural barriers are related primarily to the practices followed in business operations, practices, knowledge and awareness, and attitudes. Both potential users and customers are used to the linear practices applied in a 'business as usual' mode. Companies may have doubts about the business potential while customers could find it challenging to alter their own behaviour. End users' attitudes and culture-related issues pose obstacles to acceptance of CE-based products. Also, CE solutions demand new competencies and development of additional know-how, coupled with intensified co-operation between businesses and education/research institutions within innovation ecosystems.

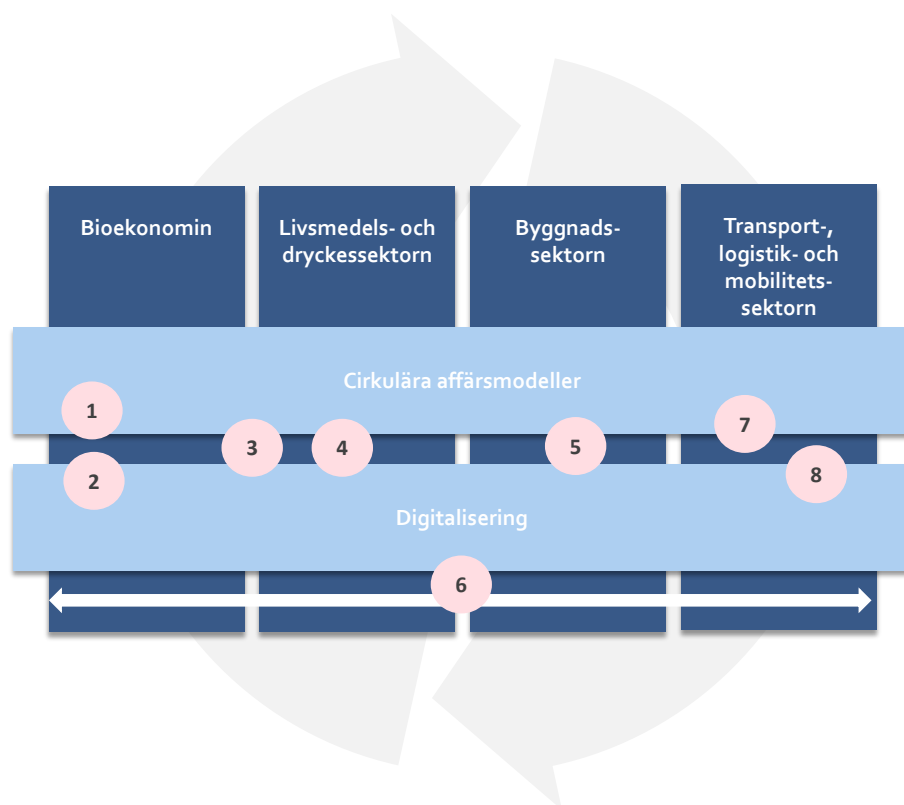
The analysis of barriers and of solutions for removing them will be continued in the third and final part of the study, to be realised in March–October 2022. The aim behind the forthcoming remaining work is to identify what the Nordics can do to accelerate the circular transition by harnessing potential in selected areas and lowering barriers.

Sammanfattning

Syftet med studien om cirkulär omställning i Norden med titeln "Low-Carbon Circular Transition in the Nordics" är att generera kunskap om den cirkulära ekonomins potential i Norden och ge rekommendationer om hur denna potential kan främjas. Denna rapport täcker den andra delen av studien. Den fokuserar på att **identifiera, beskriva och bedöma konsekvenserna av cirkulär omställning samt de främsta hindren för utveckling**.

Denna andra del av studien baserar sig på de potentiella områden inom cirkulär ekonomi som identifierades i den första delen av studien. Dessa omfattar följande sektorer: bioekonomin, livsmedels- och dryckessektorn, byggsektorn, samt mobilitets-, transport- och logistiksektorn. Vidare identifierades två viktiga drivkrafter för cirkulär omställning: digitaliseringen och nya cirkulära affärsmodeller.

Vår hypotes var att särskilt intressanta möjligheter för cirkulär omställning kan frigöras i kopplingarna mellan traditionella sektorer genom att främja cirkulära mekanismer som skapar ringverkningar både inom och tvärsöver sektorerna. Vårt tillvägagångssätt i denna andra del av studien var därför att presentera ett antal fallstudier och analysera deras potentiella effekter på de valda sektorerna. Fallstudierna belyser olika mekanismer som driver den cirkulära omställningen inom de valda sektorerna och studierna är ämnade att ge inspiration gällande sådana mekanismer som de nordiska länderna kunde främja i syfte att pådriva den cirkulära omställningen i ett hållbart och integrerat Norden.



Följande fallstudier valdes för att belysa olika mekanismer inom cirkulär omställning: 1) slutna kretslopp för träbaserade textiltillfibrer, 2) nya tillämpningar för blå biomassa, 3) prediktivt

underhåll inom jordbruket som stöd för cirkulära livsmedelskedjor, 4) nya affärsmodeller och digitala plattformar för minimering av matsvinn, 5) modeller för ökad (åter)användning av byggnader, 6) digitala plattformar och marknadsplatser för materialflöden, 7) smarta mobilitetslösningar, och 8) cirkulär transportlogistik.

Varje fallstudie omfattar en lägesbeskrivning, identifiering av framtida potential och en bedömning av konsekvenserna för 1) affärsutveckling och tillväxt, 2) klimat och miljö, inklusive biologisk mångfald, och 3) sociala och ekonomiska förhållanden i Norden, inklusive eventuella variationer mellan olika nordiska regioner. Vidare omfattar fallstudierna en beskrivning av de största hindren för att förverkliga potentialen i de cirkulära möjligheterna.

Fallstudierna visar att cirkulära lösningar är efterfrågade inom många områden och kan bidra till att förbättra de industriella processerna genom värdekedjan och hela livsloppet för material och produkter. Det finns ett tydligt behov av att öka värdet som kan utvinnas ur våra knappa resurser och utveckla mer hållbara produktions- och konsumtionsmönster genom att omvandla lineära resursflöden till kretslopp. På ett generellt plan kan den cirkulära ekonomin bidra till affärsutveckling och innovation, minska utsläppen av växthusgaser, bidra positivt till bevarandet av biologisk mångfald och en renare miljö (luft, vatten och mark). Den cirkulära omställningen har varierande socioekonomiska konsekvenser, vilka också varierar mellan olika nordiska regioner. Detta blir viktigt att beakta i en cirkulär, grön och rättvis omställning.

Fallstudierna belyser följande allmänna trender som de viktigaste drivkrafterna för att förverkliga potentialen i den cirkulära omställningen:

- Den allmänna efterfrågan på resurseffektivitet, frikoppling av värdeskapande från resursanvändning, och avfallsförebyggande cirkulära lösningar ökar.
- Marknadens efterfrågan på cirkulära lösningar ökar då priserna på nya råvaror och kostnaderna för avfallshantering ökar, vilket leder till mer affärsdugliga modeller inom cirkulär ekonomi.
- Regleringsåtgärderna inom olika sektorer och industrier främjar den cirkulära omställningen. Ett viktigt exempel är EU:s förbud mot deponering av restavfall från och med 2025.
- Den tekniska utvecklingen skapar nya cirkulära möjligheter och livskraftiga affärsmodeller. Digitaliseringen är en viktig drivkraft i denna utveckling.

Bioekonomin: Bioekonomin valdes som fokusområde för studien eftersom det finns ett stort behov av att utforska möjligheterna för en mer hållbar och cirkulär nordisk bioekonomi som kan förbereda oss för framtiden och säkerställa att de nordiska länderna behålla sina konkurrenspositioner i den cirkulära omställningen. Betydande affärspotential identifierades i möjligheten att expandera och skala cirkulära processer och tekniker, samt utveckla nya materialflöden, affärsmöjligheter och marknader. Å andra sidan identifierades också en risk för konkurrens, överlapp och splittring i utbudet av cirkulära lösningar. Väsentliga klimat- och miljökonsekvenser identifierades i potentialen att minska koldioxidutsläppen, minska behovet av icke förnybara resurser och nya råmaterial, och främja bevarandet och framväxten av kolsänkor. Samtidigt identifierades i en växande cirkulär bioekonomi också risker för förlust av biologisk

mångfald och negativa effekter på ekosystemen. De viktigaste socioekonomiska konsekvenserna identifierades i stärkta regionala innovationsnätverk och en diversifierad sysselsättningsbas. Indirekta konsekvenser för hälsa och välfärd inom nordiska samhällen kunde också identifieras.

Livsmedels- och dryckessektorn valdes som fokusområde för studien främst på grund av behovet att genom cirkulär ekonomi skapa mer hållbara konsumtions- och produktionsmönster i Norden, från primärproduktion till matavfall. Mat- och dryckessektorn visar på goda förutsättningar för cirkulär affärsutveckling och för ny affärsverksamhet genom hela värdekedjan, och många av de identifierade möjligheterna är kopplade bättre användning av data och digitala verktyg. Potential för affärsutveckling identifierades främst i möjliga kostnadsbesparingar genom prediktivt underhåll och välplanerad logistik, nya företagsmöjligheter relaterade till data och digitala lösningar och bättre hantering av logistikkedjor för att minska matsvinnet. Klimat- och miljökonsekvenser identifierades i relation till kvalitet och minskade utsläpp av näringsämnen i luft, vatten och mark, minskad vattenförbrukning och fosforbrytning, samt minskat avfall genom effektivare användning av producerade livsmedel mot slutet av deras livslopp. En effektivare hantering av livsmedelskedjorna kan leda både till ett minskat produktionsbehov och mindre avfall. som tillsammans kan ha betydande positiva konsekvenser för miljöbelastningen från livsmedelsproduktionen. Möjliga socioekonomiska konsekvenser identifierades främst i indirekta effekter på hälsa och välfärd, samt i förändrade sysselsättningsstrukturer och potentiellt bättre tillgång till förmånliga livsmedel.

Byggnadssektorn står för en ansevärd del av den totala materialförbrukningen, energianvändningen och avfallsgenereringen i Norden. Sektorn skapar också betydande ekonomisk aktivitet i de nordiska länderna. En cirkulär omställning av byggnadssektorn intar därför en central plats inom den cirkulära ekonomin. En cirkulär omställning av sektorn kräver att man omprövar hela livscykeln i en byggnad, från att minska behovet av nya råmaterial och öka energi- och resurseffektiviteten (genom god design, materialval, projektledning och logistik) till att optimera byggnaders användningstid (inklusive återanvändning för nya ändamål och delad användning för olika ändamål) och slutligen förbättra hanteringen av byggavfall. En nyckelfråga är att möjliggöra reparation och ombyggnad genom ett cirkulärekonomiskt tänkande redan i planerings- och byggfasen. Affärspotential identifierades särskilt i utvecklandet av cirkulära krav för byggmaterial och design, möjliga kostnadsbesparingar, ökade marknader för materialflöden och nya affärsmodeller och affärstillväxt kopplad till marknadsplatser och logistik. Viktiga klimat- och miljökonsekvenser var kopplade till utsläppsminskningar genom mindre materialproduktion, ökad återanvändning och återvinning, minskat behov av utvinning av nya råmaterial (genom återanvändning), materialsättning och avfallsförebyggande samt minskad avfallsdeponering. Potentiella miljörisker identifierades i hanteringen av farligt avfall. De socioekonomiska konsekvenserna var främst kopplade till utvecklingen av bostäder, arbetstillfällen och affärsverksamhet inom olika områden genom adaptiv (åter)användning av byggnader, kompetensutveckling inom byggsektorn, nya arbetstillfällen relaterade till digitala plattformar samt säkerhets- och hälsoeffekter till följd av smartare användning av byggnader.

Mobilitets-, transport- och logistiksektorn valdes som fokusområde för studien, främst eftersom transport och logistik utgör en förutsättning för hanteringen av resursflöden inom en cirkulär ekonomi. Samtidigt står inrikestransporterna i de nordiska länderna för en betydande

andel av utsläppen och alla länder i regionen har satt upp mål för att minska utsläppen från transporter. Det finns ett tydligt behov av att utveckla effektiva transport- och logistiksystem och innovativa mobilitetstjänster. Det pågående strävandet att minska miljöbelastningen från mobilitets- och transportsektorn innebär att det finns en enorm potential och behov av Mobility-as-a-Service-lösningar (MaaS). MaaS förväntas bidra till ökad FoU-verksamhet inom den tillverkande industrin och därmed skapa nya affärsmöjligheter inom transportsektorn. En ökad affärsvolym för materialtransportsektorn som helhet är en uppenbar förväntad effekt av MaaS, som i sin tur förväntas öka effektiviteten och ekonomin i hela sektorn. MaaS innebär att fokus förflyttas från materiella tillgångar mot informationshantering och kan därmed förväntas öppna nya möjligheter för innovation. Digitaliserade tjänster är skalbara och öppnar för möjligheten att dela med sig av god praxis i hela Norden som kan bidra till ytterligare effektivitet. De viktigaste konsekvenserna för företagsverksamhet ligger i potentialen för ökad effektivitet och skalning, kostnadsbesparingar inom logistik, minskning av outnyttjade/underutnyttjade tillgångar och nya affärsidéer baserade på digitala lösningar och plattformsekonomi. Förväntade klimat- och miljökonsekvenser omfattar minskningar av koldioxidutsläpp och luftföroreningar genom ett minskat behov av resor och genom att flytta transportutbudet bort från fossilbaserade lösningar; minskning av koldioxidutsläppen till följd av effektivare logistikverksamhet; minskad användning av naturresurser för tillverkning av privata fordon och bättre utnyttjande av landområden eftersom effektivare mobilitets och transportsystem kräver mindre utrymme. De socioekonomiska konsekvenserna omfattar ökad efterfrågan och utbud på kvalificerad arbetskraft, eventuella minskningar i den totala sysselsättningen inom sektorn, lägre transportkostnader för enskilda personer, men också ojämlika möjligheter för befolkningen i olika regioner.

I studien identifierades också väsentliga hinder för cirkulär omställning, i fyra kategorier: tekniska hinder, regleringshinder, marknadshinder och kulturella hinder.

Tekniska hinder uppstår främst i samband med nya strukturer i värdekedjorna och nya sätt att samarbeta, särskilt när det gäller de kritiska stegen från pilot- och demonstrationsfas till produktionsfas, när man ska få cirkulära lösningar baserade på ny teknik att fungera i industriell skala. Digitaliseringen är en av de viktigaste drivkrafterna för cirkulär ekonomi, medan de viktigaste utmaningarna i detta avseende är relaterade till sådana faktorer som kontinuerlig brist på harmoniserade datastandarder, otillräcklig kvalitet på tillgänglig data och begränsad tillgång till data.

Regleringshinder kan uppstå på grund av brist på reglering, existerande reglering som förbjuder eller komplicerar användningen av cirkulärekonomiska lösningar, eller motstridig /kontraproduktiv reglering. Regleringshinder verkar på flera nivåer, där särskilt EU-lagstiftningens växande roll har betydande konsekvenser också för utvecklingen inom Norden och utrymmet för politikinverkan från den nordiska samarbetet.

Marknadshinder består i Norden främst av underutvecklade marknader för cirkulär ekonomi, som förhindrar levnadskraftig företagsverksamhet. Orsakerna kan vara bland annat låga marknadsvolymer, att det känns fördelaktigt att fortsätta affärsverksamheten i gamla lineära banor i förhållande till kostnaderna med att införa nya lösningar, eller att nödvändig infrastruktur saknas. Låga priser för nya råmaterial och problem förknippade med avfallshantering förhindrar

också genomslaget för cirkulära lösningar. Eftersom en cirkulär omställning kräver nya modeller för samarbete och omstrukturering av befintliga värdekedjor och -nätverk kan man förvänta sig en tid av viss affärsturbulens och högre risker, liksom också hinder kopplade till moderna industrins bristande beredskap att ändra sina strukturer och affärsmodeller.

De kulturella hindren är främst relaterade till de processer som tillämpas inom affärsverksamhet, avsaknad av praxis och kunskap samt bristande medvetenhet och varierande attityder. Slutanvändare och kunder är också vana vid de lineära processer som ordinärt tillämpas inom företagsverksamheten. Företag kan vara tveksamma till affärspotentialen i cirkulär ekonomi, medan konsumenter kan finna det utmanande att ändra sina egna beteendemönster. Slutanvändarnas attityder och kulturellerelaterade frågor kan också utgöra hinder för acceptering av cirkulära produkter. Vidare kräver många cirkulära lösningar ny kompetens och utveckling av ny know-how samt intensifierat samarbete mellan företag och utbildnings-/forskningsinstitutioner inom olika innovationsekosystem.

Analysen av hinder och möjliga åtgärder för att avlägsna dem kommer att vidareföras i den tredje och sista delen av studien, som genomförs under mars–oktober 2022. Målsättningen är att identifiera vad Norden kan göra för att påskynda den cirkulära omställningen genom att avlägsna hinder och förverkliga potentialen som identifierats inom utvalda områden.

1. Introduction

1.1 Background and objectives

Rising awareness of the limits of natural resources, climate change, and biodiversity loss is leading to heightened calls for more sustainable and responsible allocation, use, and conservation of our valuable resources. In the context of circular economy (CE), this awareness means not only risk and concern but also significant opportunities for the Nordic region.

Circular economy enables us to obtain greater value from our resource use and render our production and consumption more sustainable by transforming linear resource flows into loops. In a CE setting, value is created in three ways, depicted in Figure 1: **closing** resource loops via reuse and recycling of materials, **slowing** resource flows through those loops by designing long-life goods and extending products' service life, and **narrowing** resource flows via resource-efficiency¹.

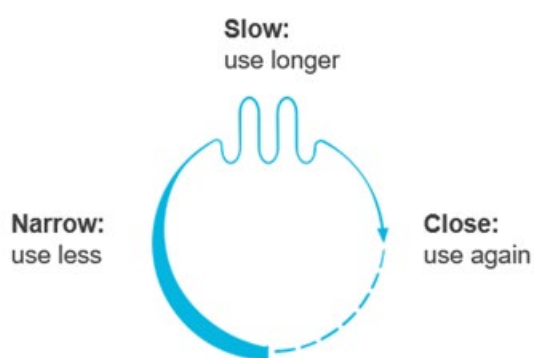


Figure 1. Visualisation of the circular economy. Modified from Konietzko et al. (2020)'s diagram of the initial set of principles for circular ecosystem innovation.

The Nordic region aims to be a forerunner in the transition to circular economy². This transition, which builds on increased utilisation per unit of material, can facilitate less use of virgin resources but also encourage business development and innovation, reductions in greenhouse gas emissions, positive effects on biodiversity, a cleaner environment (air, water, and soil), and numerous other positive outcomes³. The circular transition is, however, a complex systemic change, and reaping positive effects from its potential requires in-depth understanding of the various and sometimes conflicting impacts that different choices can have on the climate and environment, economies, and societies of our Nordic areas. Nordic-level collaboration can aid in understanding this transition, provide opportunities for learning from each other, and support gaining fuller awareness of the broader context of circular economy. With shared understanding comes deeper insight related to the diverse opportunities and barriers related to the transition. This insight can help Nordic policymakers develop incentives that can support the Nordic

¹ Bocken et al. 2016.

² Nordic Council of Ministers 2021.

³ Ellen MacArthur Foundation 2017.

region's transformation into a world-leading force for circular-economy inspiration, in line with the ambitious Nordic vision for 2030.

The objectives for the Low-Carbon Circular Transition in the Nordics study, outlined in Figure 2, are to generate insight on the potential of circular economy in the Nordic region and to provide recommendations for unlocking that potential. This report covers the second part of the study.

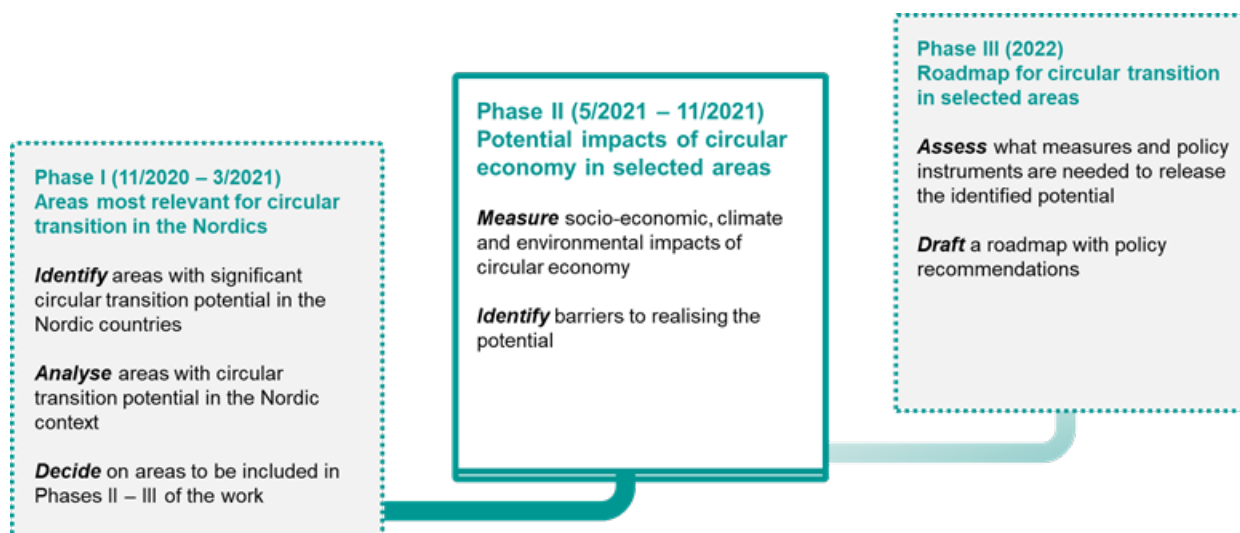


Figure 2. The study is being conducted in three parts. This report covers the findings from its second portion, on potential impacts of circular economy in selected areas.

The portion of the study presented here was carried out for the Nordic Council of Ministers by Gaia Consulting Ltd, PlanMiljø, the Norwegian Institute for Sustainability Research (NORSUS), RISE (Research Institutes of Sweden), and Environice. The research team – and the authors of this report – are Mari Hjelt, Susanna Sepponen, Matleena Moisio, and Jenni Nurmi, for Gaia Consulting Oy; David McKinnon, Bjørn Bauer, Kia Egebæk, and Elvira Borgman, with PlanMiljø; John Baxter and Ole Jørgen Hanssen, of NORSUS; Katherine Whalen and Josefina Sallén, with RISE; and Environice's Stefán Gíslason. The second part of the study, reported upon in this document, was carried out in May 2021 – January 2022.

1.2 Summary and key findings of part I of the study

Conducted in 2020–2021, the first part of the work for Low-Carbon Circular Transition in the Nordics focused on questions⁴ related to which areas of the economy are especially important for the Nordics in the circularity transition and what circularity potential these areas hold. For instance, could the transition lead to changes that give the Nordics competitive advantages or other benefits for our economies, societies, and environment?

In the early stages of the study, the areas to be examined were further scoped to include

⁴ The questions were set out in the Terms of Reference and project description for the study.

- **Sectors and industries** as groups of businesses with a related primary activity and usually grouped into the same category or sub-category in statistical industry classifications (such as 'Manufacturing industries' with the sub-group 'Manufacturing of food products');
- **Material flows** as specific loops of material use that are crucial in the context of circular economy (such as packages or plastics); and
- **Enablers or transition-drivers** that can support achieving circular economy in various industries/sectors (such as digitalisation).

The first part of the study consisted of a mapping of areas with potential in the circular transition, identified on the basis of the most relevant analyses and reports available.

The mapping in part I of the study was performed by means of a systematic approach including

- 1) A review of relevant national strategies, roadmaps, and other literature on circular-economy commitments. Most of the Nordic countries have developed national strategies, roadmaps, and programmes for promoting transition to circularity or are in the process of doing so. Several common strategic interests of the Nordic countries were identified on the basis of the national priorities expressed in these documents.
- 2) Analysis of the areas and themes identified in the national documents, conducted in aims of assessing which areas hold the greatest circularity potential in each country's efforts. This potential was identified via national statistics on turnover, employment, CO₂ emissions, and waste amounts in each of the countries, in combination with qualitative data on resource use, where available.
- 3) A synthesis of similarities and differences in CE priorities across the individual countries and preliminary analysis of the expected contributions of specific areas to the Nordic region. This analysis used the following criteria, judged via the documentation available: 1) circularity potential; 2) potential environmental impact; 3) potential socio-economic impact; 4) potential Nordic synergies, such as co-operation or learning opportunities; and 5) potential for implementing effective measures at Nordic level.
- 4) A validating series of workshops in Denmark, Finland, Iceland, Norway, and Sweden, supplemented with interviews of stakeholders in the Faroe Islands, Greenland, and Åland. The aim was to inform key stakeholders about the project, involve them in the process, and foster buy-in that supports the results' usability. The workshop participants discussed the preliminary findings and conclusions from the national desk-study work, and input was gathered for the Nordic-region-level analysis, to inform policy-recommendation efforts.
- 5) Final selection of circular-economy areas for in-depth study in part II of the work and approval of the selection, by the steering group.

Part I of the study resulted in the selection of four value-chain-based industrial areas, coupled with two enablers/drivers of change that were assessed to hold **great potential in the circularity transition** (Figure 3 presents the space thus delimited).

The areas selected and the motivation for their choice are summarised below.

The bioeconomy was chosen because the Nordic countries are rich in bio-based resources and skilled in their management and use. Climate change, resource scarcity, and biodiversity together have drawn international attention to the need for more efficient and sustainable use of bio-based materials, and the Nordic countries are change-makers at the forefront of innovation in this regard.

The food and beverage industry includes key resource flows in the Nordic countries that generate significant amounts of waste along the value chain from primary producers to final consumers. The

sustainable use of natural resources and the development of sustainable production and consumption patterns in the Nordic region require systemic change in food value chains.

The real estate and construction industry accounts for a large proportion of materials' consumption, energy use, and waste generation⁵, as well as economic activity. Transforming the sector is a central component in creating economically and environmentally sustainable societies. In addition, the Nordic countries are home to advanced construction know-how and to related markets that transcend national boundaries and encompass significant export activities.

Transport, logistics, and mobility was chosen since transport and logistics operations constitute a prerequisite for circular economy, enabling, for example, reverse resource flows. At the same time, domestic transport in the Nordic countries accounts for a significant share of CO₂ emissions⁶ and all countries in the region have set targets for reducing their emissions from transport. A clear need exists to lower emissions, develop efficient transport systems and logistics, and support innovative transport services.

The findings from part I of the study indicate, furthermore, that the circular transition in these and other areas of the economy is heavily dependent on two significant transition-drivers or enablers of change: digitalisation and the development of new circular business models.

For our purposes, **digitalisation** is a constellation of practices that support circular activities by enabling better use of data and digital tools. These include a wide range of new practices, such as digital product-tracing, predictive maintenance and optimisation of side and waste streams (including their flows), and sharing-economy platforms, to mention only a few. Among the relevant digital technologies are the Internet of Things (or IoT), artificial intelligence (machine learning etc.), and blockchain technology.

New circular business models refer to new ways of providing products and services – techniques that maintain value longer and facilitate better end-of-life management. Opportunities for new business models can be found in, for example, servitisation, sharing, looping, and changing the ownership models for materials, products, and services.

⁵ The waste generation was found to be especially high in part I of the study, when placed in relation to the other bioeconomy sectors selected and to the food and beverage industry.

⁶ See the part I figures for CO₂-equivalent tonnes from mobility, transport, and logistics, in relation to the other areas of bioeconomy selected for study, the food and beverage industry, and the construction and real-estate industry.

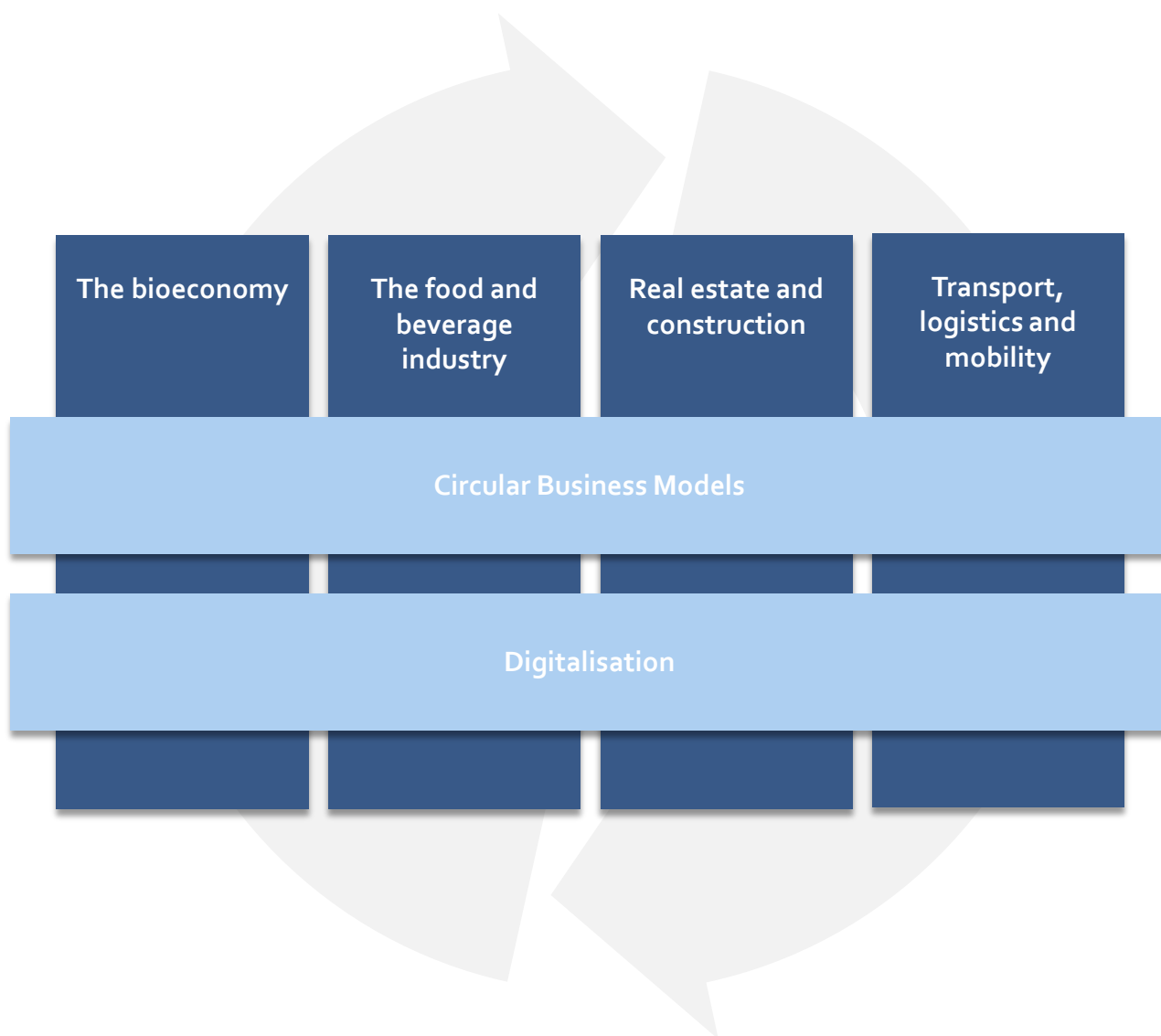


Figure 3. Circular-economy areas identified in part I of the project (source: Gaia Consulting 2021).

Together, the four value-chain-based areas of industry chosen account for considerable material flows in the Nordic region. They heavily affect land use and the extraction of natural resources, the climate, and the countries' environmental footprint throughout the life span of the materials and products involved. All of them play a prominent role in the economies of the Nordic countries⁷.

The national priorities for accelerating the circular transition call attention to several cross-cutting enablers of CE transformation. Digitalisation and new business models were added to the scope of this study because of their striking role in provision of tools for transformative ways of developing the economy. Circular economy evolves within a variety of ecosystems, value chains, and networks wherein materials and value flow through various actors and across traditional industry boundaries. The use of data and

⁷ According to the report from part I of the study, these areas of economy represent nearly half of the total turnover in the countries in question, when one includes the manufacturing industries partly encompassed by these value chains.

digital tools and platforms, coupled with new service and business models, brings completely new possibilities within the value chains, such as⁸

- Circular supply models that replace virgin materials with bio-based, renewable, or recovered materials;
- Resource-recovery models for recycling waste into secondary raw materials;
- Product-life-extension models that slow the flow of materials through the economy and reduce the rate of new resources' extraction and of waste generation;
- Sharing-based models for underutilised products, whereby there is less need for new products; and
- Product–service system models, for selling services rather than items.

The part I work found that, notwithstanding a few differences in industry structure and operations in the areas selected for attention, the countries' economies and societies display sufficient similarity to enable reasonable joint analysis of impacts and barriers, as well as identification of useful opportunities for joint policy development and collaboration.

⁸ OECD 2019.

2. Framework and methodology

2.1 The aim and scope of the study

This second part of the Low-Carbon Circular Transition in the Nordics study focused on **identifying, describing, and assessing impacts of circular transition, alongside barriers to development**. Of continued interest was the question of what competitive advantages and innovation potential the transition to circular economy may bring in the key areas chosen for attention in part I. Among the other questions considered in this research are what the circular transition means for the use of resources in the Nordic region, how the use of resources could be rendered more efficient through industrial co-operation (e.g., via alternative service models or through industry symbiosis), and what impacts there might be on the availability of biomass for various relevant purposes.

The circular transition is expected to have positive impacts on the region's climate and environment. However, it was recognised that such impacts can be complex and partly conflicting. They may be positive or negative, short- or long-term, temporary or permanent. The same solutions can bring positive impacts in one area and negative ones in another. In this study, specific attention was directed to the impacts on climate emissions in key sectors, on both biodiversity and the status of the oceans, waters, soil, and air.

The circular transition is expected to have significant impacts also on the region's constituent economies and societies. On one hand, the transition is expected to generate new jobs and business models. On the other hand, the researchers are aware that the transition will affect different regions in different ways, and that changes in industrial and employment structures can have positive and negative implications, for the short and long term, with temporary or permanent impacts for economies and people in several regions. For this study, it was seen as important to look into challenges specific to the Nordic region in relation to such features as vast geographic areas with low population density, the areas' long distances, varying geography, and socio-economic structure. Some elaboration on regional variations in socio-economic impacts was undertaken in the earlier parts of the work, and these will be expanded upon still further in the final part of the study (to be conducted before the end of 2022).

In addition to the analysis of impacts within selected areas of CE transition, this study identified barriers to the transition. There may be hurdles of a technological, economic, or regulatory nature, while other impediments are connected with factors such as knowledge, attitudes, or the surrounding environment. In the forthcoming part III of the project, the barriers identified will be analysed further in relation to possible actions and the policy instruments conceptualised as the work develops.

The transition to circular economy involves activities on several levels, from national and cross-border operations to regional and local ecosystems. The Nordic industries are tightly bound up with global value chains, and business activities here are not restricted by national borders. While the work's scope was delimited to the Nordic region, the broader framework of international systems, especially EU-level regulation and the EU circular economy action plan, needs to be considered. This said, it was also of specific interest to identify specific conditions of the Nordic region that can help the countries escalate the transition and engage in pioneering international CE development.

2.2 The approach and methods

2.2.1 *The selection of topics for in-depth analysis*

This portion of the study proceeded from the four areas of industry and two change-drivers identified in part I of the work (presented in Figure 3, above). Our hypothesis was that potential with specific relevance for circular transition can be found at the nexus of these areas, in releasing circular mechanisms that could be expected to have broader impacts within and across the sectors. We therefore chose an approach of building strong cases that illustrate these mechanisms and their potential impacts on the fields of industry identified in part I, to form a basis for further study. The purpose for examining these cases was to afford interesting and valuable insight highlighting the dynamism of the CE transition in the Nordics, by pointing to various sorts of mechanisms for realising the transformation. The topics at the core of the cases, which we denote as CE opportunities, were selected from among the interesting examples identified in the part I report.

The **circular-economy opportunities** chosen showcase a wide range of mechanisms that drive the circularity transition within important areas of the economy and industrial activities. The opportunities were chosen so as to represent different branches of industry, different stages in circular loops' development, and different levels of activity. They differ in scope, content, and maturity. This methodological choice was aimed at emphasising the diversity and complexity of the transformation while simultaneously supplying very concrete examples of drivers of change that can release the potential for economic transformation and renewal across a broad industrial landscape.

The opportunities should not be compared or accorded any particular order of importance. Neither can they be summed up to describe the circular economy as a whole.

The case studies are meant to serve as inspiration with regard to mechanisms that the Nordic countries can support for unlocking the potential of circular transition in a sustainable and well-integrated Nordic region.

The project team agreed early on that the CE opportunities selected for analysis need to be sufficiently focused to enable in-depth description. At the same time, they must be sufficiently relevant and significant as examples of how to unleash the potential amid strivings toward circular transition. These issues were discussed with the steering group, and a set of criteria was created to facilitate choosing the most suitable CE opportunities for the case studies. This is presented in Table 1, below.

Table 1: The criteria for selecting the focal circular-economy opportunities

Criterion	Description and operationalisation
Relevance for the Nordic region	The areas identified in part I were selected for their relevance for all the Nordic countries. In the selection of opportunities, the project team performed a preliminary qualitative assessment of the topics in terms of 1) high relevance for several countries (in light of national priorities), 2) their significant role in Nordic national or regional economies and/or 3) their role in dealing with challenges that are significant for many Nordic areas, and 4) strategic relevance in terms of scalability of models or transferability and potential application in other sectors or contexts.
Significance in the circularity transition	In the selection of opportunities, the project team carried out a preliminary qualitative assessment of the potential contribution of the CE opportunity to slowing, narrowing, and/or closing resource loops . Specific emphasis was put on novel, innovative, and scalable solutions for the future. Strategic relevance (explained above) in terms of scalability or transferability was considered another sign of significance. The aim was to showcase concrete examples that bear more general significance for the circularity transition, by describing impact pathways arising from various circularity mechanisms.
Nordic collaboration potential	The Nordic countries are small economies, requiring co-operation for advancing circular practices. One of the main aims behind the study as a whole is to develop insight as to collaboration opportunities and policy recommendations. In the selection of opportunities, the project team conducted a preliminary qualitative assessment of Nordic collaboration potential with regard to potential synergies of clusters/competencies that are prerequisites for collaboration. The goal was to identify similar examples in several Nordic countries (volume potential) or opportunities to learn across areas and countries (comparative and complementary potential).
Climate and environmental impacts for the Nordic region	It is crucial to support a circular green transition that reduces the climate and environmental footprint of the economy. The Nordic countries will need actions that aid in decoupling economic activities and resource use, thus decreasing the burden on the environment and the climate. In the selection of opportunities, the project team carried out a preliminary qualitative assessment of the potential each opportunity represents for reducing the need to extract natural resources, preserving biodiversity, and reducing emissions and waste.
Socio-economic impacts for the Nordic region	The aim of a green, competitive, and sustainable Nordic region implies that the socio-economic impacts of the circularity transition need to be kept in mind. A just transition needs to consider how various regions within the Nordics are affected by the transformation of industries. In the selection of opportunities, the project team carried out a preliminary qualitative assessment of the expected positive impacts on national and regional development in employment, alongside the societal impacts on such factors as health, welfare, and education.
Business potential for the Nordic region	A competitive Nordic circular economy demands transformation that boosts business development and growth. In our selection of opportunities, the project team, therefore, included preliminary qualitative assessment of the potential of each CE opportunity to increase 1) the expected volume of business development and growth over a relatively short time horizon and 2) innovativeness and the possibility of creating new circular business models or better use of data and digitalisation.

By following these criteria through a systematic process, the project team chose eight distinct kinds of CE opportunities:

1. Closed-loop wood-based textile solutions
2. New applications for ocean biomass
3. Predictive management supporting circular food-chain solutions
4. New business models and digital platforms for the minimisation of food loss
5. Models for increased (re)utilisation of buildings
6. Digital platforms supporting circular economy
7. Smart mobility solutions
8. Circular transport logistics

Figure 4 presents the positioning of the selected CE opportunities with regard to the main branches of industry and the cross-cutting themes of digitalisation and new business models. The precise scope of each CE opportunity case study is described in Chapter 3.

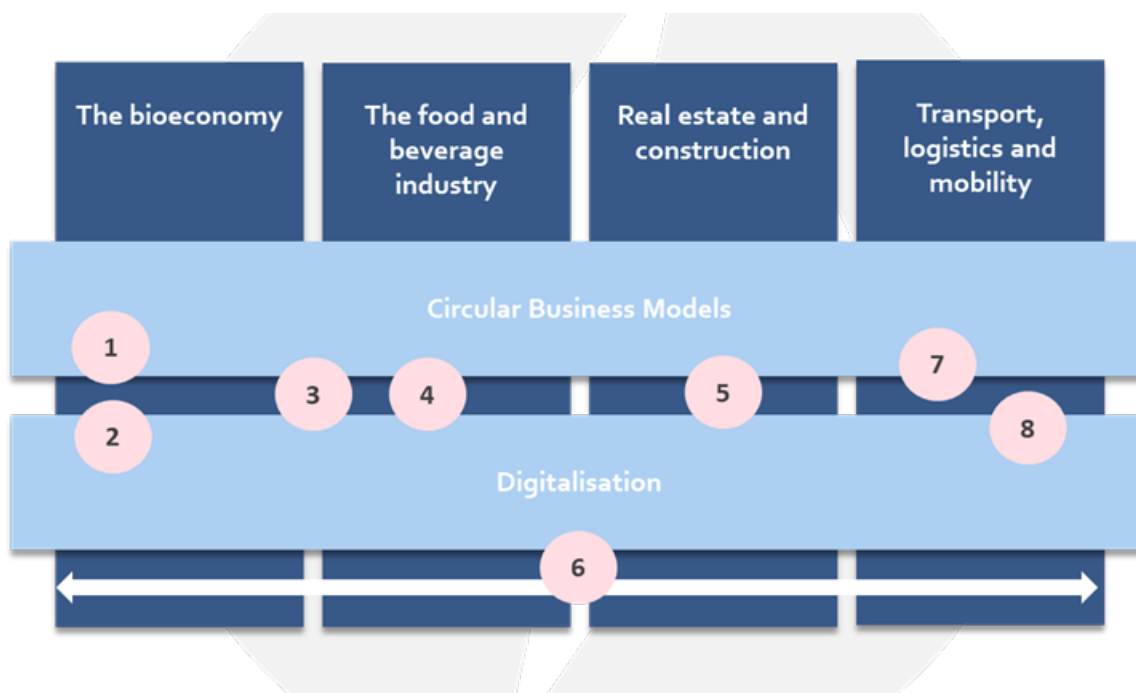


Figure 4. The circularity opportunities identified in areas of special significance for Nordic CE transition: 1) closed-loop wood-based textile solutions, 2) new applications for ocean biomass, 3) predictive management supporting circular food-chain solutions, 4) new business models and digital platforms for the minimisation of food loss, 5) models for increased (re)utilisation of buildings, 6) digital platforms supporting circular economy, 7) smart mobility solutions, and 8) circular transport logistics.

2.2.2 *Assessment of impacts*

Assessing the impacts of circular transition is a challenging task that requires understanding of industry-sector details, impact-category-specific models (e.g., models addressing climate impacts, business impacts, and environmental impacts), and clear scoping of the systems to be analysed in detail (e.g., global systems, regional ones, levels of specific industry value chains, and appropriate time horizons). Research and analysis efforts in this field are moving ahead rapidly, thus yielding new understanding constantly. An example is the research related to the role of CE in halting biodiversity loss⁹.

Since the scope of this study extended to several key categories of impact, multiple areas of focus for examination of CE, and the Nordic region, it was early in the process delimited by these system boundaries that the researchers acknowledged the need for the impact assessment to be based primarily on prior literature and qualitative assessment of existing data, instead of modelling of actual quantitative impacts.

The descriptions of the impact pathways for the CE opportunities selected are based on their role in narrowing, slowing, or closing resource loops (see the introductory chapter). From the standpoint of material use, the paths can be characterised thus: Direct impacts of narrowing loops through resource-efficiency can be estimated in light of such factors as the volume of natural resources going into the processes and the material costs. Likewise, direct impacts of closing the loops via recirculation can be calculated in relation to the volume of waste, the material quantities entering reuse or recirculation, etc. Slowing the loops by means of longer-term value creation in the 'inner loops' increases the value created per unit of material (including value produced in new business growth) and indirectly affects both the virgin-material needs at the beginning of the cycle and the end-of-life waste generation. Most of the circular solutions include quite complex processes, with which new operation models transform the whole value chain, so the impact-assessment models should cover many distinct factors. Also, when it comes to the longer-term climate and environmental impacts, in combination with the socio-economic impacts of industrial transformation, an in-depth impact assessment would necessitate quite complex modelling of multiple branches of industry and several geographic regions.

For this study, impacts were divided into the rough categories of

- 1) business impacts (such as innovation and new business development);
- 2) climate and environmental impacts (such as CO₂ reductions; resource savings; and changes in the quality of oceans, other bodies of water, soil, and air); and
- 3) socio-economic impacts (such as total growth in business or economic volume, employment, development of residential areas, health and welfare, and education).

In light of the data available, the researchers assessed the impacts qualitatively with regard to their direction (positive/negative), pathway (direct/indirect), volume (high/medium/low), significance (high/medium/low), and duration (short-term/long-term/permanent).

⁹ One example is a study in which Finnish Innovation Fund Sitra and Vivid Economics are involved, titled 'Circular Economy Solutions for Halting Biodiversity Loss'. The full results from that project, which is among the first of its kind, are due to be released in early 2022.

2.2.3 *Identification of barriers to circular transition*

The potential for circular transition is affected by barriers on many levels. We use the term to refer to circumstances that counteract the transition impetus and should be regarded as possible targets for change. The Nordic countries operate within the European regulatory framework, which creates important prerequisites of its own for the circular economy. At the same time, there exist various cross-border barriers between the countries in relation to regulation, market entry, and a host of operations/cultural factors. Better sharing of information and best practice can help us overcome or minimise the impacts of at least some of these barriers.

Therefore, the study effort focused also on identifying some of the main barriers to CE transition, which will be further analysed in part III of the project, together with actions and policies aimed at accelerating the transition.

For purposes of the study, barriers to circular economy were categorised into

- **regulatory barriers**, which encompass both lack of laws/regulations and hindrance-creating ones, along with conflicts of regulatory instruments between sectors or countries;
- **market barriers**, such as high investment costs and low raw-material prices;
- **technology barriers**, among them lack of such elements as data, demonstration projects, and circular design; and
- **cultural barriers**, such as rigid linear value chains, problematic company culture, and low consumer awareness.

Throughout the study, we have recognised boundaries imposed by climate and environmental targets also, since the circular transition must be implemented such that it enables meeting the targets. These were not, however, treated as barriers to transition as such.

2.3 How the work was conducted

The work conducted for this part of the study was structured in phases. These are depicted in Figure 5. Then, the discussion presents the implementation of this work in more detail.

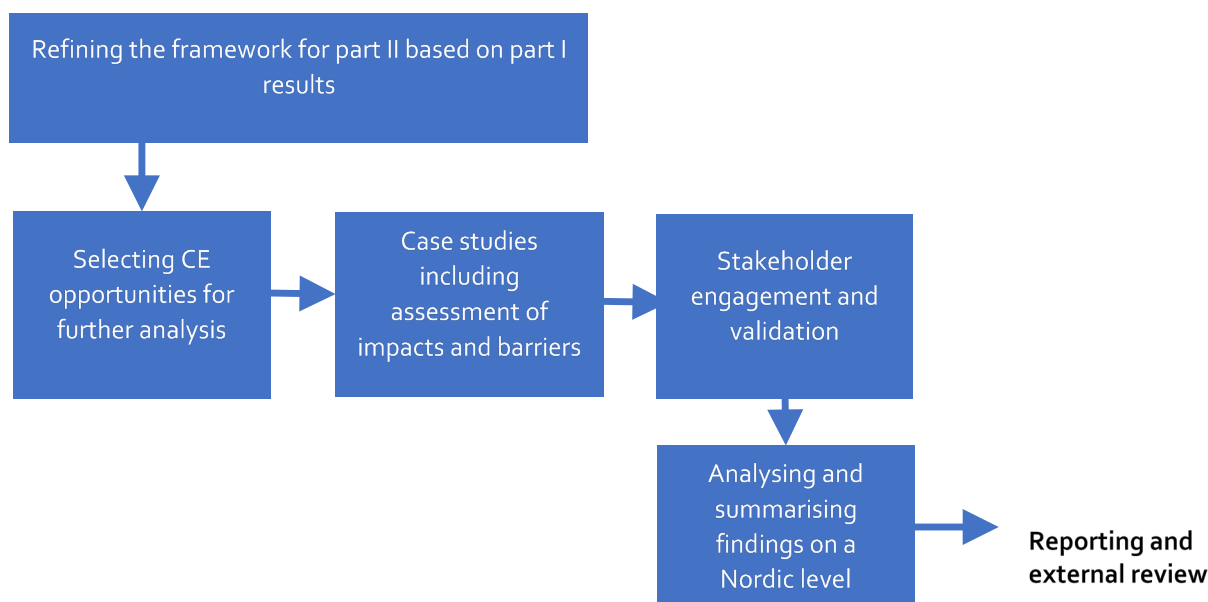


Figure 5. The structure of the work done for this portion of the study, including 1) refinement of the framework for part II on the basis of part I's results; 2) selection of specific CE opportunities for further analysis; 3) case studies (comprising assessment of impacts and barriers); 4) stakeholder engagement and validation; 5) analysis and summarisation of findings on Nordic level; and 6) reporting and external review.

Element 1: Refining the framework for part II in line with part I's results

The first step in carrying out the work included scoping of the endeavour, as presented in the previous section, and longlisting of potential CE opportunities upon compilation of the examples from the part I report.

Element 2: Selecting specific CE opportunities for further analysis

The project team designed a stepwise approach, with work sessions conducted via an online platform, to refine the criteria and select suitable opportunities to be analysed.

Firstly, the longlist of potential circular opportunities¹⁰ was compiled from part I's final report and qualitatively evaluated 1) against the criteria formed in the part I work for choosing the areas (see Section 1.2) and 2) on the basis of assessment of how well the selection covers the branches of industry and the transition-drivers chosen. The analysis yielded a preliminary set of 11 CE opportunities¹¹.

The final selection and scoping were completed through a series of three joint work sessions, in which 1) the set of criteria for the final selection of cases was refined and the CE opportunities were assessed accordingly, 2) the revised 11 CE opportunities were discussed and rated (for low/medium/high impact) against the criteria developed, and 3) the eight highest-rated opportunities were chosen and their scope refined. The team decided to choose cases that differ in scope and in their level of impact, to bring

¹⁰ See Annex 2.

¹¹ These are 1) wood-based textile fibres, with focus on supply chains' optimisation; 2) new value chains for ocean biomass; 3) digital marketplaces for side streams promoting new uses; 4) precision agriculture and aquaculture for a sustainable food-supply chain; 5) new business models and digital platforms for the minimisation of food loss and other waste; 6) buildings' information-management systems and digital product passports; 7) sharing of business models, for an increased rate of utilisation of those assets used; 8) IoT solutions and predictive maintenance; 9) mobility as a service, with passenger-transport focus; 10) logistics as a service; and 11) reverse logistics with focus on recovery and reuse of materials from vehicles.

understanding of the various paths and tools for executing the circularity transition. Then, the selection was presented to the steering committee.

Element 3: Conducting case studies, including impact and barrier assessment

The case studies relied on the expertise of the project team, desk-study work, and complementary interviews where relevant. In the desk study, the team utilised the material reviewed in part I, relevant recent studies and reports, and statistics provided by the national statistics bureaux. All case studies encompassed 1) description of scope and the case's significance for the circular transition; 2) the current state of the opportunities in the Nordics; 3) future potential, with special attention to key trends in circular development; 4) general impacts of the opportunities with regard to business, socio-economic development, the climate, and environmental factors; 5) and the main barriers to scaling of the opportunities, with focus on regulatory, technological, market, and cultural hurdles, alongside tentative ideas for how to eliminate the barriers, as a foundation for part III of the study (the stage to be carried out in 2022).

Element 4: Examining stakeholder engagement and validating the results

A workshop was held online for discussing the impacts and barriers and for validating the results of part II. The target group consisted of key stakeholders from each country and in Nordic co-operation. The aim was to inform key stakeholders about the project, to involve them in the process, and to foster buy-in that supports the results' usability. The workshop participants discussed the preliminary findings and conclusions from part II, and input was gathered for the conclusions. Annex 1 presents the programme and the participants.

Element 5: Analysing and summarising the findings on Nordic scale

The lessons learnt from the case studies were summed up at Nordic level, and the team analysed the key implications within the selected areas of study. This portion of the study serves as the starting point for part III, in which barriers and, addressing these, enabling actions and policy instruments will be further assessed and developed.

Element 6: Reporting and external review

The findings were summed up in this final report of part II and subjected to external review. Meetings were held with the steering group throughout the project work. The most important of these were held in May 2021 (for kick-off), August 2021 (related to the selection of cases), November 2021 (for discussing the tentative results), and February 2022 (on the final report).

3. The CE opportunities selected

3.1 Closed-loop wood-based textile solutions

3.1.1 *Introduction*

Man-made cellulosic fibres (MMCF), fibres made from wood or other sources of cellulose, account for the third largest share in global fibre production after polyester and cotton¹². Wood-based textiles can be characterised as a type of MMCF that traditionally covers viscose, modal, lyocell, acetate, triacetate, and cupro. The feedstock for MMCF materials includes rapidly growing regenerative virgin wood such as eucalyptus, beech, and pine; plant matter (e.g., bamboo); reclaimed material, with components from agricultural waste and by-products (e.g., straw) and from pre- and post-consumer waste (cotton); and other feedstock, such as flax. The cellulosic matter of these plants or reclaimed material is processed into a pulp, dissolved, and then regenerated into a staple or filament yarn through several chemical processes.

The focus of the case study¹³ in this domain is on wood-based textiles, but, since other closed-loop solutions for textile fibres play a significant role in the value chain, these should be seen as parts of the broader context. Global textile-fibre production has doubled in the last 20 years, reaching an all-time annual high of 111 million metric tons in 2019, and pre-COVID-19 results point to potential growth to 146 million metric tons by 2030. Prior to the pandemic, MMCF volumes were projected to increase rapidly over the next 15 years, possibly reaching 10 million tons per year. By some estimates, MMCF production is going to show an even higher compound annual growth rate than cotton fibres.¹⁴

While statistics specific to the Nordic region were not available for this study, the global numbers articulate the importance of the textile-fibre market and wood-based textile solutions for the Nordics well. For example, in Finland, a renewed textile industry would entail an estimated billion euros in investments and nearly 17,000 new jobs by 2035¹⁵.

Textile fibres are commonly produced in developing economies with lower labour costs. The opportunities arising for the Nordics lie mainly in novel technological solutions for sustainable MMCF production in Sweden, Norway, and Finland¹⁶. With their long history of bioeconomy solutions, this makes wood-based-textile and circular-bioeconomy solutions particularly interesting opportunities for the Nordic countries.

3.1.2 *The current state of Nordic CE*

The Nordic countries are rich in bio-based resources and skilled in their management and use. Discussion of climate change, resource scarcity, and biodiversity has drawn international attention to bio-based materials, and the Nordic countries are change-makers and at the forefront of innovation in this regard.

¹² Hugill et al. 2020.

¹³ The case study was carried out under the leadership of RISE.

¹⁴ According to textile-exchange figures for 2021.

¹⁵ Kamppuri et al. 2021.

¹⁶ Hugill et al. 2020.

The Nordics are leaders in the production of dissolved pulp, from which MMCF is made: Three Nordic mills export pulp that can be turned into textile fibre, and most of the dissolved pulp produced is exported¹⁷.

Nearly all of the Nordic governments have goals or programmes aimed at strengthening the national bioeconomy, with an example being Sweden's objective to replace fossil raw material with renewable and bio-based raw materials. Furthermore, biomass is one of the key areas of focus in the current Danish circular-economy action plan. The aim is to better exploit Danish biomass through investigating emerging technologies that can be used for new bio-based products. For several of the Nordic countries, at least Iceland, Denmark, and Sweden, recent years' employment growth attributable to bioeconomy opportunities has been estimated at 5–15%¹⁸.

Use of existing textiles or agricultural by-products in the production of MMCF through recycling is expected to bring significant opportunities for a more circular and sustainable future. It should contribute to more efficient resource use and to decreased waste by reducing the quantities of waste already generated and reducing the need for virgin materials. High-value recycling of wood-based textiles is critical for their long-term sustainability. The latter is currently a pressing problem: such recycling methods are not available at scale in the Nordics at present¹⁹. That said, several interesting pilot projects and industrial production investments are in progress in the Nordics that deal with new and more eco-friendly textile fibres, as well as recycled textile fibres.

Moreover, textiles are a priority area for quite a few of the Nordic countries, among them Finland, Åland, Sweden, and Denmark. Existing strategies emphasise textile-recycling solutions, new business models for increased utilisation of the textiles produced, and use of renewable materials such as wood. For example, in Finland, about a fifth of used textile materials reaches dedicated collection, and the majority of used textiles (80%) gets burned for energy, with only 1.5% of clothes getting recycled. In Denmark, meanwhile, textiles generate 0.016 million tonnes of CO₂ emissions (eq.) and 6944 tonnes of waste²⁰.

Exploring local and regional solutions for the Nordic bioeconomy, possible material flows, innovation, and new circular business models could replace some of the virgin cotton with fibres from the well-maintained Nordic forests and locally circulating textile-waste fibres even though the value chain of the textile industry is going to remain international. This addition to the picture would considerably benefit closed-loop transition for the textile industry.

Potential for digital tools

As a responsible and knowledge-based textile industry emerges, it enables individualised solutions aligned with the digital age. Digital solutions that provide information about post-industry flows and post-consumer textiles hold great potential for increasing the amount of textiles waste that can be used in the production of MMCF, as such tools can help provide more knowledge about the textiles and their fibre contents. Automated sorting and identification of textile materials is currently being studied and developed in Finland.

¹⁷ Hurmekoski et al. 2018.

¹⁸ Refsgaard et al. 2021.

¹⁹ Hugill et al. 2020.

²⁰ Luoma et al. 2021. The figures are based on data for the national priority areas identified for Denmark, Finland, Iceland, Norway, and Sweden, not on totals for entire sectors.

Digital solutions such as digital platforms for material exchange may extend the value chain beyond the country's borders. This is a promising avenue since it is not possible to achieve a significant textile-recycling system within national borders.

Moreover, digital solutions to trace the origin of the MMCF feedstock will improve transparency along the value chain. Especially for speaking to concerns about water use, deforestation, and land exploitation, solutions that promote full-value-chain traceability and transparency are needed.

Ensuring full recyclability of wood-based textile-fibre solutions requires complex product modelling and supportive artificial intelligence.

Although Nordic examples are not available yet, the blockchain-based GREENTRACK™ traceability platform, from one of the largest MMCF producers in the world (Birla), is an international example of digital tools of this sort.

Potential for new business models

Wood-based closed-loop MMCF solutions show great potential for new business opportunities. It has been estimated that global fibre consumption will grow to 150–155 million tonnes by 2030. The Finnish company Spinnova expects the shortage of natural fibres to become a business opportunity worth €45–60B by 2030. In some assessments, if the development of new sustainable cellulosic fibres is successful, the MMCF-use growth rate would even exceed these forecasts. Nordic pulp-makers are currently developing novel ways of cleanly turning, for example, birch and pine trees into MMCF with a smaller environmental footprint than traditional MMCF fabrics'.

New business models will be needed especially to commercialise and scale up MMCF production technologies. For example, leasing of materials and comprehensive tracking systems that cover materials throughout the ecosystem and their life cycle would enable closing loops.

Currently, several initiatives and commercial solutions in the Nordics exist that are centred on wood-based textiles. As forestry is of specific significance in Sweden and in Finland, most of the relevant activities are taking place in these two countries.

Commercial examples

Infinite Fiber Company (IFC) is a Finnish firm that has created a technology to turn textile and agricultural waste, along with cardboard, into new fibres. The process does not use harmful chemicals, so it is a safer alternative to several conventional MMCF processes. Also in Finland, the above-mentioned Spinnova turns paper-based cellulosic raw materials into fibre without employing any chemical processes.

Södra, the Swedish forest-owners' association, has created a process for industrial-scale recycling of textile waste that results in an MMCF called 'OnceMore'. The process currently uses pulp created from 20% recycled polycotton blended textiles and 80% wood. Södra is working to increase the recycled content to 50%.

In other developments, TreeToTextile, owned by H&M Group, Inter IKEA Group, Stora Enso, and LSCS Invest, offers a newly developed technology that produces bio-based textile fibres with a small environmental footprint at an attractive cost level. A demonstration plant for bio-based textile fibres is under construction in Sweden.

Finally, Renewcell will begin operating a full-scale waste-textile recycling plant in Sweden in 2022. Renewcell's process converts natural waste-textile fibres into a dissolved pulp to produce new fibres.

Initiatives to catalyse CE

The Bio and Circular Finland Program is an innovation programme aimed at providing solutions to recycle textiles and at creating bio-based textile fibres that render the textile industry more sustainable.

Another initiative is the Full Circle Textiles Project, an MMCF-focused project led by the global initiative Fashion for Good that brings together multiple stakeholders from the MMCF value chain, including Nordic companies, to help scale chemical-based recycling technology.

3.1.3 Future perspectives and impacts

Future perspectives

A shift of the global textile value chain from a linear to a circular model over the coming decades is foreseen, with drivers consisting of new regulations, a desire for resource-efficiency, cost concerns, and consumer demands. Disruptive innovation replacing the use of virgin-wood feedstock in MMCF by means of, for example, existing textiles or agricultural by-products' use in MMCF production through recycling is an area that is expected to bring significant opportunities for a more circular and sustainable future. Promising innovation in chemical recycling of textiles is emerging and is growing in significance. Still, wood-based MMCF needs to be produced at a responsible and regenerative rate, as it could otherwise contribute to deforestation and biodiversity loss. Organisation-based initiatives such as Canopy's Next Generation Action Plan have created roadmaps to tackle deforestation and create plans for sustainable use of MMCF. Additionally, the need for virgin-wood-fibre-based MMCF could be minimised over time by means of feedstock from existing waste streams. For example, producing a tonne of MMCF requires only a tonne of cotton waste, as compared to 2.5–3 tonnes of traditional wood input.²¹

Impacts of closed-loop MMCF

Business impacts

Expansion and scaling up of existing MMCF activities and technologies is expected to bring new business opportunities, which, in turn, should have both immediate and long-term positive impacts. Fast growth in the demand for cellulosic textile fibres will catalyse the development of new technologies for producing textile fibres from wood, and it is expected to propel growth in R&D operations too. Development of new material streams can simultaneously bring new business to companies utilising side streams in MMCF solutions. However, significant financial investment is still needed before closing the loop becomes reality for such textiles and materials. Moreover, if demand for wood-based textile pulps rises significantly, one would expect competition to develop between pulp production for textiles and pulp supply for creating

²¹ Canopy 2020.

paper and panels. A recent study²² anticipated increased prices for wood fibres, which could lead to (direct and indirect) negative impacts on businesses along the value chain, in multiple sectors.

Global wood prices are increasing in response to heightened demand for wood for most forest products, with wood-based textile fibres being no exception. Pulp producers' market input is the stuff of competition between textile uses of feedstock pulpwood and chips, on one hand, and industries producing paper and paperboard, particle board, and other panel products on the other. This competition over pulpwood and chips is favourable for the solid-wood industries producing chips and sawdust as by-products: wood-based textile solutions enable higher-value use of the side streams, which in the long term has positive effects both for business development and for the climate and natural environment.

An increase in the use of long-life solid-wood products to replace more carbon-intensive materials has been found desirable in the climate-change mitigation context, on account of the carbon storage and substitution benefits. Because wood-based textiles could play a role in economic transition toward a sustainable circular bioeconomy, there are synergies to be gained by promoting the two product groups, insofar as their production levels remain sustainable with respect to forest-land use. If these synergies can be fully exploited, one would expect a significant impact on businesses.

Additionally, a need has been forecast for new greenfield wood-based textile-pulp mills or further conversion of paper pulp mills into textile-pulp mills down the line as the need for paper-pulp mills declines. This transition may have significant direct and indirect long-term impacts on Nordic bioeconomy businesses.

Climate and environmental impacts

The climate impacts of MMCF depend significantly on how they are produced. Issues to be considered include where the wood feedstock is obtained from, whether renewable energy is used in the fibre and pulp production, and the types of chemicals used (and how they were produced). These factors determine whether MMCF ranks among the fibres with the worst climate impacts or, instead, the best.²³ For example, studies have put the climate impacts of MMCF at between -2 and 13 kilograms CO₂ equivalent per kilogram of fibres,²⁴ whereas the climate impact of cotton usually is calculated to be within the range 0.5–4 kg CO₂ equiv. / kg fibres.²⁵ As there are multiple complex issues to consider in assessing and validating the CO₂ emissions and in comparing among MMCF solutions, one should thoroughly investigate various MMCF, for full understanding of the climate impacts.

MMCF materials are generally considered to consume less water than other fibres (e.g., cotton) in the course of production; however, most studies do not consider the water used in the process of growing the wood needed for the feedstock. While Nordic wood-based feedstock comes from natural forests, where watering is not an issue, the share of this feedstock in the total volume is low. Most of the pulp comes from outside the Nordics, so the sourcing of wood feedstock in production of MMCF demands careful attention: obtaining wood for MMCF involves a significant risk of negative environmental and climate impacts, which can be both short-term and long-term. Canopy estimates that around half of all MMCF inputs come from ancient and endangered forests, and the value chain (including logistics) is not transparent. Additionally, undesirable types of land exploitation in forest-farming are likely to lead to loss of biodiversity and should be monitored carefully in the sourcing.²⁶

²² Kamppuri et al. 2020.

²³ Sandin et al. 2019.

²⁴ Schultz and Suresh 2017.

²⁵ Laursen et al. 1997.

²⁶ Hugill et al. 2020.

Therefore, consideration must be given to where the crops are grown and how they get processed and transported. A further challenge is visible in the large amount of chemical fertilisers and pesticides used on the plantations and the large quantities of water that release pollution to both soil and waterways. Deforestation and biodiversity impacts related to raw-material sourcing, problems with safe chemical use, and labour-rights issues arising in the production process all are best mitigated by sourcing only from certified forests (with PEFC certification) and from operators whose value chains are transparent.

The market share of 'recycled MMCF' is currently estimated at below 1%, but there is considerable research and development, so a significant increase over the coming years is expected. Also, with new standards introduced for pulp and fibre, action is likely to increase further. Finally, MMCF is expected to reduce the use of fibres from non-renewable resources (such as polyester). Closing the loop on MMCF would also reduce the need for virgin raw materials and lead to further positive impacts on environment and climate. That said, the level of significance is uncertain, since the full potential of closed-loop MMCF production has not yet been revealed.

Socio-economic impacts

Industry-led business and innovation ecosystems are a key enabler for up-scaling of closed-loop textile solutions. Therefore, adopting a closed-loop MMCF strategy is likely to strengthen regional innovation networks and co-operation within the Nordic countries, creating potentially significant positive short-term and long-term socio-economic effects in the Nordic areas concerned. The expected impacts are both direct and indirect. Previous research, including Nordic bioeconomy case studies²⁷, has demonstrated the importance of co-operation – and even new institutional structures – in facilitating collaboration among various types of stakeholders: companies, public-sector actors, research institutions, etc. Such co-operation has been found to offer potential for creation of added value and new jobs at regional and local level, thereby resulting in direct positive socio-economic impacts both in the short term and in the long run.²⁸

Local and regional ecosystems provide multiple business opportunities along the value chain, from collection to sorting and upstream operations. The associated actors in the ecosystem can provide employment opportunities, in that many of the operations involved (e.g., sorting and logistics) are rather labour-intensive. Some of the positions do not require very much prior knowledge or training at all and might offer employment opportunities for people who otherwise face challenges with employment. It should be noted, however, that many tasks in areas such as sorting will be automated in the future, bringing less need for manual labour and greater demand for digital skills²⁹. Accordingly, there may be both positive and negative socio-economic impacts and both short-term and long-term ones, in various Nordic settings.

3.1.4 Barriers to seizing the CE opportunity and possible solutions

Barriers related to this opportunity were identified in the following domains:

Technology barriers: The current lack of chemical-based recycling technologies' availability at scale poses significant challenges to our ability to close the loops for wood-based textiles. Technologies to ensure

²⁷ Gíslason and Bragadóttir 2017.

²⁸ Hugill et al. 2020.

²⁹ Kamppuri et al. 2021.

transparency and traceability of raw materials are at a very early stage of development, and there is no evidence that fully commercial, scalable tracing solutions are on the market.

Regulatory barriers: Regulation for enhancing textile fibres' recycling remains absent. Sweden is among Europe's first countries preparing for extended producer-responsibility legislation for clothing and textiles (with work in progress as of January 2022)³⁰. The EU regulatory landscape for textile-recycling brings with it some common barriers³¹ for Finland, Sweden, and Denmark, among them impediments to automated textile-sorting and recycling on account of the required labels³² lacking precise information about materials and there being no EU-specific end-of-life criteria or any sorting criteria for textile waste³³. Furthermore, the ecological criteria for awarding the textile-related labels do not reward the use of MMCF or recycled content in natural fibres such as wool or cotton.³⁴

Market barriers: Today's chemical-based recycling technologies are not deployed at scale, largely because of lack of interest among brand-owners and investors. Investors are hesitant to finance these technologies since there is not enough brand-level demand currently. One reason for this is that recycled fibres are more expensive than virgin fibres.

Cultural barriers: The fashion industry is highly trend-driven, and its 'use-and-discard' attitude to clothing makes it difficult to apply circular business models focused on longevity.

The following avenues are possible ways forward:

- A dramatic increase in quantities of textiles collected in the Nordics countries, arising from EU policy stating that textile waste streams must be collected separately from other waste streams by 2025, offers new opportunities for sourcing textile waste that could be incorporated into the production of wood-based textiles.
- Improved capabilities of sorting textiles could lead to quality-assured, high-quality textile recycling. Recently, the world's first automated industrial textile-sorting plant, in Malmö, Sweden³⁵, began operation.
- Investment in chemical-based recycling technologies could help accelerate the creation of a closed-loop system for MMCF. Chemical recycling has several advantages over mechanical recycling. Chemical recycling does not shorten the fibres and does not require as pure a feedstock (it can, for example, separate blended cotton and polyester fibres). It also leads to higher-quality fibres.
- Tightening EU legislation is accelerating the transition to bio-based and recycled raw materials, alongside a shift to textiles and fashion designed to be durable and recyclable.
- Forecasts of growth for MMCF highlight the fact that there are increasing opportunities for the industry to determine how forests as carbon sinks are managed and how biodiversity outcomes might be optimised in the sourcing of MMCF feedstock.

³⁰ SOU 2020.

³¹ European Commission 2021b.

³² Textile Regulation: Regulation (EU) No 1007/2011.

³³ Waste Framework Directive: Directive 2008/98/EC.

³⁴ EU Ecolabel for textile products 2014/350/EU with the respective amendment (2017/1392/EU).

³⁵ Sysav 2021.

3.2 New applications for ocean biomass

3.2.1 *Introduction*

Oceans and seas play a significant economic, environmental, and socio-cultural role in the Nordic context. As the global ocean economy rapidly expands³⁶, the associated ecosystems and sustainable use of oceans become an increasing concern both globally and for the Nordics in particular.

The case presented here³⁷ involves improving, optimising, and developing new value chains for ocean biomass and finding routes to higher-value circular utilisation of material streams. In the Nordic context, this brings in a broad range of potential material streams: fisheries and aquaculture, mussel and other shellfish cultivation, and plant-based biomass in the form of seaweed and algae. These resources can potentially serve as inputs to value chains in multiple sectors – primarily food, drink, and agriculture but also potentially packaging, medicine, textiles, building and construction, and energy generation.³⁸

Up to 70% of the aquatic resources extracted ends up as side-stream materials, currently used in low-value applications or disposed of as waste³⁹. Utilising ocean biomass as a renewable resource within a CE framework involves ensuring that all material flows are circular by nature, that waste in the production phase is minimised and by-products utilised, and that the products are able to re-enter the biosphere at end of life safely.

3.2.2 *The current state of Nordic CE*

Fisheries and aquaculture provide a significant economic input, particularly in coastal and island communities, and there are strong bioeconomy clusters in several Nordic countries. As found in part I of the study, the bioeconomy sector (including agriculture, forestry, and fishery operations) accounted for less than 5% of total turnover in the overall economies of the Nordic countries. That said, fisheries and aquaculture have a substantial role in employment and export in coastal locations all over the Nordic area. While most of the fishery and aquaculture material flows are not circular in themselves, the size and significance of the industry imply that there is untapped potential especially in relation to resource-efficiency, utilising the material streams in more optimal ways, and exploring new material streams in the ocean-biomass arena.

- In some parts of Norway, a full 48% of the regional workforce is engaged in aquaculture. Fish export is Norway's third-largest export class, and the country is the world's second-largest fish exporter⁴⁰. In 2017, approximately 8% of Norwegian exports were from the seafood industry, and seafood contributed about NOK 95 billion to the Norwegian economy, a figure that is anticipated to grow substantially in the coming decades. Around 58,000 people are employed either directly or

³⁶ Per 2016 OECD estimates of its value creation doubling from 2010 to 2030.

³⁷ The case study was carried out under the leadership of PlanMiljø.

³⁸ According to the SUBMARINER Network.

³⁹ Waseabi 2019.

⁴⁰ Norwegian Ministries 2020.

indirectly by the seafood industry in Norway. It is noteworthy that aquaculture accounts for the largest share of GDP but fisheries employ more people.⁴¹

- In Iceland, around 7,500 people (amounting to approximately 3.9% of the total labour force) worked directly in fisheries and fish-processing in 2019. Fish export is Iceland's second-largest export group. Fish products accounted for 27% of exports from Iceland in 2019, while fisheries, aquaculture, and processing together account for 7% of the country's GDP.
- The economy of Greenland depends on fish and shrimp export.⁴² Fisheries account for well over 90% of Greenland's total exports for the past 20 years. Fishing and fish-processing constitute the primary industry of Greenland, employing around 16% of the workforce in 2019, with fishery products accounting for 93% of export by value.⁴³
- In the Faroe Islands, fishing and associated activities account for 20% of total added value and employ around 15% of the labour force⁴⁴.
- The Danish fishing fleet caught fish to a value of DKK 3.1 billion in 2020, with about DKK 2.7 billion of that amount being from within Danish waters.
- Finland is the biggest fishing state in the Baltic Sea area. The value of its fish-economy value chain is estimated at about a billion euros a year⁴⁵.
- In Åland, fisheries and aquaculture make up the third-largest economic sector⁴⁶.
- For Sweden, the fishing and aquaculture sector is less crucial, but it is still important to the national economy, supporting around 1,900 jobs in 2018 (down from roughly 5,000 in 2008) and producing SEK 1.5 billion in value, of which 27% came from aquaculture and 73% from fisheries.

Potential for digital tools

While the exploration of new material streams from ocean biomass in the Nordics is still in its infancy, there is potential for digital tools to enable a more efficient and responsive system through digital monitoring and demand-based response. For example, more active use and generation of ocean data could help to identify and minimise any environmental impacts from activities while also aiding in identification of suitable sites and monitoring for optimal conditions. Land-based aquaculture has the benefit of being a more closed system, which affords close monitoring of conditions, careful management of materials, and minimisation of environmental impacts. Potential in these areas is under exploration by the Nordic Testbed Network in pursuit of digitally oriented transformation of the Nordic bioeconomy. Also part of this effort are the Latvian Institute of Aquatic Ecology and AquaVIP, a joint research project of southern Baltic universities⁴⁷.

The Nordics hold internationally leading positions especially in technology and innovations for sustainable aquaculture. In general, these countries are strong in cultivating technologies for demanding environments, digitalisation, robotics, automation, and artificial intelligence. For example, opportunities exist for combined offshore solutions that apply distance monitoring and maintenance of offshore aquaculture sites and for exploring new ways to develop co-location-based sustainable use of ocean areas for multiple purposes. Developing new, better use of data and digital tools can open opportunities to find

⁴¹ Johansen et al. 2019.

⁴² CIA 2021.

⁴³ Grønlands Statistik 2021.

⁴⁴ Government of the Faroe Islands 2019.

⁴⁵ Rahkonen 2018 – Publications of the Ministry of Agriculture and Forestry 6a/2018 (ISBN: 978-952-453-986-9), p. 35.

⁴⁶ Sepponen et al. 2021.

⁴⁷ See <https://nordictestbednetwork.se/>.

new applications for technology and know-how across sector boundaries and help Nordic businesses both thrive in changing operation environments and maintain their status as significant innovation environments.⁴⁸

One example showcasing the possibilities of digital tools for aquaculture is AquaCloud, a Big Data platform for the fish-farming industry that involves data-sharing services and a digital standard for the aquaculture industry. The platform, addressing standardisation needs related to sensor-transmitted data, fish health, and environmental data, is being developed by Ocean Innovation Norwegian Catapult, a centre that offers shared design, prototyping, testing, and verification facilities for the maritime industry.

Potential for new business models

There are vast areas of potential in terms of developing new uses for ocean biomass, including side streams from existing processes. While the majority of these may not consist of a new business model *per se*, they often are centred on new material streams, which will require building new networks and supply/value chains and exploiting those already in place. Better use of data and digitalisation, including platforms for co-operation and industry symbioses, can support these advances.

Commercial examples

BlueGreenFuture aims to develop a functional blue biorefinery producing industrial and consumer commodities from sustainable cultivated seaweed. The seaweed products could be used as a partial replacement for many artificial ingredients in fish feed.

Nordlaks has aims to develop Havfarm, a new type of offshore salmon-farm platform. However, the Norwegian Directorate of Fisheries has turned down a related application for 13 development permits to be converted into permanent licences.

Further along in its efforts, Seagarden produces pure marine collagen made from the skin of cod living wild in the Norwegian and Barents seas. The collagen is sold as a cosmetic and well-being product.

Sweden's Nordic SeaFarm is among Europe's leading producers of sustainably grown seaweed and is collaborating with some of the country's most well-regarded chefs and food companies to establish a market for seaweed-related food products.

Another pioneer in this realm is Finnforel, a Finnish technology start-up with a focus on sustainable development in the aquaculture food chain. It employs a land-based aquaculture method that utilises circulating water. In November 2021, Finnforel announced a €45M investment programme⁴⁹ for first-phase scaling up of the company's technology and concept.

Finally, Ocean Rainforest is a company that, from locations in the Faroe Islands and California, offers a collection of seaweed products intended mostly for feed, food, and cosmetics producers. The company has developed special farming racks for seaweed.

Initiatives to catalyse CE

⁴⁸ Sepponen et al. 2021.

⁴⁹ STT 2021.

The proponents of the EU-funded WASEABI development project seek to develop new solutions and value chains that can optimise and utilise the side streams and by-products from aquaculture, fisheries, and the fishing industry. Their aim is to ensure that these side streams can be input to higher-value applications – as, among other things, new ingredients for food-industry use. This Technical University of Denmark project has 13 partners in its sector, many from Nordic countries.

National programmes under the European Maritime, Fisheries and Aquaculture Fund (EMFAF)⁵⁰ support the development of innovation and sustainability in the fisheries and aquaculture sector.

The SUBMARINER Network for a Baltic blue economy⁵¹ supports the development of a sustainable bioeconomy for the region.

The Nordic Innovation Program on Sustainable Ocean Economy (2021–2024)⁵² focuses on, among other things, innovative and sustainable aquaculture. Among the foundations for its work are the results from previous Nordic Marine Innovation programme activities and the Nordic Bioeconomy Initiative, NordBio.⁵³

3.2.3 *Future perspectives and impacts*

Future perspectives

The growth of aquaculture is expected to continue as people switch from meat-based diets and as industry players capitalise on Nordic experience with aquaculture. Fishing is likely to remain stable or decline, with its fate depending on the strength and sustainability of fish stocks, coupled with the impacts of climate change, including ocean acidification.

There is burgeoning interest in blue forests and in coastal and marine habitats such as kelp forests, seagrass meadows, mangrove areas, rockweed beds, and salt marshes. Exceptionally productive ecosystems, these support coastal and island well-being around the world.

Utilisation of alternative products here is likely to increase, but it is greatly dependent on technical products' development and on supporting-framework conditions for increased utilisation. Norway is one of the leading countries in Europe in seaweed production for food, feed, and bio-based replacement of other products, and it hosts pioneering companies in this area⁵⁴. Other Nordic countries too show promising development. Denmark produces around 40–60,000 tonnes of blue mussels annually, but scaling for 300,000 tonnes a year is possible. This could yield significant environmental benefits: it is estimated that such a scale of production would filter up to 5,000 tonnes of nitrates and 500 tonnes of phosphorus compounds from coastal waters and create as many as 800 jobs⁵⁵. Seaweed, on the other hand, can be encouraged to grow and harvested for use in diverse applications in a cascade starting with high-value substances extracted through biorefining for the medical, food, and cosmetics industries, with

⁵⁰ See https://ec.europa.eu/oceans-and-fisheries/funding/emfaf_en.

⁵¹ SUBMARINER Network 2021.

⁵² Nordic Innovation 2021.

⁵³ Gíslason and Bragadóttir 2017.

⁵⁴ Sepponen et al. 2021.

⁵⁵ According to the Danish Bio-economy Panel 2017 (a collection of bioeconomy experts supporting the national government in strategic development, highlighting the potential for increasing value and job numbers that could arise through the development of material flows around mussels and seaweed).

the residual components seeing use as fertiliser or fodder. Also, seaweed can be stabilised and treated such that it is suitable for use in construction as insulation.

Co-operation on novel approaches and for solutions related to new protein sources; new applications for aquaculture products; and better use of technology, data, and digitalisation could further strengthen existing ecosystems for sustainable onshore and offshore aquaculture, while at the same time promoting Nordic solutions in international markets.⁵⁶

Impacts of increased utilisation of ocean biomass

Business impacts

There is great potential in expansion of existing activities – related particularly to aquaculture. Potential can be found also in the development of new material streams, primarily from seaweed and shellfish.

Improved utilisation of side streams is extremely important, in that much of the materials harvested now ends up discarded or entering low-value applications. New solutions could help drive new business opportunities in the food and ingredients industry and also promote efficiencies in (and greater returns from) the aquaculture and fishing industries.

Use of aquaculture by-products and associated biomass could contribute to additional applications, such as use for food, pharmaceuticals, cosmetics, and chemicals. There is already a large amount of promising activity using side streams in the general fish value chain (although much of it is not commercial at large scale), and other species are being explored in connection with blue biomass. For example, seaweed species are full of proteins, minerals, and antibacterial substances, and they can be used both in food applications and as feed for biofuels and fertilisers.

In contrast, operations such as kelp farming are still in their research and development phase. Feedback from companies that have commenced sugar-kelp production shows indications of success. However, there remain various issues related to kelp biology, documentation of food safety, development of equipment, product development, and markets that need to be resolved before the industry can become commercially viable.

Some other possible aquaculture activities are production of sea cucumbers, which can consume waste from other aquaculture activities; sea ranching of native species; and rearing of wild-caught organisms such as sea urchins.⁵⁷

Climate and environmental impacts

Climate change and various burdens on the environment are expected to result in major changes to the sizes and distribution of fish stocks in the years ahead, creating challenges for fisheries and their management. Marine forests help combat climate change by soaking up CO₂ from the atmosphere and locking it away on the seabed. Hence, for instance, seaweed cultivation can help reduce CO₂ in the atmosphere.

Replacement connected with alternative biomass produces secondary reduction of CO₂ emissions. Even though aquaculture is interwoven with many sustainability challenges, it provides alternatives to less sustainable material flows. Since the climate footprint of fish is small in comparison with other animal-

⁵⁶ Hasselström et al. 2018.

⁵⁷ Norwegian Ministry of Climate and Environment 2019.

based production, increased use of fish protein and products holds potential for significant positive economic, environmental, and social impacts. Ocean biomass can serve as an alternative protein also, which could lead toward reduced reliance on carbon-intensive protein sources. Blue carbon's potential to contribute to carbon capture and storage is currently an important area of research⁵⁸. At present in the Nordic countries, this carbon capture primarily takes the form of maintaining and protecting ocean grasses and kelp forests.⁵⁹

New applications for ocean biomass could produce negative impacts, particularly in coastal ecosystems of wild fish and seashells, where overfishing and aquaculture have created various environmental problems (nutrient leaching, diseases, etc.) that continue to present risks. Further development of the sector must be sensitive to these problems. This matter is relevant not only for establishment of new sites (which may be near sensitive areas) and the operation of aquaculture facilities (which can have serious consequences for water quality and surrounding ecosystems) but also for decommissioning – ensuring that facilities are removed properly and that the area gets restored once the business moves on. Currently, environmental-permit conditions for aquaculture sites are fairly strict, at least in EU states.

It is essential that the nutrient excesses be addressed, particularly through recycling of nitrates and phosphorus. This probably is going to require specific legislation addressing the management of aquaculture facilities, since voluntary agreements are considered unlikely to be sufficient. Benefits could arise from extracting nitrates and phosphorus compounds from coastal waters, but they require both legislation and investment.

It is already clear, however, that, for example, seaweed farming counteracts loss of oxygen, marine pollution, and acidification in the ocean by taking up carbon dioxide and phosphorus and contributing to reduced eutrophication of the oceans. Plant-based food from large-scale seaweed farms and cultivation performed in a well-structured and sustainable manner (with the seabed left untouched) improves land use and biodiversity.

Socio-economic impacts

On one hand, aquaculture contributes to value creation and income for enterprises, municipalities, and the state. On the other, it tends to be associated with negative environmental impacts, adversely affecting the image of the industry and its possibilities for further growth.

New applications for ocean biomass and expansion of the aquaculture sector could lead to higher employment, especially in rural and coastal areas, while also providing replacement employment in those areas currently heavily reliant on the oil and gas industry in the North Sea area. There are knock-on employment effects too. Similarly, better utilisation of side streams should drive value generation and employment at processing sites.

It should be noted, though, that with more large-scale ocean biomass farms may come negative impacts on recreation-related values, through physical obstacles, through an impact on aesthetics, and through disturbance to alternative activities around the site.

3.2.4 Barriers to seizing the CE opportunity and possible solutions

⁵⁸ Blue Carbon Initiative 2019.

⁵⁹ Nordic Blue Carbon 2021.

Barriers related to this opportunity were identified in the following domains:

There are **technology barriers**, connected mainly with the fact that existing technologies are not sufficient to enable sustainable circular aquaculture and ocean-biomass utilisation. Further development of technologies is required especially for inland recirculating aquaculture systems (RAS) and seaweed-farming solutions. Also required is more advanced development of materials, systems, and operations that can withstand cold water and harsh conditions while coping with the challenges of ecosystem effects (e.g., suitable farming technology, vaccines, biological delousing using wrasse, large-scale mechanical delousing, and electrified fences).

The **regulatory barriers** stem primarily from the environmental permits for aquaculture, which is strictly regulated in comparison with other bioeconomy activities. Further, all use of ocean biomass in the food and beverage industry and as animal feed requires scrutiny of the requirements set by national health and safety legislation. For instance, utilising seaweed and mussels as fodder for organic food production may require additional assurances that the material is suitable and free from pollutants such as heavy metals.

Market barriers revolve around the fact that the markets for alternative uses of biomass streams are currently underdeveloped. While there are many development projects, involving co-operation between research and industry settings, considerably less activity at commercially viable scale is evident. For example, large-scale production of seaweed and shellfish is a new and challenging area, one that for many reasons could bring long lead times and uncertainty about eventual outcomes. Networks and value chains for realising the potential require further development and support.

One factor related to **cultural barriers** is that some parts of the sector are conservative or handled by small enterprises, and circular value chains are not mainstream. Know-how needs to be increased in relation both to new ways of operating in the aquaculture domain and to the recognition of new ways to catalyse the preferred changes in attitudes and cultural perceptions. Efforts to develop new food products from side streams could face difficulties also with regard to acceptance by the food industry and consumers.

Another challenge is that, while aquaculture plays an important role in the Nordic countries, at the same time critical public opinions are likely to affect opportunities for business's future development. Strong opportunities for sustainable blue growth have been identified, but lack of a social licence to operate may pose significant obstacles to the moving forward.

The following avenues are possible ways forward:

- The fishing industry is under pressure arising from reductions to fish quotas in the Baltic region and will be looking for alternative income streams.
- The gradual shift toward diets with reduction in their meat component points to a need for additional protein sources.
- Farming of mussels and seaweed provides direct environmental benefits since these activities extract nitrates and phosphorus compounds from coastal waters, thereby helping to mitigate eutrophication and meet EU targets.

3.3 Predictive management supporting circular food-chain solutions

3.3.1 *Introduction*

The food-chain-centred case study⁶⁰ focuses on analysis-based precision fertilisation in agriculture using recycled nutrients. The case ties in with the larger context of agricultural residues' utilisation, biogas production, and the broader issue of bio-plants⁶¹. Protecting our water bodies and soil, saving virgin resources that contain nutrients (e.g., phosphate rock), minimising emissions, and saving money can function as drivers to the most precisely targeted use of recycled nutrients possible. New technologies enable this activity by facilitating production of recycled nutrient products and by increasing the opportunities for precise application of the nutrients. Coupled with these factors, well-developed regulation should support building of recycled-nutrient markets.

The goal behind nutrient recycling is optimal use of nutrients in crop production and superseding the use of synthetic fertilisers. Key issues connected with nutrient recycling are fertiliser applications consistent with the plants' actual needs, good soil health for optimal nutrient intake, efficient manure management, the return of nutrients from the food industry's side products to the fields, reduction of food waste from retail and from home consumption, and proper handling of the sludge from wastewater-treatment plants for the nutrients' safe return to the soil.⁶² Nutrients should not go to waste, whether through leaching or as food waste, in any part of the production or consumption chain.

Biogas production plays a central role in nutrient recycling. Biogas plants collect large amounts of nutrient-rich organic wastes from agriculture, food-industry operations, and households as raw material. During processing, they form biogas, which can be utilised for renewable energy. As for the agricultural domain, material such as grass and manure; such by-products as slaughter waste, other biowaste, and sewage sludge; and biodegradable waste in general can feed the biogas-production process. Residual sludges and more solid digestate from biogas plants constitute potential fertilisers.

For this report, we have chosen to focus specifically on the opportunity to use recycled nutrients in a resource-efficient way with the aid of data and digital tools. That focus was chosen because it provides an opportunity to consider new business models enabled by digitalisation.

With the assistance of precision agriculture⁶³, the nutrients supplied can be tailored to each field plot (or even sub-plot), and the fertilising adjusted accordingly. While precision targeting is possible with synthetic fertilisers, the use of organic ones diminishes the need for these and enables circular economy. Using recycled nutrients thus promotes the nutrient cycle. The nutrients used can come either from the same farm or from outside, but in both cases special processing must render them suitable for this use.

Accuracy in fertiliser-planning is crucial for resource-efficiency and also for reduced impact on the watercourses and climate. The better the fertilising meets the actual nutrient needs of the crop and is based on the condition of the given plot's soil, the greater the proportion of the nutrients reaching the crop and the smaller the losses to water bodies and the atmosphere.⁶⁴ This is especially crucial in the Nordic context in light of the alarming state of the Baltic Sea.

⁶⁰ The case study was carried out under the leadership of Gaia Consulting.

⁶¹ By 'bio-plants' we mean biogas facilities, bio-refineries, and compost facilities.

⁶² HELCOM 2017.

⁶³ DTN 2021.

⁶⁴ Horn et al. 2020.

3.3.2 *The current state of Nordic CE*

Nordic agriculture is the primary producer of resource flows for the food and beverage industry, which is among the critical industries in many parts of the Nordic region. Conditions for agriculture vary greatly across the Nordics. For example, 60% of Denmark's land area is used for farming, which makes this one of the most intensively farmed countries in the world, while agriculture accounts for just 7–8% of Sweden's land area.⁶⁵ Throughout the region, agriculture plays a central role in the food and beverage sector's value chain, but significant amounts of waste get generated along the entire chain from primary producers to final consumers – 4.3 million tonnes in total from Denmark, Finland, Iceland, Norway, and Sweden⁶⁶.

As agriculture forms the heart of the Nordic food-supply chain, it is among the critical industries for food security. More sustainable nutrient management is essential to food security and for improved water quality globally, and European Union policies emphasise both these aspects of its importance. For yields and the cultivation to be successful, the fields need to be fertilised. Generally, synthetic fertilisers get used. However, all fertilisers have negative environmental impacts. Firstly, losses of nitrogen (N) and phosphorus (P) to inland and coastal waters cause eutrophication, which may lead to hypoxic conditions in aquatic ecosystems. Furthermore, most of the climate impact of food stems from the use of fertilisers or from animals, in the form of various greenhouse gases.⁶⁷ Emissions from agriculture account for approximately 10% of all emissions in the European Union, with most of the emissions coming from livestock activities⁶⁸.

Synthetic fertilisers create larger climate impacts than organic fertilisers do. The climate burden from the production phase of synthetic fertilisers is as great as 8.5 kg CO₂-eq. per kilogram of water-soluble nitrogen, whereas the impacts of the production phase for organic fertilisers are below 0.8 kg CO₂-eq.⁶⁹ The bulk of the emissions caused by fertilisers stems from synthetic nitrogen-based fertilisers. Per estimates from recent research, the global climate impacts of synthetic N fertilisers, covering the entire production chain, account for 2.4% of global emissions, making this one of the world's most climate-polluting industrial chemicals⁷⁰. The synthetic N fertiliser supply chain was responsible for emissions to the tune of 1,250 million tonnes CO₂-eq. in 2018, an estimate equivalent to roughly 21.5% of the annual direct emissions from agriculture (5,800 million tonnes) globally. For comparison, the global emissions from commercial aviation in 2019 came to around 915 million tonnes of CO₂.

Animal manure is used alongside fertilisers on farms. As the total number of farms decreases, the Nordics' remaining animal-husbandry facilities are becoming larger, and the manure is more concentrated in the landscape. This has often led to nutrients' overapplication in fields close to where manure is produced and stored. Accordingly, there is increased risk of larger losses of both N and P to water bodies from those areas. About 50% of Finland's phosphorus and nitrogen use is connected with fertiliser use. In Sweden, the agricultural sector contributed 10% of total NO_x emissions in 2018⁷¹. Therefore, one critical question is how to ensure that fertilisers are used in a resource-efficient manner and only to the necessary extent. In

⁶⁵ Lund Gade et al. 2021.

⁶⁶ See part I of this study report.

⁶⁷ Luke 2021.

⁶⁸ Lund Gade et al. 2021.

⁶⁹ Horn et al. 2020.

⁷⁰ IATP 2021.

⁷¹ Naturverket 2020.

all of the Nordic countries, the need to develop and apply more precision-oriented fertilising has already been recognised⁷².

Potential for digital tools

Precision fertilising requires further development of digital tools and technology. This could bring about new business not only in the service domain but also in that farms can create procurement co-operatives. The emergence of brokerage services and a growing need for profitability calculations (e.g., involving analytics services combined with distance monitoring) represent additional potential.

'Climate-smart' precision fertilisation requires data on what fertilisers have been used, the state of the yield, what emissions were caused by the activities, and how the various growing seasons compare. All of these require digital tools.⁷³

Potential for new business models

Under a fertiliser-rental concept (with implementation as a service), a nutrient service can be purchased against the crop's response or soil conditions. For example, the United Nations Industrial Development Organization (UNIDO) has been exporting a chemical-leasing business model, including a concept for fertiliser-leasing. In pilot projects carried out in Sri Lanka, the savings achieved via fertiliser-leasing in potato farming amounted to as much as 40–50%. The same model has been piloted in Serbia, where the savings on fertiliser activities costs in wheat farming came to 5% while the yield increased by 2%.⁷⁴

There are several alternative technologies for creating digestate, some of which are still under development. Plant operators have encountered challenges when seeking workable and profitable technologies for further processing.⁷⁵ Some innovations have been devised to enrich the digestate by optimising biogas feedstock, which, in turn, produces recycled organic fertilisers and nutrients, for meeting the precise needs of the agriculture in a given region. In another approach, enrichment could be done after the biogasification process. This would support more industrial-scale fertiliser production, wherein digestate is among the raw materials, mixed with other industrial by-products (such as meat and bonemeal or molasses).

Commercial examples

The biogas company BioKymppi Oy, with a plant operating in Kitee, Finland, specialises in various organic by-products' processing into renewable energy and fertiliser products. In addition to energy production, both liquid fertiliser and solid fertiliser are produced.⁷⁶

Finnish deep-tech company Kuva Space offers precision agriculture solutions globally to improve crop yields by as much as 30% while simultaneously decreasing the necessary inputs by 15%. The company

⁷² Lantmännen 2019.

⁷³ Onstot 2021.

⁷⁴ Aho et al. 2015.

⁷⁵ Horn et al. 2020.

⁷⁶ Ibid.

offers situational awareness for agricultural policies, supplies emission details, and provides tools for verifying the actual effects of various bio-asset carbon-sequestration methods.⁷⁷

Sweden has significant phosphorus reserves, mainly in its slag heaps from mining, which could provide an opportunity for phosphorus self-sufficiency. Also, the plant nutrients available in wastewater fractions could be used more extensively through development of new technology and business models. Business development in the relevant sector is under way for commercialisation of circulated plant nutrients.⁷⁸ A technology called N-sensor, installed on a tractor cab's roof to measure the optimal fertiliser rate, is already used in Lantmännen's cultivation programme Climate & Nature⁷⁹.

Finally, entities such as the global fertiliser company Yara offer precision fertilisation services. Providing these in Sweden, Finland, Denmark, and Norway, the firm recently acquired Finnish company Ecolan Oy, experts in organic fertilisers created from side streams from the food industry and forestry, to promote organic precision fertilisation⁸⁰.

Initiatives to catalyse CE

The Center for Precision Agriculture (CPA) was established in August 2016 as part of the Norwegian Institute of Bioeconomy Research. The mission of the CPA is to contribute to resource-efficient and sustainable agriculture by shortening the time required for farmers to adopt new agricultural technology, through information and pilot projects.

CropSAT is a Web-based application freely available for satellite-based production of variable-rate application (VRA) files for such substances as nitrogen and fungicides currently available in Sweden and Denmark. Even in areas frequently covered by clouds, vegetation-index maps created from data derived from freely available or low-cost optical satellite imagery constitute a practical tool for handling such time-critical applications as optimised nitrogen use cost-efficiently. The initial version of CropSAT was fruit of a research project at the Swedish University of Agricultural Sciences (SLU), and since its launch (in 2015) it has been continuously developed via a private–public partnership involving SLU, private companies, and the Swedish Board of Agriculture.

3.3.3 Future perspectives and impacts

Future perspectives

Climate change is going to have serious effects on agriculture, among which the changing conditions increase demand for new fertilising solutions. The role of agriculture in reaching the climate targets set will grow more urgent, and demand for various ways to optimise food production and, through this, reduce CO₂ emissions is going to rise. The transition toward circularity is further complicated by the simultaneous need to replace fossil-fuel use with renewable energy production such as biogas operations. The value of precision fertilisation for the European and specifically the Nordic agricultural sector has already been recognised by several institutional and industrial actors: its use constitutes an important element of

⁷⁷ Kuva Space 2021.

⁷⁸ Lantmännen 2019.

⁷⁹ Ibid.

⁸⁰ Yara 2021.

sustainable farming practices. Additionally, the perilous state of the Baltic Sea necessitates actions to reduce nutrient loads. Precision agriculture provides one avenue for decreasing the need for fertilisers. Targeted and tailored fertilisation that gives the plants the amount of nitrogen needed at the right time while also adjusting phosphorus application to site-specific soil properties enables more efficient crop production and decreased emissions into the Baltic Sea.⁸¹

Within an appropriate legislative framework, precision agriculture solutions could play a vital role in the context of EU ambitions for leadership in sustainable agricultural production and could help the union maintain a strong industrial base while at the same time shifting toward a decarbonised economy. However, the agricultural sector and policies vary from each Nordic country to the next – both conditions and the measures for meeting the climate targets differ. Sweden, Denmark, and Finland operate under the EU's Common Agricultural Policy (CAP), while the other Nordic countries have their own agricultural policies.

Recently, the importance of soil conditions has gained more attention, in terms of increasing yields but also for mitigating CO₂ emissions. Soil is recognised to be the largest carbon storage pool, with approximately twice the amount of carbon in the atmosphere and three times that in terrestrial biomass⁸². However, agricultural soil loses its carbon via erosion and as organic matter decomposes, so recovery is required. Nutrient recycling and precision fertilisation can play an important role in the recovery process. More advanced techniques and cultivation methods that contribute to better soil health and carbon sequestration on farmland are needed. These cultivation techniques are usually referred to collectively as conservation agriculture. Having more carbon in the soil not only reduces emissions of carbon dioxide into the atmosphere but also contributes to healthier soils, which are more resistant to the effects of climate change.⁸³

Impacts of precision fertilisation using recycled nutrients

Business impacts

There are numerous positive business impacts, both long-term and short-term, that are likely both for farmers and for other parties in the value chain. More extensive utilisation of data and soil analytics enables savings and increased productivity in Nordic agriculture. Combined with a better understanding of ways to keep soil in good condition, this could, in the long run, result in increased yields and more optimal use of fertilisers, leading, in turn, to increased earnings. Additionally, local business opportunities are likely to emerge around the feedstock materials needed in the biogas- and digestate-production optimisation processes, since manure digestate on its own may not suffice as fertiliser.

Because transportation is a logistically complex and economically intensive endeavour, it is often viewed as a major barrier to effective recycling of organic waste and to balancing agricultural landscapes' nutrient budgets. However, the logistics chain for fertilisers shows potential for some direct and indirect positive business impacts both in terms of cost savings from more efficient logistics in agriculture and in new business opportunities in the logistics-services field. Fuller information on the spatial distribution of nutrient availability is required if we are to seize this opportunity to take full advantage of organic waste's nutrient resources and decrease the risk of nutrient losses from animal-dense regions.

⁸¹ HELCOM 2018.

⁸² Schlesinger and Jeffrey 2000.

⁸³ Nordic Council of Ministers 2019.

Climate and environmental impacts

Using less fertiliser is likely to reduce emissions and increase the organic carbon content of the soil. Precision agriculture considers the fields' needs in spatial and temporal perspective, thereby enabling emissions to be cut via, for example, reductions in the amounts of land needed for agriculture purposes⁸⁴. Furthermore, reports from the UK government have been characterised as suggesting that 'improved nutrient management in crops has a far higher potential for emission mitigation than livestock-related practices'⁸⁵. The climate-influence potential must be considered even though most of the emissions from agriculture are connected with livestock.

Phosphorus and nitrogen are essential for the growth of plants and, hence, are vital nutrients for food production. Phosphorus is a non-renewable resource. Furthermore, global phosphorus resources are limited and situated in geopolitically sensitive areas.

Among the environmental impacts are reduced negative environmental impacts on such resources as our waters (especially the Baltic Sea) and soil-quality improvements created by an increase in the soil's organic matter. One knock-on effect is better retention of water by the soil. Taking this opportunity could also minimise phosphorus mining and ultimately lead to devoting less land and water to agriculture.

Socio-economic impacts

Many of the socio-economic impacts of precision fertilisation with organic fertilisers are linked to farmers transitioning from conventional farming to organic farming. Moving over to organic farming is predicted to result in better yields and higher crop quality, produce savings, and improve profits, thus enhancing farmers' welfare. An estimated 7% increase in net income has been cited as possible for fields where variable-rate seeding and data-influenced management zones are used⁸⁶. From a broader perspective, higher crop yields equate to more food from the same resources. This increases food security and safety⁸⁷. However, as the value chain of the food and beverage industry is rather complex, there remains uncertainty with regard to these positive impacts.

There are already indications of small improvements in employment arising via this opportunity. The impact can grow if the significance of precision agriculture using organic fertilisers does. Logistics, biogas plants, service providers, etc. represent employment options. In a study from 2015, researchers estimated, for example, that replacing imported phosphorus with recycled nutrients would directly create 66,000 new jobs in Finland.⁸⁸

3.3.4 Barriers to seizing the CE opportunity and possible solutions

Barriers to realising this opportunity were identified in the following domains:

Technology barriers: The use of recycled nutrients requires some planning. It is seldom feasible to switch from fossil nutrients to recycled nutrients instantly; incrementally raising the proportion of recycled nutrients is more commonplace. Secondly, although organic nutrition sources contain nitrogen, the amount of plant-available nitrogen is low until microbes in the soil have processed it. Some plants may

⁸⁴ Balafoutis et al. 2017.

⁸⁵ Cutress 2020.

⁸⁶ Ibid.

⁸⁷ SourceTrace 2021.

⁸⁸ Aho et al. 2015.

need more plant-available nitrogen early in the growing season, so synthetic fertilisers are readily employed to speed up the initial growth. Another dimension to the use of synthetic fertilisers is that precision is more easily achieved when the products are of uniform quality and easy to handle. Through processing, recycled nutrients can meet these criteria. Another issue is the many technology problems to be solved for biogas and other plants' recycling of nutrient sludges. However, technological development in this field is rapid.

Regulatory barriers: There are regulatory challenges related to nutrient use overall, accompanied by issues specific to biogas production and the by-products from which the nutrients can be derived. Legislation limits further cycling of by-products to feed organic fertiliser production and application in the fields – the restrictions may be lifted only after food-safety assessments. To a lesser extent, similar restrictions are imposed on the use of side streams (mostly from food waste, such as meat bonemeal and biodegradable municipal waste) as sources for organic fertilisers⁸⁹.

Market barriers: Prices of synthetic fertilisers are low, so switching to new, more expensive alternative could be a risk.

Cultural barriers: Farmers may be unaware of the potential economic, productivity, and environmental gains from precision fertilisation with recycled nutrients. Also, farmers may incur economic risk when making changes to how they care for their fields. Furthermore, consumers may express negative attitudes to using by-products from certain aspects of society (biowaste, slaughter waste, sewage sludge, etc.) in food production.

According to a 2019 report by Finland's Ministry of Agriculture and Forestry⁹⁰, a true breakthrough in nutrient recycling is going to require systemic transformation that cannot be achieved on market terms alone or by fine-tuning legislation and subsidies. Instead of individual 'levers', it would be wise to focus consistently on well-functioning combinations of them, supported by strong guidance.

The following avenues are possible ways forward:

- Availability of biogas or other plants that recycle nutrient sludges could be greatly expanded in the Nordic countries. As organic fertilisers can be made in conjunction with such production, existing plants are of value in increasing organic-fertiliser use.
- Practical tools/guidelines and general advice to farmers could assist them with the transition.
- Pilot experiments that provide possibilities for farmers to follow the process could help lower the cultural barriers related to factors such as attitudes.
- Ecosystem support mechanisms in which connections are established and maintained between service providers and farmers could boost the transformation.
- Support from industry organisations and advocates would help develop trust in the technology and communicate the potential benefits.

3.4 Digital platforms for minimisation of food waste

⁸⁹ EU 2019.

⁹⁰ Luostarinen et al. 2019.

3.4.1 Introduction

Food waste accounts for up to 10% of global greenhouse gas emissions, and reducing food waste is considered to be the most effective means of combating climate change⁹¹.

Food loss and food waste occur at all stages along the food and beverage value chain. 'Food loss' refers to spoilage, spillage, and other quality/value reductions or loss occurring in the food-supply chain before final-product stage. The term does not cover unavoidable losses related to, for example, weather-damaged crops.⁹² Food loss takes place most typically in the production, post-harvest, processing, and distribution parts of the supply chain. 'Food waste', on the other hand, refers to final products that, although fit for consumption, are not consumed but discarded (before or after their 'use-by' or 'best-before' date. Food waste does not include inedible elements such as bones or food packaging and wrappings.⁹³ Typically, but not exclusively, food waste takes place at the retail and consumption stages in the supply-chain process. Among the precipitating factors may be an approaching or passing 'best-before' date, variations in shape, or unusual colour of the produce.⁹⁴

Food loss and food waste constitute an economic, environmental, and ethics problem. This waste represents lost value to consumers and has an unnecessary impact on the climate and nature. Preventing food waste is key to achieving sustainability and is in the interest of both producers and consumers. The Nordic countries have signed up to meet the target of SDG 12 for sustainable consumption and production patterns: to halve per-capita global food waste at retail and consumer levels and reduce food losses along production and supply chains by 2030. Halving food waste by 2030 calls for radical changes in the food-related chain. These changes require work along four dimensions: a technology push, a societal pull, a market pull, and a regulatory push.⁹⁵

The case study presented here⁹⁶ focuses on digital platforms for minimising food loss and food waste both. It displays a two-pronged approach:

- 1) The presentation describes how digitalisation can help maintain value from food resources that are lost or wasted, throughout the food-related chain, from primary production and food-processing, through wholesale and retail, to serving of the food.
- 2) It describes how digitalisation can reduce food waste along the value chain, by informing the market (especially consumers) about surpluses that can be utilised – rather than go to waste – through price reductions and exercise of customer awareness.

3.4.2 The current state of Nordic CE

The food and beverage sector is a key component of the bioeconomy in the Nordic region, with solid potential for more effective resource management through food-waste reduction. According to a Nordic study from 2017, approximately 3.5 million tons of food is wasted in the Nordic region every year.⁹⁷ More

⁹¹ Drawdown 2020.

⁹² Farm to Fork 2021.

⁹³ Ibid.

⁹⁴ UNEP 2021.

⁹⁵ Nordic Council of Ministers 2017.

⁹⁶ The case study was carried out under the leadership of PlanMiljø.

⁹⁷ Nordic Council of Ministers 2017.

recent statistics are consistent with that figure. In Sweden, more than 1.3 million tons of food waste is generated along the food-supply chain annually, coming to 134 kg per capita.⁹⁸ The corresponding total in Finland is about 0.4–0.5 million tons a year, and the country's average annual food waste totals about 90 kg per person.⁹⁹ Norway's figures for annual food wastage are similar: about 0.4 million tons in all and approximately 85 kg per capita.¹⁰⁰ In Denmark, around 0.7 million tons of food is wasted each year over the full value chain, generating 124 kg of food waste per capita.¹⁰¹ Finally, there is about 0.04 million tons of food waste a year in Iceland, or 112.6 kg/person per year.¹⁰²

This represents significant resources and value simply being lost. By means of new solutions to tackle food waste and food loss, the Nordics may be able to ensure optimal utilisation of resources' value and closing of resource loops in the food value chain. Statistics from the UN Food and Agriculture Organization (FAO) indicate that most of the inefficiency in the food-related chain in the Nordic countries arises at the end of the supply chain and is due to consumption behaviours of end consumers.¹⁰³ Food is wasted at all steps through the food-supply chain, but households are the most wasteful element, generating up to 50–70% of food waste.¹⁰⁴

All of the Nordic countries have started focusing on the food waste generated by society and on how to prevent it. For example, the Swedish National Food Agency, in collaboration with the Swedish Environmental Protection Agency and the Swedish Board of Agriculture, has developed the action plan *More To Do* to reduce food waste along the entire related value chain. The target of the action plan, which extends over six years, is to decrease per-capita food waste by 20% by weight from 2020 to 2025.¹⁰⁵ In Finland, efforts are being made to intensify the monitoring and reduction of food waste and food loss. Natural Resources Institute Finland is developing a national food-waste-monitoring solution for the whole food-supply chain. The aim of the project is to develop associated indicators and systems for data-monitoring and data-processing. Also, part of the project's work is the development of a National Food Waste Road Map.¹⁰⁶

In Denmark, meanwhile, the national think tank ONE\THIRD was established by the Ministry of Environment and Food to strengthen efforts to prevent food waste and food loss. Voluntary agreements and joint initiatives between food producers and retailers have been established for reduction of food waste, and in 2021 Denmark negotiated an agreement for the development of international standards to reduce food waste.¹⁰⁷ In Norway, November 2021 saw the first national food-waste-totals report produced via the annual waste-monitoring that has been in place since 2010. An industry agreement on reducing food waste was signed in 2017 by five ministries¹⁰⁸ and 12 industry organisations.

In the first part of this study, the food and beverage industry was found to have high transition potential. The development of technology and adoption of sustainable production methods represent rich opportunities, and work in both areas is moving forward at a fast pace. In addition, there is huge economic and environmental potential in minimisation of food loss and food waste 'from farm (or sea) to fork'. At

⁹⁸ IVL 2020.

⁹⁹ Silvennoinen 2020.

¹⁰⁰ Matvett 2020.

¹⁰¹ Pace 2020.

¹⁰² Umhverfisstofnun 2020.

¹⁰³ FAO 2019.

¹⁰⁴ IVL 2020.

¹⁰⁵ Swedish Waste Management Association 2018.

¹⁰⁶ Luke 2021.

¹⁰⁷ Danish Standards 2021.

¹⁰⁸ Matvett 2020. The ministries involved are the Ministry of Climate and the Environment, the Ministry of Agriculture and Food, the Ministry of Health and Care Services, the Ministry of Children and Family Affairs, and the Ministry of Fisheries.

the same time, barriers to improvement may exist with regard to policy and regulations, common practices, culture, and behaviour.

Potential for digital tools

There is great potential for use of digital tools in food-waste prevention within at least three main areas:

- Sharing information about effective logistics between supply-chain actors could support optimising production and storage for market demand. Sharing information about sales forecasts for retail outlets or serving companies, inventory levels along the supply chain, and production plans should make it easier to adjust production for the expected sale demand.
- There is potential in information-sharing related to surplus food that – because of approaching expiry dates, closing times, or unexpected stock volumes – cannot be sold through normal sales channels. This is already visible in some sectors and among some companies in the Nordic region, especially in the retail arena and food-service sector.
- Registration and management of data about food waste generated by shop and other facilities could render the waste's monitoring more efficient and afford sharing data more easily with other organisations. Electronic balances with online registration of food waste are already available in some companies that serve food, while many retail and wholesale companies etc. engage in scanning of packed food before donating or otherwise disposing of it.

Potential for new business models

Several start-up companies in the Nordic countries have already begun to capitalise on the combined potential of food waste plus digital tools, addressing food waste issues related to business-to-business (B2B) supply-chain relationships and business-to-consumer (B2C) transactions. These companies facilitate selling or redistribution of surplus food and apply digital tools (holdbart.no, Matsentralen, Stadsmissionen, etc.) to manage food inventories. The following list provides an indication of the activity in this burgeoning area.

Commercial examples

- Eat GRIM provides a platform whereby B2B and B2C customers can order produce that, for reason of overproduction or aesthetic issues, would otherwise not have been sold for food use.
- FreshLand has created a platform that reduces the complexity of the food value chain connecting primary producers with consumers.
- WhyWaste is a digital tool for tracking foods' use-by and best-before dates in the retail sector and automating price reductions as 'expiry' approaches.
- TotalCtrl digitalises professional kitchens' food inventories and makes it easier both to monitor food waste and to register the types and amounts of food waste directly in a database.
- Too good to go (TGTG), Throw no more, and ResQ Club provide platforms whereby retailers and restaurants can share data about surplus foodstuffs and sell them at discounted prices.
- Circular Food Technology is a concept for utilising spent grain from breweries to produce flour.
- The company Beyond Coffee produces mushrooms by utilising coffee grounds.

Future perspectives

Food-waste prevention has received focus in the Nordic countries for more than a decade and has recently grown in importance among broader EU priorities because of the Circular Economy Action Plan and associated adoption of union-level waste legislation in 2019. The main global, European, and national goal for developments by 2030 is to reduce food waste and loss by at least 50% from a 2017 baseline level, thus creating significant opportunities for more sophisticated, effective digital tools for all parts of the value chain related to food. Accurate, traceable, and comparable measurements constitute a key starting point for national food-waste strategies and policies consistent with realising a 50% reduction in food waste.¹⁰⁹ The Nordic region boasts well-established systems for monitoring food waste, with Finland and Norway especially noteworthy for a 'bottom-up approach' that makes it possible to monitor the food-waste prevention efforts of a relatively large number of companies.

Digital tools that support food-waste reductions via reallocation of excess edible food could also form another part of the reporting schemes for this monitoring, and such tools' use can aid in follow-up on the waste-reduction work. For example, there are already digital tools for advertising the surplus food one has available (e.g., from restaurants at the end of the day or from hotel breakfast and lunch buffets), which is sold at reduced price to registered users. Other services advertise discounted food from the retail sector. Information generated via such tools can be utilised in the above-mentioned data-gathering too.¹¹⁰

Real-time data collection and compilation – pooling of data from the supply chain, transactions, domestic food waste, and other dimensions of the picture – can yield insight through the operation of artificial-intelligence-fuelled algorithms. When hidden behaviour patterns are thus uncovered, we can redefine consumer preferences via a new formula that sends timelier and more accurate signals to the market about demand.¹¹¹

Impacts of the minimisation of food waste

Business impacts

Better management of food production chains minimises economic losses from food waste and food loss. Optimising procurement supports minimisation of waste at source and affords more precise response to consumer needs. Among the potential direct benefits for organisations from reducing food waste are greater customer retention through attention to a well-publicised critical issue.

Often, produce is fragile and has a short shelf life, with the window of opportunity for its utilisation frequently being very short. In consequence, the immediate response afforded by digital tools holds great promise related to new business models that involve shorter value chains and better management of professional kitchens and retail stores. Also, digitalisation provides an opportunity to link food producers with surplus food or to integrate side streams into new business upcycling these streams and to sell discounted products to consumers.

¹⁰⁹ FAO 2019.

¹¹⁰ Schroder et al. 2021.

¹¹¹ UNEP 2021.

The value of information on food's consumption after purchase lies in disruption potential associated with greater predictability of consumers' actions. This gives the food industry an opportunity to alter its approach to business, from a model of simply producing more to one of wisely tailoring production to demand. However, such change typically necessitates additional procedures for managing the waste-prevention processes.

Climate and environmental impacts

Discussion of CO₂ reductions often underestimates the importance of food waste, even though this factor accounts for 8–10% of global greenhouse gases, which is nearly equivalent to the entire world's road-transport emissions. When food is sent to a landfill and rots, it produces methane, a greenhouse gas even more potent than carbon dioxide. Therefore, the waste has a huge impact on global warming and the future of our society.

Digital solutions to reduce food waste can support better utilisation of the food produced and aid in minimising waste. The amount of food that must be produced becomes lower, and, consequently, food production and rotting food waste produce fewer greenhouse-gas emissions. Both better utilisation of food and minimisation of food waste, by reducing the amount of food that needs to be produced, cut down on land use; waste; and the pesticide, herbicide, and fertiliser use involved in food production.

Socio-economic impacts

Although the world supplies enough food for everyone, nearly a billion of its people suffer from hunger and malnutrition. The food system is insufficient, and more than 30% of the food produced at global level is wasted while at the same time one in nine people lacks access to enough nutritious food. Better value-chain management for food should create improved access to it for low- or no-income households/individuals. Redistributing one's edible surplus food could yield the additional social benefit of improving the dietary health of lower-income end consumers by supporting a much higher intake of dietary fibre, vitamins, and minerals than many lower-end-cost food choices supply.¹¹²

Growing global demand for food is expected to put extra pressure on the agricultural sector. However, much of the need to produce more food can be offset by reducing the amount of food that goes to waste. Alongside this dramatic impact, minimisation of loss more broadly makes our food system more efficient, and fuller understanding of how and where food is being wasted helps us build a more robust food system.

3.4.4 Barriers to seizing the CE opportunity and possible solutions

Barriers related to this opportunity were identified in the following domains:

Technology barriers are created by factors such as the short life of produce, which requires smooth logistics if upcycling is to be guaranteed. These tools are not perfect – they do not yet represent a complete solution in their own right, particularly with their current limited implementation and market penetration. There is a significant gap between those who could benefit most from these tools (people/households possibly standing on the verge of food poverty) and those possessing the knowledge and capacity to use them.

¹¹² FAO 2019.

In food production, any suspected contamination of food leads to significant waste, as the current tracking technology cannot isolate individual batches of a product.

Regulatory barriers are created by food-safety regulations and tax laws surrounding food waste and products in retail. Many regulations make it difficult for stores to do anything with products that are close to their expiry date, while economic incentives, such as those of tax structures¹¹³, can render it less costly to discard food than employ any of the more sustainable alternatives. Regulations specify that some food products are to be stored warm for only a certain span of time, after which they may not be chilled or frozen and must be discarded if left unsold. With regard to digital solutions, data protection in accordance with the EU's General Data Protection Regulation (GDPR) must be considered in any application or service that uses consumer data.

Among the **market barriers** are incentives created by low waste-handling costs and strict food-safety regulations: wasting food rather than donating it may seem a safe precaution. In primary production, barriers could arise from conflict between farmers' desire for economic growth and the lower need for primary production should loss and waste be managed better.

In retail, there is a paradoxical relationship between discounts that prevent waste and a desire to sell products at full price. Discounting products close to their sell-by date can help reduce the amount of food wasted by supermarkets and other food shops but is still relatively uncommon.

Also, there are non-financial transaction costs associated with platforms, in the form of time requirements and sporadic availability.

Cultural barriers: Consumers' desire for food that looks as good as it tastes – and lack of willingness to accept produce that looks less appealing (although otherwise identical to aesthetically pleasing produce) – means that much of the produce waste that occurs for aesthetic reasons in primary production is driven by market demand for 'perfect food'. In addition, consumers still struggle to differentiate between use-by and best-before dates.

The following avenues are possible ways forward:

- Political and consumer awareness are vital – food waste is high on the agenda, with clear goals and both international and national policies/regulations promoting action.
- There are already cases showcasing successful co-operation along the value chain and demonstrating economically feasible digital redistribution solutions.
- More prediction-oriented and precise data-driven production and handling of surplus food more effectively, closer to the consumer, hold great potential for savings.

3.5 Models for increased (re)utilisation of buildings

3.5.1 Introduction

¹¹³ Until recently, the Danish VAT rules meant that retailers had to pay VAT on donations, making free food costly. A workaround has been found.

The next case study¹¹⁴ focuses on increased utilisation and value from the space that buildings present and provide. Better (re)utilisation of buildings and other structures may be exemplified by the following hierarchy, modelled on the waste-prevention hierarchy:

1. With the highest priority, using unoccupied space for its original purpose (e.g., putting vacant office space to use as office space)
2. Repurposing unoccupied space for a new purpose (e.g., in office-to-housing use) or occupied space for a new purpose (e.g., in office-to-housing use)
3. Reusing superstructure
4. Reusing building elements (i.e., doors, windows, etc.)
5. Reusing the material (for instance, after demolition)

Table 2, below, outlines construction by type in selected segments of the building sector in the Nordic countries.¹¹⁵ It is noteworthy that the share of renovation in monetary terms accounts for a significant proportion of the market activities.

Table 2: Construction, by type

Construction, by type Volume, in millions of euros at 2020 prices, excluding taxes		Sweden	Finland	Norway	Denmark
Residential construction	New	9,771	4,356	9,454	5,175
	Renovation	8,158	2,601	8,247	14,017
Non-residential construction	New	7,291	10,516	7,116	7,608
	Renovation	7,194	3,505	8,725	4,534

The case presented here focuses mainly on items 1–4 in the hierarchy of good building (re)utilisation presented above. While increasing the quality of construction and demolition waste such that it can be reused (item 5) is important for circularity and sustainable development of the construction sector, it was not the main focus of study here. This is because these areas have gained significant attention in the Nordics in recent years, while initiatives higher up in the value chain (e.g., for increased utilisation) are not particularly prevalent yet. Still, the opportunities identified in this case are not completely disconnected from initiatives such as recycling: best practice for increased utilisation of existing buildings can also help support higher-quality materials, related knowledge, and easy separation of waste, thereby enabling more extensive recycling.

¹¹⁴ The case study was carried out under the leadership of RISE.

¹¹⁵ EUROCONSTRUCT, June 2021.

Construction and demolition waste (C&DW) accounts for more than 30% of the waste generated in the European Union and at Nordic level. Today, the recovery-rate figure for mineral C&DW apart from waste soils is rather high in all of the Nordic countries (especially Denmark and Finland); however, this recovery consists largely of backfilling or low-grade recovery, such as using recycled aggregates in road sub-bases (downcycling).¹¹⁶

The national CE policy framework in the Nordic countries displays strong representation of the construction sector in CE policies on national level, both for mandatory waste-management/prevention plans and in other strategies. All these countries have set objectives or targets for this sector at multiple levels of policy. Furthermore, our review revealed the national policy scene to be somewhat similar across all the countries with respect to target-setting and objectives.

Numerous activities in the Nordics currently focus on increased building (re)utilisation. Nordic countries are taking action aimed at amending EU legislation in such a way as to facilitate the CE transition. For example, Finland's goal of being a leader in circular economy by 2025 is reflected both in its regulation of the construction sector and in policy planning. The pending reform of the Land Use and Building Act is to include proposals for numerous provisions that promote circular economy, such as requirements related to the longevity of new buildings and how they are best repaired and demolished. From a regulatory perspective, all of the national Nordic governments – with Denmark, Norway, and Sweden as striking examples – have articulated action plans related to circular economy in the construction sector.

Various organisations in the Nordics are engaged in supporting circular construction initiatives, among them Green Building Council Finland and the Confederation of Finnish Construction Industries, which has created a low-carbon roadmap for the construction industry in Finland. Also, collaboration and knowledge-sharing hubs are being formed in Sweden (one example is Centrum för Cirkulärt Byggande). In addition, green building certification systems are in use to help companies improve buildings' sustainability. Some are connected with international schemes such as BREEAM and LEED¹¹⁷, as well as the Nordic-developed Miljöbyggnad.

Also, local and regional administrations (municipalities and counties) throughout the Nordics have a wide variety of strategies at their disposal, alongside tools serving the promotion of circular and sustainable construction. It should be noted that most targets in the Nordics are focused mainly on preventing/reducing C&DW, though these vary between regions. Some examples are

- Helsinki City Strategy 2017–2021, targeting reduction of greenhouse gas emissions through Helsinki's construction work and buildings;
- Byggeri København, prioritising circular economy in construction projects undertaken by the City of Copenhagen, in line with a handbook on circularity principles that the initiative developed to guide such projects;

¹¹⁶ Zu Castell-Rüdenhausen et al. 2021.

¹¹⁷ Høibye and Sand 2018.

- The 'Upphandlingskrav för cirkulära flöden i bygg- och rivningsprocessen' procurement requirements established by the City of Gothenburg to encourage circular economy in construction and demolition; and
- At Nordic level, the New European Bauhaus¹¹⁸ endeavour, complemented by shaping of a Nordic perspective¹¹⁹. A creative initiative designed to combine sustainability, inclusion, and aesthetics, New European Bauhaus is an environmental, economic, and cultural project initiated by the European Commission.

In its present form, the EU Construction Products Regulation requires products used in construction to bear the CE mark in most cases. Usually, this is not possible for reusable materials and construction components, so full-scale utilisation of circular construction materials nearly impossible. That said, for reaching the targets for circular construction in the Nordics, seeking ways in which existing buildings could be better utilised or retrofitted to serve new purposes represents a much more promising path.

Potential for digital tools

Currently, little digitalisation is visible in the Nordic building and construction sector; however, there is significant potential. Digital tools suited to the early building-design stages can help designers select materials and production methods that enable structures to be designed for later adaptability (i.e., for the ability to adapt as needs change). Creation of 'digital twins' could inform virtual models for new-building design, models via which building activities can be tracked by means of real-time operation data. These would also facilitate maintenance. Since most building maintenance today is reactive, remote sensors (e.g., to measure moisture levels) have much to offer for predictive-maintenance purposes and for contributing to longer building service lives. Simultaneously, tracking resource use in buildings (e.g., water and electricity consumption) and installing smart sensor technology can contribute to energy-efficiency and reductions in carbon emissions.

Digitally enabled tracing for waste and building materials' information can facilitate reuse and recycling. For example, digital material passports can enable reuse of building components, thanks to documentation of a building's elements and use patterns. Digital platforms can facilitate optimised building use, such as sharing of unused office space. They can also contribute to reuse efforts, through such mechanisms as a marketplace where organisations can trade surplus materials.

Potential for new business models

Such new business opportunities as leasing, sharing, or rental of unused space show great potential for fuller utilisation of existing buildings and their structures/components.

The related commercial practices visible in the Nordics often focus on reusing surplus materials and interiors, rather than on structural elements. However, some examples of designing for easy disassembly and reconstruction do exist. The following list of building (re)utilisation efforts from around the Nordic region is organised in accordance with the hierarchy presented earlier in this section.

¹¹⁸ European Commission 2021.

¹¹⁹ Ministry of the Environment of Finland 2021.

1. Using unoccupied space for its original purpose (e.g., office-to-office or housing-to-housing use)

- In Stockholm, Arcona is renovating and modernising the property Skjutsgossen 12, on Södermalm¹²⁰. Projects of this type can often take the form of renovation projects.
- The suburb of Kummatti¹²¹, in Finland's Raahe, demonstrates improved living comfort, energy-efficiency, and maintaining a larger area put to its originally intended use. Prior to the renovation project, 13 apartment buildings had deteriorated beyond repair, while the demand for large family homes declined simultaneously. Unneeded concrete elements were reused locally, and the energy-efficiency of the remaining building stock was improved. Smaller new flats were built, to mirror current needs more closely.

2. Repurposing spaces for new purposes, whether unoccupied ones (e.g., in office-to-housing or warehouse-to-office use) or occupied ones (e.g., in office-to-housing use)

- In Helsinki, the company Auratum converted a former office building on Munkkiniemi¹²² for modern residential use. In addition to a complete overhaul, the building stock was complemented by a townhouse building. The flats were built to high quality standards and were modern in their solutions, respecting the spirit of the building.
- In Sweden, NCC converted an old jam-manufacturing facility into a creative office space¹²³. The new space maintained its factory character, yet the new space was modern and creation-supporting. Open-plan office spaces are in white to give employees the opportunity to create character themselves when they move in, while the many meeting rooms have black floors, wood panelling, and a more playful and creative feel.

3. Reusing superstructure

- Blixens – OPS GellerupBlizen – has provided a Danish building whose structures feature recycled materials and parts (floors, walls, and façade) and also has incorporated sustainability into the building's use (e.g., supplementing toilet-flushing with rainwater and optimising the use of solar and other energy).
- FM-Haus Oy is a Finnish company creating structures from wooden modules that can be unmounted for transport and later reconstructed.
- Hollow-core concrete slabs represent another promising area. For instance, Oslo's new emergency medical centre will utilise reused concrete slabs.
- In Oslo, the Høybråten¹²⁴ primary school was completely renovated save for its superstructure. Built in 1923, the building itself could be improved while at the same time the renovation preserved the local historical environment.

4. Reusing building elements (doors, windows, etc.)

¹²⁰ Arcona 2021.

¹²¹ Finnish Association of Architects 2021.

¹²² Auratum Asunnot 2021.

¹²³ NCC 2020.

¹²⁴ Høybråten skole 2021.

- Upcycle Studios / the Resource Rows are construction projects by the Danish company Lendager that reuse existing building components from vacant houses (mainly windows) and other recycled materials (such as concrete from construction waste).

5. Reusing materials (after demolition)

In Vantaa, Finland, environmental management company Remeo has invested in downstream production based on building-waste separation with a newly constructed waste-separation facility¹²⁵. The facility makes use of advanced robotics in its operations.

Initiatives to catalyse CE

- The Nordic Network for Circular Construction project aims to create insight into the status of circular construction in the Nordics and of best practice surrounding it, create a voluntary system of goals and indicators, improve dissemination of the good practices identified, and create lasting impacts on Nordic construction culture.
- CIRCWASTE is a seven-year LIFE IP project that promotes efficient use of material flows, waste prevention, and new waste- and resource-management concepts. Most of its subsidiary projects address construction. In this project, programmed for 2016–2023, all actions contribute to implementing the national waste-management plan and guiding Finland toward circular economy. The CIRCWASTE project, a creation of 20 partners and 10 funding organisations, is co-ordinated by the Finnish Environment Institute (SYKE).
- FutureBuilt is a collaborative undertaking of six municipalities in the Oslo region striving to support climate-friendly urban development. The project is organised in terms of various thematic criteria, including conditions for circular buildings and circular neighbourhoods. By September 2021, FutureBuilt already was involved in 69 pilot projects, both public and commercial. Among these are creation of a new municipal work centre and housing for people with disabilities in Asker that has applied FutureBuilt's criteria for circular buildings. For example, the rebuilding will entail use of existing wood materials and stone walls.

3.5.3 *Future perspectives and impacts*

Future perspectives

New design methods and approaches geared for increased building (re)utilisation are gaining traction. The work includes designing buildings for multiple types of use and enabling circular-economy services and models (e.g., in line with the Finnish example of Savonkatu¹²⁶). In this field, modular design, design for disassembly, and advanced reconstruction techniques can contribute to structures that adapt to users' changing needs and encourage reuse.

A case from outside the Nordic region is worth noting here for its incorporation of modular design, coupled with biomimicry: the UK-based company Biohm uses plant-based materials such as mycelium and applies

¹²⁵ Remeo 2020.

¹²⁶ NCC 2021.

modular construction principles that afford easy rearranging of structures. Such developments could dovetail well with the Nordics' attention to wood as a promising construction material, thanks in part to Finland and Sweden being the two most heavily forested countries in the EU¹²⁷ and to wood being viewed as a sustainable building material there.

It is anticipated also that office buildings will see significant changes in a post-COVID world, with some market analysts predicting 30% lower demand for office space.¹²⁸ There are plenty of opportunities to increase space utilisation, rethink existing office designs to accommodate changes in work patterns, and potentially avoid new construction. Considering buildings from a user-centred design perspective instead of a purely technological one is likely to help create buildings that can contribute to better quality of life for their main occupants.

Impacts of building (re)utilisation

Business impacts

The (policy-driven) growth in demand for circularity of buildings is expected to have a direct impact on building-material producers and – especially – on buildings' owners and developers, who will need to account for such requirements in their sourcing of building materials and in their design, refurbishment, and demolition activities. The impact could either offer or diminish business opportunities.

Positive long- and short-term business impacts on direct cost savings in resource consumption are expected to manifest themselves as buildings remain in use longer, resources are shared, more building materials get reused and recycled, and hence fewer are produced from new primary resources. There are also predictions for some temporary (direct and indirect) negative impacts amid the transition toward circular economy in construction, connected with a greater need for good planning, documentation, logistics, storage, and transportation of building materials; with regulations; and with overall resource-efficiency.

Opting for more circular methods instead of conventional construction practices may create additional operations costs during the implementation phase. For example, in a Swedish case study, selective demolition was estimated to be nearly twice as expensive as conventional demolition¹²⁹. For the long term, though, the positive impacts can be expected to offset temporary negative ones that may be created during implementation.

Building (re)utilisation may cost less than demolition and rebuilding, yet prior studies point to potential for higher resale value of buildings that have been repurposed. While rebuilds may entail remediation for the existing structures (i.e., hazardous materials' removal or structural reinforcement), which can be costly, refurbishment still can bring lower risks than new builds – e.g., with less time required for refurbishment than for new buildings. At the same time, diverting and salvaging raw materials from waste streams can lead to cost savings or new economic inputs (from saving on disposal fees or from reselling materials). Since the solutions for building (re)utilisation are developing continuously and at a fast pace, in response to complex needs, case-specific evaluation of the short- and long-term impacts is necessary.

Climate and environmental impacts

¹²⁸ CNN 2021.

¹²⁹ Sheidaei and Serwanja 2016.

The most obvious direct positive impact lies in a smaller material footprint. Reuse, material substitution, and reduction in construction-sector waste are projected to reduce resource consumption in the Nordics by 20% from current levels¹³⁰. However, environmental impacts must be evaluated on a case-by-case basis. This is due to potential for generation of hazardous waste in existing buildings and to the energy consumption of the older building stock, which is often high. If such buildings are repurposed, consideration must be given to improving their energy-efficiency and ensuring that exposure to hazardous materials is minimised.

Increased rates of reuse and recycling are expected to bring lower carbon emissions. For instance, it is often more carbon-efficient to retain certain parts of built structures rather than demolish them. By some forecasts, incorporating circular economy into the Nordic construction sector could decrease greenhouse gas emissions by approximately 10 million tonnes in total (for the four Nordic countries studied)¹³¹. In the above-mentioned Swedish case study¹³², selective demolition was found to contribute to considerable reduction of global-warming impacts relative to conventional demolition.

Nonetheless, climate impacts may differ greatly, depending on the initial components (and constituent materials) to be repurposed or reused. In their analysis of creating new building components from discarded construction materials, the Nordic Built Component Project concluded that bricks, metal, windows, and wood display environmental benefits while concrete does not – because its reuse demands more energy consumption than new production does. Another factor is that further emission reductions can be achieved by incorporating the use of sustainable design techniques into buildings' design. This includes using roofing as a source of carbon-sequestration, cooling, and biodiversity benefits.

Increasing the degree of buildings' utilisation possesses potential to reduce the need for new construction significantly, thus contributing to resource-efficiency and reduced carbon emissions during both creation and use, while also reducing so-called embodied carbon (held within the building materials themselves). Again, it may prove more carbon-efficient to keep certain parts of built structures in place rather than demolish them. One example is the superstructure, which can be easily retained if structurally sound while still serving, if desired, creation of an entirely new architecturally entity.

Socio-economic impacts

Buildings play an essential role in how people live and inhabit areas. Transition toward circular designing, building, operating, and maintaining of buildings comes with direct socio-economic impacts linked to living environments, health, and well-being. For example, building (re)utilisation implemented as repurposing can also help to revitalise existing neighbourhoods and communities – bringing new housing, jobs, and business activities to previously underutilised areas, both urban and rural. Reuse allows for continued use of a building and helps it remain a viable community asset. Additionally, buildings represent social and cultural capital. Therefore, their increased (re)utilisation contributes to preserving Nordic heritage and history.

Adaptive (re)utilisation can lend renewed vitality to any buildings that may be underused, abandoned, vacant, dilapidated, or obsolete in their function. The sites of existing structures are often in established growth areas with a significant population density and in developed areas. Repurposing these existing structures should assist in supporting regional development and providing facilities where there is high demand.

¹³⁰ Høiby and Sand 2018.

¹³¹ Ibid.

¹³² Sheidaei and Serwanja 2016.

Notwithstanding its promise, building (re)utilisation is not always possible. Also, negative impacts are possible, in both the short and the longer term. Existing buildings, their elements, and the materials used cannot always meet new building standards. Building materials may present safety concerns, some of them related to potential health impacts. For example, some toxic materials once commonplace in building construction are now banned and should not be reused, and human exposure to them should be limited.

Moreover, significant expertise and testing are required for guaranteeing safety when buildings are being repurposed, or components reused. While this represents significant investment, it can also lead to cultivating valuable skills since R&D and innovative solutions are needed if one is to undertake fruitful building (re)utilisation.

3.5.4 *Barriers to seizing the CE opportunity and possible solutions*

Barriers standing in the way of this opportunity were identified in the following domains:

Technology barriers: Digital solutions used to store information on buildings' components and materials must be kept compatible with technological developments throughout the life of the building and be updated accordingly – otherwise, accessibility of the information may be compromised by the time it is needed. Additionally, a standardised method should be applied, lest many distinct (potentially conflicting) approaches vie for dominance.

One significant source of challenges is the life span of buildings. Buildings normally last 50 year or more, in which time technologies and styles change significantly. This means that components might not end up reused, for reason of obsolescence. Energy consumption is another key factor with relevance for any built environment, so estimates should consider this too, for the space's entire life cycle, also in terms of CO₂ equivalents for a wide range of alternatives and space-use/utilisation scenarios¹³³.

Regulatory barriers: Disparate building regulations, displaying differences between individual EU member states, can hinder trade both within the European Union and between Nordic countries. In spring 2020, the Nordic countries set up a joint steering group to co-ordinate their harmonisation of building regulations. However, experts expect new harmonised regulations to be unable to overcome the above-mentioned barriers on their own, let alone suffice as the policy instruments for accelerating transition toward CE in the Nordic construction sector. Expectations are that companies may need stronger economic incentives to switch from their – often linear – current business approach.¹³⁴

Hazardous substances contained in existing buildings often preclude their reuse. Old buildings and their materials cannot always meet new building standards. End-of-life waste protocols are not sufficient to keep various of the materials in market circulation longer. Article 6 of the Waste Framework Directive (WFD), Directive 2008/98/EF¹³⁵, states that criteria specific to end-of-life-waste should be considered at least for aggregates, paper, glass, metal, tyres, and textiles, but there is no direct imposition of any obligation to set such criteria. Consequently, the Nordic countries could differ vastly in how their C&DW is treated.

¹³³ Confederation of Finnish Construction Industries 2020.

¹³⁴ Høiby and Sand 2018.

¹³⁵ See <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN>.

Market barriers: Another ramification of buildings' typically long service life is that the building materials are tied up in use for a long time, rendering return-on-investment arguments challenging – arguments for designing buildings for ease of repurposing or disassembly seem less compelling. Simultaneously, market demand for recycled and reused building materials is lacking, on account of competition between such materials and non-recycled, non-reused ones.

Closed material loops require effective and well-connected processing infrastructure that incorporates selective waste-collection points, processing facilities, adequate organisation among demolition companies, suitable online platforms, and databases informing about the market for reused and reusable materials. This value chain has only just started to take shape.¹³⁶ Since it is underdeveloped, substantial market barriers remain.

Cultural barriers: As multiple case studies of building reuse in the Nordics attest, additional knowledge and testing are required if we desire solid quality assurance for reused building materials. In contrast, the current landscape lacks quality-assurance marking schemes for reused building materials. Moreover, the lack of building-information modelling and material passports for old buildings – coupled with low quality of statistical data on material flows – poses a major challenge to implementing building (re)utilisation.

The following avenues are possible ways forward:

- Digital material passports support progress by making product information available.
- Circular design techniques such as design for disassembly enable disassembly, reconstruction, and materials' separation.
- Reducing the amount and number of hazardous materials in buildings lowers barriers.
- Public-procurement systems can create incentives for green building guidelines, circular construction methods, and thorough investigation of all possible alternatives prior to new construction (repurposing).
- Policy measures could encompass mandatory quotas for reused/recycled materials in building construction or a contractor-responsibility mechanism to sort reusable and recyclable materials from others during construction and after demolition.
- Price increases for virgin raw materials push the building industry toward resource-efficient alternative materials, reuse, and recycling.

3.6 Digital platforms supporting circular economy

3.6.1 Introduction

The team also undertook a case study¹³⁷ focusing on digital platforms as a means for increasing the degree of utilisation of surplus resources already available and for, by minimising waste, slowing and closing the loops in circular-economy activities. Digital platforms can establish circular business models based on data-enhanced recovery and reuse of functions and materials. At their optimum, well-constructed digital

¹³⁶ Høiby and Sand 2018.

¹³⁷ The case study was carried out under the leadership of Gaia Consulting.

platforms enable data-driven, cross-sector, end-to-end interactions for circular economy by overcoming information asymmetry between actors. In their simplest form, the digital platforms provide information about underused resources and material streams, thereby enabling resource-efficiency and tightening the material loops. At their best, digital platforms catalyse collaboration and shared benefits by unlocking relevant information and by actively orchestrating interaction among stakeholders on the platform, so as to generate novel CE solutions and joint ventures. This collaboration and the concept of shared benefit creation in the ecosystems are widely accepted as one of the key drivers of the circularity transition.¹³⁸

Marketplaces for repairing and maintaining products¹³⁹, alongside markets for consumer goods and services, were beyond the scope of this study, because they are described in connection with other cases (e.g., in relation to food waste and smart mobility). This section of the report focuses on those digital marketplaces intended for non-expert B2B operators, though it touches on digital platforms more generally and their role in enhancing interoperability, information exchange, and knowledge-sharing.¹⁴⁰

If we wish to make use of the various by-products of industry, construction, and demolition and to generate profitable business, we require information on usable materials and their volumes, properties, and location. Providers and users of the materials need to find each other. Digital platforms can act as a marketplace for materials and promote the emergence of markets, new product innovation, and the development and use of various services.¹⁴¹

This opportunity ties in with all of the areas identified in part I of the study¹⁴². Here, emphasis is given especially to construction and real-estate markets since the reporting on other CE opportunity case studies overlaps more extensively with discussion of digital platforms.

3.6.2 *The current state of Nordic CE*

There is ongoing work on development projects related to new and existing digital platforms in the Nordic region. Digital platforms' development is supported also at European Union level. For example, the DigiPrime project is an EU-funded Innovation Action aimed at developing and demonstrating a digital platform with corresponding services. The project encompasses 20 pilot cases, from many sectors of European industry (automotive operations, renewable energy, electronics, textiles, construction, etc.),¹⁴³ and 11 European countries are involved, with Sweden being one of the participants.

Experiments with digital platforms for the trade and exchange of side streams have been carried out in many countries in the context of material-efficiency programmes, some international examples being industrial symbiosis programmes led by the company International Synergies Limited (ISL). There also exist Nordic platforms for more general knowledge exchange, such as Nordic Circular Arena¹⁴⁴ and the Circular Regions Platform¹⁴⁵ (to be launched in March 2022). These platforms support the development

¹³⁸ DigiPrime 2021.

¹³⁹ In Finland, examples include lainaa.se (meaning 'borrow.it'), for sharing such resources as tools and equipment, and korjaa.se ('repair.it'), for connecting owners of broken goods with local professionals who may be able to repair them, alongside platforms for selling companies' used computers, furniture, etc.

¹⁴⁰ DigiPrime 2021.

¹⁴¹ Motiva 2021.

¹⁴² Luoma et al. 2021.

¹⁴³ DigiPrime 2021.

¹⁴⁴ Nordic Circular Arena 2021.

¹⁴⁵ Circular Regions Platform 2022.

and implementation of better policies and economic incentives for circular economy, as well as the establishment of new market opportunities via pilot projects.

Availability of individual platforms and marketplaces has so far been limited to relatively small audiences. Nonetheless, several of these marketplaces compete with each other. A common challenge is that many of these digital platforms are established through public development projects and lack the ability to expand their services to commercial scale.

Whether existing platforms have brought business benefits to their users remains unclear. A true breakthrough of digital marketplaces for materials in the Nordic countries is still unrealised. Interaction and exchange of information **between** platforms is necessary for their improved performance, alongside addressing the crucial need for higher-volume material flows over the platforms.

Notwithstanding the current challenges, digital platforms are a necessity for ensuring circular practices connected with material flows, and they are needed for maintaining the value from circulating materials as long as possible. Since using recycled materials can greatly reduce the consumption of natural resources, places where one can promote the reuse of waste and by-products are crucial. Digital platforms provide a 'meeting place' for operators and users of recycled materials. The emergence of such industrial symbioses is seen as a prerequisite for the circulation of materials. Digital platforms make the material flows more visible, such that new means of utilisation can emerge around them. In the ideal case, the platforms should form an ecosystem with a marketplace for CE data, information, know-how, and material resources (materials, energy, etc.) and an incubator for new ideas and business opportunities.

As the digital platform is itself a digital tool, there is no separate introduction to digital tools in the reporting here. Also, again, the discussion here is focused on stimulation via B2B platforms.

Potential for new business models

Platform-provision businesses are taking over every industry and are already woven into day-to-day life, whether we recognise this or not. A platform business applies a business model of creating value by attracting and connecting participants in large numbers, then enabling transactions among them. The platform businesses sell services and access to the platform. No physical products trade hands.

Commercial examples

- Upcycling Forum is a Denmark-based digital platform that both serves as a marketplace for residual and demolition materials and grants access to shared knowledge, simultaneously creating sustainable collaboration among members, against a membership fee.
- The Upcycl, also from Denmark, is a digital platform and catalyst for the utilisation of multiple material streams, such as leather waste from sofa production. There is a membership fee, which participants pay to gain access to the resources and connections. The revenue from membership fees enables further development of the platform.
- In Finland, Maapörssi provides a marketplace for land-based resources and infrastructure-construction materials. Site managers may announce their need for land-based materials or look for a place to deliver the excess material from their site. A digital app provides guidance in navigating the environment-related procedures involved.
- Materiaalitori is Finland's digital marketplace for exchange of waste and production side streams among companies and municipal organisations. For further development of the collaboration,

Motiva is working alongside Finnish regional authorities to develop a data platform that could bring together Finland's various marketplaces already active in this field.

- Kompanjonen.se, in Sweden, provides a digital platform for buyers and sellers in resale transactions involving used interior building materials and products. There is also ReAppli, developing an app for reuse of white goods from renovation projects. Another illustrative collaboration and knowledge-sharing platform in the country's construction sector is ccbuild.se.
- Loopfront is a Norwegian platform for circular partnerships in the real-estate sector. It covers circularity-oriented property management, collaboration, and exchange of reusable materials between stakeholders.

3.6.3 *Future perspectives and impacts*

Future perspectives

With increased pressure for resource-efficiency, decoupling economic growth from resource consumption, and waste prevention, the need to make sure of materials' optimal use will increase. It seems inevitable that marketplaces for materials exchange will have a role in this development. They offer means of building viable business models by increasing volumes.

Increasing costs facing various industries from the waste they produce is pushing demand for efficient material markets. Ultimately, digital marketplaces are needed to meet that demand. Development of digitalisation that enables better tracing and the use of AI tools to match demand to supply of materials is a key driver for making these platforms an efficient and practical foundation for new business models. Building a well-functioning platform ecosystem requires synthesising and harmonising data from many sources, in multiple formats.¹⁴⁶

The public sector has an important role in developing material markets. Incentives to use recycled materials must be created, both via regulatory action and through rendering their use appealing to customers. Public procurements play a vital role in developing these markets. When public actors demand circular procedures in their (often large) purchases, the suppliers' response supports development toward more sustainable procurement.

Impacts of digital platforms for materials exchange

Business impacts

Digital platforms offer utility for CE within all sectors, as a tool for increasing material-efficiency and especially for narrowing and slowing (but also closing) the circular loops. However, it should be borne in mind that the digital platforms reflect the actions of the operators and other stakeholders using them. The impact of these platforms hinges on the materials provided, the specific volumes of particular materials, and their providers and users. Digital marketplaces can differ greatly in their business impacts, which depend on the segments of the material markets possibly targeted. Some of the generic business impacts are related to cost savings from avoiding waste-handling fees by means of more extensive use of the materials and side streams. Waste-reception fees are still relatively low in most Nordic countries, but, as

¹⁴⁶ Motiva 2021.

these costs increase, the use of recycled materials will become more profitable. When the side streams can be sold at a price that covers the logistics costs, this activity starts turning a profit. This can create significant positive impacts on businesses both in the short and in the long term.

Digital platforms enable the optimisation of logistics and can help decrease transportation costs. Algorithms can facilitate optimal distribution of resources in the short term, and automation can eliminate much of the drudgery of modern work for the longer term. Digital marketplaces can also generate new business for circular-economy companies, entities that produce side streams, and even completely new businesses. Optimisation and matchmaking can pave the way for new types of business models. For instance, advanced data-analysis-based business models may emerge.

Climate and environmental impacts

It is evident that bringing about circular economy requires establishment of digital infrastructure wherein the physical and digital elements go hand in hand. Tracking complex circular flows of material, their environmental safety and potential CO₂ emissions, and material-efficiency is important if we are to meet the circular-economy targets, which ultimately are derived from the will to live within the environment's limits and to tackle CO₂ emissions. It is safe to say that digital platforms hold massive potential for positive impacts on the climate and our natural environment. However, there are multiple uncertainties linked to the volume and the pace of those predicted impacts.

A digital sharing economy is of interest both to companies and to consumers, who recognise economic as well as social benefits in environmental protection. Replacing many elements of the production process and in distribution of products and services with information-mapping performed via online platforms makes it possible to optimise resource use. Better circulation of materials helps to avoid emissions by reducing waste-linked logistics and reducing the use of virgin resources. Logistics around materials' circulation must be planned and timed well, to avoid unnecessary transport costs and emissions.

Digital platforms offer new market opportunities and allow the vision of a genuine sharing economy to be realised. Thus moving away from 'owning' to 'using' should lead to a reduction in consumption and in the negative impacts on the environment. Typically, 'using instead of owning' models have been more prevalent in B2C markets, while product-as-a-service ones accompanied by digital platforms have become more common in B2B and B2C markets both. However, some logistics challenges remain, such as frequent mismatch between the location of the material and its potential place of use. It should be recognised also that digital services, platforms, and infrastructure consume significant amounts of electricity, as global totals remind us.

Socio-economic impacts

The onward march of technological progress in nascent digital platforms in recent years implies numerous transformations in various areas, such as consumption and business transactions. While these changes, in turn, are likely to create significant socio-economic impacts, their impacts remain somewhat veiled. Still, they are predicted to be positive on balance in terms of social inclusion, employment opportunities, and cost reductions. Digital marketplaces can play a significant part in bringing circularity targets closer to our reach. If business services around such platforms come to fruition, employment opportunities should follow. There is no indication that any negative effects could arise with regard to a decreasing need for labour, yet negative impacts may emerge if platforms contribute to the increase in job insecurity by promoting practices referred to as fictitious self-employment.

Digital platforms also play a role in knowledge-sharing and in making data available to a wider audience. These platforms are becoming useful for developing new earning models too, by providing access to

lower-cost services and products and by encouraging social inclusion. Circular economy in the Nordics will benefit from consumers and businesses increasingly taking responsibility for promoting contemporary models of consumption and production, while simultaneously generating well-being and prosperity.

3.6.4 *Barriers to seizing the CE opportunity and possible solutions*

Barriers connected with this opportunity were identified in the following domains¹⁴⁷:

Technology barriers: The digital platforms need to enable good interfaces if one wants to encourage the development of new business models around them. Challenges are still visible in relation to keeping the data up-to-date and reliable. There is also need for a process that functions well enough in the interim before such services work properly. Furthermore, the quality and comparability of data on the materials offered are usually insufficient. Irrespective of the digital information flows and development of services, large challenges exist in relation to storage and logistics.

Regulatory barriers: Systems for environmental permits can vary even within a given country, so a solution that works in one place may not receive a licence to operate somewhere else. There are challenges connected with classifications and procurement criteria also – e.g., in relation to end-of-life waste definitions. For the material's full potential to be unleashed, it ought to lose its designation as waste. However, one should also examine whether regulations truly create barriers or, rather, the actors do not understand how to interpret the regulation. So far, though, the legislation seems to lag behind innovation and does not offer enough incentive for a shift to more recycled materials. The lack of regulation that could somewhat 'force' data-sharing strips the digital platforms of their fullest potential. Since actors need not share information about side streams or the waste generated in production, the loss of materials in the cycles is inevitable.

Market barriers: Market barriers include difficulties of timing between supply and demand; problems in matching demand with exactly the right material (e.g., building materials that have been treated in different ways are not always interchangeable); and the small size of local markets, especially in more sparsely populated Nordic locations. Long-distance transport of materials is rarely justified. In many Nordic countries, waste fees are too low for it to be profitable or otherwise attractive not to send the material to a waste plant. Furthermore, the markets need to be highly specialised if these transactions are to function well. National or international platforms do not appear to be a solution. While the former might work in smaller countries, the lack of economies of scale would be expected to remain a major obstacle. Still, the concepts might have export potential.

Cultural barriers: Attracting users to a new marketplace is especially challenging in B2B environments. Intermediate services could help in this regard, as information and marketplaces tend to be difficult to find otherwise and the benefits may seem unclear to particular companies. Another factor is the attitudes of authorities, which do not always support such processes. Furthermore, some sectors, such as the building and construction sector, can be conservative and reluctant to alter seemingly well-functioning processes.

The following avenues are possible ways forward:

¹⁴⁷ See also, for instance, Silfver 2021.

- There is potential for practices in which the materials get reported upon via a digital platform long before dismantling, discarding, or availability of surplus material. Also, deeper analysis of the materials and their properties over various stages of their use cycle could prove beneficial.
- The rapid growth of digital platforms and the sharing economy in the B2C market could be exploited in a manner that renders B2B platforms too easier to adapt.
- Know-how can be shared among companies, city entities, Nordic countries' national actors, and other authorities, with generation of supportive intermediate services related to platforms.
- There is value in establishing regional hubs for materials instead of treating the material as waste. Likewise, generating opportunities for pilot projects for the solutions developed to utilise waste materials could yield benefits (via both Nordic co-operation and pilot networks).
- Financial sanctions on dumping and higher gate fees at waste facilities would make virgin material much more expensive, thereby rendering recycling and circulation of existing materials more appealing.
- Public procurement holds potential – if public buyers demand circular processes and use digital platforms actively in their procurements, the markets will develop.

3.7 Smart mobility solutions

3.7.1 Introduction

Part I of the study¹⁴⁸ clarified that transport and logistics are engines of circular economy in themselves, important parts of the economy as it stands, and particularly significant sources of environmental burdens. The business area can be subdivided into two parts, of which the presentation of this case¹⁴⁹ deals with the transport of people (as opposed to goods or resources). We have excluded consumer aviation from our examination of this aspect of transition, since it is considered to present qualitatively different challenges and opportunities relative to surface transport. Furthermore, the focus was restricted predominantly to domestic transport – there is a clear need and desire for lowering emissions related to personal transport, which is manifested in specific targets for reduced emissions from transport in nearly all countries.

There are two fundamental pathways to reducing the environmental burdens from personal transport. Firstly, obvious potential exists for reducing emissions from private vehicles' ownership, through such mechanisms as electrification of motoring and the phasing out of impactful fossil fuels. This move, while already well under way across the Nordics, is arguably not particularly circular. Of more relevance for our purposes is the development of mobility solutions that reduce the demand for private vehicles' ownership and use. This transition opportunity is focused specifically on mobility as a service (MaaS) solutions, where the domain has been defined by the MaaS Alliance¹⁵⁰ as 'the integration of various forms of transport services into a single mobility service accessible on demand'.

¹⁴⁸ Luoma et al. 2021.

¹⁴⁹ The case study was carried out under the leadership of NORSUS.

¹⁵⁰ See MaaS Alliance 2021.

The key elements of MaaS are the integration of several transport services/modes and the on-demand accessibility of the service. In essence, MaaS solutions encompass two sets of transport modes:

- 'Public' transport modes, the crucial element of which is specific obligations to public authorities. Since they may be owned/operated privately or publicly, perhaps their clearest defining property is the provision of scheduled transport services between established nodes. Examples are heavy rail, metro, bus, and ferry services.
- 'Private' transport modes, which often provide first-mile or last-mile services. They often operate on an on-demand rather than a scheduled basis, and they may be (but are not necessarily) privately owned/operated. Among them are taxis, ride-sharing and carpooling, car hire, and some scooter and bicycle services.

The level and nature of integration between distinct transport nodes and, especially the spanning of the 'public'/'private' divide, might well constitute the defining characteristic of MaaS solutions. Sochor and colleagues¹⁵¹ have presented an informative 'level model' or hierarchy:

- Level 0: no integration between services
- Level 1: integration of information (e.g., travel planning across transport modes)
- Level 2: integration of booking, ticket services, and payment
- Level 3: integration for a full service offer (consumers being offered packaged or subscription alternatives)
- Level 4: integration of policies and controls

MaaS initiatives lie somewhere between levels 1 and 3, although the positioning of any specific initiative is often unclear. For example, Transport for London has been cited as a Level 0 operation, yet this seems curious – as in many other cities, worldwide, elements of levels 2 and 3 (integrated ticketing across multiple transport modes and bundled offerings) are obviously in evidence. With Västtrafik, in Gothenburg, being a very similar example, the authors of the study report must acknowledge the relevance of classification difficulties¹⁵². One pattern visible nonetheless, in London and many other cities, is that bundling and integration across 'public' modes is common while 'private' modes are integrated poorly, if at all.

Level 4 should be viewed more as a set of enabling conditions than as a distinct service level of the sort levels 1–3 are. Furthermore, there seem to be few examples, if any, of true level-4 integration. Even descriptions have proved to be tricky: while it has been characterised as 'integrating societal goals', such a definition is probably inadequate. In the London example, the competent authority combines the bundling of public transport modes with road-congestion-based fees, citing the expressly stated societal goal of reducing congestion and pollution in the city. In contrast, full level-4 integration in practice should probably imply treating 'private' transport modes and 'public' ones in a fundamentally similar manner; that is, incentives and instruments normally directed solely at public modes should instead span the whole service spectrum. This may include (but not be restricted to) the sharing of revenues, subsidies, information, and regulation across the full range of transport modes within MaaS solutions. There are obvious difficulties in implementing such a solution.

¹⁵¹ Sochor et al. 2018.

¹⁵² Ibid.

3.7.2 *The current state of Nordic CE*

Several Nordic countries have been at the forefront of MaaS developments, particularly at the more advanced levels in the hierarchy, for a considerable while. Their work incorporates established large-scale operations, smaller-scale and/or preliminary pilot operations, and underpinnings in research and development.

While implementations vary in scope, they feature any or all forms of public transport (local rail service, a metro, buses, ferries, etc.), city bicycle and scooter schemes, taxis, and rental cars, with various, option-rich pricing and bundling structures targeting distinct consumer groups. This appears to be a well-functioning and established level-3 implementation.

Some commercial-scale solutions are evident in, for example, Finland and Sweden, but there appear to be only a few MaaS operations at this scale in Norway or Denmark (even though Oslo, Copenhagen, and other cities do have co-ordinated multi-mode transport offerings from the relevant local transport authorities). Other examples can be found in Sweden's Skåne county and Linköping.

Potential for digital tools

Digital tools are an enabler of every MaaS solution, almost by definition: in essence, all MaaS operation and pilot schemes for MaaS are presented to end consumers via digital mobile applications. Also, tools for assimilating, gathering, and analysing relevant data are in widespread use.

The significance of this is highlighted by a recent study report presenting the argument that MaaS sits 'at the crossroads of the digital revolution and the transition to carbon neutrality'¹⁵³.

Potential for new business models

New business models are an almost inevitable consequence of MaaS developments. The basics of supplier–consumer relationships are witnessing fundamental change here – no longer does the consumer have a series of (unconnected) binary relationships with separate transport suppliers; instead, there is a holistic relationship with the larger system. Also, MaaS implies a shift away from a supplier-centred paradigm typical of traditional public transport, toward a user-centred one wherein both users and suppliers shift and adjust their behaviour, often in real time. Similarly, issues of competition and co-operation between transport operators are subject to radical change under the MaaS paradigm. Level-4 integration invites actors to consider what might seem almost unthinkable in terms of policy, regulatory, and financial considerations spanning the full range of public and private actors.

Commercial examples

Finland's MaaS Global created the application Whim, the first all-inclusive commercial MaaS solution on the market. Whim is widely recognised as a pioneering implementation of MaaS at large scale. Established

¹⁵³ CERRE Mobility 2021.

city-wide MaaS solutions now are in place for Helsinki and Turku and have been deployed in numerous other cities and regions, around the world.

A relatively well-established and mature solution was deployed by UbiGo, which operated a platform in Sweden (expanding from Gothenburg to include Stockholm). The company recently ceased these operations in the wake of the pandemic.

Initiatives to catalyse CE

The Nordic Open Mobility and Digitalisation (NOMAD) project aims to enable seamless mobility by means of several modes of transportation integrated across the Nordics. The project is slated to introduce a market-enabler framework of technology and business practices for MaaS operations and other smart mobility services.

Intelligent Transportation Society of Finland – ITS Finland is a forum for collaboration that brings together representatives from a wide range of government bodies, research and education institutions, and businesses to work on sustainable and circular transport.

A relatively novel MaaS implementation can be found in Aarhus, Denmark. Operated by the Federation of Danish Motorists, the service focuses on peer-to-peer car-sharing as a feeder to various modes of public transport.

3.7.3 Future perspectives and impacts

Future perspectives

There is considerable scope both for introducing new MaaS implementations across the Nordic region and for driving new and existing implementations alike toward a more advanced position in the hierarchy. These seem to be vital to (continued) circular transition in this area. In most cases, fuller integration at level 3, with public–private integration of transport modes, is probably the practical optimum at present. Level-4 integration seems largely a concept for the future and/or may evolve from solid level-3 implementations.

Public-transport nodes are central to MaaS in practice – a genuine MaaS application that lacks comprehensive public-transport integration seems inconceivable. Therefore, the implementations inevitably stem, directly or indirectly, from public-transport offerings and those responsible for them (regional transport authorities). Hence, the main enablers for profound circularity transitions are policies and targets from local, regional, or national governments. Technological developments could influence the transition in several ways – e.g., shaping the extent and range of transport modes available (for instance, through the development of autonomous vehicles) and the administration or organisation of MaaS solutions, such as the new platform developments in the NOMAD project.

At present, MaaS remains largely an urban/metropolitan concept. With a few exceptions, such as pilot projects in Finland and Sweden, almost all MaaS initiatives are based in cities or urban areas. However, the extension of MaaS into rural areas seems inevitable among future developments. Partly because of substantial natural differences in the general transport landscape between urban and rural areas, it seems clear that rural MaaS will look quite different from its urban equivalent, though. One of the more

interesting and potentially significant opportunities involves combining two elements that remain clearly separated in the urban environment: transport of humans and of goods and other resources.

Impacts of smart mobility solutions

Business impacts

Market-based services have been described as the drivers of mobility's transformation¹⁵⁴.

At global level, people spend 11% of their disposable income on personal mobility, making it the second-largest item in household spending. In Finland in 2015, the annual market in the transport sector was worth €30 billion, with personal mobility making up about half of it.¹⁵⁵

Growth in business volume for the non-personal-transport sector as a whole is an obvious expected impact of MaaS. Increased efficiency and economy of scale across the entire sector can be anticipated too.

The main source of potential for MaaS lies in digital services. The cost structure of these differs fundamentally from that of traditional services. While personnel costs typically account for approximately 50% of the total cost of traditional transportation services, the percentage can be expected to fall if smart mobility solutions are implemented. Also, digitalised services are scalable, representing potential to share best practice throughout the region and, thereby, bring greater effectiveness.¹⁵⁶

MaaS will accelerate R&D activity in the manufacturing sector, thus creating business opportunities in that sector. Mobility services' providers have been largely local so far, but MaaS brings scaling opportunities. According to the Finnish Transport Agency, the most promising area for global business opportunities is in the organising sector – solutions for car manufacturers and transit operators, on one hand, and for consumers, on the other.¹⁵⁷

A thorny problem remains for business, however: how costs are best identified and revenues shared among the parts of a truly integrated multi-modal system. The economic sustainability of MaaS implementations is far from self-evident, and on current evidence most represent a considerable business risk. The main issue facing newcomers to the market is achieving critical mass¹⁵⁸. Bringing in foreign investors has been proposed as one possible solution¹⁵⁹.

Climate and environmental impacts

The transport sector's emissions are a major source of greenhouse gases and other pollutants, constituting a contribution to climate change and also to public-health problems¹⁶⁰.

MaaS promises considerable cuts in direct emissions relative to conventional transport ecosystems, although careful like-with-like comparison is necessary for proper evaluation in this regard. According to a 2018 study¹⁶¹, Nordic households that replace use of a private car with car-sharing can reduce their number of vehicle-travel kilometres (VKT) by roughly 30–45% and their greenhouse gas emissions by 130–980 kg CO₂-eq. per year.

¹⁵⁴ Finnish Transport Agency 2015.

¹⁵⁵ Ibid.

¹⁵⁶ Ibid.

¹⁵⁷ Ibid.

¹⁵⁸ CERRE Mobility 2021.

¹⁵⁹ Finnish Transport Agency 2015.

¹⁶⁰ Laine et al. 2018.

¹⁶¹ VTK.

Researchers have examined the Nordic region's country-level reduction potential too. It has been estimated that, were 5% of households to switch from car ownership to ride-sharing, there would be potential to reduce greenhouse gas emissions by between 0.7% and 5.3% from the current baseline (the Nordic countries differ in potential).¹⁶²

Other air pollutants, such as CO, HC, NO_x compounds, particulate matter, and SO₂, were estimated to be reduced by 7–36 kt/year¹⁶³, and fewer motors running can also mean less noise pollution. However, the CO₂-equivalent savings, VKT reduction potential, etc. depend on the total number of kilometres travelled per passenger in the individual countries. The potential CO₂-equivalent savings figure is affected also by whether the shared cars are electric, hybrid, or traditional non-electric cars.¹⁶⁴

It has been noted that not all new mobility services lead to a more sustainable mobility system in urban areas¹⁶⁵. In some cases, shared-mobility solutions lead to **more** emissions. For example, shared electric scooters are reported to create more greenhouse gas emissions per passenger kilometre than the modes of transport they are viewed as replacing – and most users have reported using scooters in place of walking or riding a bicycle.¹⁶⁶

MaaS is heralded as reducing use of natural resources in connection with the manufacture of private vehicles, although the services' ability to truly suppress consumer demand for private-vehicle ownership is unproved. Alternatives to personal cars must be able to genuinely compete with them. That has been challenging, so it remains unclear whether MaaS will significantly reduce manufacturing and, thereby, the use of virgin resources.

Socio-economic impacts

Potential exists for reduced congestion and greater liveability of urban spaces in MaaS conditions, although seemingly paradoxical rises in congestion accompanying reduced traffic-flow volumes have been identified in some cases. There is potential also for greater focus on skilled employment for the design and operation of 'smart' MaaS-linked solutions.

MaaS implies that end consumers will have to make, or be seen as making, compromises in their personal-transport activities. Even the best-designed, best-operated MaaS systems in some sense fail to match the generally complete flexibility and availability afforded by the private motor vehicle. Also, tension in transport-provision and policy developments designed for urban and for rural areas may be exacerbated if efforts focused predominantly on urban MaaS plough onward. Consumers' awareness, values, attitudes, intentions, experiences, and behaviour must be taken into account. Communication can stress the value provided too. It has been stated that, for example, a highly efficient and productive transportation system adds to people's quality of life.¹⁶⁷ If MaaS results in city areas that have fewer cars, more space may be left, in turn, for the citizens. Fewer vehicles can also mean fewer traffic accidents.¹⁶⁸

Thus far, Nordic MaaS solutions have seemed able to thrive only in the more densely populated capital districts, so limits seem evident with regard to potential for the region at large.

¹⁶² Laine et al. 2018.

¹⁶³ Ibid.

¹⁶⁴ Ibid.

¹⁶⁵ CERRE Mobility 2021.

¹⁶⁶ Statistics Finland 2019.

¹⁶⁷ Finnish Transport Agency 2015.

¹⁶⁸ European Commission 2016.

Barriers connected with this opportunity were identified in the following domains:

Technological barriers: The difficulties in sharing data and information between public and private actors, evident in practical efforts involving multiple operators and transport modes, are complex and multifaceted. Technical problems emerge in relation to the need for harmonised platforms and APIs, both of which have been identified as major investment necessities in many cases. Moreover, there is a more general unwillingness to share data in some situations, owing to routine considerations such as protection of commercially sensitive details or concerns over privacy/security. Finland's pioneering position in MaaS development can to some degree be traced to progress on these fronts in comparison with most other countries.

Regulatory barriers: Making an integrated system economically viable for all actors is difficult, especially where competition and co-operation exist side by side. Weak co-ordination and duplication of effort seem commonplace in MaaS initiatives. For example, the public-transport authority for the Oslo region (Ruter) and the Norwegian state railway company (Vy) offer seemingly separate parallel multi-modal route-planning and integrated-ticketing services across the region. Similar conflict/competition between regional and national operators or authorities can be seen in many other cities, including London and Paris. Sochor et al.¹⁶⁹ have suggested that MaaS is currently in a 'fluid phase of development' and that such competition is to be expected, even welcomed. Nonetheless, it gives at least the appearance of duplication and redundancy. Preservation of separate apparently duplicated elements may be a natural outgrowth from organisations' concern with preserving their brand, protecting their data, and avoiding mutually harmful competition with others. Optimising operations and lowering costs, especially for on-demand elements, will be taxing but necessary. Sharing public funding, subsidies, etc. between public and private actors is probably needed for any properly integrated multi-modal model (at level 4) but is clearly problematic.

Market barriers: The business case for MaaS is unclear. It appears that every MaaS implementation beyond pilot stage in the Nordics has experienced significant economic difficulties. Economic viability of the MaaS ecosystem as a whole implies viability for each of its constituent parts (and/or some level of cross-subsidy), and the individual viabilities almost certainly vary considerably. The issues are concentrated around uncertain willingness to pay and market demand. Bundling and subscription models may provide some insulation. Nonetheless, MaaS remains in competition with the always-available, hugely flexible privately owned vehicle, and users must be willing to compromise in terms of the utility and flexibility they seek.

Cultural barriers: Finally, there are significant potential cultural barriers in that deploying even already mature MaaS solutions is far from guaranteed to draw users away from concentrating on private vehicles. The greatest barriers to MaaS and to ongoing circular transition are almost invariably connected with the private transport modes and how they are integrated into the broader system. When an agency responsible for developing expertise in urban planning analysed early MaaS implementations in several cities¹⁷⁰, it identified multiple governance principles underlying MaaS that, in effect, lock in such redundancy and duplication in certain cases. There is broad-based commitment to MaaS, and funding has been made available for numerous pilot projects. However, a somewhat scattergun appearance is evident, and co-ordination related to the lessons and findings appears patchy.

¹⁶⁹ 2018

¹⁷⁰ Cerema 2019.

The following avenues are possible ways forward:

- More radical and innovative ideas entail a shift away from direct subsidising of providers and toward subsidies for target user groups
- Development of technologies related to MaaS places increasing focus on real-time information contained in the system (for example, from crowdsensing users).
- The main political drivers are a desire for reduced climate impacts – related in particular to ownership and use of private cars.
- Among the demographic shifts are larger proportions of the general population being unwilling or unable to drive private vehicles, alongside hopes for more pleasant, less crowded cities.
- The rising overall cost to the economically squeezed consumer could be a major driver toward lower-price, more efficient shared mobility.

3.8 Circular transport logistics

3.8.1 Introduction

Transport logistics – operations related primarily to the movement of goods or resources rather than people – is a significant source of emissions across the Nordic region, with obvious potential for efficiency improvements and greater sustainability via circular transition. Complications for countries' internal logistics arise in parts of the Nordic region where populations are relatively dispersed and remote (conditions that are most visible in parts of Norway, Sweden, and Finland), and cross-border logistics present difficulties for higher-level geographical units that are remote from others (such as Iceland, Greenland, the Faroe Islands, and Åland). There are obvious analogues and parallels with activity in the personal mobility/transportation arena, addressed here as a separate circular transition opportunity.

In this case¹⁷¹, as for the personal-mobility opportunity, we have elected to focus on surface transport (with aviation largely excluded) and, more specifically, on land-based transport (though recognising that maritime transport is obviously very significant in some parts of the Nordics).

In both personal mobility and transport logistics, assets can often be identified as 'over-specified'. In the latter arena, some of these are vehicles and crew/personnel – assets that may often sit idle, may be inefficiently managed, and are generally much more burdensome (economically, environmentally, or socially) than the minimally achievable alternative. This over-catering is often connected with a perceived need for flexibility and ready availability of logistics, though the logistics could be provided in ways other than via always-available vehicular solutions.

There are (at least) two distinct pathways to circular transition in the land-based transport logistics sphere:

- 1) Increasing operations' efficiency while retaining the overall vehicle-ownership paradigm. This implies improvements to the planning, organisation, or co-ordination of logistical operations – processes that are almost inevitably digitally driven. In some respects, this is analogous to electrifying the personal-transport vehicle fleet – the fundamental business models remain unaltered, but efficiency improves, and, through it, so does sustainability. Actual electrification of

¹⁷¹ The case study was carried out under the leadership of NORSUS.

the freight-transport fleet is recognised as a distant aim for heavier modes such as long-distance haulage.

- 2) Revising the paradigm connected with vehicle-ownership/operation, with the implied shift away from a privately owned always-available vehicular solution. This extends well beyond simply contracting out services, instead involving alternative (often shared) vehicular/mobility services. These are logistics-as-a-service entities with direct analogues in the MaaS domain for the personal-transportation arena. In contrast, MaaS equivalents for freight are relatively underdeveloped.

Other elements of the transport-logistics 'life cycle', while amenable to sustainability or circularity improvements, probably should be accorded lower priority with regard to circularity potential. Some of these are circular design of vehicles, more circular use of materials, the enhancement of recycling, and reduction of waste volumes generated by the industry. All of these are important but perhaps are less significant than reducing the total 'volume' of logistics activity implied by the two above-mentioned pathways.

3.8.2 *The current state of Nordic CE*

Many examples along pathway 1 can be found in the reverse-logistics arena, related to the collection and transport of wastes rather than the forward logistics of goods. Two common cases are the collection and transport of domestic waste and that of consumer-electronics waste. Each of these has been subject to significant research efforts, which continue both in the Nordics and beyond.

- For the **collection and transport of electronic waste**, research projects such as LogiWEEE (based in Sweden) and SmartEERE (in Norway) have examined problems related to the design and operation of waste electrical and electronic equipment (WEEE) transport networks, with the factors including the locations of collection facilities and the vehicular flows through these networks. Issues such as the relevant regulatory frameworks and the organisation of the sector more generally also featured strongly in the research. A key element of these efforts was deep involvement of the actors responsible for the practical operation of transport logistics (the producer-responsibility organisations for electronics collection and their logistics partners).
- The **collection of domestic waste** is the subject of the ongoing Norwegian research project Innovativ Avfallslogistikk. This extensive project examines issues stretching from the operation efficiency and sustainability of waste collection to such organisation-related matters as creating contracts and co-operation between various types of actors in the value chain. Once more, close involvement of the relevant actors (municipalities and similar responsible organisations), with a view to using the findings as input to solving real-world problems, is central.

Concrete examples representing pathway 2 for transport logistics are arguably less advanced at present than either those for path 1 or the pathway-2 efforts for the personal-transport arena. Nonetheless, clear examples of activity and further potential exist.

- **Online food retail and home delivery** is a relatively familiar and mature example of circular transport logistics on pathway 2. It is considered an exemplar here since using private vehicles for food retail is completely subsumed by a logistics-as-a-service alternative. Many examples of this activity can be found in each of the Nordic countries. Whilst accelerated by the pandemic, the market penetration of online activity in this massive market remains quite limited, leaving

significant further potential. Planning and scheduling of these operations is a hugely complex problem dependent on the digitally driven gathering and analysis of very large datasets.

- **Autonomous-vehicle solutions** for land-based transport are an example of pathway 2, on which the Nordic region is at the forefront of developments.

Potential for digital tools

In a parallel with the personal-transport arena, digital tools will always lie at the heart of circularity developments for transport logistics. Developments along both pathways depend on complex data analysis and calculations. In some cases, these activities may be conducted offline, but there is growing need for such operations to be handled online and in real time (this is self-evident for autonomous vehicles, in that calculations and digital frameworks for the vehicles are going to extend to planning, scheduling, and routing alongside driving the vehicle itself).

Potential for new business models

The pathway-1 activities as presented above involve largely unchanged business models, although future changes in the reverse-logistics field are probable. On the other hand, the activities on pathway 2 imply inevitable business-model shifts, just as MaaS does for the personal-transport arena. Particularly where autonomous vehicles are involved, it seems evident that owner-operators (or third-party logistics providers) are likely to be replaced by 'network operators'¹⁷² facilitating the provision of transport services.

Limestone transport utilising entirely autonomous trucks has been introduced for internal operations at a Norwegian quarry complex (**Bronnøy Kalk**), and trials of similar vehicles within the Gothenburg port area are under way. Also, a prototype for operation on US motorways has been unveiled. The Bronnøy Kalk example is particularly noteworthy since it is a true logistics-as-a-service operation – the customer purchases the mobility service rather than owning the vehicles.

The Swedish company **Einride** too is developing solutions in this field, notably in collaboration with logistics provider DB Schenker. All such projects are set in a context of obviously different levels of vehicular autonomy, with the most advanced of these (Level 5), in which human supervision is completely absent, remaining somewhat distant for personal or freight transport, at least on public roads.

3.8.3 *Future perspectives and impacts*

Future perspectives

Transport logistics continues to evolve along a trajectory of ever greater 'smartness', with digitally driven planning and co-ordination propelling efficiency improvements and impact reductions in such fields of business as reverse logistics (the collection and transport of wastes) and online shopping and delivery (particularly groceries). The push to develop and deploy ever more autonomous vehicles in the transport-logistics sector continues apace.

¹⁷² Monios and Bergqvist 2020.

Impacts of circular transport logistics

Business impacts

According to Finland's VTT, cost-efficient and ecologically sound supply-chain management will be a fundamental requirement for well-functioning circular economy.¹⁷³

Circular logistics should drive increases in efficiency and lowering of costs, related to personnel but also to infrastructure and operation costs. We are likely to see a shift in emphasis away from physical assets and toward information management. This opens new avenues representing potential for innovation.

According to the researchers behind VTT's AARRE project, circular economy requires a myriad of new services from logistics companies. For example, more business opportunities are created in trade between customers when consumers adopt a more active role. Logistics of circular economy needs a wide range of IT services: utilisation of data from sensors around the full delivery circle, and smarter meshing of transport needs. The logistics of circular economy will demand new technologies also. Development of solid services promotes embracing circular-economy approaches at various scales while opening significant business opportunities for logistics and technology companies.¹⁷⁴

It has been estimated that logistics companies could generate up to 10% added revenue from new blockchain-related services. In the context of autonomous driving in particular, blockchain shows potential to bring significant new business.¹⁷⁵ Reportedly, blockchain technology can contribute to circular economy by helping to reduce transaction costs and shrink carbon footprints.¹⁷⁶ In an Arthur D. Little study, a use case was addressed that involves 'around 25 percent additional sales through creating a customer ecosystem that allows it to sell additional services along the transportation chain in a convenient way'.¹⁷⁷

One area with potential tension or lack of clarity that could ripple along value chains involves sharing of costs and the risks of technological obsolescence. It is acknowledged that owners and operators assume most of these risks in conventional logistics value chains and that more circular models imply a shift of these risks – but the mechanism is not yet clear.

Furthermore, the logistics costs of circular economy are, for the most part, deemed too high¹⁷⁸.

Climate and environmental impacts

There is huge potential for reduced environmental impact, at first through more efficient use of existing transport modes but also through developments such as electrification. 'Green logistics' is the main development trend in modern logistics and an inherent prerequisite for development of circular economy.¹⁷⁹

The climate effect of circular logistics on indirect, infrastructural elements of the value chain is less clear. Thus far, analyses of possible systems of the future have given seemingly insufficient consideration to infrastructure factors. For example, a need for huge and increasing amounts of computation power seems evident, and this is far from climate-neutral.

¹⁷³ VTT 2018.

¹⁷⁴ Ibid.

¹⁷⁵ Arthur D. Little 2018.

¹⁷⁶ Upadhyay et al. 2021.

¹⁷⁷ Arthur D. Little 2018.

¹⁷⁸ VTT 2018.

¹⁷⁹ Seroka-Stolka et al. 2019.

Reductions in 'capital' environmental expenditure and use of natural resources (particularly linked with the manufacture of vehicles and related infrastructure) seem reasonably predictable outcomes.

Socio-economic impacts

Automation and 'smart' operation may increase the degree of the need for highly skilled labour bound up with the business sectors in question. The total level of employment available may fall, however. Emerging technology is likely to reduce the number of people required in some areas of the logistics space. Meanwhile, skilled workers will be needed to manage the processes – hence, different skill sets may be needed.¹⁸⁰

3.8.4 Barriers to seizing the CE opportunity and possible solutions

In relation to this opportunity, we identified barriers in the following domains:

Technological barriers: There are clearly high technological barriers to be cleared both in terms of smarter, circular operation of logistics value chains and in the development of autonomous-vehicle solutions in particular. Both elements require highly complex computation work, often performed in real time.

Regulatory barriers: Deployment of autonomous freight vehicles on public roads is a centrepiece of ongoing developments in the regulation sphere, and clearly there are enormous regulatory barriers to be cleared before this can become routine.

More generally, reverse logistics is going to be subject to especially strong policy and regulatory pressure whenever public bodies are involved, as they often are in such areas.

Market barriers: In some cases, market competition may prove more of a hindrance to efficiency gains than a driver for them and ultimately for enhanced circularity transition. Online food retail currently displays rather limited market penetration – deliveries remain relatively sparse even in densely populated urban areas. Delivery density is expected to increase naturally as the online market share grows. However, diseconomies of scale could arise too, accompanied by relative inefficiency where separate, presumably non-co-ordinated competitors criss-cross the same geographical regions. It seems logical to expect such development in the freight sector also, though ever more efficiency gains for the system as a whole could be achieved via co-ordination of efforts among existing competitors.

Cultural barriers: The shift away from always-available solutions (typified by end consumers' direct ownership of vehicular solutions) implies a loss of flexibility and immediacy. Consumers may accept that felt loss to varying degrees. The extent of circular transition possible hinges on consumer acceptance. For example, a Finnish study of home grocery delivery showed that when customers require relatively narrow delivery-time windows (<1 hour), the potential emissions reductions are much smaller than if they are prepared to accept much wider windows (delivery on a given day). The emissions savings relative to use of a private vehicle varied between less than 20% and nearly 90% in these two scenarios. In similar fashion, studies of domestic-waste collection show the emissions savings to be highly sensitive to the frequency of waste collection and the requirement to source-sort specific waste fractions that consumers are willing to accept.

¹⁸⁰ White Recruitment 2019.

The following avenues are possible ways forward:

- Research in existing areas of study enables and supports ongoing development.
- Development and innovation activity in the search for advantage in a competitive marketplace could yield rewards.
- There is vast potential in the development of technologies for systems and processes that assist with the gathering and processing of large quantities of data, in addition to addressing specific technological requirements.

4. Summary of results at Nordic level

4.2 Introduction to CE transition's potential for the future

Through the case studies presented in Chapter 3, we have sought to highlight examples of the types of potential for circular economy existing in various areas, sectors, and industries in the Nordics. With Chapter 4, we tie the results together at a more general level to elaborate on what the circular transition will mean for the four key areas of industry focused upon: the bioeconomy; the food and beverage sector; the building and construction sector; and mobility, transport, and logistics.

The cases attest that there is great demand for CE solutions and for the benefits that can be reaped through them throughout the life cycle of the industrial processes described. Clearly, a need exists for obtaining greater value from our resource use and for cultivating more sustainable production and consumption patterns by transforming linear resource flows into loops. In the big picture, CE solutions hold great potential to facilitate business development and innovation, reduce greenhouse gas emissions, bring positive biodiversity effects, and support a cleaner environment (air, water, and soil). In addition, CE solutions have various socio-economic implications, which differ between settings in the Nordic region and need to be considered as CE becomes a key tool in the process of a green and just transition.

Our case studies of the CE opportunities highlight the following general trends as the main drivers manifesting future potential:

- The main trend at the core of developments is increased demand for the resource-efficiency, decoupling, and waste prevention for which CE provides solutions.
- Market demand for CE solutions is rising as prices of virgin materials increase in tandem with waste-handling growing more expensive. Hence, CE solutions will become a more viable business option.
- Regulatory actions affecting various sectors and branches of industry boost the circularity transition. An important example is the EU ban on landfill disposal of all residual waste from 2025 onward.
- Technological development enables new solutions and makes new business models viable. Digitalisation is the main driver impelling this development.

4.2.1 *Business impacts*

Part I of the study highlighted the vast economic and business potential of CE in the Nordics. Circular economy possesses potential for increasing companies' profits through expansive transition of business practices and for creating value through new business models, such as servitisation, sharing, and looping¹⁸¹.

All of the case studies outlined in this report point to various impacts on business volume in the Nordic region. The CE opportunities analysed represent potential for expansion and scaling up of existing activities and technologies. They can help to bring about cost savings and minimise losses. They also offer

¹⁸¹ Various business models and their benefits are presented also in, for instance, the Nordic Circular Economy Playbook; see Nordisk Ministerråd - US2021-402 (at <http://nordicinnovation.org>).

possibilities for completely new business development, in which traditional value chains are transformed and new material streams and value networks develop.

4.2.2 *Climate and environmental impacts*

The role of CE as a tool in reducing greenhouse gas (GHG) emissions is relatively well-researched, with several international impact studies covering the Nordics specifically. Estimates put the possible reduction in global GHG emissions via CE at as much as 39% and cuts in virgin-resource use at 28%¹⁸². An Ellen MacArthur Foundation study from 2015 cited a range of 5–50% reduction in virgin resources' consumption by 2035. With approximately 70% of the world's emissions coming from mobility, housing, and nutrition, each CE solution targeted at these sectors could be expected to have positive climate and biodiversity impacts¹⁸³. The key assumption behind all these estimates, though, is that the CE solutions are not based on fossil fuels and that the use of biomass and bio-based materials in them can fully offset the 'need' for fossil fuels.

Climate and environmental-impact assessments are based on various scenarios, and their results can vary considerably also with their scope (the system boundaries considered etc.). We could not identify any study that consistently analysed CO₂ emissions in all of the Nordics in a comparable way. That said, some studies have examined multiple Nordic countries. For example, Wikman and Skånberg assessed the potential climate effects of CE in Sweden and Finland were these countries to take three major steps to maximal extent. This resulted in estimates of 66% and 68% CO₂ emission reductions by 2030 for Sweden and Finland, respectively¹⁸⁴. An Ellen MacArthur Foundation study from the same year concluded that CE could reduce Denmark's carbon footprint by 3–7% by conservative estimates. This reduction was 'measured as a change in global carbon emissions divided by "business as usual" Denmark carbon emissions'¹⁸⁵. All in all, the potential of CE to reduce GHG emissions has been documented fairly well.

CE solutions are designed to reduce the use of resources and the need for virgin materials. In principle, then, CE solutions should have positive environmental impacts. However, the impacts are not always purely positive. A CE initiative can affect the quality of the oceans, other waters, soil, and air in many ways, depending on the production processes employed. The variety of potential environmental impacts from CE depends on the specific solutions, sectors, and geographical locations targeted. An oft-cited example is the increased need that CE processes bring for chemicals with possibly negative environmental impacts. Therefore, specific attention must be given to sustainable CE processes.

One area of special interest is the link between CE and biodiversity. Food and agriculture; forestry, pulp, and paper; buildings and construction; and fibre production and textiles are projected to be responsible for 60% of the world's mean species-abundance loss by 2050. These sectors impinge on 80% of the species that are threatened or rendered near-threatened by various business activities.¹⁸⁶

¹⁸² The Platform for Accelerating the Circular Economy 2021.

¹⁸³ Ibid.

¹⁸⁴ Rizoz et al. 2017.

¹⁸⁵ Ibid.

¹⁸⁶ Gorst and Forslund 2021.

4.2.3 Socio-economic impacts

If circular economy is accepted as a pathway to ensuring well-being within the planet's limits, it will in the long run have measurable impacts on health, education, safety, income, equality, community, and other aspects of society. However, well-developed metrics do not exist yet for measuring these parameters at national level¹⁸⁷. Among the most important measurable socio-economic impacts of the circularity transition are those connected to the quality and quantity of jobs: new jobs will be created, some are likely to disappear, and the content of most jobs is going to change in one way or another.¹⁸⁸ Estimating job creation is complex since new opportunities may overshadow some occupations or even make them obsolete as technological developments change the nature of work¹⁸⁹. Nevertheless, there are estimates that CE could create 700,000 jobs¹⁹⁰ in Europe by 2030, though mainly in Central and Eastern European countries¹⁹¹. The same project estimated that CE could create more than 100,000 new jobs in Sweden and 75,000 in Finland¹⁹². Another study suggests that circularity holds potential to increase Danish GDP by 0.8–1.4% and lead to the creation of additional 7,000–13,000 full-time-equivalent jobs by 2035. It could also increase net exports by 3–6%.¹⁹³

The circular transition will result both in high-tech jobs and in manual and service-sector jobs – the potential job creation via CE is not tied to any specific education level.¹⁹⁴ One should note also that many of the skills needed for CE activities already exist among the highly educated and digitally competent residents of the Nordics¹⁹⁵.

Differences between Nordic settings are expected to emerge as circular economy develops in local and regional ecosystems. For example small island societies have experienced difficulties in developing cost-efficient circular models¹⁹⁶, and societies reliant on utilising and exporting natural resources may experience negative socio-economic effects from the economy's transformation that create a need for diversification of the economy, to avoid 'slow-burn' lag of the vulnerable regions¹⁹⁷. Also, the content of the transformation will vary in line with the industry dynamics of the various regions. For example, all the Nordic countries depend on the bioeconomy, but the bio-based resources and the value chains of the bioeconomy differ, with these factors also affecting the employment structure and competencies needed in a circularity- and biomaterial-based economy.

Employment-related developments are the main socio-economic impact identified also via the CE opportunity case studies. Most of the opportunities bring increased employment opportunities. They should help to diversify Nordic employment too and lead to new skills development and greater focus on skilled employment. However, some of them could lead to reductions in total employment. Moreover, the

¹⁸⁷ Potočník 2021.

¹⁸⁸ Sitra 2021.

¹⁸⁹ Extensive studies of impacts of the transformation of work in the 'fourth industrial revolution' have been conducted (e.g., by the OECD), although most of these do not specifically address circular economy.

¹⁹⁰ The figure is for net increase.

¹⁹¹ Jensen-Cormier 2018.

¹⁹² The four main assumptions made by Jensen-Cornier 2018 are that energy-efficiency is going to rise by 25%; there will be increased use of renewable energy relative to other sources; material-efficiency will rise, with a 25% increase emerging; and overall use of virgin materials will decline by 50% in a phenomenon coupled with doubling of product service lives.

¹⁹³ Rizoz et al. 2017.

¹⁹⁴ Sitra 2021.

¹⁹⁵ See, for instance, Teräs et al. 2021, along with Nordregio's other work on skills needs and digital transformation in resilient and innovative Nordic areas.

¹⁹⁶ Indicated by the interviews for part I of this work.

¹⁹⁷ Explored in, for example, Nordregio's work on building the economic and social resilience of Nordic locations (e.g., Giacometti et al. 2019).

large differences between areas in the Nordics are important with regard to harnessing the benefits represented by CE potential.

Among the other socio-economic impacts highlighted are well-being benefits for some professions (such as farmers) and potential for diversification of some sorts of work, leading to more variety-rich economic structures. Hence, positive impacts could arise for some more remote regions through the new opportunities. The case studies uncovered few potential negative socio-economic impacts related to health and safety.

4.3 The bioeconomy

4.3.1 *Potential and business impacts*

Climate change, resource scarcity, and biodiversity concerns have drawn international attention to the importance of more efficient and sustainable use of bio-based materials. The Nordic countries are rich in bio-based resources and skilled in their management and use. These countries cannot unlock potential for economic growth in the bioeconomy by harvesting more natural resources; instead, they must use their resources more wisely, at the same time ensuring that the green and blue ecosystems are preserved.

A circular bioeconomy can be understood at a basic level in terms of narrowing the loop in which biomass is used, so that it is put to use in the most resource-efficient manner possible, by means of digital predictive management, utilising side streams for bioenergy (or other purposes) or in higher-value chains, and minimising waste. The key question for a sustainable and resource-smart bioeconomy is how to prioritise the use of biomass for food and feed, energy, construction, and diverse products.

This report presents the cases of wood-based textiles and alternative uses of ocean biomass for examples of how to employ more sustainable materials in the value chains of, for instance, packaging, textiles and plastics, cosmetics, and medicine. Volume-wise, the cases presented in this report do not yet offer significant economic opportunities for Nordic areas, but in terms of novel potential and business opportunities they represent interesting growth areas and also illustrate how the circularity transition disrupts traditional value chains. Such examples of forward-thinking development are part of change on a larger scale, as there are synergies to be gained from promoting biomass as a sustainable low-carbon alternative to fossil, synthetic, and other such materials in many sectors. Synergies with the food and beverage sector are also to be found in using yellow and blue biomass for food while directing the side streams to other purposes. New business models will be needed especially to commercialise and scale up production technologies that use feedstock from existing waste streams. The other end of the chain offers potential for a loop, via synergies with recycling solutions for other novel materials, since many new materials will require more advanced recycling technologies to be scaled. Partnerships across national and industry boundaries are crucial in the development of new technologies and areas of business.

Digital solutions and both digital and region-linked platforms have a vital role in seizing opportunities for improving circular design, tracking material flows, optimising side- and waste-stream management, advancing data-driven precision agriculture and forest management, and up-scaling new business solutions. Work with circular business models in this area entails, among other activities, applying new service-business models that cover both production and consumption (e.g., related to sharing, trading, or leasing resources and services). These cases show that exploring different solutions for a more sustainable

and circular Nordic bioeconomy is necessary in preparing for the future and in ensuring that the Nordic countries can preserve their competitiveness as pioneers of CE development.

Table 3: The bioeconomy – business impacts

Business impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The bioeconomy	Expansion and up-scaling of circular processes and technologies	Positive	Certain for some, for others not Potential medium to high significance Long-term (not materialising immediately)
	Development of new material streams	Positive	Certain Potential medium to high significance Medium- to long-term
	New opportunities and markets	Positive	Fairly certain Potential high significance Long-term (not materialising immediately)
	Risk of competition, duplication of effort, and diseconomy of scale	Negative	Certain Medium significance Short- to medium-term (as competition will be natural once models are established)

4.3.2 Climate and environmental impacts

Most bio-based material flows produce lower CO₂ emissions than other material production, and they function as active carbon sinks in the process. As new technologies and investments for recirculation are developed, the useful life of more bio-based materials will grow longer. Another positive impact that has considerable importance is a decreased need for non-renewable resources, thanks to new applications for bio-based materials (e.g., from replacing plastics). End-of-life treatment still has challenges to face, as many higher-value products from bio-based materials may contain chemicals and other contaminating substances that can render their return to the ecosystems problematic.

Biodiversity issues such as deforestation or overfishing, with related negative impacts on ecosystems, pose significant risks if sourcing of feedstock for new biomass applications is not handled sustainably. It is important to understand that if positive impacts are to be realised, new circular uses of biomass should not increase total resource exploitation but, rather, assist in focusing the biomass use in resource-efficient and smarter ways.

Fishing is likely to remain stable or decline in volume, depending on political decisions about quotas – the newly released cod quota for the Baltic is a prime example (an 88% drop for 2022). At the same time, the growth of aquaculture is expected to continue as people switch from meat-based diets to more sustainable ones. Although the climate impacts of fish farming are far smaller than those of other animal farming, it is imperative that this growth not result in shifting the environmental burdens of meat production to the oceans.

Table 4: The bioeconomy – climate and environmental impacts

Climate and environmental impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The bioeconomy	Reduced CO ₂ emissions (compared to other material production)	Positive	Certain Medium significance (in relation to overall production) Short- to long-term
	The possibility of locking carbon from the atmosphere	Positive or negative (depending on the direction of the activity)	Certain High significance Long-term
	Use of non-renewable resources and need for virgin materials	Positive (if the overall growth is sustainable and decoupling is successful)	Certain High significance Long-term duration (not materialising immediately)
	Risk of biodiversity loss	Positive/negative	Uncertain – environmental assessments need to be done (to ensure protection of ecosystems), and the sustainability of the solutions varies High significance Long-term to permanent
	Impacts on the ecosystems	Positive/negative	Uncertain – inputs (nutrients and chemicals) need to be controlled, and the sustainability of the ecosystems varies

4.3.3 Socio-economic impacts, also encompassing regional differences

Natural resources play a large role in the industries and exports of the Nordic countries, and the bioeconomy is a strategic priority for all of them, constituting a significant part of their regional and national economies. Their natural variations are reflected in the availability of biomass (forest biomass in Finland, Sweden, and Norway; ocean biomass in Norway, Iceland, the Faroe Islands, Greenland, and Åland/Finland; and agriculture in all of the countries but especially Denmark, Sweden, Norway, and Finland). The countries are similar in their societal structure, and all face the same sustainability challenges related to sustainable consumption and production.

In the various regional economies, new applications of biomass are expected to have impacts that are largely indirect or realised over the long run. Among the direct impacts, scaling of new business activities and industry processes is forecast to strengthen the regional innovation networks that form a prerequisite for development especially in the bioeconomy area. If transition to a circular bioeconomy is realised at larger scale, it will ultimately influence employment opportunities. These opportunities are not expected to emerge within all regions, however, or to equal extent. Also, the industrial transformation is going to lead to a more diversified employment base in the end, which could have negative impacts on specific local communities, especially locales that are heavily dependent on primary production while not necessarily possessing the skills base and technology that a green circular transformation requires. In the long run, though, diversification of the employment base still can be regarded as a positive development with regard to the resilience of different regions in the Nordics. The principles of just transition imply that specifically targeted support might be needed in heavily affected regions.

Health and welfare impacts are expected to emerge as indirect consequences of the climate and environmental impacts explained above.

Table 5: The bioeconomy – socio-economic impacts

Socio-economic impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The bioeconomy	Strengthened regional innovation networks	Positive	Fairly certain Low to high significance, depending on the region Short- to medium-term benefits anticipated
	Employment opportunities	Positive or negative (depending on the region)	Fairly certain Low to high significance, depending on the region Medium-term
	A diversified employment base	Positive or negative (depending on the region)	Fairly certain Low to high significance, depending on the region Medium- to long-term (typically negative effects in the short term and possibilities of positive effects growing in the long term)
	Health and welfare impacts	Positive	Mainly indirect long-term impacts of changing lifestyles and environment quality

4.4 The food and beverage sector

4.4.1 Potential and business impacts

The food and beverage sector comprises key resource flows in the Nordic countries, with considerable turnover and employment figures. Also, food production is a necessity for the region's supply security. At the same time, the sector generates significant amounts of waste along the value chain from primary producers to final consumers, and it brings one of the key challenges for reaching the global goals of sustainable consumption and production in the Nordic region.

The key issue demanding attention in studying this sector is how to create more sustainable consumption and production patterns throughout the food and beverage sector, from primary production to food waste, by applying principles of circular economy. The case studies presented in this report focused on different parts of the value chain.

Agriculture provides the primary resources for many parts of the food and beverage industry. Therefore, it was of great importance to study how to use bioresources for food production in a resource-efficient and sustainable way through predictive and more sustainable nutrient management and to consider what role the principles of circularity can play in these processes. This is essential both for food security and to improve water quality globally, and the issues are closely linked to developments within other parts of the bioeconomy, as well.

At the other end of the value chain, minimising both food loss and food waste is a global effort that demands actions throughout the value chain from farm to fork. Minimising food waste requires well-developed logistics and advanced handling procedures, procurement based on consumer-related insight, and informed and active consumers. The issues studied are closely linked to the development of digital platforms supporting circular economy, just as they are closely bound up with logistics in general.

The food and beverage industry presents good conditions for circular business development and establishment of new businesses throughout its value chains. Use of data and digital tools is the key for unlocking many of these opportunities. Within primary production, the utilisation of data and soil analytics can produce savings and increase productivity, largely by enabling more optimal use of fertilisers and, thereby, increased earnings. Local business opportunities might well be arising already around the feedstock materials needed in the biogas- and digestate-production optimisation process, as well as in the logistics chain for fertilisers. Realising the opportunities requires spatial details of the availability of nutrients, though. Better management of food-production chains also minimises economic losses from food loss and food waste. Optimising procurement could lead to the minimisation of waste at source and more precisely targeted consumer needs.

Table 6: The food and beverage sector – business impacts

Business impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The food and beverage sector	Cost savings through predictive management and logistics throughout the value chain	Positive	Certain Moderate significance Long-term
	New business opportunities related to data and digital solutions	Positive	Uncertain Low to high significance (increasing over time) Short- to long-term

	Management of logistics chains	Positive or negative	Uncertain Of high significance but costly in the short term (see the logistics case), with potential for savings and opportunities for business development in the long run
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4.4.2 *Climate and environmental impacts*

Climate change is going to affect the agriculture and food-production conditions, coupled with biodiversity in the Nordic countries, leading to rising demand for optimisation in primary production and for better management of fertilisers. By some estimates, a circular food and agriculture sector alone could possibly stem and reverse this century's global biodiversity losses by 2050.¹⁹⁸

Improved nutrient management holds potential to cut emissions significantly, reduce the burden on our waters (especially the Baltic Sea), and improve soil quality through the resulting increase in the soil's organic matter. In turn, the water retention of the soil should improve, and seizing the opportunity could also minimise phosphorus mining and lead to less need to direct land and water to agriculture.

More than three million tons of food is wasted in the Nordic region every year. Optimising management and logistics along the entire value chain and minimising both food loss and waste also offers potential to lead to decreased food production and, consequently, fewer greenhouse gas emissions and less land use, waste, pesticide and herbicide application, and fertiliser use from food production.

¹⁹⁸ Gorst and Forslund 2021.

Table 7: The food and beverage sector – climate and environmental impacts

Climate and environmental impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The food and beverage sector	Reduced nutrient emissions to the air, water, and soil, through less use and recycling of fertilisers	Positive	Certain (if new techniques are adopted) Significance dependent on the volume and spread of activities Short- to long-term impacts
	Improved soil quality, less water consumption, and reduced mining of phosphorus	Positive	Uncertain Longer-term impacts if the volume and spread of activities are sufficient
	Reduced food waste through greater end-of-life use of the food produced	Positive	Certain Moderate to high significance Short-term realisation possible
	Reduced emissions and environmental burden from food production, through decreased production	Positive	Uncertain Moderate significance No immediate effects (effects may emerge in the long term)

4.4.3 *Socio-economic impacts, also encompassing regional differences*

The socio-economic impacts of precision agriculture should usher in savings and higher profits, thus increasing the welfare of farmers. Currently, pursuing this opportunity has only small impacts on employment, but the impact can grow if the significance of precision agriculture using organic fertilisers grows – via employment related to logistics, biogas plants, service providers, etc. At the same time, preventive food-waste management could ultimately decrease the need for agricultural products, thus creating potential also for negative employment effects on farmers. Because the value chains in the food and beverage industry are rather complex, there remain great uncertainties surrounding these impacts.

Also, there is a risk of regional differences in capacities to adopt various technologies and practices needed for resource-efficient agriculture. Some solutions, building on such elements as precise information about the physical availability of fertilisers, might require critical mass from the markets and not be available to farmers in more remote regions.

The socio-economic impacts of food-waste prevention will affect consumer behaviour and lifestyles. Accordingly, consumers' awareness is central to the outcome. Varied digital solutions (such as diverse kinds of smart food applications) have potential to make food available at lower cost and, thereby, improve food access for low-income and no-income households/individuals. At the same time, applications of this nature require critical mass in some respects and at present are available primarily to urban consumers, in metropolitan areas. Also, if the ultimate goal is to manage the food-supply chain such that waste is minimised, the availability of food should over time be easier to match with the demand.

Ultimately, minimisation of loss more broadly makes the food system more efficient and builds a more robust one. This could have indirect positive impacts on health and welfare, due to a reduced climate and environmental burden from the value chain. However, there is great uncertainty surrounding the associated impacts, which also are unlikely to occur immediately.

Table 8: The food and beverage sector – socio-economic impacts

Socio-economic impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The food and beverage sector	Employment	Positive or negative	Uncertain Low to high significance, with regional variations Medium- to long-term
	Improved access to food for low- or no-income households	Positive	Certain Moderate significance Short- to medium-term (rising over time)
	Impacts on health and welfare	Positive	Uncertain and indirect Moderate significance Long-term (growing over time)

4.5 The building and construction sector

4.5.1 *Potential and business impacts*

The real-estate and construction sector accounts for a significant proportion of materials' consumption, energy use, and waste generation – and for economic activity more generally in the Nordic countries. Transforming this sector, therefore, is one component at the heart of circular economy. In addition, the Nordic countries possess advanced expertise in construction, including extensive competence and technology specific to building and construction in cold environments and in remote or otherwise challenging areas, such as parts of the Arctic region. This represents a significant competitive advantage also in export markets.

Circularity opportunities in this sector require rethinking the entire life cycle of a building, from reducing the need for virgin resources and increasing energy- and resource-efficiency (by means of good design, choices of materials, project management, and logistics) – to optimising the use, reuse, and shared use of buildings for different purposes, while also improving construction-waste management. Another key issue in this regard is to make sure that reparation and rebuilding are enabled via circularity-oriented thinking already in the planning and construction phase.

The case reports here focus on how to 1) extend the life cycle of buildings through new design methods and approaches that increase structures' reuse and 2) improve reuse and recirculation of building and construction materials with the aid of digital platforms.

The growing demand for circularity of buildings will have a direct impact for producers of building materials, buildings' owners, and developers. These impacts can either create or diminish business opportunities. Digitalisation is vital throughout the service life of a building, enabling new business models

to emerge. Traceability (via digital product passports) and use of AI-based tools for analytics, for example, open new opportunities for material markets.

Positive long- and short-term business impacts alike – in the form of direct cost savings – are expected in relation to resource consumption when utilisation of buildings is prolonged, resources are shared, and more building materials get reused and recycled. There may be transitory direct and indirect negative impacts during the transition toward CE in construction, stemming from the growing need for planning, documentation, logistics, storage and transportation of building materials, and overall resource-efficiency, along with associated regulation. The positive impacts are expected to offset temporary negative ones in the long run.

Also, using raw materials from waste streams can lead to cost savings or new economic streams (from saving on disposal fees or from reselling materials). Digital marketplaces and platforms for materials exchange have a role in such development. Among the business impacts of larger material markets might be cost savings on waste-reception fees if more materials and side streams are used. Digital platforms enable the optimisation of logistics too and can help decrease transportation costs, simultaneously bringing new business for CE-based companies, businesses that create side streams, or completely new businesses. Optimisation and matchmaking can pave the way to new types of business models, and data-analysis-based approaches to business may emerge. Still, some logistics challenges remain to be addressed, on account of differences between where the material is and where it is needed. Additionally, it should be noted that digital services, platforms, and infrastructure consume significant amounts of electricity.

Table 9: The building and construction sector – business impacts

Business impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The building and construction sector	Circularity-related requirements for building materials and design impacts for building-material producers, building-owners, and developers	Positive or negative	Significance and short- or long-term effects unclear
	Cost savings	Positive or negative	Uncertain Significance that may vary (e.g., negative influence in the transition phase and positive long-term effects)
	Larger markets for the material streams	Positive	Uncertain (while in development, as business impacts remain to be scaled) but expected to increase over time
	New business models and business growth connected with marketplaces and logistics	Positive	Impact and significance uncertain (many business models are under development)

4.5.2 *Climate and environmental impacts*

Reuse, material substitution, and reduction of waste in the construction sector are anticipated to together reduce resource consumption in the Nordics, thereby shrinking the material footprint. However, there is a possibility of hazardous waste being generated from existing buildings, and older building stock often consume large amounts of energy. These factors have to be considered in any repurposed older buildings.

Researchers have estimated that incorporating circular economy into the Nordic construction sector could decrease GHG emissions significantly. However, the climate impacts that are possible differ with the initial components/materials to be repurposed or reused. Alongside such efforts, further emission reductions could be achieved by incorporating the use of sustainable design techniques into building design.

Increasing the utilisation of existing buildings is a promising avenue for reducing the need for new construction, thus contributing to resource-use efficiency and reduced carbon emissions, during both construction and use. Likewise, better development of markets for excess construction materials could decrease the need to pour resources into new materials and assist in tracking complex circular material flows, their environment safety and potential CO₂ emissions, and material-efficiency. It is safe to say that digital platforms hold massive potential for positive impacts related to the climate and environment; however, there are multiple uncertainties as to the volume and pace of the predicted impacts coming to pass.

A digital sharing economy is of interest to companies and consumers alike, who envision both economic and social benefits in the form of environmental protection. Replacing many material elements of the production process and distribution of products/services with mapping of information via online platforms enables optimising utility from the resources used. Increased circulation of the materials already present

aids in avoiding emissions, through less burdensome waste logistics and reduced use of virgin resources. Logistics activities related to circulation of materials need to be planned and timed well, for avoidance of unnecessary transport costs and emissions.

Table 10: The building and construction sector – climate and environmental impacts

Climate and environmental impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The building and construction sector	Reduced emissions through less production of materials and via increased reuse and recycling	Positive	Uncertain (depending on the material and the loops) Realised mainly in the long term
	Reduced extraction of virgin materials via reuse, material substitution, and waste reduction	Positive	Fairly certain Significance and volume uncertain, as is the time needed for transition
	Decreased landfilling of materials	Positive	Fairly certain Significance and volume uncertain, as are time horizons
	Hazardous waste	Negative	Fairly certain in the short to medium term Significance expected to decline over time as design and material management improve

4.5.3 Socio-economic impacts, also encompassing regional differences

Buildings play a fundamental role in how people live and inhabit areas. Transition to circular design, building, operation, and maintaining of buildings promises strong direct socio-economic impacts that reverberate on the living environment, health, and well-being. Building (re)utilisation in the form of repurposing can assist in revitalising existing neighbourhoods and communities – bringing new housing, jobs, and business activities to previously underutilised areas in both urban and rural areas. Reuse allows for a building's continued use and helps it remain a viable community asset. Additionally, buildings represent social and cultural capital; therefore, greater (re)utilisation of buildings contributes to preserving Nordic heritage and history.

One of the trends today, strengthened by the SARS-CoV-2 pandemic, is multilocation. Adapting buildings for new purposes (e.g., remote office spaces) can also affect people's options for choosing where to live on other grounds than proximity to one's place of work, thus affecting demographic and socio-economic elements of various Nordic locations.

Adaptive (re)utilisation can provide renewed vitality to any building that may be underused, abandoned, vacant, dilapidated, or obsolete in function. However, building (re)utilisation is not always possible. Existing buildings, their elements, and their materials cannot always meet new building standards. There may also be health and safety concerns connected with building materials. For instance, now-banned toxic

materials once used in building construction should not be reused, and human exposure to them should be limited.

Moreover, significant expertise and testing are needed, for guaranteed safety when buildings are repurposed and when components get reused. Yet, this can also lead to new skills development as R&D and innovative solutions are needed to undertake building (re)utilisation. Smart utilisation and better (re)utilisation of buildings can have multiple impacts on the people and societies.

If business services coalesce around material markets and other digital platforms, they will support knowledge-sharing, business development, and new employment. There is no indication that any negative effect should ensue with regard to decreased need for labour, yet negative impacts may still occur when platforms contribute to job insecurity (this is one of the general challenges associated with platform economies).

Table 11: The building and construction sector – socio-economic impacts

Socio-economic impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
The building and construction sector	Development to housing, jobs, and business activities in various areas by means of adaptive (re)utilisation of buildings	Positive	Uncertain Potential high significance
	Skills development in the building and construction sector	Mainly positive, though regional variations may arise	Uncertain Potentially moderate to high significance, with regional variations Long-term
	Safety and health impacts stemming from buildings and their use	Positive or negative	Uncertain, requiring consideration in planning and development Short- to medium-term (with effects decreasing over time as material management develops)
	New employment opportunities related to digital platforms	Positive (perhaps negative too)	Uncertain (developing) Comes with the general platform-economy-related challenges and changes in job security

4.6 The mobility, transport, and logistics sector

4.6.1 Potential and business impacts

Transport and logistics operations constitute a prerequisite for circular economy, and its resource flows. At the same time, domestic transport in the Nordic countries accounts for a significant share of emissions and

all countries in the region have set targets for reducing emissions from transport. A clear need exists to lower emissions, develop efficient transport systems and logistics, and support innovative transport services.

The cases in this report focus, on one hand, on aspirations to change individuals' mobility habits by offering readily available, affordable alternatives to private transport, with emphasis on domestic road-based transport of people, and, on the other hand, on transport logistics – stressing movements of goods and materials. The bulk of the attention in these case studies was on road-based transportation, with acknowledgement that sea-based transport and logistics are crucial to many parts of the Nordic region. The common denominator between the case studies is the significance of data and digital solutions in ensuring a smart, efficient, and more sustainable mobility, transport, and logistics sector.

Continuing desire to reduce environmental burdens from the transport sector is indicative of huge potential and a need for MaaS solutions. The greatest potential of MaaS is related to its digital nature. The cost structure of such digital services differs fundamentally from traditional services'. Also, digitalised services manifest scalability, which brings potential to share the best practices across the Nordic region. That could usher in greater effectiveness.

There are projections that MaaS will accelerate R&D activity in the manufacturing sector, thus bringing that sector business opportunities. While providers of mobility services have been local so far, MaaS brings scaling possibilities. Nonetheless, the economic viability of MaaS implementations is far from proven. Many examples represent considerable business risk, with the main critical issue being the Nordic markets' relatively small size and lack of critical mass.

Cost-efficient, eco-friendly supply-chain management will be a fundamental requirement for well-functioning circular economy. Expansion of business volume in the non-personal-transport sector as a whole is an obvious impact foreseen for MaaS, with an increase in efficiency and economy of scale expected across the whole sector. Circular logistics should drive increases in efficiency and lowering of costs, related to personnel but also infrastructure and operating costs. There is likely to be a shift in emphasis away from physical assets and toward information management. This creates new potential avenues for innovation.

The CE transition is going to require new logistics services, including IT services, as well as new technologies, with these opening significant business opportunities for logistics and technology companies. For example, it has been estimated that logistics companies could generate up to 10% further revenue from new blockchain-related services.

There is potential for lack of clarity along value chains – even culminating in tension – with regard to sharing the costs and risks of technological obsolescence. Owners or operators take on most of these risks in current logistics value chains, and more circular models evidently imply a shift of these risks, but the mechanism of change and the model are far from clear. Furthermore, the logistics costs of circular economy are, for the most part, high.

Table 12: Mobility, transport, and logistics – business impacts

Business impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
Mobility, transport, and logistics	Increased efficiency and economy of scale, with cost savings in logistics	Positive	Certain Reduction of logistics costs as a continuous key driver for various industries and individuals, of high significance Short- to medium-term
	Reduction in idle or underutilised assets	Positive or negative	Certain in logistics but uncertain with personal transport since it is not entirely clear whether the solutions are going to reduce personal-vehicle ownership High significance Medium- to long-term
	New digital-solution- and platform-economy-based business concepts	Positive	Certain in that many winning business concepts will emerge, but many will still fail High significance Long-term impacts but costs remaining high in the short term

4.6.2 Climate and environmental impacts

Transport-sector emissions are a major source of greenhouse gases and other pollutants.

In the context of personal mobility, MaaS promises considerable direct emissions savings when compared to conventional transport ecosystems, in that there is room for Nordic households to shrink their transport-related climate footprint significantly. Nonetheless, country-specific variations are to be expected, depending on the passenger kilometres travelled in various countries and regions. The commercial viability of today's MaaS solutions is largely limited to urban or even metropolitan areas. It is noteworthy too that not all shared-mobility services increase sustainability: where they replace walking or bicycling with electricity- or fuel-powered alternatives, these solutions can increase emissions.

One of the major impacts predicted to arise from MaaS is reduced use of natural resources connected with the manufacture of private vehicles. However, its ability to actually reduce consumer demand for owning private vehicles is not proven. Alternatives to the personal car must be genuine competitors with cars. Achieving that position has been challenging, so it remains unclear whether MaaS is going to reduce manufacturing in this area significantly and hence influence the use of virgin resources much.

In the transport and logistics sector, 'green logistics' is the main thrust of advances and a precondition for fuller development of CE. The climate effect of circular logistics on indirect, infrastructural elements of the

value chain is less clear. Reductions in so-called capital environmental expenditure and use of natural resources (particularly linked with the manufacture of vehicles and related infrastructure) seem reasonably self-evident. However, the infrastructural elements seem not to have received sufficient attention in analyses of potential future systems thus far. For example, a need for increasing and ultimately vast quantities of computation power seems clear. Such factors, which are anything but climate-neutral, constitute an area that demands considerably more analysis.

Table 13: Mobility, transport, and logistics – climate and environmental impacts

Climate and environmental impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
Mobility, transport, and logistics	Reduced emissions (as judged by CO ₂ -eq. figures) and air pollution through reduced travel and via transport modes shifting away from fossil-fuel-based solutions	Positive (negative impacts may emerge in some areas)	Fairly certain and highly significant Some potential negative impacts if walking and cycling get replaced with electricity- or fuel-driven vehicles; also, uncertainty related to infrastructural changes Short- to medium-term
	Reduced CO ₂ emissions from more efficient logistics operations	Positive	Certain and highly significant Short- to medium-term
	Reduced natural-resource use connected with the manufacture of private vehicles	Positive or negative	Uncertain because the number of private vehicles might not fall and because of the materials used (e.g., in electric vehicles) Short-term
	Better utilisation of space when less land is needed for mobility	Positive	Certain Significant Long-term because of the long time scales of spatial planning and development of urban environment and infrastructure

4.6.3 Socio-economic impacts, also encompassing regional differences

Globally, people devote 11% of their disposable income to personal mobility, making this the second-biggest contributor to household spending. A highly efficient transportation system is expected to improve quality of life by reducing this spending. If MaaS leads to less private-vehicle traffic and increased use of public transport and sharing-based services, potential exists for more liveable urban areas, but these impacts are highly uncertain.

Embracing MaaS implies a need for end consumers to make compromises related to their personal-transport activities. Even the best designs for MaaS and the best-operated systems cannot

match the flexibility and availability options that the private motor vehicle gives many people. There are also significant region-to-region differences, which may lead to tension in transport-provision and policy developments between urban and rural areas if MaaS developments maintain their current (largely urban) focus. In relation to such factors, consumers' awareness, values, attitudes, intentions, experiences, and behaviour are vital. So far, Nordic MaaS solutions have survived only in the more densely populated capital areas, thus highlighting possible limits to their potential over the whole Nordic region.

In logistics, automation and smart operations may increase the skill level demanded for labour connected with these fields of business, while the total number of employment opportunities may well fall. Emerging technology is likely to reduce the quantity of people needed in some parts of the logistics space. Simultaneously, skilled workers will be required to manage processes, representing the likelihood of different skill sets being required.

Table 14: Mobility, transport, and logistics – socio-economic impacts

Socio-economic impacts			
Area of potential	Impact	Positivity vs. negativity	Certainty, significance, and duration
Mobility, transport, and logistics	Increased focus on skilled labour	Positive	Certain Highly significant Short-term
	More skilled workers	Positive	Certain Fairly significant as there will be new types of jobs, over new value networks
	Possible reductions in total employment	Negative	Uncertain Moderate significance Long-term
	Reduced cost of transport for individuals	Positive	Uncertain since the increased costs of energy and infrastructure may result in overall increase in transport costs Highly significant Long-term
	Unequal opportunities for people living in different regions	Negative	Fairly certain since many of the solution are developing and are applicable only in urban areas Moderate significance Long-term

4.7 Barriers to the circularity transition

All of the case studies outlined in this report attest that the full potential has not yet materialised, on account of barriers of various kinds. The key observations on barriers are presented in the sections below and summarised at the end of the chapter.

4.7.1 *Regulatory barriers*

Standards and regulation may preclude or at least complicate unleashing the potential of CE solutions. When practices even within a given country differ with regard to what is allowed and what is not, it becomes more difficult to scale the business cases. Also, legislation in general lags behind in some cases. In other contexts, even very detailed policies and regulation may be counterproductive, leading to barriers created by conflicting aims¹⁹⁹. With regard to regulatory barriers, it is important to note in addition that they act at several levels, with the increasing role of EU regulation affecting how Nordic co-operation may be able to make an impact (e.g., via co-ordinated action on EU level vs. advising on national regulatory developments through statements of the Nordic Council and the Nordic Council of Ministers).

4.7.2 *Technology barriers*

CE solutions are often based on new technologies that are under development. Frequently, the critical step is to get the solutions to work on industrial scale after their pilot and demonstration phase. New value-chain structures and new ways of collaborating require a large amount of planning. Digitalisation is one of the main drivers for CE, but it also represents an area that demands considerable development, and barriers do exist. The main challenge related to digitalisation is today's lack of data harmonisation, low-quality data, and limited access to data.

4.7.3 *Market barriers*

For many of the CE solutions, the main barriers are connected with underdeveloped markets. The CE solutions are not yet business-ready, on account of low market volumes, the lower costs of business-as-usual solutions relative to new CE solutions, and lack of necessary infrastructure elements. Both low costs of virgin materials and waste-handling issues pose further impediments to implementation of CE solutions. Another market-related barrier is the requirement for new models of co-operation and for restructuring of existing value networks before CE transition can unfold. Various industries are not necessarily ready to alter existing structures, and current business models are more profitable in the short run. One should also take into account that separate CE solutions often compete with each other. In sum, transition entails business turbulence and higher risks.

4.7.4 *Cultural barriers*

The cultural barriers are related mainly to business-operation practices, knowledge and awareness, and attitudes. Potential users and customers alike are used to their current linear, business-as-usual practices. Companies may doubt the business potential represented, while customers may find it challenging to change behaviour. End-user attitudes and culture-related issues hamper the acceptance of CE-based products. For example, willingness to accept products that are based on 'waste' may be low. Increased

¹⁹⁹ As outlined in, for example, the recent report titled 'How Can the Nordic Mix of Policy Instruments Become More Effective?' (TemaNord 2021, p. 539), which looks into climate policies in the Nordic countries.

knowledge, information-sharing, and campaigning work are needed, to convince the markets as to the benefits and to decrease misinformation about such matters as health risks. In addition, CE solutions require new competencies and know-how, which must be strongly developed, partly via intensified co-operation between businesses and education/research institutions in settings of innovation ecosystems. Even within the Nordic region, business environments and the cultures and languages can create barriers.

Examples of barriers identified in the case studies

Technology barriers:

Multiple technological barriers were identified in the building and construction sector. There is a lack of building-information modelling and high-quality data, and additional testing is needed. New design practices are required too, so that design for reuse can become a common practice.

In the transport and logistics sector, difficulties plague the sharing of data and information between public and private actors in the fields of smart mobility solutions and circular transport solutions both. Importantly, complex computation-related issues affect logistics planning and the vehicles' operation.

As for new applications for biomass, all of the case studies revealed several sorts of technology that are not available at scale or require further development.

Regulatory barriers:

One of the central regulatory barriers visible with regard to new applications for biomass is linked to the need to use hazardous chemicals in the production processes for higher-value bioproducts.

In addition, nutrient-use standards in the various countries were identified as a regulatory barrier to developing new agricultural processes.

Strict food-safety regulations are another barrier in this category that could influence developing new ways to prevent food waste.

Finally, the transport and mobility arena faces barriers related to the regulatory acceptance of new practices such as deployment of autonomous vehicles.

Market barriers:

In connection with development of predictive management of bioresources, it was noted that the potential remains invisible to most producers while those who are aware often fear the economic risk that accompanies the opportunity. This ties in with a lack of incentives to change practices.

When examining new applications for ocean biomass, the researchers concluded that the markets are underdeveloped. This may be true for many other new applications in the bioeconomy sector.

In the food-waste case, low costs of waste-handling and lack of economic motivation to adjust one's practices create market barriers to unleashing the potential.

Cultural barriers:

In the B2B²⁰⁰ environment, attracting users to new marketplaces is especially challenging and must be supported by more intermediate services. Many branches of industry, such as the building and construction sector, often take a conservative approach to altering their processes.

Likewise, the competent authorities' attitudes are not always supportive of change.

An important barrier detected in nearly all of the case studies was an overall lack of consumer awareness and of consumer acceptance of changes and new solutions.

²⁰⁰ Here defined as covering all business-to-business relations (i.e., business arrangements or trade between distinct businesses, rather than between businesses and the public).

5. Conclusions on unleashing the potential – considerations for part III of the study

What is needed, then, for releasing the potential so that the Nordics can become a leading region for circular economy and an inspiration to other regions, globally?

The case studies presented in this report point to a wide range of actions, of many kinds, that can assist in overcoming some of the barriers. Table 15 offers a compilation of examples.

Table 15: Possible actions to release the circularity potential

Standards	Digital material passports Green building guidelines Practical guidelines that address how to increase CE opportunities
Technology and innovation	Circular design techniques such as circular construction methods Pilot projects Foresight centred on materials' availability through, for instance, digital platforms Harnessing of industrial symbiosis synergies (e.g., production of organic fertilisers in conjunction with biogas plants' operation)
Investments	E.g., the world's first automated industrial textile-sorting plant and investments in chemical-based recycling technology Support for redistribution stakeholders
Financial incentives	Requirements in public-procurement settings Customer prices The need to find alternative income streams Ecosystem-support mechanisms
Awareness-raising	Communicating the benefits to politicians and consumers Sharing the best practices Showcasing successful models of operating and of co-operation in value chains

To answer the question properly, in the third and final part of the project work, we will identify and analyse crucial actions and policy instruments for releasing the circularity potential we have identified.

The purpose of the final part of the study will be to identify what the Nordics can do to accelerate the circularity transition by harnessing the potential in selected areas and lowering barriers. Nordic policy measures of several types may have a large role to play in creating an environment conducive to CE transition.

The work will proceed from more detail-oriented classification and analysis of the barriers identified, which were briefly introduced in the previous chapter. Our analysis also is going to encompass further elaboration on the specific strengths and challenges the Nordic region possesses (e.g., with regard to geography, population, distances, the industrial base, and environment), the areas in which there are significant conflicting interests, and which areas might offer the most fertile ground for agreeing on measures. This analysis would be expected to form a solid foundation for discussion of what types of actions and policy instruments are necessary and desired for unlocking the potential and tearing down the barriers. Actions suitable for promoting circular economy in selected areas could extend to a wide range of areas (infrastructure development, development of inter- and intra-industry collaboration, transformation entailing emission-free fuels, adoption of new digital solutions, innovation in new areas, etc). The policy

instruments, in turn, can be characterised in accordance with the type of measure involved (e.g., legislative/regulatory, economic, and 'soft' instruments), the level of operation (EU, Nordic, national, regional or local, and/or sectoral), and the scope and significance for circularity transition. Finally, it is important to delineate the temporal dimension: which of the necessary actions and policy instruments are needed in the short, medium, and long-term, in light of each of the areas and value chains selected for attention.

The assessment will, further, involve considering the benefits and costs for society from releasing the potential for circularity transition in these areas, both within the Nordic region and, where feasible, with exploration of considerations related to the costs and benefits beyond the region's borders (e.g., in connection with global value chains).

In the final part of the study, the enablers and the specifics of each particular measure and policy instrument required will be examined in greater detail and discussed with key stakeholders. Through this endeavour, our effort will lay the foundation for a jointly created roadmap for Nordic co-operation that can help remove barriers and create incentives for releasing the potential of low-carbon circularity transition in the Nordics. The assessment produced, which will rely heavily on consultation with relevant stakeholders and ongoing Nordic projects, is intended to articulate its conclusions in a draft 'roadmap' with suggestions for concrete actions and projects that the Nordics could commit to together, presented alongside recommendations for future policy development.

Sources

Aecom (2021). 'The carbon and business case for choosing refurbishment over new build', available at <https://aecom.com/without-limits/article/refurbishment-vs-new-build-the-carbon-and-business-case/>, accessed 20.12.2021.

Aho, Maija; Pursula, Tiina; Saario, Mari; Miller, Tea; Kumpulainen Anna; Päällysaho, Minna; Kontiokari, Venla; Autio, Miikka; Hillgrén, Anna; Descombes, Laura (2015). 'The economic value and opportunities of nutrient cycling for Finland', available at <https://media.sitra.fi/2017/02/28142456/Selvityksia104.pdf>, accessed 16.12.2021.

Arcona (2021). 'Batteriet/Skjutsgossen 12', available at <https://www.arcona.se/produktomraden/kontor/batteriet-skjutsgossen-12/>, accessed 20.12.2021.

Auratum Asunnot (2021). 'Munkkiniemen Kone', available at <https://auratumasunnot.fi/referenssit/munkkiniemen-kone/>, accessed 20.12.2021.

Balafoutis, A., Bert, B., Fountas, S., Vangeyte, J., Van Der Wal, T., Soto Embodas, I., Gomez Barbero, M., Barnes, A. and Eory, V. (2017). 'Precision Agriculture Technologies positively contributing to GHG emissions mitigation, farm productivity and economics', SUSTAINABILITY, ISSN 2071-1050, 9 (8), p. 1339, JRC106659.

The Blue Carbon Initiative (2019). 'MITIGATING CLIMATE CHANGE THROUGH COASTAL ECOSYSTEM MANAGEMENT', available at <https://www.thebluecarboninitiative.org/>, accessed 21.1.2022.

Bocken, Nancy; Miller, Karen; and Evans, Steve (2016). 'Assessing the environmental impact of new Circular business models', presented at New Business Models – exploring a changing view on organizing value creation, in Toulouse, France, 16–17 June.

Canopy (2020). 'Survival - A Plan for Saving Forests and Climate A Pulp Thriller', available at <https://canopyplanet.org/wp-content/uploads/2020/01/SURVIVAL-Next-Gen-Pathway.pdf>, accedes 16.12.2021.

CCN (2021). 'The pandemic forced a massive remote-work experiment. Now comes the hard part', available <https://edition.cnn.com/2021/03/09/success/remote-work-covid-pandemic-one-year-later/index.html>. accessed 20.12.2021.

Cerema (2019). 'MaaS in Europe: Lessons from the Helsinki, Vienna and Hanover experiments', available at https://www.cerema.fr/system/files/documents/2020/04/cerema_parangonnage_maas_synthesis_eng.pdf, accessed 20.12.2021.

CERRE (2021). 'Mobility as a Service (MaasS): A digital roadmap for public sector authorities', available at https://cerre.eu/wp-content/uploads/2021/01/CERRE_EN_Mobility-as-a-Service-MaaS_A-digital-roadmap-for-organisational-authorities_January2021.pdf, accessed 21.1.2022.

Confederation of Finnish Construction Industries (2020). 'Low carbon road map of construction industry', available at https://www.rakennusteollisuus.fi/globalassets/ymparisto-ja-energia/vahahiilisyys_uudet/rt-low-carbon-roadmap-summary-2020-08-20.pdf, accessed 20.12.2021.

Cutress, David (2020). 'Can Precision Farming Help Mitigate Climate Change?', available at <https://businesswales.gov.wales/farmingconnect/news-and-events/technical-articles/can-precision-farming-help-mitigate-climate-change>, accessed 16.12.2021.

Digiprime (2021) 'Digital Platform for Circular Economy', available at <https://www.digiprime.eu/>, accessed 21.1.2022.

DTN (2021). 'Precision Farming vs. Digital Farming vs. Smart Farming : What's The Difference?', available at <https://www.dtn.com/precision-farming-vs-digital-farming-vs-smart-farming-whats-the-difference/>, accessed 16.12.2021.

Ellen McArthur Foundation (2021). 'The Nature Imperative: How the circular economy tackles biodiversity loss', available at <https://emf.thirdlight.com/link/yxmranfkw1r7-03wk36/@/preview/1?o>, accessed 21.1.2022

Ellen MacArthur Foundation (2017). 'The circular economy in detail', available at <https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail>, accessed on 16.12.2021.

European Commission (2021). 'New European Bauhaus: new actions and funding to link sustainability to style and inclusion', available at https://ec.europa.eu/commission/presscorner/detail/en/IP_21_4626, accessed 20.12.2021.

European Commission (2021, b). 'Study on the technical, regulatory, economic and environmental effectiveness of textile fibres recycling. Final Report', available at <https://www.ecologic.eu/sites/default/files/publication/2022/50030-study-textile-recycling-web.pdf>, accessed 4.2.2022.

European Commission (2020). 'Circular economy action plan', available at <https://ec.europa.eu/environment/circulareconomy/>, accessed on 16.12.2021.

European Commission (2016). 'Science for environmental policy: Car-free cities – healthier cities', available at https://ec.europa.eu/environment/integration/research/newsalert/pdf/car_free_cities_healthier_citizens_476na1_en.pdf, accessed 21.1.2022.

European Commission (2021) 'Farm to Fork', available at https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en, accessed 24.1.2022

FAO (2019). The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. available at <https://www.fao.org/3/ca6030en/ca6030en.pdf>, accessed 12.1.2022

Finnish Association of Architects (2021). 'Kummatti', available at https://www.google.com/search?q=safa+kummatti&rlz=1C1GCEA_enFl926Fl926&oq=safa+kummatti&aq=s=chrome..69i57j69i60.1775joj4&sourceid=chrome&ie=UTF-8, accessed 12.10.2021.

Finnish Transport Agency (2015). 'MaaS Services and Business Opportunities', available at https://julkaisut.vayla.fi/pdf8/lts_2015-56_maas_services_web.pdf, accessed 21.1.2022.

FutureBuilt (2022) 'Låve blir sirkulært FutureBuilt-prosjekt', available at <https://www.futurebuilt.no/Nyheter#!Nyheter/Laave-blir-sirkulaert-FutureBuilt-prosjekt>, accessed 3.2.2022.

GDPR.eu, 'What is GDPR, the EU's new data protection law?' <https://gdpr.eu/what-is-gdpr/>, accessed 4.2.2022

Giacometti, Alberto & Teräs, Jukka (2019) 'Regional economic and social resilience: An exploratory in-depth study in the Nordic countries'. Nordregio report 2019:2.

Gíslason, Stefán and Bragadóttir, Hrafnhildur (ed.) (2017). 'The Nordic Bioeconomy Initiative, NordBio', available at <http://norden.diva-portal.org/smash/get/diva2:1084345/FULLTEXT01.pdf>, accessed 16.12.2021.

Gorst, Ashley and Forslund, Tim (2021). 'The circular economy can turn the tide on biodiversity loss', available at <https://www.sitra.fi/en/articles/the-circular-economy-can-turn-the-tide-on-biodiversity-loss/>, accessed 20.12.2021.

Government Office for Science (UK) (2018). 'Mobility as a Service (MaaS) in the UK: change and its implications', available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766759/Mobilityasaservice.pdf, accessed 20.12.2021.

The Government of the Faroe Islands (2019). 'A Dynamic and Resilient Economy', available at <https://www.faroeislands.fo/economy-business/economy/>, accessed 16.12.2021.

Grønlands Statistik (2021) 'Grønland i Tal', available at <https://stat.gl/publ/da/GF/2021/pdf/Gr%C3%B8nland%20i%20tal%202021.pdf>, accessed 16.12.2021.

Hasselström Linus, Vischc, Wouter, Gröndahl Fredrik, Nylund Göran M. Paviac Henrik, 2018, available at <https://doi.org/10.1016/j.marpolbul.2018.05.005>, accessed 12.1.2022

Hanssen, Ole Jørgen; Östergren, Karin; Hartikainen, Hanna; Andersson, Tova; Werge, Mads and Prestrud, Kjersti (2021). 'Monitoring Food Waste and Loss in the Nordic region - Definitions, methods and measures for prevention', available at <https://pub.norden.org/temanord2021-504/temanord2021-504.pdf>, accessed 16.12.2021.

Horn, Susanna; Seppänen, Ari-Matti; Winquist, Erika; Lehtoranta, Suvi; Luostarinen, Sari (2020). 'Biokaasulaitoksen mädätysjännöksenhyödyntämismahdollisuudet – vaihtoehtojen ilmastovaikutukset ja taloudellisuus', available at https://helda.helsinki.fi/bitstream/handle/10138/321266/SYKEra_42_2020_BioRaEE.pdf?sequence=1&isAllowed=y, accessed 16.12.2021

Hugill, Rory; Ley, Katrin; and Rademan, Kathleen (2020). 'Coming full circle: innovating towards sustainable man-made cellulosic fibres', available at <https://fashionforgood.com/wp-content/uploads/2020/09/Coming-Full-Circle-Innovating-Towards-More-Sustainable-MMCFs.pdf>, accessed 16.12.2021.

Hurmekoski, Elias; Jonsson, Ragnar; Korhonen, Jaana; Jänis, Janne; Mäkinen, Marko; Leskinen, Pekka; and Hetemäki, Lauri (2018). 'Diversification of the forest industries: role of new wood-based products', Can. J. For. Res. 48: 1417–1432 (2018) dx.doi.org/10.1139/cjfr-2018-0116.

Højbye, Linda and Sand, Henrik (2018). 'Circular economy in the Nordic construction sector', available at <https://www.diva-portal.org/smash/get/diva2:1188884/FULLTEXT01.pdf>, accessed 20.12.2021.

Høybråten skole (2021). Velkommen til oss, available at <https://hoybraten.osloskolen.no/>, accessed 20.12.2021.

IATP (2021). 'New research shows 50 year binge on chemical fertilisers must end to address the climate crisis', available at <https://www.iatp.org/new-research-chemical-fertilisers>, accessed 16.1.2022.

IVL (2020). 'Food waste in Sweden.', available at [vl.se/english/ivl/topmenu/press/news-and-press-releases/press-releases/2020-02-20-foodwaste-in-sweden-could-fill-the-ericsson-globe-arena-four-times-over.html](https://www.ivl.se/english/ivl/topmenu/press/news-and-press-releases/press-releases/2020-02-20-foodwaste-in-sweden-could-fill-the-ericsson-globe-arena-four-times-over.html), accessed 10.1.2022.

- Jensen-Cormier, Steph; Smith, Robert; and Vaughan, Scott (2018). 'Estimating Employment Effects of the Circular Economy', available at <https://www.iisd.org/system/files/publications/employment-effects-circular-economy.pdf>, accessed 20.12.2021.
- Johansen, Ulf; Bull-Berg, Heidi; Vik, Lars H.; Stokka, Arne M.; Richardsen, Roger; Winther, Ulf (2019). 'The Norwegian seafood industry – Importance for the national economy', Marine Policy, Volume 110, 2019.
- Kallio, A. Maarit I. (2021). 'Wood-based textile fibre market as part of the global forest-based bioeconomy', available at <https://www.sciencedirect.com/science/article/pii/S1389934120306900#!>, accessed 16.12.2021.
- Kamppuri, Taina; Kallio, Katri; Mäkelä, Satu-Marja; Harlin, Ali (2021) "Finland as a forerunner in sustainable and knowledge-based textile industry - Roadmap for 2035" https://cris.vtt.fi/ws/portalfiles/portal/52199670/Finland_as_a_forerunner_in_sustainable_and_knowledge_based_textile_industry_Roadmap_for_2035.pdf, accessed. 16.1.2022
- Laine, Anna; Lampikoski, Tommi; Rautiainen, Tuukka; Bröckl, Marika (2018). 'Mobility as a Service and Greener Transportation Systems in a Nordic context', available <http://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A1267951&dswid=-7221>, acceded 21.1.2022.
- Lantmännen (2019). 'Farming of the Future: The road to climate neutral farming 2050', available at <https://www.lantmannen.com/contentassets/a7c4d84884744bco82914ffeca6a4ff7/lantmannen-farming-of-the-future.pdf>, accessed 16.12.2021.
- Luke (2021) 'Ruoantuotannon ja -kulutuksen vaikutukset ympäristöön ja ilmastoon', available at <https://www.luke.fi/tietoa-luonnonvaroista/ruoka-ja-ravitsemus/ruoan-ilmastovaikutukset/>, accessed 16.12.2021.
- Lund Gade, Annika; Jørgensen, Leif Bach; Ekqvist, Ida; Holter, Therese; and Pira, Kajsa (2021). 'Nordic Food Transition- Low emission opportunities in agriculture', available at <https://pub.norden.org/temanord2021-525/temanord2021-525.pdf>, accessed 16.12.2021.
- Luostarinen, Sari; Tampio Elina; Berlin, Titta; Grönroos, Juha; Kauppila, Jussi; Koikkalainen, Kauko; Niskanen, Olli; Rasa, Kimmo; Salo, Tapio; Turtola, Eila; Valve, Helena; Ylivainio, Kari (2019). 'Keinoja orgaanisten lannoitevalmisteiden käytön edistämiseen', available at https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161419/MMM_2019_5_Orgaaniset_lannoitevalmisteet.pdf, accessed 16.12.2021.
- MaaS Alliance (2021). Front page. Available at <https://maas-alliance.eu/>, accessed 20.11.2021.
- Matvett (2020) "Food waste reduction in Norway", available at <https://www.matvett.no/uploads/documents/Food-waste-reduction-in-Norway-2020.pdf>, accessed 10.1.2022
- Ministry of Environment of Finland (2021). 'The New European Bauhaus', available at <https://www.nordicbauhaus.eu/#/page=1>, accessed 20.12.2021.
- MONIOS, J. & BERGQVIST, R. (2020). Logistics and the networked society: A conceptual framework for smart network business models using electric autonomous vehicles (EAVs). Technological Forecasting and Social Change, 151, 119824.
- Motiva (2021). 'Materiaalikiertojen data-alusta ja ekosysteemi', available at https://www.motiva.fi/ratkaisut/materiaalitehokkuus/materiaalikiertojen_data-alusta_ja_ekosysteemi, accessed 16.12.2021.

Naturverket (2020). Informative inventory report Sweden 2020', available at <https://www.naturvardsverket.se/upload/sa-mar-miljon/klimat-och-luft/luft/luftfororeningar/informative-inventory-report-sweden-2020.pdf>, accessed 12.10.2021.

NCC (2021). 'Savonkatu', available at <https://savonkatukehitty.fi/en/>, accessed 20.12.2021.

NCC (2020). 'Massive flyttar in i nytt kontor totalomvandlat av NCC', available at <https://www.ncc.se/media/nyheter/massive-flyttar-in-i-nytt-kontor-totalomvandlat-av-ncc/>, accessed 20.12.2021.

Nordic Blue Carbon (2021). Nordic Blue Carbon, available at <https://nordicbluecarbon.no/>, accessed 21.1.2022.

Nordic Circular Arena (2021). 'Welcome to the Nordic Circular Arena', available at <https://nordiccirculararena.com/>, accessed 16.12.2021

Nordic Council of Ministers (2021). 'Our vision 2030', at <https://www.norden.org/en/our-vision-2030>, accessed on 16.12.2021.

Nordic Council of Ministers (2018). 'Nordic Bioeconomy Programme: 15 Action Points for Sustainable Change', available at <http://norden.diva-portal.org/smash/get/diva2:1222743/FULLTEXT01.pdf>, accessed 16.12.2021.

Nordic Council of Ministers (2017) 'Nordic Bioeconomy; 25 cases for sustainable change', available at <https://norden.diva-portal.org/smash/get/diva2:1065456/FULLTEXT01.pdf>, accessed 7.1.2022.

Nordic Council of Ministers (2017). 'PREVENTING FOOD WASTE – better use of resources', available at <https://norden.diva-portal.org/smash/get/diva2:1115667/FULLTEXT01.pdf>, accessed 16.12.2021.

Nordic Council of Ministers (2019) 'Nordic Agriculture and Climate Change: Mitigation and Adaptation' available at <https://norden.diva-portal.org/smash/get/diva2:1135119/FULLTEXT01.pdf>, accessed 16.12.2021

Nordic Council of Ministers (2016). 'End-of-Waste Criteria for Construction & Demolition Waste' at <https://www.norden.org/en/publication/end-waste-criteria-construction-demolition-waste>, accessed on 8.2.2022.

Nordic Innovation (2021). 'Invitation to Tender: Sustainable Ocean Economy Ecosystem and Strongholds Mapping', available at <https://www.nordicinnovation.org/programs/invitation-tender-sustainable-ocean-economy-ecosystem-and-strongholds-mapping>, accessed 16.12.2021.

Norwegian Ministries (2020) Blue Opportunities The Norwegian Government's updated ocean strategy available at https://www.regjeringen.no/globalassets/departementene/nfd/dokumenter/strategier/w-0026-e-blue-opportunities_uu.pdf, accessed 19.1.2022

Norwegian ministry of Climate and Environment (2019). 'Norway's integrated ocean management plans — Barents Sea—Lofoten area; the Norwegian Sea; and the North Sea and Skagerrak— Report to the Storting (white paper)', available at <https://www.regjeringen.no/en/dokumenter/meld.-st.-20-20192020/id2699370/?ch=5>, accessed 21.1.2022.

Nußholz, J.L.K., Rasmussen, F.N., Whalen, K.A., & Plepys, A. (2020). Material reuse in buildings: Implications of a circular business model for sustainable value creation. *Journal of Cleaner Production*, 245, 118546.

OECD (2019). 'Business models for the circular economy. Opportunities and challenges for policy'. <https://www.oecd.org/environment/business-models-for-the-circular-economy-g2g9dd62-en.htm>, accessed on 16.12.2021.

OECD (2016). 'The Ocean Economy in 2030', available at https://www.oecd.org/sti/ind/Session%201_b%20-%20Claire%20Jolly%20-%20Web.pdf, accessed 21.1.2022.

Onstot, Casey (2021) 'Digital Agriculture Tools Enable Farmers to Make Proactive Decisions', available at <https://www.precisionag.com/digital-farming/with-digital-agriculture-farmers-become-proactive-not-reactive-decision-makers/>, accessed 16.1.2022.

The Platform for Accelerating the Circular Economy (2021). 'The Circularity Gap Report', available at <https://www.circularity-gap.world/2021>, accessed 20.12.2021.

Pace Circular (2020). 'Denmark against Food Waste', available at <https://pacecircular.org/denmark-against-food-waste>, accessed 13.1.2022.

Potočnik Janez (2021) at OECD roundtable on Circular Economy in cities and regions, May 2021. https://www.oecd.org/cfe/cities/CE_RT3_Highlights.pdf

Ramboll (2019). 'Vantaan Ankkapuiston hankkeelle kunniainnointi', available at <https://fi.ramboll.com/media/rfi/vantaan-ankkupuiston-kunnostukselle-kunniainnointi>, accessed 16.12.2021.

Refsgaard, Karen; Kull, Michael, Slätmo, Elin; Woien Meijer, Mari (2021). 'Bioeconomy – A driver for regional development in the Nordic countries', available at <https://www.sciencedirect.com/science/article/pii/S1871678420301746>, accessed 16.12.2021.

Remeo (2020). 'Remeo toteuttaa Suomen edistyskeskeisimmän kierrätyslaitoksen', available at <https://remio.fi/kiertotalous/tulevaisuuden-kierratyslaitos/>, accessed 20.12.2021.

Rizos, Vasileios; Tuokko, Katja; Behrens, Arno (2017). 'The Circular Economy: A review of definitions, processes and impacts', available at https://www.researchgate.net/publication/315837092_The_Circular_Economy_A_review_of_definitions_processes_and_impacts, accessed 20.12.2021.

Sandin, Gustav; Roos, Sandra; Johansson, Malin (2019). 'Environmental impact of textile fibers – what we know and what we don't know', Mistra Future Fashion report number: 2019:03 part 2, available at http://mistrafuturefashion.com/wp-content/uploads/2019/03/Sandin-D2.12.1-Fiber-Bibel-Part-2_Mistra-Future-Fashion-Report-2019.03.pdf, accessed 16.12.2021.

Schlesinger, W.H., Andrews, J.A. (2000) 'Soil respiration and the global carbon cycle'. *Biogeochemistry* 48, 7–20.

Schulz, Tobias & Suresh, Aditi (2017). Life Cycle Assessment Comparing Ten Sources of Manmade Cellulose Fiber. Available at <https://cdn.scsglobalservices.com/files/resources/SCS-Stella-LCA-MainReport-101017.pdf>, accessed 21.1.2022.

Sepponen, Susanna; Hjelt, Mari; Kuusela-Opas, Emma; Pakkala, Anna; Suominen, Fanny; and Värre, Ulla (2021). Sustainable ocean economy. Mapping of Nordic Strongholds. Nordic Innovation 2021. Available at <https://norden.diva-portal.org/smash/get/diva2:1611425/FULLTEXT01>

Seroka-Stolka, Oksana and Ociepa-Kubicka, Agnieszka (2019) 'Green logistics and circular economy', *Transportation Research Procedia* 39 (2019) 471–479.

Sheidaei, M. and Serwanja, E. (2016). Evaluation of Recycling & Reuse of Building materials from Demolition: Cost feasibility and environmental impact assessment. Master's thesis, Chalmers University of Technology.

Silfver, Vesa (2021) 'Key factors in design of a new B2B circular economy platform ecosystem', available at https://www.motiva.fi/files/19053/Key_Factors_in_Design_of_a_New_B2B_Circular_Economy_Platform_Ecosystem_-_Vesa_Silfver_Henley_Business_School.pdf, accessed 16.12.2021.

Silvennoinen, Kari (2020) 'Food Waste Amount, Type and Origin in Finland – Focus on Households and Food Services', available at <https://helda.helsinki.fi/bitstream/handle/10138/318224/FoodWast.pdf?sequence=1&isAllowed=y>, accessed 24.1.2022

Sitra (2021). 'How does the circular economy change jobs in Europe?', available at <https://media.sitra.fi/2021/03/27163705/sitra-how-does-the-circular-economy-change-jobs-in-europe-v2.pdf>, accessed 20.12.2021.

SOCHOR, J., ARBY, H., KARLSSON, I. M. & SARASINI, S. (2018). A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. *Research in Transportation Business & Management*, 27, 3-14.

Statistics Finland (2019). 'Sähköpotkulautojen ympäristöystävällisyys oletettua vähäisempää – liikenneturvallisuus herättää huolta', available at <https://www.stat.fi/tietotrendit/artikkelit/2019/ovatkosahkopotkulaudat-hyva-vaihtoehto-kaupunkiliikenteessa/>, accessed 21.1.2022.

STT (2021) 'Finnforel to Invest EUR 45 Million in New Production Facilities and Build First Selective Breeding Centre for Rainbow Trout in Finland', available at <https://www.sttinfo.fi/tiedote/finnforel-to-invest-eur-45-million-in-new-production-facilities-and-build-first-selective-breeding-centre-for-rainbow-trout-in-finland?publisherId=58763726&releasId=69924027>, accessed 21.1.2022.

SourceTrace (2021). 'Impact of Climate Changes on Agriculture', available at <https://www.sourcetrace.com/blog/combating-climate-change-precision-agriculture-help/>, accessed 16.12.2021.

SOU (2020). Producentansvar för textil – en del av den cirkulära ekonomin. Betänkande av Utredningen om producentansvar för textil. Statens offentliga utredningar SOU 2020:72. Stockholm 2020. Available at <https://www.regeringen.se/4ada18/contentassets/b6ad93ca7b9a40518355624c010dea7d/producentansvar-for-textil--en-del-av-den-cirkulara-ekonomin-sou-202072>, accessed 4.2.2022.

Sønvisen Signe and Vik Christian Shaping Aquaculture Management—An Interest Tug O' War, <https://doi.org/10.3390/su13168853>, accessed 12.1.2022

Submariner Network (2021). 'Together we improve the Baltic Sea environment', available at <https://www.submariner-network.eu/>, accessed 16.12.2021.

Swedish Waste Management Association 2018. More to do more. Action plan for food loss and food waste reduction by 2030 – SUMMARY. June 2018, available at <https://www.livsmedelsverket.se/globalassets/publikationsdatabas/rapporter/2016/2018-more-to-do-more-action-plan-for-food-loss-and-food-waste-reduction-by-2030-summary.pdf>, accessed 4.2.2022

Sysav (2021). 'Siptex som forskningsprojekt', available at <https://www.sysav.se/om-oss/forskning-och-projekt/siptex/>, accessed 16.12.2021.

Textile Exchange: "Preferred Fiber & Materials Market Report "(2021) available at https://textileexchange.org/wp-content/uploads/2021/08/Textile-Exchange_PREFERRED-Fiber-and-Materials-Market-Report_2021.pdf, accessed 20.12.2021

Teräs, Berlina & Wøien Meijer 2021. The Nordic Thematic Group for Innovative and Resilient Regions 2017–2020. Final report. By Jukka Teräs, Anna Berlina & Mari Wøien Meijer. Nordregio report 2021:3. <http://norden.diva-portal.org/smash/get/diva2:1523000/FULLTEXT01.pdf>

Umhverfisstofnunar (2020). 'Food waste statistics for Iceland in 2019', available at <https://samangeignsoun.is/wp-content/uploads/2021/08/Matarsounarrannsokn-Umhverfisstofnunar-2019.pdf>, accessed 12.1.2022

UNEP (2021). UN environment programme, "Definition of food loss and waste" available at <https://www.unep.org/thinkeatsave/about/definition-food-loss-and-waste> , accessed 12.1.2022

Upadhyaya, Arvind; Sumona Mukhutyb; Vikas Kumarc; Yigit Kazancoglud (2021). 'Blockchain technology and the circular economy: Implications for sustainability and social responsibility', Journal of Cleaner Production, Volume 293, 15 April 2021.

Vandkunsten Architects (2016). 'Final Report /Nordic Built Component Reuse', available at <https://norden.diva-portal.org/smash/get/diva2:1431214/FULLTEXT01.pdf>, accessed 20.12.2021

VTT (2018). 'Logistics is challenging in a circular economy', available at <https://www.vttresearch.com/en/news-and-ideas/logistics-challenging-circular-economy>, accessed 21.1.2022.

Wahlström, Margareta; zu Castell-Rüdenhausen, Malin; Fruergaard Astrup, Thilde; Oberender, Anke; Jensen, Carl; Johansson, Pernilla and Wærner, Eirik (2021). 'Strategies and methods for implementing CE in construction activities in the Nordic countries – supporting cases', available at <https://www.diva-portal.org/smash/get/diva2:1543438/FULLTEXT01.pdf>, accessed 16.12.2021.

Waseabi (2019). 'About the project', available at <https://www.waseabi.eu/about-waseabi/>, accessed 21.1.2022.

White Recruitment (2020). 'The future of talent in the logistics sector', available at <https://www.whiterecruitment.com/blog/2020/08/future-of-logistics-skills>, accessed 21.1.2022.

Yara (2021). 'Solutions and tools for modern farming', available at <https://www.yara.com/crop-nutrition/products-and-solutions/precision-farming/>, accessed 16.12.2021.

Zu Castell-Rüdenhausen, Malin; Wahlström, Margareta; Fruergaard Astrup, Thilde; Jensen, Carl; Oberender, Anke; Johansson, Pernilla; Waerner, Eirik Rudi (2021). 'Policies as drivers for circular economy in the construction sector in the nordics' available at <https://cris.vtt.fi/ws/portalfiles/portal/52582025/su13169350.pdf>, accessed 14.1.2021

Annex 1. Stakeholder workshop

A Nordic stakeholder workshop was held online on 14 October 2021, attended by 22 participants.

The workshop agenda included presentation of the project, presenting and discussing the potential and barriers of selected opportunities.

The workshop agenda was the following:

1. Introduction to the project
2. Presentation of identified circular economy opportunities and discussion
3. Next steps of the project
4. Discussion and conclusions

Participating organisations are listed in the Table 9.

Table 9. Nordic Stakeholder workshop participants

Circular Sweden
Danish Agriculture & Food Council
Danish Business Authority
Dansk Industri
Finnish Forest Industries Federation
Icelandic Association of Local Authorities
IVL Swedish Environmental Research Institute
KPMG Iceland
Ministry of Environment of Finland
Motiva, Finnish State Company for Sustainable Development
Norsk Industri
Norwegian Centre for Circular Economy
SFF Finance Iceland

Annex 2. Longlist of circular opportunities identified

Sector	Potential opportunity
All	Transparency and traceability of products
All	Consumer awareness and sustainable consumption patterns
All	Supply chain/material flows management
All	Efficient recycling infrastructure
Real estate and construction	Building information management systems and digital product passports (link to construction waste management)
Real estate and construction	Sharing business models to increase rate of utilisation of assets
Real estate and construction	Using robots and 3D printing to contribute to fuller utilisation of reuse and recycling and to cutting construction waste;
Real estate and construction	Optimising initial and final activities such as construction-waste management
Real estate and construction	IoT and predictive maintenance
The bioeconomy	Wood-based textile fibres with focus on supply chain optimisation
The bioeconomy	New biomaterials: wood
The bioeconomy	New biomaterials: ocean biomass
The bioeconomy	Pharma / Chemicals
The bioeconomy	Digital market places for side streams promoting new uses
The bioeconomy	Precision agriculture
The bioeconomy	Precision aquaculture
The bioeconomy	Precision forestry
The food and beverage industry	New business models and digital platforms for the minimisation of food loss and other waste
The food and beverage industry	Sustainable diets
The food and beverage industry	Food waste to biogas
Transport, logistics and mobility	Logistics as a service: 3D printing
Transport, logistics and mobility	Logistics as a Service: Changes in ownership
Transport, logistics and mobility	Logistics as a Service: Drones
Transport, logistics and mobility	Reverse logistics for circular economy
Transport, logistics and mobility	Recycling infrastructure, e.g. recovery and reuse of materials from vehicles