

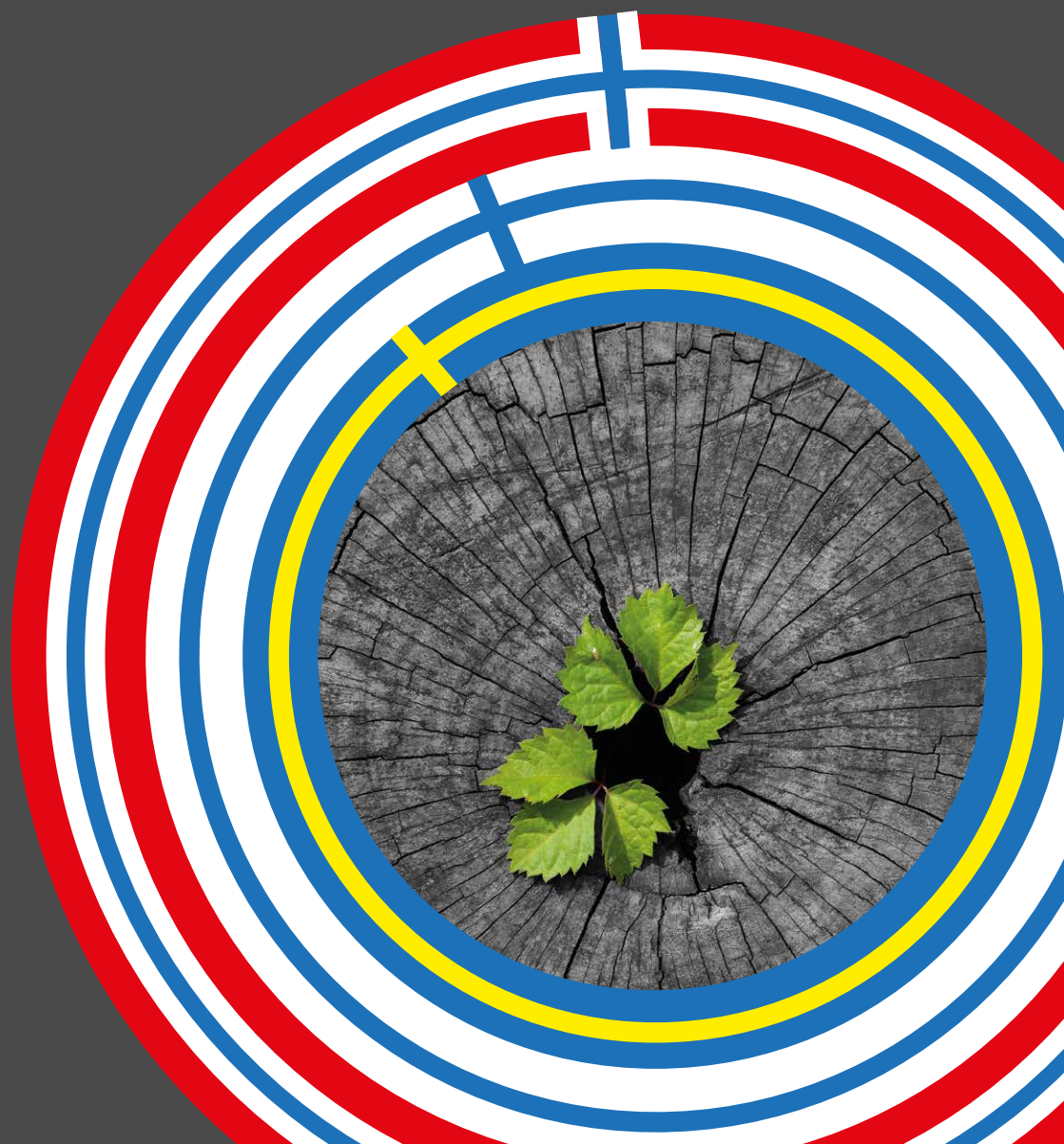
Report

The Forest in Northern Europe's Emerging Bioeconomy

Reflections on the forest's role in the bioeconomy

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For authors' biograph, see page 63.

December 2020

Foreword

The Barents Euro-Arctic Council (BEAC) was launched on 11 January 1993 in Kirkenes, Norway. The BEAC has since been the forum for intergovernmental cooperation in the Barents region with a view to strengthen peace, stability and sustainable development by improving opportunities for cooperation across borders. The different Barents working groups constitute a cross-border platform for exchange for the civil servants and professionals of the respective field. The aim of the Working Group for Barents Forest Sector (WG BFS) is to promote sustainable management and utilization of forest resources and ecosystem services in line with the 2030 Agenda for Sustainable Development, the United Nations Strategic Plan for Forests as well as the Paris Climate Agreement.

The forest sector is an important part of the economic, social and environmental development in the Barents region and the forest plays a central role in the transition to a bio-based circular society. However, the concept of bioeconomy and how it relates to the forest is not always well understood. It was against this background the WG BFS, under the Swedish chairmanship (2017-2019), initiated the study “The forest in the emerging circular bioeconomy in northern Europe”. The study compares and analyzes the role of forests in the bioeconomy of northern Europe. It also highlights challenges and opportunities to increase its contribution to climate change mitigation, human wellbeing and the transfer to a fossil-free society.

From my position at the Swedish Forest Agency (SFA) I think the report comes timely as the Swedish Government is now well underway to formulate a national bioeconomy strategy. SFA has been assigned to contribute to this work.

I would like to express my sincere gratitude to Camilla Widmark and the group of experts that contributed to this report.

I hope you will find the report informative, thought-provoking and a useful reference-point in your own endeavor to make a case for the forest sector’s role in a bio-based circular society.

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Acknowledgements

The initiative of the report springs from the Barents Forest Sector Network, now Working Group on Barents Forest Sector (WG BFS) of the Barents Euro-Artic Council (BEAC). The report has been financed by the Swedish Government via the Swedish National Forest Programme. The Swedish University of Agricultural Sciences (SLU) and the EFI Forest Bioeconomy Network lead the development of the report.

A working group consisting of experts from Finland, Norway and Sweden has developed the report. The views expressed in this publication are those of the authors. The development of the report started during a workshop at the Barents Forest Forum (in Umeå – Sweden, 2019), and a number of workshops was further planned. However, as the Covid-19 pandemic developed in 2020, shorter workshops and discussions were carried out via online meetings. It is based upon published research papers, grey literature, official statistics, and reports. The authors acknowledge the kind support by the Swedish Forest Agency, and especially thank the Steering group of the Barents Forest Forum for support and engagement during the process of developing the report.

The editor, Camilla Widmark, also appreciates the input and collaboration with the writing team. Further, the report has also benefited from the assistance of intern Aemiro Melkamu Daniel (SLU) and Prof. Peichen Gong (SLU), who have provided helpful comments and helped in developing background material for this report.

Summary

The forests in Nordic countries have been a source of food, products and welfare for both local communities and for the nations as long as there has been any settlement. More recently, the way the forest supports the climate has become more pronounced. However, humans now face major challenges due to climate change as well as societal and environmental challenges. Fundamental changes are needed to ensure future prosperity in the face of growing resource depletion, climate changes and environmental degradation. What has become clear is that fossil dependence must be overcome and be replaced with bio-based materials and innovations to support the more efficient use of resources — thus, creating a more bioeconomy-based society.

This report describes the role of the forest in bioeconomy transformation and green innovation in the northern part of Europe — Finland, Norway and Sweden — and highlights the challenges facing forests in this emerging bioeconomy. These countries are also part of the Barents area, thus the northern part of Finland, Norway, Sweden and Russia. In summary, the report discusses several common features and lessons learned from these countries:

- Forests are crucial for the development of sustainable bioeconomy in the Nordic countries in substituting fossil fuel-based materials and energy. Forest biomass has a large potential for developing new bio-based products.
- Bioeconomy and circular economy transformation depend on both technical and social innovations together with societies adapting to a bio-based sustainable future, which emphasises the ecologic, economic, and social functions of forests. In policymaking and forest management, synergies need to be realised and trade-offs evaluated and addressed in forest management in general.
- Bioeconomy transformation is driven by the development of forest value chains and innovations based on forest biomass, in which research and development go hand in hand with investments and policy regulations.
- Consumers are a main driver of bioeconomy transformation replacing the demand of fossil-based materials with bio-based.
- Choices, both in policy and forest management, have to be made to support the continuous provision of all forest ecosystem services.
- The contributions of forest to bioeconomy are regional, national, as well as cross-country (e.g. Baltic, Barents or Nordic), and international (e.g. EU) and the forest's contribution to bioeconomy has to be considered in relation to properties of the forest, sustainability, innovations, knowledge development, green investment structures as well as national policies.

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List of abbreviations

LIST OF ABBREVIATIONS

BSE	Building Sink Effect
CBD	Convention on Biological Diversity
EU	European Union
FSC	Forest Stewardship Council
FORMAS	Swedish Research Council for Sustainable Development
GDP	Gross Domestic Product
GHG	Green House Gas
GROT	Branches, tops, roots
NCoM	Nordic Council of Ministers
NWFP	Non-Wood Forest Product
PEFC	Programme for Endorsement of Forest Certification
RHD	Reindeer Herding Districts
RMA	Reindeer Management Areas
SDG	Sustainability Development Goal
SFA	Swedish Forest Agency
UN	United Nations

LIST OF UNITS

bn	billion
EUR	Euro
m ³ sub	Cubic meter solid wood without bark
ha	hectare
k	thousand
m	million
m ³	Cubic meter timber
NOK	Norwegian krona
SEK	Swedish krona

EXCHANGE RATES (BY DECEMBER 29, 2020)

1 EUR = 10.56 NOK	1 NOK = 0.094 EUR
1 EUR = 10.08 SEK	1 SEK = 0.99 EUR

1 Introduction

By 2050, the Earth's population will have reached 9.7bn, with a large portion (66%) of people living in urban areas and living an urban lifestyle (DESA 2015). Humanity's biggest challenge is to preserve the planet for further generations, and there is a constant call for solutions to tackle this challenge. In order to be feasible, such solutions must be both available and affordable to people, and, furthermore, their technical performance has to be equal to or better than that of the competing, less sustainable solutions (e.g. Heräjärvi & Marttila 2016). The world has developed into a global, digitalised, and urban society, with an economy driven mostly by fossil-based fuels and resources, which has contributed to demographic and economic growth. However, this economy has also resulted in negative effects, such as accelerated climate change, intense land use, air and water pollution, soil degradation and biodiversity loss. To find solutions to these challenges, alternatives are needed for maintaining economic growth while minimising energy and material consumption (e.g. Winkel 2017). A new economic paradigm is needed to manage this transformation in accordance with the Paris Agreement on climate change and the UN Sustainability Development Goals (SDG). To reach the UN SDGs, the economy must undergo a green transition in which economic development and environmental policies are intertwined (D'Amato et al. 2017).

The bioeconomy has been identified as one possible alternative economic paradigm for “greening” the economy. EU policy, for example, emphasises biotechnologies, sustainability as well as a reliance on renewable biological resources. The success of the bioeconomy depends on society's ability to adapt to and to transform production and consumption patterns into renewable bio-based materials, to increase energy and material efficiency, as well as to utilise technological development. The bioeconomy can be considered as a biologisation of the economy. This process involves transforming economic sectors — for example, transportation, construction, material, energy, and fashion — by developing digital bio- and nanotechnologies to maximise the use of the biomass and to minimise the use of non-renewable materials (D'Amato et al. 2017; Schütte 2018).

Society faces many challenges in transforming itself into a bioeconomy, as the biomass is limited, and its use can conflict with environmental and societal use of the resource. It is, thus, important to include ecosystem services — the service that nature provides for human well-being — in the bioeconomy to ensure societal and environmental sustainability (Hetemäki et al. 2017; Martinez de Arano et al. 2018). In the Baltic Sea region, urbanisation was identified as a challenge for developing the bioeconomy, given that younger people are moving to cities, hindering the growth of the bioeconomy in rural areas (NCoM 2020).

Drivers supporting the growth of the bioeconomy can also be found among the economic changes experienced by societies. For instance, in the Baltic sea region as well as the Barents region, digitalisation has been identified as a driver of bioeconomy, which can potentially change business models. It may generate more efficient resource use and create value-

producing opportunities. Increased investment trends in green sectors provide opportunities for the development of the bioeconomy, together with a new political interest in supporting sustainability as well as bio-based sectors. The final driver identified in the Baltic Sea region is the electrification of energy and transport services, which has replaced fossil fuels but also reduced the need for bio-based fuels (NCoM 2020).

For the northern European economies, like Finland, Norway and Sweden, the forest is one important source of biomass but also an important provider of other ecosystem services, such as climate change mitigation, non-wood forest products (NWFP) (e.g. berries and mushrooms as well as recreation and tourism), biodiversity support and air and water purification. Nature tourism is, for instance, a growing sector adding value to the GDP (Gross Domestic Product). Forests and the forest sector are already transitioning from producing traditional goods — such as timber, pulp, and paper as well as bioenergy — to implementing techniques to develop new forest-based bio-based products, such as replaceable plastics, new pharmaceuticals, wood as a building material (replacing steel and concrete) and textile fibres. However, the forest is sensitive to management and extreme events, which may disturb its biological integrity through, for example, unsustainable management or climatic events. Bioeconomy transformations based upon forest contributions, thus, depend on a delicate balance between biomass production and sustainable ecosystem management (e.g. Hetemäki et al. 2017; Kleinschmit et al. 2017).

For the process of transforming the economy into bioeconomy, as well as meeting challenges of climate change, collaborations on both national, regional, and international scales are essential in future policymaking. International collaborations on UN and EU are already ongoing. However, given the specific characters of forest and their roles in the Nordic societies, regional collaborations within the Nordic, Baltic and Barents¹ areas may support knowledge development and strengthen their positions in international collaborations.

The main purpose of this report is to identify and describe the contributions of forests to bioeconomy transformation in the northern part of Europe — Finland, Norway, and Sweden (henceforth denoted study area) —based upon existing knowledge. The report concentrates on bioeconomy transformation related to forests and forest ecosystem services. The report further aims at discussing policy implications for further developing regional collaborations.

The report's second chapter describes the general bioeconomy strategies of the EU as well as those three Nordic countries. Chapter 3 describes the forest and forest-based sectors in the study area, while chapter 4 identifies national and regional forestry programs and their contribution to the growth of the bioeconomy. Chapter 5 describes the contribution of forests to the bioeconomy, while chapter 6 focuses on the contribution of NWFP to the bioeconomy. Chapter 7 summarises the report. Each chapter ends by summarising the key take-home messages.

¹ Barents region consists of the countries close to the Barents Sea – thus Finland, Norway, Russia and Sweden, and includes the northern part of these countries (Barents 2020)

2 Bioeconomy strategies

The European Union (EU), the three countries of the Nordic region and a number of European countries have developed bioeconomy strategies. Among the studied countries, Finland and Norway have developed national bioeconomy strategies in addition to the EU strategies, while Sweden has chosen to only implement the EU-based strategies. However, in 2020, the Swedish government initiated the development of bioeconomy strategy as well. In this chapter, the bioeconomy strategies affecting the three Nordic countries are summarised.

2.1 The European Union bioeconomy strategies

The concept of a knowledge-based bioeconomy was officially introduced in EU policy in 2005, the policy emphasised biotechnologies and sustainability as well as transforming life science knowledge into sustainable, eco-efficient and competitive products. In 2007, biomass transformation was stressed in the document *En route to the bio-based economy*. Between 2007 and 2013, the EU also put forward research initiatives to promote a knowledge-based bioeconomy, including biotechnologies focused on agriculture, fisheries and forestry (EC 2018a). The EU Bioeconomy Strategy adopted in 2012 addressed

‘the production of renewable biological resources and their conversion into vital products and bio-energy’ (EC 2012).

The EU Bioeconomy strategy was updated in 2018, addressing the transformative potential of bioeconomy to address

‘the decarbonization of energy markets, lower greenhouse gas emissions, sustainable management of natural resources, the reduction of social inequality, and meeting the food security demands of a growing global population’ (EC 2018a p. 105).

The strategy continuously emphasises economic growth and living standards. In the present EU bioeconomy strategy, bioeconomy is defined as follows

‘covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. [...]. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources; i.e. agriculture, forestry, fisheries and aquaculture; and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services’ (EC 2018a p. 105).

Additionally, the EU bioeconomy strategy addressed the SDG to ensure energy access, food and nutrition as well as health.

The strategy includes five main objectives:

- Ensuring food and nutrition security;
- Managing natural resources sustainably;
- Reducing dependence on non-renewable, unsustainable resources whether sourced domestically or from abroad;
- Mitigating and adapting to climate change; and
- Strengthening European competitiveness and creating jobs (EU 2018a).

The EU has implemented 14 actions concerning unlocking investment opportunities in the bio-based sector, deploying local bioeconomy strategies over Europe and better understanding the ecological boundaries of nature. Each action has a number of sub-actions (EC 2018b).

Recently initiated, as well as upcoming, strategies or directives at EU level (e.g. European Green Deal, the EU Common Agriculture Policy, the EU Biodiversity Strategy and the EU renewable Energy Directive) are also closely related to the sustainable use of natural resources within the bioeconomy.

According to the EU Green Deal, forests in the EU area need to be improved and extended to contribute to a climate-neutral EU and a healthy environment. *‘Sustainable re- and afforestation and the restoration of degraded forests can increase absorption of CO2 while improving the resilience of forests and promoting the circular bio-economy’* (EC 2019 p. 13).

A new EU forest strategy is to be developed in 2020 with the primary target to while considering the forest ecological principles that contributes to biodiversity, promote

- Efficient re- afforestation;
- Conserve and restore forests in Europe;
- Contribute to increasing carbon mitigation; and
- Promote bioeconomy (EC 2019).

2.1.1 The contributions of the bioeconomy in the EU 27

In 2017, the bioeconomy² generated about EUR 2.232bn turnover, and it contributed EUR 614bn in added value. In total, the bioeconomy employed 17.5 m within the EU27. The bioeconomy sector agriculture and the manufacture of food, beverages and tobacco is the largest contributor to the bioeconomy, comprising about 76% (EUR 404bn) of the added value and 78% (13.67m) of the employment in the bioeconomy. The contribution of the forest-based bioeconomy³ accounted for 19% (EUR 114bn) of the value added and 15% (2.53m) of employment of the entire bioeconomy. More labour-productive sectors, such as the manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber, accounted for 9.8% (EUR 60bn) of the value added and 2.3% (396k) of employment in the bioeconomy sectors (EC 2020a).

Between 2008 and 2017, the value added per person employed in bioeconomy increased from about EUR 25k to about EUR 35k and by 2017, 2.5m people were employed in the bioeconomy sectors. Employment mostly increased in the following sectors: bio-based electricity (increased by 232.46%), bio-based chemicals, pharmaceuticals, plastics and rubber (excluding biofuels; increased by 7.73%), forestry (increased by 6.05%) and food, beverage and tobacco (increased by 2.10%) (EC 2020a).

² These calculations were done for the following bioeconomy sectors: agriculture; forestry; fishing and aquaculture; manufacture of food, beverages and tobacco; manufacture of bio-based textiles; manufacture of wood and wooden furniture; manufacture of paper and paper products; manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excluding biofuels); and production of bio-electricity.

³ Including forest, paper, wood products and furniture. The value added may be larger than presented, as the division of categories are not separated according to resources type, for example bio-based textiles, bio-based chemicals and bio-based electricity.

The presented data and information on the contribution of the bioeconomy to the EU 27 does not reflect the state of the present bioeconomy in each EU country. A study by Ronzon et. al. (2020) shows that there are differences in the contribution of the bioeconomy between national economies, especially in terms of labour productivity as well as diversification of bioeconomy.

2.2 Nordic Council of Ministers bioeconomy strategy

The Nordic Council of Ministers (NCoM), an official body for inter-governmental co-operation in the Nordic region, envision ‘*that the Nordic region will become the most sustainable and integrated region in the world by 2030*’ (NCoM 2020). The NCoM’ bioeconomy program, initiated in 2018, combines terrestrial and aquatic bioresources with technological advancement to develop the bioeconomy as a fundamental part of nations’ economy, specifically in rural areas (NCoM 2018). The 2018 – 2020 NCoM’ bioeconomy programme,

‘aims to create new industries and value chains and to facilitate and guide the transition of traditional bio-based industries (agriculture, forestry and fishery processing) into technologically advanced industries and small and medium-sized enterprises (SMEs). It also aims to optimise the use of biomass in order to unlock its full potential and generate value. The overarching aim of the programme is to contribute to the rapid development of the Nordic bioeconomy through strong policy support at both national and Nordic level’ (NCoM 2018, p. 7).

The programme sets out a vision for the Nordic bioeconomy based on four pillars or objectives:

- Competitive bio-based industries;
- Sustainable resource management;
- Resilient and diverse ecosystems; and
- Inclusive economic development.

The related fifteen action points (see Table 1) support the objectives grouped under the categories innovate, accelerate and network (NCoM 2018).

Table 1. Fifteen action points of the Nordic Council of Ministers

Supporting research, innovation and human capital	1. Increased R&D funding; 2. More coherent policies; 3. Investment support; 4. New educational opportunities; 5. Provide intelligence;
Developing policies and the market	6. Targeted public procurement; 7. Regulatory frameworks; 8. Labelling and certificates; 9. Regional innovation strategies; 10. Promote cross-border freedom of movement;
Forging new and stronger connection	11. Support bioeconomy clusters; 12. Open access to test and demonstration centres; 13. Macro-regional co-operation; 14. Bolstering networking activities; 15. Nordic impact and branding

(NCoM 2018)

2.3 The Finnish Bioeconomy Strategy

The Finnish Bioeconomy Strategy was initiated in 2014 when the government introduced bioeconomy-based policies. The strategy defines bioeconomy as

‘an economy that relies on renewable natural resources to produce food, energy, products and services. The bioeconomy strives to reduce our dependence on fossil natural resources, to prevent biodiversity loss and to create new economic growth and jobs in line with the principles of sustainable development. The most important renewable resources in Finland are the biomass, or organic matter, in the forests, soil, fields, water bodies and the sea, and fresh water. Ecosystem services are the services offered by the environment, including binding carbon dioxide and opportunities for recreation. Another key aspect of the bioeconomy is not wasting natural resources but using and recycling them efficiently’ (The Finnish Bioeconomy Strategy 2014 p. 6).

The main objective of the Finnish bioeconomy strategy 2014 is to create economic growth and new jobs. The high value-added products and services from bioeconomy, together with securing conditions to protect the ecosystem, become the cornerstone of the economy:

‘The leading idea of the strategy is that competitive and sustainable bioeconomy solutions for global problems will be created in Finland, and that new business will be generated both in the Finnish and international market, thus boosting the welfare of the whole of Finland’ (The Finnish Bioeconomy Strategy 2014 p. 19).

The strategic goals of the bioeconomy strategy are as follows:

- A competitive operating environment for the bioeconomy’
- New business from the bioeconomy;
- A strong bioeconomy competence base; and
- Accessibility and sustainability of biomasses.

Furthermore, the goal of the strategy is to reduce fossil-based natural resource dependence and prevent biodiversity loss while creating new economic growth and jobs and reaching the SDG. The strategy concludes that the objective *‘is to push our bioeconomy output up to EUR 100 billion by 2025 and to create 100,000 new jobs’* (The Finnish Bioeconomy Strategy 2014 p. 3).

2.3.1 The Finnish value added and employment in bio-based sectors

Data and information on the bioeconomy sectors have been presented annually since 2010. Between 2010 and 2019, the value added in almost all bioeconomy sectors rose from EUR 5.5bn to EUR 26bn. By 2019, bioeconomy investments had also increased from EUR 1.8bn to 5.6bn and the value added per person employed in the bioeconomy sectors increased from EUR 20k to EUR 86k. However, by 2019, the number of people employed in the bioeconomy sector also decreased by 14k to 301.8k persons (see Table 2) (Luke 2020a).

As Table 2 illustrates, in 2019, the contribution of the forest-based⁴ bioeconomy to the whole bioeconomy accounted for 35% (EUR 9bn) of the value added and 21% (EUR 63k) of bioeconomy employment. In 2018, the bioeconomy sectors of food, agriculture, and fishing and hunting contributed about 16% (EUR 4.3bn) of the added value and 35% (104k) of the persons employed to the entire bioeconomy.

⁴ Including forestry, manufacture of wood and wooden furniture as well as manufacture of pulp and paper products.

Table 2. Value added and employment in Finnish bioeconomy sectors (in EUR)

	Employed persons, k persons	Output, EUR m	Value added, EUR m
FOOD SECTOR, TOTAL	104.1	4767	4328
FOREST SECTOR, TOTAL	63.3	5452	9041
Forestry	22.3	6622	3902
Wood-products industries	22.2	16 006	1315
Pulp and paper industries	18.8	8603	3824
OTHER INDUSTRIES	25.7	4008	3637
Chemical industry	4.8	2326	1231
Pharmaceutical industry	4.8	2269	1600
Other	16.1	4379	806
ENERGY	5.6	11 940	2088
CONSTRUCTION	63.3	799	4610
WATER TREATMENT AND SUPPLY	2.6	4030	457
BIOECONOMY SERVICES, TOTAL	37.2	3859	1852
Nature tourism and recreation	37.2	97	1681
Recreational hunting	0.0	74	97
Recreational fishing	0.0	74 380	74
BIOECONOMY TOTAL	301.8	452 871	26 012
National economy	2670.1	16	208 049
Share of bioeconomy, per cent	11		13

(LUKE 2020a)

Since the Finnish Bioeconomy Strategy was published in 2014, several national bioeconomy-related strategies, programmes and action plans have been published or will be published

- Regarding the use of renewable natural resources (National Forest Strategy adapted in 2019, and renewed in 2020);
- Achieving carbon neutrality (e.g. a roadmap for fossil-free transport and sustainable transport taxes and payments reform anticipated in 2020 as well as the National Energy and Climate Strategy anticipated in 2020); and
- Preventing biodiversity loss (Biodiversity Strategy and Action Plan anticipated 2020).

2.3.2 Gaps, challenges and opportunities in Finnish Bioeconomy Strategy

The Finnish Bioeconomy Strategy 2014 is currently under revision, and an updated strategy is planned to be presented by 2021.

The Finnish Bioeconomy Strategy 2014 was one of the first bioeconomy focused strategies in the EU, the National Audit Office reviewed it in 2018 and recommended inter alia that

‘ministries that took part in the drafting of the Finnish Bioeconomy Strategy should formulate strategy alternatives, assess their economic impacts and make systematic comparisons between the alternatives when drafting strategies, and should review the risks connected with the strategies and other similar programmes in a systematic manner and prepare for them’ (National Audit Office 2018).

2.4 The bioeconomy strategy in Norway

The Norwegian government uses the following definition of bioeconomy in their 2016 strategy:

'Within the framework of this strategy, the concept includes sustainable, efficient and profitable production, extraction and use of renewable biological resources for food, feed, ingredients, health products, energy, materials, chemicals, paper, textiles and other products. The use of enabling technologies such as biotechnology, nanotechnology and ICT is, in addition to conventional disciplines such as chemistry, key to the development of a modern bio-economy' (Norwegian Ministries 2016 p.13).

This strategy aims to increase value creation and employment, reduce the emissions of climate gasses and to encourage more efficient, profitable and sustainable use of renewable biological resources (Norwegian Ministries 2016).

The strategy highlights four priority areas:

- Cooperation across sectors, industries and thematic areas;
- Markets for renewable bio-based products;
- Efficient use and profitable processing of renewable, biological resources; and
- Sustainable production and extraction of renewable biological resources.

The strategy emphasises actions that should prioritise these four areas (Norwegian Ministries 2016).

The strategy underlines the potential across sectors for developing technologies and encouraging technology platforms capable of using renewable biological resources and applying them in several industries (Norwegian Ministries 2016).

Cooperation across sectors and thematic areas are important for growing the bioeconomy sector in Norway. Nevertheless, the strategy also contains sector specific recommendations for selected areas. It contains recommendations for the forestry sector as well as for the processing of forest products, which cover investments in the forest and timber industry, investments in transport and logistics industry as well as advancements in climate policies (Norwegian Ministries 2016).

2.4.1 The value added by the bioeconomy in Norway

Over the last 10 to 15 years, the bioeconomy in Norway has significantly increased its value added but also experienced a decline in number of people employed. The value added in the Norwegian bioeconomy sector was around 130bn NOK (approximately EUR 12.312bn⁵) in 2017, an increase from 76bn NOK (EUR 7.198bn) in 2008 (Capasso et al. 2020) (see Table 3). During the same period, the number of people employed in the bioeconomy decreased from more than 144k persons in 2008 to approximately 130k in 2017 (Capasso et al. 2020).

The main contributions to the increase in value added in the Norwegian bioeconomy sector has come from a steady growth in the manufacture of food and beverages and from fishing and aquaculture. These sectors are partly interlinked and contributes together approximately 80% of the Norwegian bioeconomy sector. The main reason for the decline in the workforce employed in the Norwegian bioeconomy sector stems from a decline in people working in agriculture from around 47k people in 2008 to around 35k in 2017. The reduction in the employment in forestry activities is less steep, from around 4.4k in 2008 to around 3.8k in 2017 (Capasso et al. 2020).

Table 3. Quantified socioeconomic indicators of Norway's bioeconomy in 2017 (in NOK)

⁵ Exchange rate 1 EUR = 10.56 NOK, December 29, 2020

	<i>Employed in bioeconomy</i>	<i>Value added, m NOK</i>	<i>Value added, m EUR</i>
<i>Agriculture</i>	34 700	16 112	1 515
<i>Forestry</i>	3 800	5 419	509
<i>Fishing and Aquaculture</i>	17 501	43 601	4 098
<i>Manufacture of food, beverages and tobacco</i>	51 625	45 573	4 284
<i>Manufacture of bio-based textile</i>	1 289	771	72
<i>Manufacture of wood products and furniture</i>	16 016	10 190	958
<i>Manufacture of paper</i>	2 899	2 981	280
<i>Manufacture of bio-based chemicals, pharmaceuticals and rubber</i>	2 423	4 743	446
<i>Production of bioelectricity</i>	4	28	3
<i>Bioeconomy</i>	130 257	129 418	12 165

(Capasso & Klitkou 2020)

2.4.2 The relationship between the bioeconomy and related strategies

Several strategies and plans for a green transition in Norway have been presented since 2015. A report on environmental pricing from an expert group mandated by the Norwegian government was presented in 2015 and discussed policy options for this transition (Official Norwegian Report 2015). Furthermore, the government mandated an expert group to explore green competitiveness (Hedegaard et al. 2016). This report was created with major stakeholder involvement; 11 sectors provided roadmaps to improve green competitiveness. Several recommendations from this expert group overlap with the recommendations from the work on environmental pricing.

Prior to, and initially independent from, the development of the Norwegian bioeconomy strategy, separate work was begun on the future potential of the Norwegian forest sector. The process was labelled Forest 22⁶ and was carried out with strong stakeholder participation. This forest strategy focused on thematic areas, for example the forest and timber, fibre, energy and building sectors. Forest 22 estimated a potential turnover of four times the level in 2012, from 43bn NOK (EUR 4.072bn) to 180bn NOK (EUR 17.047bn). The strategy explains pathways and actions to utilise this potential. Several of the main recommendations have been implemented in the Norwegian bioeconomy strategy. The rationale and recommendations were further presented in a white paper to the Norwegian parliament in 2015 (Olofsson 2015).

Following the Norwegian bioeconomy strategy presented in 2016, a direct follow-up action plan was mandated by Innovation Norway and the Norwegian Research Council (Capasso et al. 2020).

2.4.3 Challenges for the bioeconomy strategy in Norway

The bioeconomy strategy's approach is multisectoral, but some other policy documents are very sector specific. The challenge will be to create the multisectoral linkages necessary to move the Norwegian bioeconomy from sector-specific and technology-focused development to a development plan that relies less on fossil fuel production and exports and more on bio-based activities. This is a massive challenge for Norway but also presents many opportunities.

⁶ Skog 22 in Norwegian

2.5 The bioeconomy strategy in Sweden

In Sweden, bioeconomy-related strategy documents and reports use the terms ‘bioeconomy’ and ‘bio-based economy’; synonymously. The Swedish Research Council for Sustainable Development (FORMAS) in consultation with Vinnova and the Swedish Energy Agency define, on commission of the government, bioeconomy and bio-based economy as:

‘an economy based on:

- 1. Sustainable production of biomass to enable a growth in use within a number of different social sectors. The objective is to reduce climate effects and the use of fossil-based raw materials.*
- 2. Increased added value for biomass materials, together with a reduction in energy consumption, and recovery of nutrients and energy from the end products. The objective is to optimize the value and contribution of ecosystem services to the economy’* (FORMAS 2012).

The bioeconomy, as discussed by FORMAS et al. (2012), follow four strategies:

- The replacement of fossil-based raw materials with bio-based raw materials;
- Smarter products and smarter use of raw materials;
- Change in consumption habits and attitudes; and
- Prioritisation and choice of measures.

At present, Sweden has no official bioeconomy strategy; rather, it is implementing the EU’s bioeconomy strategy. However, in March 2019, the Swedish parliament commissioned the government to develop a national bioeconomy strategy, and the forthcoming bioeconomy strategy was well-debated during the Bioeconomy Parliament⁷ conference in October 2019. The focus of the discussion was not only on the need to have a national bioeconomy strategy but also on the purpose, goals and boundaries of the strategy (e.g. Skogsindustrierna 2019a). In 2021, a bioeconomy strategy is to be developed during 2021 (Regeringen 2020).

In recent strategies, the bioeconomy concept is mentioned and discussed in relation to, for example, the forest as a provider of ecosystem services. For instance, in a government document evaluating ecosystem services, the government

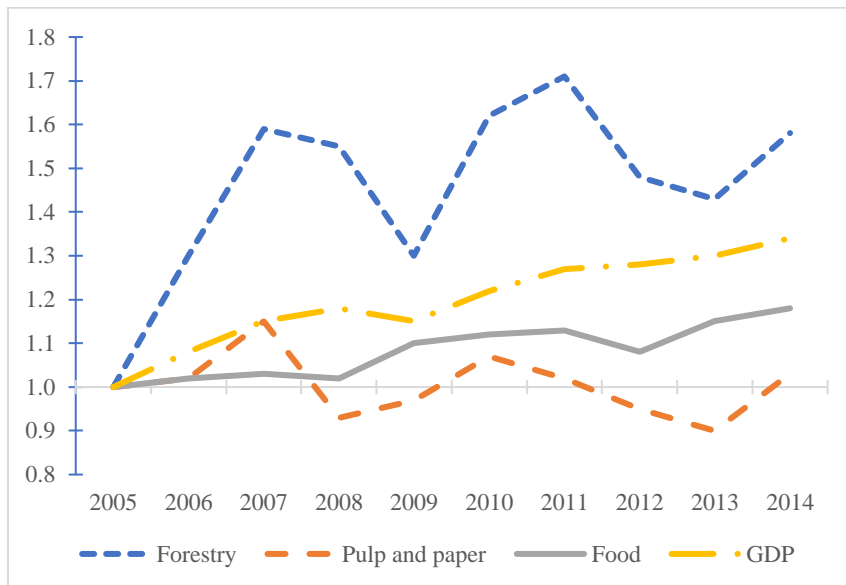
‘considers green infrastructure in Sweden to be an important method to achieve representativeness, ecological connection and resistance as well as favourable conservation status of biological diversity in the country’ (Miljödepartementet 2017 p. 48).

2.5.1 The value added by the bioeconomy in Sweden

As Sweden lacks a comprehensive and overall bioeconomy, it is challenging to evaluate the value added. However, following the delimitations used in the Finnish Bioeconomy Strategy (Ministry of Economic Affairs and Employment of Finland 2014), the Stockholm Environment Institute estimated that the total production value of the Swedish bioeconomy sector was approximately 680bn SEK (EUR 66.911bn⁸) in 2013. The report shows that in 2013, the contribution of the bioeconomy sector to value added, export earnings and employment was approximately 200bn SEK (EUR 19.680bn), 180bn SEK (EUR 17.712bn) and 250k persons, respectively (SEI 2016).

⁷ Bioekonomiriksday in Swedish

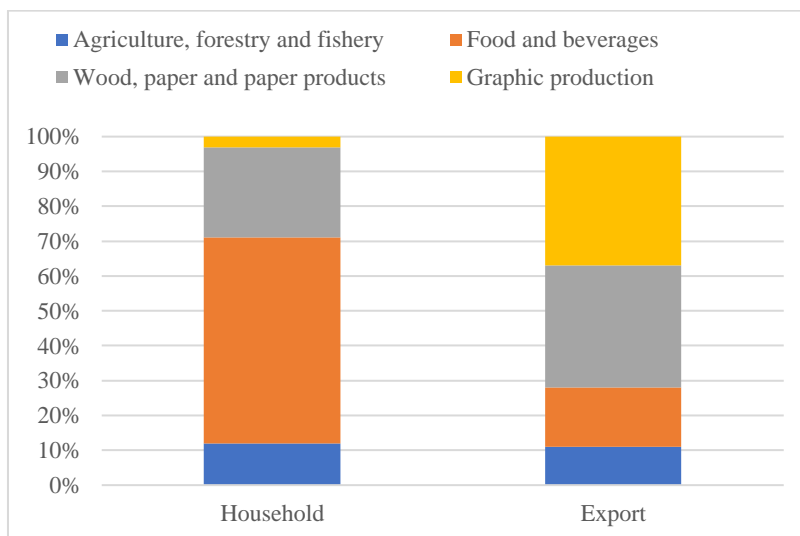
⁸ Exchange rate 1 EUR = 10.08 SEK, December 29, 2020.



Source: Growth Analysis 2016

Figure 1. The relative development of the value added of bioeconomy in relation to GDP

About two thirds of the total value added within the bioeconomy in 2014 originated from forestry activities, as Figure 1 illustrates. The largest single added value was produced within the food industry (Growth Analysis 2016), and most of the domestically produced food was consumed domestically, while a larger share of the forest-based products was exported (see Fig. 2.).



Source: SCB, 2018.

Figure 2. The exports and domestic use of bioeconomy products, 2014

2.5.2 The relationship between the bioeconomy and related strategies

There are several policy and strategy documents that highlight strategies to develop national and local bioeconomy initiatives in Sweden in the absence of an official bioeconomy strategy. In the Swedish national forest program, the forest is targeted as a key player in developing a bioeconomy in Sweden (see the section on the forest program below).

In a joint report, FORMAS, Vinnova and the Swedish Energy Agency identifies the need for more involvement from users/consumers in prioritising knowledge gaps and new problem areas for research, development and innovation related to bioeconomy initiatives in Sweden. The report indicates that organising funding research, development and innovation within the area of bioeconomy is functioning well (FORMAS 2012). Growth Analysis (2016) highlights how the exports of bioeconomy products, specifically pulp and paper ones, face challenges due to international competition in the industry, and, therefore, the bioeconomy strategy action should focus on developing new products, made from forest raw materials, for new markets. Yet the report also shows that building houses and flats using forest products increases the value added by the bioeconomy.

2.6 Key take-home messages concerning bioeconomy strategies

- The EU bioeconomy strategy defines the bioeconomy as including all bio-based sectors and their use in the production of food as well as bio-based products, energy and services.
- Within the EU, the manufacture of food, beverages and tobacco is the largest contributor to the bioeconomy.
- The Nordic Council of Ministers particularly target agriculture, forestry and fishery processes as important in the bioeconomy transition.
- Finland (2014) and Norway (2015) have established a bioeconomy strategy. Sweden has currently no official bioeconomy strategy; however, the Swedish parliament commissioned the government to develop a national bioeconomy strategy to be finalized in 2021.
- The forest-based value added in the bioeconomy is largest in Finland and Sweden, while food and fishing and aquaculture are the largest in Norway.
- The bioeconomy in national policy, as well as the role of the forest and forest-based products, are important in the study area.

3 Setting the scene: the forest and forest-based sectors in three Nordic countries

The development of a forest-based circular bioeconomy depends on a combination of economic, social and environmental preconditions. What is the situation of the forest and forest-based sectors in three Nordic countries and how do they adapt to bioeconomy? This chapter describes the forest and forest-based sectors in the three northern-most countries in Europe.

3.1 Forests in the north

Finland, Norway and Sweden make up close to 32% of the total amount of forests in Europe. Of the three countries, Finland has the largest share of forest land (86%, total 26,3m ha), followed by Sweden (69%, total 28m ha) and Norway (44%, total 14m ha) (Forest Europe 2015; Luke 2020d).

As shown in Figure 3, the study area is dominated by coniferous forests; the majority of forests are located in the northern parts of Finland and Sweden, whereas in Norway, forests are mainly found in the southern part of the country. Urban areas in all three countries are typically located along the coastline or in close to water (see fig. 3.).

Most forests in Finland and Sweden are productive, 77% and 84%, respectively; in Norway, approximately 70% of all forests are productive (Luke 2020d; Riksskogstaxeringen 2020; Statistics Norway 2020).

Finland's forests are almost fully located in the boreal zone. The most common tree species in Finnish forests are pine, spruce, downy birch and silver birch; 67% of the forests are pine, 22% are spruce and 11% are broadleaves. Broadleaves, which are important to forest biodiversity and the soil and grow mostly in mixed stands, account for 20% of the total volume of growing stock, which is clearly more than the total area of predominantly deciduous stands (Vaahtera et al. 2018).

In Norway, conifer forests cover 57 % of the forested area, and deciduous forests 41%. National parks and nature reserves constitute about 4.8% of the forested area. Currently, there are close to one billion cubic meters (978m³) of timber in Norway's forests, and the annual increment is approximately 25m cubic meters. The standing volume of forests in the Norwegian forests has tripled since the inauguration of the first national forest inventory in 1919 (Statistics Norway 2020).

Swedish forests are mostly located in the boreal and sub-boreal vegetations zones, and most parts of the country are covered by coniferous forests, approximately 82%, (39% Scots pine, 41% Norway spruce and 2% Lodgepole pine) while deciduous forests correspond to approximately 7.3%. Since mid-1980s, a strategy to increase deciduous forests in Sweden has

almost doubled the number of deciduous tree species. Geographically, deciduous forests are mostly found in the southern part of the country (Riksskogstaxeringen 2020).

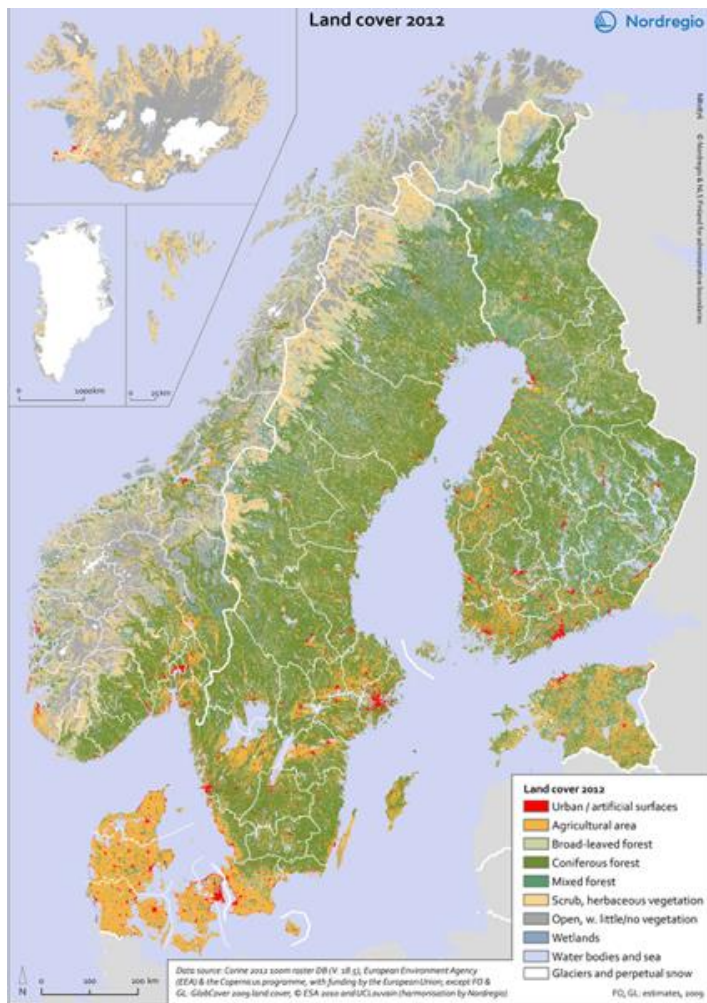


Figure 3. Land cover in Finland, Norway and Sweden, 2012, including forest coverage (Nordregio 2020)

The annual increments follow similar development curves in the three countries (see Fig. 4.). The decrease in the last years may depend on warm and dry weather, storms as well as increased harvesting (Riksskogstaxeringen 2020).

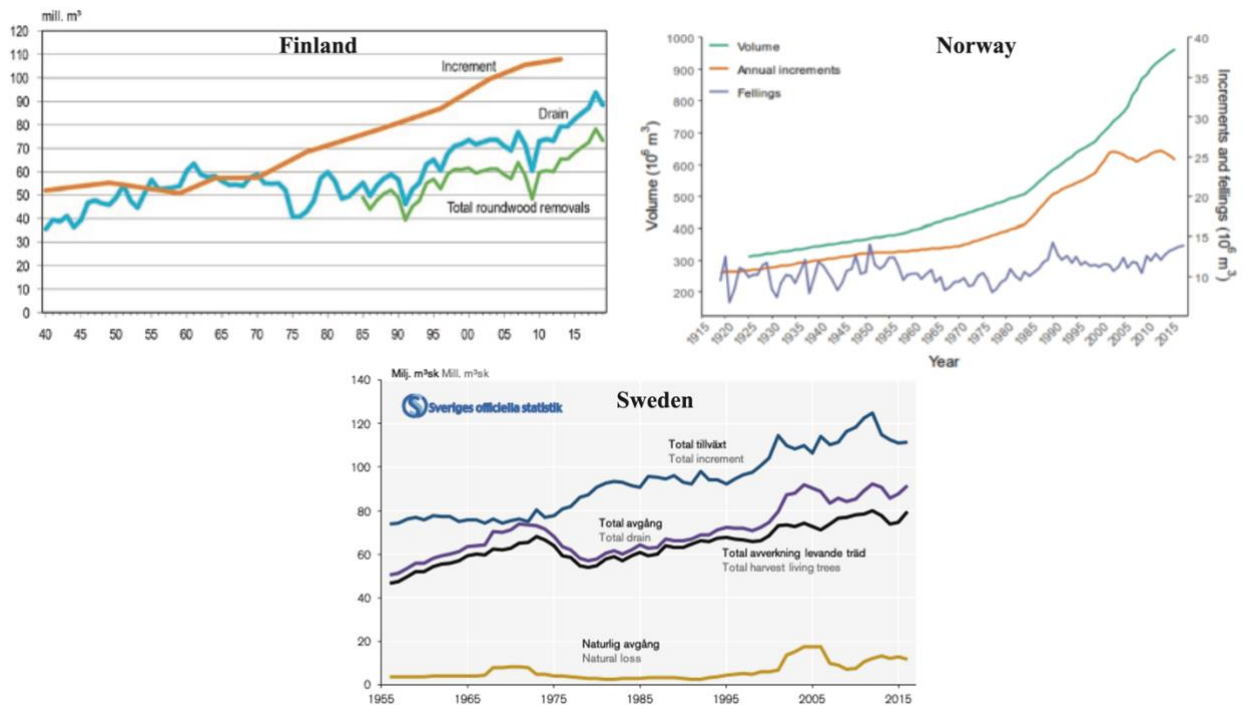


Figure 4. Annual increments and harvesting in Finland, Norway and Sweden (Luke 2019; Norwegian NIR 2020; SFA 2014)

During a five-year period (2014–2018), the average annual increment of the growing stock totalled 107.8m m³ in Finland, with an average annual increment of 4.7 m³ per hectare over all the forested land. Finland’s roundwood removals remained at the same level during the period from 2016 to 2019 and in 2019, they totalled 91% of the felling potential (Luke 2020g). The annual increment has exceeded the annual removals, leading to continuously growing timber reserves (Luke 2019).

The annual harvest in Norway has been between 8–11m m³ for the last 100 years. On top of this another 2-3m m³ are used as firewood on farms. Thus, the utilisation of forests in Norway is about 50% of the increments (Norwegian Ministries 2016).

In Sweden, the standing stock of timber has increased at a steady path since the beginning of the 20th century, to 3.116m m³sk, with an increase of around 55% since the 1950s. During the same time, older and lower productive forests have been replaced with regenerations of a high quality to encourage growth. These increasing increments have, however, lately slowed down, or even decreased, probably as a result of drought in the summer 2018 and more harvesting. The annual harvest has been approximately 84m m³ over the last 5–6 years (Riksskogstaxeringen 2020).

In the three countries, the main harvest method is clear-cutting of evenly aged stands. In Finland, forest management practices generally focus on small forest stands with trees of a similar age. Management follows a regeneration cycle, from planting or natural regeneration to the final harvesting. Forests may be regenerated naturally by leaving a few selected seed trees during final harvesting or, artificially, by sowing seeds or planting seedlings. The length of the regeneration cycle can be between 50 and 120 years, depending on the tree species and the location of the forest stand. Thinning and removing seed trees and shelterwood trees accounted for most of the felling areas. Clear cutting made up 16% and seed tree and shelterwood felling accounted for 4% of the total felling area in 2019 (Luke 2020e).

An alternative method involving evenly aged forests without final clear-cut felling has been possible in Finland since the revision of the Forest Act in 2014. Under this method, forest

regeneration is done by light selective felling's or through small-scale group selection system; forests regenerate naturally after harvesting (Luke 2020e).

During 2016, in Norway, clearcutting and the seed tree system was used in 70% and 22% of the regeneration area, respectively (Granhus et al. 2014). Mechanical site preparation was used for 15% of the planted areas and on 38% of the areas subject to natural regeneration. In recent years, the overall trend has been an increase in the use of site preparation prior to planting. Planted areas constitute 57% of the regeneration area. A combination of planting and natural regeneration was used on 7.5% of regenerated areas, and natural regeneration on 22% (Granhus et.al. 2013).

In Sweden, the main prevailing harvest method is the clear-cut method. However other methods may be used as long regeneration is ensured. There are also regulations concerning the age of the trees and harvesting. For instance, conifers can be harvested if they are between 45 and 100 years, depending on the production ability (SFA 2020a).

3.2 Forest ownership structures in the three Nordic countries

Forests in the three Nordic countries are generally privately owned, either by private companies or non-industrial private forest owners (hence, private persons). The state owns less forest. As Table 4 shows, a majority of the owners are non-industrial private forest owners in all countries, while the share of forest land owned by private companies is largest in Sweden, followed by Finland and Norway. In Finland, the state owns 35% of the forested land, mainly in the north (Vaahtera et al. 2018).

Table 4. Forest Ownership in the three Nordic countries

(in %)	Finland	Norway	Sweden
Non-industrial private forest owners	52	79	48
Private company	7	5	24
State	35	9	13+7*
Other	6	6	8

*State-owned consolidated company own 13%, and 7% is owned directly by the state (SFA 2018; Statistics Norway 2018; Vaahtera, et. al. 2018)

3.3 Forest-related regulations

There are extensive regulations related to forests and forest use in the three countries. The regulations not only deal with the standing timber but also relate to biodiversity, ecosystem services and cultural as well as social values of the forests. This section intends to give a brief background to these forest-related regulations.

3.3.1 Forest laws and regulations in Finland

The legal framework that regulates forest management has undergone comprehensive changes in recent years. New forest laws and related decrees entered into force at the beginning of 2014 and include the Forest Act, the Forest Management Associations Act, the Forest Damages Act, the Act concerning the Placing of Timber and Timber Products on the Market and the Timber Measurement Act.

The Forest Act sets the minimum requirements for how a forest can be harvested and managed, including an obligation to renew the harvested area. Within these requirements, the

forest owners have the freedom to pursue their own interests and to purchase forest services. Compared to the earlier legislation, this act allows unevenly aged forest stands and the use of a more diverse range of tree species; it also removes age and diameter limits in regeneration and increases the habitats of different species.

The purpose of the Forest Damages Prevention Act is to ensure good forest health by preventing the damages caused by insects. The act about selling timber and timber products implements the EU Timber Regulation No 995/2010 in Finland. The purpose of the act is to prevent the entry of illegally produced timber into the Finnish market. The Timber Measurement Act ensures the reliability of different kinds of measurement methods for different timber assortments, and the Forest Management Associations Act regulates the role and operation of forest service providing organisations.

In addition to specific forest legislation, several other laws are also relevant. These include legislation concerning nature conservation, land use, zoning, and taxation.

3.3.2 Forest laws and regulations in Norway

The Norwegian Forestry Act (2006) applies to all ownership categories. It regulates managed forests and outlines the objectives of the Norwegian forest policy. The central objective of this act is to promote local and national economic development and to secure biological diversity; it also focuses on the landscape, outdoor recreation and the cultural values associated with the forest. The Forestry Act also contributes to the conservation of biodiversity and the sustainable use of natural resources (Lovdata 2020).

Additionally, the forest is regulated by the Nature Diversity Act (2009), which manages and protects biological, geological and landscape diversity as well as ecological processes through conservation and sustainable use. The Nature Diversity Act applies to Norwegian land territory, including the river systems, and to Norwegian territorial waters. This act is also based on certain principles, such as the precautionary principle, the ecosystem approach and cumulative environmental effects. Furthermore, it includes the user-pay principle, which means that the costs associated with preventing or limiting any damage to nature diversity are borne by the project owner. The act also includes several regulations concerning hunting and fishing, EU timber regulations, as well as the import of non-native species and more (Lovdata 2020).

Additionally, there is Norway's Climate Change Act of 2017, which implements Norway's climate targets as part of its process of transformation to a low-emission society by 2050. In its budget proposal for 2018, the government provided an account of how they would achieve their climate targets, including a reduction in greenhouse gas emissions (Lovdata 2020).

3.3.3 Forest laws and regulations in Sweden

The Forest Act has a long history in Sweden. The first general Forest Act was implemented in 1903 and valid for all the country, apart from the two northmost counties (Västerbotten and Norrbotten) and Gotland, which had their own laws. The first law addressed the issue of poor regeneration and the fear that Swedish forestry was not sustainable. For this reason, the first law was called the Regeneration Law. During the 20th century, the legal framework has revisited the issue of sustainable forestry. In 1979, the act became applicable in all counties and covered all forest land in Sweden. The act focused mainly on economic return and the need of raw materials provisioning to the Swedish industry, hence emphasising forest production, and environmental goals were given second priority. As environmental issues and sustainable development rose on the international policy agenda, the Swedish government completely revised the Forest Act in 1994, and environmental and production goals were

given equal importance. Furthermore, in the act, the social value of forests is also stressed (SOU 2017:81). The act is a frame law, which implies that act sets the frames and intentions of forest policy, while the detailed decision-making is left to the forest owner – the so-called *freedom under responsibility*⁹.

Complementing the Forest Act, the government introduced 16 environmental quality goals in 2010, including the ‘living forests’¹⁰ goal (see chapter 6). The goal centres on the crucial role of forests in supporting and protecting biodiversity and their importance for cultural heritage and social values. Some of the other forest goals relate to climate change and water protection (SOU 2017:95).

Unique for Swedish forest policy is the Swedish model for forestry, which was introduced in 1994 when the Forest Act was revised. The model implies that the use of forests should emphasise both high production and protection. It outlines what should be harvested (thinning or final harvest) while protecting waterways, sensitive areas, and particular types of trees. It is applied to all forest owners. Moreover, each forest owner should set aside some forest area for biodiversity preservation or social values, without compensation from the government. The third part of the model consists of those forested areas that are set aside for protection of biodiversity or other values, and the forest owner is compensated (SOU 2017:81). To assist forest owners, a number of targets and recommendations have been developed for specific situations in forest management to protect the forested area (SFA 2020b).

A number of other Swedish laws and regulations also apply to the forest, for example Environmental Act and the Cultural Heritage Act. Additionally, Swedish climate regulations also affect forest management.

3.3.4 Forest certification in Northern Europe

As a complement to national forest laws and regulations, voluntary certification schemes are available in all three countries. Two major certification schemes are available: the Forest Stewardship Council (FSC) and the Programme for Endorsement of Forest Certification (PEFC). The main aim of the certifications is sustainable forestry; both target forest management and forest-based products.

Forest being certified by both programs is not uncommon, which makes the statistics of certified land somewhat uncertain. In Sweden, 50% of forests are certified according to the FSC, and 56% are certified according to the PEFC. In Finland, approximately 85% of the forests are PEFC certified and 10% are FSC certified (FSC 2020; Metsäkeskus 2020c; PEFC 2020). In Norway, 60% of the forest are certified through PEFC. Basically, all traded timber in Norway is certified (Tomter 2014).

3.4 Forest-dependent people in the north

The historical public right of access in Finland, Norway and Sweden gives each person the right to, for example, pick mushrooms and berries and use the forest for recreational purposes, regardless of ownership. During the Covid-19 pandemic, interest in spending time in forest areas has notably increased.

⁹ Frihet under ansvar in Swedish

¹⁰ Levande skogar in Swedish

Furthermore, there is also a long tradition in these countries of having a second home, typically in a rural area, in a forest, or along a waterway. For instance, in 2009, 64% of Finns spent time in a second home (Metla 2012).

In these three countries, hunting, and moose hunting in particular, is a source of recreation and a vital social and cultural forest activity. The public right of access does not include hunting or fishing. In Sweden, hunting licenses are required, and all killings of moose, bears and lynx must be reported to county administrative board. There are about 300k registered hunters in Sweden (Royal Swedish Academy of Agriculture and Forestry 2015). Approximately 300k persons obtain a hunting licence in Finland annually (Suomen riistakeskus 2020).

In Finland, the reindeer management area (RMA) covers 36% of the land area and is divided into 54 reindeer herding districts (RHDs). Of the total RMA area, 91% is forest, of which 62% is productive forest land. Of that productive forest, 58% is owned by the state and managed by Metsähallitus, a state-owned enterprise. State forest ownership is especially dominant (88%) in the Sami homeland (13 HDs).

Reindeer husbandry is based on the free access of semi-domesticated reindeer to pasture, regardless of land ownership. According to the Reindeer Husbandry Act (848/1990), the state land located in an area specially intended for reindeer husbandry may not be used in such a way that will cause significant disadvantages to reindeer husbandry. When planning measures concerning State land that will have a substantial effect on the practice of reindeer herding, the State authorities must consult the representatives of the reindeer herding co-operative in question. Metsähallitus consults each HD annually about forestry activities, such as building forest roads, logging and soil preparation measures (Turunen et al. 2020).

In Sweden, reindeer husbandry is carried out based on usufructuary rights on forest land in the northern part of the country (counties of Norrbotten, Västerbotten and Jämtland & Härjedalen and parts of Dalarna). Reindeer herding is organized into 52 RHD which, apart from setting geographical boundaries for grazing also constitutes the administrative organization of reindeer herding. Herding reindeer is practiced by the indigenous Sami people, for whom it has great cultural as well as economic significance. This activity has been declared a matter of Swedish national interest, emphasising the possibility of preserving reindeer grazing rights according to the law (Widmark 2009). The Reindeer Husbandry Act regulates reindeer herding, while the Forest Act regulates the land use in the consideration paragraph (Forestry Act §31 SFA 2020a), where it is stated that forest owners have to consider reindeer husbandry when planning to e.g. clear-cut areas to ensure that reindeers have areas to graze. On a yearly basis, the forest owner (that is the forest company) and the RHDs are involved in consultations to discuss land use over the next year (SFA 2020a; Widmark 2009). The relationship between forest owners and reindeer herders are also regulated in the FSC and PEFC voluntary certification schemes (Widmark 2009).

Reindeer husbandry in Norway has its origin in the Sami population. Today, reindeer husbandry is practiced mainly in the counties of Troms and Finnmark, Nordland, Trøndelag and parts of Innland county. Just over 3,000 people are associated with Sámi reindeer husbandry. More than 2,000 of them are in Finnmark alone. Reindeer husbandry in Norway is mostly practiced in mountainous area and outside of the productive forested areas. Thus, other activities than forestry compete for land use in reindeer grazing areas in Norway (Ministry of Agriculture and Food 2019).

3.5 Key take-home message about forest and forestry

- Forests in Finland, Norway and Sweden correspond to 32% of all forested land in Europe. The share of forest-covered land is largest in Finland, followed by Sweden and Norway.
- The three Nordic countries are dominated by coniferous forests (between 70 and 80%); Norway has a higher share of deciduous forests (41%).
- Even though alternative methods, such as selective felling's, are used, the dominating felling method is clear cutting of evenly aged stands.
- Forests are predominantly owned by private non-industrial forest owners. Sweden has a larger share of private company ownership, while Finland has the largest share of forests owned by the state among the three countries.
- Forest legislation in the study area is rather similar, targeting timber production, biodiversity and social values. Climate and environmental goals are also regulated by separate regulation.
- Most of the forested area in the three Nordic countries is certified by FSC and/or PEFC.
- The public right to access forests has a strong historical background in the study area, as do hunting rights. Reindeer husbandry is found in northern Finland, Norway and Sweden.

4 National and regional forestry programs

Finland, Norway, and Sweden have forest programs that focus on the role of forests in the economy as well as the forest-related environmental and social issues. What do the programs consist of and how is the bioeconomy addressed in each program? Are there similarities and differences between the programs? This chapter addresses these questions.

4.1 The National Forest Strategy in Finland

Finland's National Forest Strategy 2025 was adopted in 2015 and updated in 2019. According to the National Forest Strategy 2025, the operating environment for forest-based businesses and activities has and is undergoing a transformation for the following topics:

- Megatrends (e.g. population growth, urbanisation, changes to consumer habits etc.) will increase the demand and pressures related to forests and the sustainable use of wood;
- Increasing investments in wood processing industry (e.g. pulp plants, biorefineries and bioproducts mills);
- Increasing competition for biomass between different sectors;
- Sustainable forest management in the light of climate change mitigation and adaptation; and
- The need of using digital solutions for improving the Finnish forest sector's competitiveness and securing its sustainability (Ministry of Agriculture and Forestry in Finland 2020).

According to Finland's National Forest Strategy 2025, '*Sustainable forest management is a source of growing welfare*' (Ministry of Agriculture and Forestry in Finland, 2020). The three strategic objectives and sub-objectives related to this vision are as follows:

- Finland is a competitive operating environment for forest-based business:
 - The forest sector grows, enterprises and business are renewed, and new and growth enterprises are developed;
 - The supply of raw materials allows for increased sustainable use of forests and new investments; and
 - International forest policy and as well as EU policies promote the attainment of the SDG and good operating conditions for forest-based business and activities as well as reinforce international business opportunities.
- Forest-based business and activities and their structures are renewed and diversified:
 - Know-how considering forest-based business and activities is diverse and responds to changing needs; and
 - Administration is flexible, effective and customer-oriented.
- Forests are used in various economic, ecological, social and cultural contexts:
 - Forestry is active and business-like; and
 - Forest biodiversity and ecological, social and cultural sustainability are reinforced (Ministry of Agriculture and Forestry in Finland 2020).

Complementing the national forest program, Finland has regional forest programs as well. A regional forest programme is a development plan for the forest sector within the area covered by the regional 14 forestry centres. The objectives of the provincial forest programs stem from the regions' own development needs and the objectives of the Finland's National Forest

Strategy 2025. The programs reconcile economic, ecological, social, and cultural objectives. The preparation of regional forest programs for the period 2021–2025 will be completed in autumn 2020 (Metsäkekus 2020a).

The revision process is still going on, and the regional forest programmes differ within their objectives. For instance, the region North Karelia, in the Barents region, has a regional forest programme for 2016–2020. The regional forest program for North Karelia promotes entrepreneurship in forestry, including wood processing and nature tourism; it also supports competitiveness, profitability, and diversification in North Karelia. The objectives of the program are divided into key objectives and other objectives and measures. Other objectives and measures are intended to support the key objectives, which are as follows:

- Increasing harvesting volumes within the sustainability concept;
- Developing the ownership structure of private forests in order to increase the active use of forests;
- Maintaining the transport infrastructure;
- Securing the level of forest management;
- Utilisation of forest ecosystem services; and
- Securing and improving forest biodiversity and water protection, and in particular small water bodies (Metsäkeskus 2020b).

4.2 Forestry programs in Norway

Norway's forestry program is not located in one single document or outlined in one, single process. Through different strategies and processes, Norway has conducted the recent developments of the national forest policy.

The most recent part of this process was a white paper on forest policy presented to the Norwegian parliament in 2017 (Landbruks- og matdepartementet 2017). This program has a national scope and focuses on improving the competitiveness of the forest-based sector in Norway.

Prior to the development of the most recent white paper on the forest policy, the government initiated a strategy for the Norwegian forest sector, Forest 22, with the purpose of improving the utilisation of Norwegian forests, revitalising the Norwegian forest sector and improving competitiveness. The strategy was developed in a broad and inclusive process with working groups for different parts of the Norwegian forest sector and with an open web-based 'hearing' prior to finalisation (Olofsson 2015).

Skog 22 summarised their main findings:

- The forest sector could be a key player in the green transition in Norway; and
- The forest sector in Norway has a potential annual turnover of 180bn NOK (EUR 17.047bn), more than four times the level of 2012 (43bn NOK or EUR 4.72bn) (Olofsson 2015).

Several regions and counties in Norway have established strategies for their forest activities. A more comprehensive regional bioeconomy strategy has been developed for the Innland county in Norway, the area with the most forests and forest operations (Bioøkonomistrategi for Innlandet 2017).

Costal forestry¹¹ is a cooperative approach begun in 2015, in which the forestry sector in the coastal counties works together with the counties at the political and administrative level and is supported by the Forestry Department at the county Governor's Office (Kystskogbruket

¹¹ Kystskogbruket in Norwegian

2015). This strategy aims to quadruple value creation by 2040 in the counties participating in this project (Kystskogbruket 2020).

4.3 The National Forest Program in Sweden

Before 2018, Sweden did not have a national forest program. Before this, the forest strategy was somewhat scattered among different policy and strategy documents. The Swedish forest program was developed in a collaborative process involving a wide variety of forest-related stakeholders, including organisations representing different economic, ecological and social viewpoints.

The National Forest Program builds upon the SDG 17, which promotes a sustainable society and a growing bioeconomy. The program envisions that

‘[f]orests—our “green gold”—will contribute to creating jobs and sustainable growth throughout the country, and contribute to the development of a growing bioeconomy’
(Regeringen 2018a p. 12).

The program is directed towards five focus areas:

- Sustainable forest management with greater climate benefits;
- Multiple uses of forest resources for more jobs and sustainable growth throughout the country;
- World-class innovation and processed forest products;
- Sustainable use and conservation of forests as a profile issue in Sweden’s international cooperation; and
- A knowledge leap to ensure the sustainable use and conservation of forests. (Regeringen 2018a)

To ensure that the five focus areas and the overall objective of the National Forest Program is fulfilled, the government further decided upon action plans consisting of nine commissions, including subtasks:

- Develop and communicate interdisciplinary knowledge on the multiple use of forests;
- Develop advice regarding sustainable forestry;
- Contribute with proactive and strategic international work in forest-related questions;
- Prepare and carry out a dialogue, in collaboration with Finland, on sustainable forestry and forest industry targeting EU decisionmakers;
- Continuously run a dialogue process between policy makers, authorities, the education system and companies along the forest value chain;
- Support regional dialogues and development of regional forest programs;
- Evaluate socio-economic effects of methods to protect valuable forests;
- Develop and sustain statistics on forests; and
- Develop an educational package on moose management. (Regeringen 2018b)

Regional forest programs are under development Sweden. The first region that developed one was Småland, in the south. At present, 14 regions, of a total of 28, have developed regional forest programs (SFA 2020c).

The aim of the regional programs is to acknowledge the regional prerequisites and local strategies and policies. For instance, the regional forest program for the region of Västerbotten (in the Barents region), a region with a strong forest focus, aims at creating prerequisites for all persons living in Västerbotten to contribute with knowledge and capacity to enhance role of forests in regional development. The regional program aims to integrate the five target areas of the national forest program: sustainable forestry, the multiple use of forests, world-class innovations, international collaboration and increased knowledge. The specific aims for the region include the following:

- Clarifying the role of the forest in the economic, ecological and social sustainable development of Västerbotten;
- Making visible forest activities, and the value they create, as well as forest ecosystem services and the forest's potential to increase employment;
- Seeking synergies and encouraging cross-sectoral collaboration between different forest actors;
- Underlining the importance of equality and equal opportunities to reach goals; and
- Finding measures to reach goals conflicts as well as to reduce conflicts. (Västerbottens regionala skogsprogram 2020)

4.4 Key take-home messages concerning forestry programs

- Both Finland and Sweden have forest programs at both the national and regional levels, while Norway's forest strategy is scattered over several policy documents.
- The Finish and the Swedish strategy directly target the position of forests within the bioeconomy, emphasising the importance of forests in the development of a sustainable bio-based society.
- The Norwegian strategy describes the potential of the forest's role in developing a green transition.
- The international context of forest policy and dissemination of knowledge about the key role of forests in the development of a bio-based society are emphasised in the national forest programs of Sweden and Finland.

5 The contribution of forests to the bioeconomy

This chapter discusses the contribution of forests to the circular bioeconomy. It gives a brief overview of potential goods and services originating from forests, as well as their use, and discusses how they contribute to the bioeconomy. This description is not exhaustive; rather, it provides an overview and examples from the three countries. What services can forests provide in terms of climate change mitigation, GDP and employment? In what way can forests contribute with renewable goods?

5.1 The role of forests in climate change mitigation

Every m³ of wood grown absorbs almost 1,000 kg of carbon dioxide from the atmosphere (e.g. Birks & Birks 2004). To have a long-term climate impact, the captured carbon needs to be stored for a long period of time before it is released back into the atmosphere as a result of decomposing or burning. The production of carbon-storing goods, such as solid wood products, has two possible climate effects: first, the immediate physical storages of carbon molecules keep them away from the atmosphere, and second, the substitution of products with poorer carbon storage capacities. Although the storage of carbon within wooden construction products plays a minor role in climate change mitigation discourse (e.g. Heräjärvi 2019), they heavily contribute to sustainable forestry, which, in turn, has true measurable climate impacts. The vitality of forests and other biomasses is important because the amount of carbon stored in living trees and organic soil roughly corresponds to the entire CO₂ volume in the atmosphere (e.g. Malhi et al. 2002). The volume of the total amount of biogenic carbon stored in Europe's forests is estimated to be approximately 13bn tons, growing 167m tons per annum (Forest Europe 2015). In greenhouse gas (GHG) inventory accounting, nowadays required from each EU member state, wooden construction products represent the longest half-life (i.e. the time required for a quantity to reduce to half of its initial value) of all wood-based products (i.e. 25–35 years). Hence, long lifecycle wood products are beneficial in terms of GHG inventory accounting (e.g. Heräjärvi 2019; Malhi et al. 2002).

Long-lifecycle wood products, typically used in building or infrastructure construction, are one way to keep carbon molecules away from their circulation. Heräjärvi (2019) introduced a dynamic measure, the building sink effect (BSE), which measures a nation's annual carbon emissions with the amount of carbon stored in buildings during the same year in the form of long-lifecycle wood products. BSE tries to quantify the carbon sink caused by building construction and, particularly, to assess its role in compensating a nation's annual carbon dioxide emissions.

The climate effects and material substitution effects of wooden buildings are complex. The material and energy substitution effects of wood were discussed by Leskinen et. al. (2018). Their literature review covered 51 studies dealing with the emission effects of using wood and non-wood materials. The majority of the studies indicated that use of wood products is associated with lower fossil and process-based emissions than non-wood products. Leskinen et al. (2018) concluded that the average substitution factor of structural construction wood

products is 1.3. In the case of Norway spruce, which is the most common construction timber species in Europe, the substitution factor of 1.3 means that using one cubic metre of spruce wood (dry density approximately 420 kg/m³, carbon content assumed 210 kg) to substitute non-wood products in structural use results in an average emission reduction of 1.3×210 kg equals 273 kg of carbon.

Wood volume and subsequent carbon storage in forests have almost doubled annually, thus providing a considerable carbon sink in e.g. Finland during the past 60 years. Simultaneously, the annual drain has increased by one third (see: Vaahtera et al. 2018). This indicates the peculiar characteristics of the market economy within the framework of renewable raw material: materials can be both utilised and volumetrically increased at the same time. This system works as long as the pre-condition of value creation for forest owner is fulfilled (i.e. the produced material has an acute or expected value to its grower). Since more than 70% of the stumpage income is derived from saw logs in Finland (Vaahtera et al. 2018) and most of the wood products are applied in construction value chains, it is obvious that the construction sector is a great contributor to carbon storages, however, not as a carbon storage in building structure, rather the storage in growing forests.

Statements about wood as a substitute of concrete in construction sector are, however, hypothetical from a climate perspective; global volumetric production of concrete is 20 times higher (approximately 10bn m³/a) than the total production of wood products (approximately 0,5bn m³/a). Thus, timber construction is one step towards a better and more climate-smart future, but alone it is not sufficient. Forests play an important role as a carbon sink. Such role will hopefully be prioritised in the future by the sustainable use of wood products in the construction sector (e.g. Heräjärvi 2019).

The process of wood products is energy efficient; the incineration of the side products (bark, sawdust, chips, off-cuts, etc.) typically produces more energy than is needed in the actual production processes. Energy needed to produce a unit of steel or concrete is approximately 5–25 times higher than the energy needed to produce a unit of wood products. Still, the production of any construction material causes carbon emissions. Comparing structures of virgin steel and concrete elements, it causes at least 10 times higher carbon emissions compared to the value for sawn timber and glulam. Therefore, wooden construction products have considerably smaller environmental footprint compared to steel- or concrete-made ones both in terms of energy intensity and emissions (e.g. Heräjärvi 2019).

The recycling of demolished wood products is still in its initial stages, especially in Northern Europe, where burning wood to create energy has been the traditional way of utilising wood waste (e.g. Heräjärvi et al. 2010). This is largely due to the colder climate and the area's larger energy needs. The situation is completely different from Central and Southern Europe, where particleboard industries use most of the demolition wood as a raw material. EU waste legislation sets, however, presents challenges to further develop the recycling of all materials and products. For the time being, metal, plastic, glass, paper, and paperboard recycling are decades ahead of wood product recycling. Even environmentally sound modification processes improving the technical properties of wood products may cause difficulties for the recycling practices, which may decrease their overall environmental performance (Heräjärvi et al. 2020).

5.2 Forests, GDP and employment

In all countries, the forest sector contributes greatly to the GDP and is an important provider of employment. In Finland, in 2019, the bio-based sector employed 301.8k persons. The same

year, the forest industries employed 40k and wood-product industries and pulp and paper industries employed 20k people (Luke 2020f). In Norway, in 2019, the bio-based sector employs around 130k persons, corresponding to 5% of the total workforce. Of these, 3,8k are employed in the forestry sector (Capasso & Klitkou 2020).

In Sweden, approximately 330k people work in the bio-based sectors, corresponding to around 7% of the total workforce in 2016. There are regional differences, ranging from 13 to 3.4% (SCB 2018). The forest-dense and agriculture-dense areas show a typically higher portion of bioeconomy-related work. In terms of employment, agriculture was the predominant industry but, just like forestry, agriculture is an industry with many part-time jobs (Growth Analysis 2016). The number of people working in forest-related tasks has declined since the 1970s, but the number seems to have stabilised over the past 15 years. For entrepreneurs, the numbers are steadily increasing (SFA 2017b). At present, ca 120k persons work in forest-related industries (Skogsindustrierna 2020a).

In all countries in the study area, the forest sector contributes importantly to the national GDP and to the added value by forest-based goods. In addition to the direct effects, the forest sector, as well as the manufacturing and use of wood-based products and the processing of their side streams, and ecosystem services related to forests, have a large multiplier effect in several industries, such as transport, energy, construction, and nature-based tourism. According to Luke (2020a), in 2019, the forest sector contributed 4.3% to the Finnish GDP, and the share of forest sector in national economy was one of the highest in the world. The share of forestry, the wood products industry and the pulp and paper industry were 1.9, 0.6 and 1.8%, respectively. For Norway, the forest sector contributes 0.6% to the Norwegian GDP (Statistics Norway 2018). In 2018, the Swedish forest sector contributes around 3.5% to the national GDP, and the total bioeconomy sector contributes 7% (SCB, 2018). In comparison with industry overall in Sweden, the forest sector contributes an added value of around 11%, with large differences regionally. For instance, in the northern part of the country, the value added is over 40% for Norrbotten county (Skogsindustrierna 2019b).

5.3 The forest as a provider of goods and services

Forest-based goods originate from wood removals as well as NWFP. This section first discusses timber, pulp and paper, then energy and fuel and lastly wooden buildings. The NWFP is discussed in section 6.

5.3.1 Timber, pulp and paper

The production of forest biomass is dependent on not only economic and ecological prerequisites but also on climate and management practices.

The forest industry, in 2019, generates about one-fifth of the value of Finland's exports of goods, totalling EUR 12.5bn. Of this, the value of exports of wood products industry totalled EUR 2.76bn. The most important export products were sawn goods and plywood. Sawn goods accounted for 63% and plywood 18% of the value of exports from the wood product industry. The value of exports in the pulp and paper industry was EUR 9.7bn. Pulp accounted for 25%, paper 41% and board 30% of this value, while converted paper and board products made up 4%. Despite the gradually growing importance of Asia, and China especially, the euro area is still the most important export market for Finnish forest products (Luke 2020a; Viitanen et al. 2020).

Further, of the sawmilling industry almost one-fourth of the export volumes went to the Euro area in 2019. However, the most important single countries were Egypt and China with 17% and 14% of the shares of total exported sawn wood volume, respectively. Sawn wood exports

to China were dominated by spruce for the furniture industry, whereas exports to Egypt consisted almost entirely of low-grade pine sawn wood (Viitanen et al. 2020).

Currently, negative price trend of softwood sawnwood is a global phenomenon. The demand for sawnwood has not grown as fast as anticipated, especially in North America and China, and the Covid-19 pandemic has worsened the market outlook in the short run.

Simultaneously, the production volumes have been high, and the sawnwood stocks have grown, which has inflated the supply in many market areas. As discussed in Viitanen (2020) in more detail, pressure on sawnwood prices has also grown in Europe due to the large-scale processing of damaged wood in Central Europe. Sawnwood made of damaged wood is increasingly exported to markets outside Europe, which has further increased the pressure on prices, especially in China and North Africa. The continuing negative sawnwood price trend will eventually lead to production cuts, which will balance the supply with the demand and stabilise price development in the future.

The Finnish paper and paperboard industries are highly dependent on changes in international demand. The main destination is the EU, and more than half of paper and paperboard products are exported to EU countries. Within the EU, 39% of the export volumes of paper and paperboard products are targeted to the euro area, with Germany alone accounting for 17%. Other important export regions for paper are Asia and North America. Capacity investments in chemical pulp have enabled increases in market pulp exports, but still more than half of the production volume is used by domestic paper and paperboard industries. The main export destination of pulp is Asia. As for countries, China is currently by far the most important single market. In 2019, 42% of the Finnish pulp exports were sent to China (Luke 2020c).

There have been significant changes in the structure of the Finnish pulp and paper industry over the last 10–15 years. Due to the decline of international demand for paper, a significant number of paper machines have been closed. Capacity changes have continued recently. Despite closures, paper is still by far the most important export product of the Finnish forest industry. At the same time, with the decline in paper production, the capacity of paperboard industry and its share of the total forest industry production have increased. Significant increases have also occurred in the pulp production capacity of Finland due to the increasing international demand for pulp. In 2018, the volume of pulp production in Finland was approximately 16% higher than it was in 2014 (Luke 2020c). Currently, there are several renewal and greenfield plans to further increase pulp production capacity in Finland.

While most of the products manufactured by the Finnish forest industry are exported, the industry is highly dependent on the development and changes in international trade and demand in the main export markets. Also, the development of exchange rates (e.g. USD, CAD, SEK, GBP, JPY, RUB and CNY) with respect to Euro is an important factor of competitiveness of the Finnish forest industry not only outside of euro area to promote exports but also inside the euro area when competing against the imports from outside of the euro area (Luke 2020b).

An important part of Norwegian economic and social development in the early stages of the Industrial Revolution was based on export of timber and wood products. In the first half of the 19th century, the export of wood products reached 30% of the total export measure by value. Other sectors became more important in economic terms for the Norwegian economy after the Second World War, but the forest sector remained important for the country's economic development, particularly in rural areas. For more than 150 years, pulp and paper production used to be a major part of industrial production in Norway. This industry, however, has recently shrunken due to challenging market conditions. This once important industry almost disappeared completely after 2013. For this reason, there has been increased interest in

investigating other opportunities from renewable goods found in forests. Possibilities are numerous, but for these to materialise, massive research and development as well as significant investments are needed. Recent experiences reveal that this is not straightforward. Profitability and risk will be the most important factors guiding the development of possible industries in the years to come (Norwegian Research Council 2020).

However, in Norway, Borregaard, a former pulp and paper industry with more than 100 years of history, has recently transformed itself into one of the world's most advanced biorefineries, specialising in fine chemicals. Currently the company is, among other things, advancing the production of micro fibrillated cellulose (MFC). The product can be applied in several products and can be used in many different industries. MFC can also replace fossil-based products (Norwegian Research Council 2020).

Traditionally, Norway had a varied forest industry, consisting of an active pulp and paper industry and stable sawmilling and woodworking industries. After the 2008–2009 financial crisis, the pulp and paper industry faced market challenges and a steep economic downturn. Many factories closed. Norwegian pulp and paper industries specialised in newspaper and magazine paper. Pulp and paper industries in neighbouring countries had a more diversified structure and complex production. Prior to the collapse in pulp and paper industry, Norway was a net importer of timber. The change in the structure of the Norwegian forest industry changed the situation, and today, Norway is a net exporter of timber, exporting mainly to Sweden and Germany (Norwegian Research Council 2020).

Approximately 11m m³sub of spruce and pine are logged as sawn logs and pulpwood in Norway. Of this volume, approx. 2.3m m³sub ends up as sawn wood. Approximately 5m m³sub are used as raw material for industrial processes and energy production in Norway, and approximately 3.6m m³sub are exported, mainly to Sweden. The Norwegian wood processing industry mainly uses spruce. Wood is probably the only bio-based raw material from Norway suitable for the process industry in terms of volume and price up to 2050. In the short term, it is possible to increase felling by 2m m³sub, and this can possibly be done by increasing the felling of pine and birch. Until the 2050 it is possible that a further increase of 3 m m³sub of all wood species is possible. This will, in total, provide possible additional raw materials for the process industry of approximately 3.5m m³sub. Such an increase will depend on an increased demand for sawn logs for construction products, as this is the driver of forest harvesting due to higher prices. In addition, it is possible to harvest around 2m m³sub GROT (branches and top) if a market with the necessary technology and willingness to pay is established to use this raw material. At the same time, predictions from the Process Industry Roadmap and various new industrial projects in Norway indicate an increased need of 14–20m m³sub of raw material from the forest up to 2050. Thus, there is a significant gap between potential access of up to 5.5m m³sub and Norwegian industrial ambitions, as the expert group also concludes that it is not realistic to take back the volumes currently exported. Based on this, the expert group recommends that the process industry focus on high value-added products and products that support existing process industry and that low-value raw materials and by-products from the production processes are used for bioenergy and biofuels (Norwegian Research Council 2020).

In Sweden, the net harvest is 75m m³sub (94m m³), of which 37m m³sub is sawn timber of spruce and pine, and 32m m³sub is pulp wood, and finally 5.5m m³sub firewood (SFA 2020d). The harvested wood in Sweden is used for producing biofuels (50%) and bioenergy (25%), and to produce pulp and wood-based timber (25%) (Danske Bank 2020). Sweden is the third largest exporter of forest-based products in the world. More than 80% of the forest products produced in the country are exported to a value of around EUR 14.624bn. Of the export value, 50% constitutes paper, sawn wood, 20% and pulp, 17% (Skogsindustrierna 2018).

The total forest biomass in Sweden is increasing, providing for a basis for forest bio-based products. The Swedish forest sector uses forests and the energy potential of wood in primary wood production and in secondary production, which produces value-added forest products; thus, the forest biomass has a wide variety of uses (Kumar et al. 2020). The total export value of the Swedish forest sector was EUR 14.78bn (150bn SEK) in 2020 (Skogsindustrierna 2020b).

Swedish sawmills started to develop in the 1850s and became early a leading exporter of sawn timber. In the later part of the 20th century, the sawmills continued to develop in the light of societal developments (e.g. oil crises) and increasing competition from the pulp and paper industry. Presently, the Swedish domestic market is the single largest market for sawn hardwood, a demand driven by construction. In contrast, the softwood is to a large extent exported to the European market (68%). The future potential of the sawmilling industry in Sweden depends on the development of the bioeconomy, particularly the building sector, and on product diversification and strategic development (Kumar et al. 2020). Additionally, the development of side streams of sawn timber (e.g. bark, chips and saw dust) may affect the future of the sawmills. The export of sawn timber products corresponds to 20% of the forest export value (Skogsindustrierna 2020b).

Concerning the pulp and paper market, Sweden is the second largest exporter globally; hence, these markets are of high importance for the national economy. Although the pulp and paper market has decreased since 2000, the Swedish market share is still substantial. One of the reasons is the focus on packaging products rather than specialised newspaper production. The export of pulp increased from 2.9m to 3.6m tons and for paper from 7.7m to 9.2m tons between 1994 and 2018 (Kumar et al. 2020). In export value, paper correspond to around EUR 7.39bn (75bn SEK), while pulp corresponds to EUR 2.51bn (25.5bn SEK) in 2019.

Historically, the success of the pulp and paper industries in Sweden has depended on such factors as low energy prices, an educated work force, access to raw materials, short transportation times as well as innovative production development, such as recycling and waste management. Due to increased global competition and stronger environmental and climate mitigation demands, the pulp and paper industries were forced to become climate neutral, more energy efficient as well as producers of renewable energy (Kumar et al. 2020).

Sweden has a positive trade balance; thus, the value of exports is higher than that of imports. For the forest-based industry, the exports are worth more than three times the value of the imports, and the trade balance for forest-based goods has been rather stable over time, while the trade balance for overall products in Sweden has been declining (Danske Bank 2017). The explanation for these trends is the higher share of domestic forest-based raw materials (Skogsindustrierna 2018). The most important export market, measured in 1k m³ is the UK, followed by Egypt and Norway. Europe, the US, China, Japan and Northern Africa are also important export markets (Danske Bank 2017).

5.3.2 Energy and fuel originating from the forest

Forests and energy are important topics in the global debate on climate change. Throughout history, wood has been the most important source of energy for human beings until fossil fuels became widely available. In industrial countries, fossil fuels have replaced wood and become the dominant source of energy. Wood remains the most important source of energy for heating and cooking in developing countries. Societies are looking for ways to reduce their dependence on fossil-fuels, and forests have become more important in the debate on alternative forms of energy. At the same time, the demand for energy continues to grow with the expanding global economy.

In Finland, wood-based energy accounts for 28% of the energy consumed in 2019 (OFS 2019a). The consumption of wood fuels grew by 3% 2019, and these fuels remained the most important individual energy source in Finland. Wood fuels are the most important renewable energy source in Finland; in 2019, 20.5m m³ (39.4TWh) of solid wood fuels were used in heating and power plants. The Finnish government has set an ambitious goal for 2030: the share of renewable energy in the end consumption should increase to approximately 50%.

Bioenergy production is largely integrated into forestry and the forest industry. The share of wood fuels in renewable energy in Finland is 74%. The main source of wood-based energy is black liquor and other concentrated liquors, which represent 45% of the share of wood-based energy. The wood fuels used in industry and energy production represent 39% of the total share and small-scale represents 16%. Solid wood fuels are typically used in highly efficient district heating (DH) and combined heat and power plants (CHP) (Routa 2020). The major share of solid wood comes from the by-products of the forest industry, including bark, sawdust and other industrial wood residues. In 2019, 11.6m m³ of forest industry side products were used for energy, consisting of bark 7.9m m³ while sawdust and industrial chips is the rest (OSF 2019b).

In 2019, 7.5m m³ out of 8.1m m³ produced forest chips was used in heating and power plants (OSF 2019c). The use of forest chips increased by 2% from 2018. Small diameter trees are by far the most important raw material source for forest chips in Finland (51% of forest chips in 2019); logging residues accounts for 38% of raw material, stumps 3 and rotten stem wood 5%. The small-scale use of wood for heating in residential houses, summer cottages and farms are also significant part of bioenergy consumption in Finland. Domestic production of wood pellets in Finland was 363k tons in 2019 (OSF 2019b).

Norway is, however, different from Finland and Sweden when it comes to bioenergy development. Hydropower is the dominant renewable energy source in Norway. The calculated potential for bioenergy in Norway is approximately 16 TWh, based on the current forest management regime (Bergseng et al. 2012). Approximately 8% of Norwegian energy consumption comes from bioenergy. The main obstacle for increasing the importance of forests to the energy supply is other factors than the resources base. These factors are the availability of other renewable energy resources, such as hydropower, and the availability of infrastructure for distribution. The Norwegian government set a goal in 2008 to ensure targeted and coordinated policy instruments for the increased expansion of bioenergy up to 14 TWh by 2020.

In April 2018, the Norwegian Ministry of Trade, Industry and Fisheries initiated Process 21. The main task of this project is to provide strategic advice and recommendations on how Norway can best achieve a trend towards minimal emissions from the process industry by 2050 and, at the same time, facilitate sustainable growth in existing and new businesses. The following considerations were a result of a subgroup of *Process 21*, which dealt with bio-based processing and its prospect in Norway (Norwegian Research Council 2020).

The goal of the Swedish policy was to use at least 50% of energy from renewable sources by 2020. This target had already been reached by 2012. For 2040, the new target is that the share of renewable energy shall reach 100% and energy efficiency shall be increased by 50% compared to 2005. In 2018, renewable energy accounted for about 55% of the total energy consumption. In terms of the total energy input, nuclear power is still the dominant source of energy (34%), followed by bioenergy (25%). However, the share of energy produced by nuclear power plants in the final consumption is much lower than 34% because of the low energy-conversion rate of nuclear power. Compared with other EU countries, Sweden does not depend on imported energy, mainly because bioenergy and hydropower are well-developed in the country. Since the 1970s, the share of fossil fuels has decreased from 80% to

30%, while the use of nuclear power has increased from 0% to 30%. At the same time, bioenergy has increased from 10 to 30%. In the last 10 years, the share of renewable energy in the final energy consumption increased from 45% to 55% (Energimyndigheten 2020).

Similar to Finland, the chips produced from wood, treetops and branches correspond to close to 15k GWh, while firewood corresponds to 7.705k GWh (Energimyndigheten 2020). The number of pellets produced from the residuals from the sawmill and wood industry is increasing, reaching 1.73m tons in 2016. The import of pellets decreased, with around 87k tons being imported in 2015. The use of pellets seems to be rather stable, with around 1.78m tons in 2017 (Svebio 2017).

Forest industry residues and by-products can be used to manufacture biofuels for transport. The biorefinery's unique processes can transform crude tall oil, a residue of the pulp making process, into renewable diesel for transport. In addition to wood-based diesel, a biorefinery can also produce wood-based chemicals. Renewable diesel reduces up to 80% of the carbon dioxide emissions during its lifecycle as compared to fossil diesel. The process also generates renewable naphtha, which can be used either as a low-emission biocomponent for petrol or as feedstock for producing bio-based plastics (ETIP Bioenergy 2020). In the three countries under study, all the transport fuels contain biocomponents.

Wood fuels also play a crucial role in increasing the share of renewable energy. EU targets for renewable energy are calculated relative to final energy consumption.

In Finland, the share of biofuels in transport fuels was already 22% in 2015. According to new legislation introduced in 2019, the share of biofuels used in road traffic will be gradually increased to 30% by the year 2029 and advanced biofuel target to 10% (Biofuels International 2019).

The Norwegian quota obligation for biofuels in road transport has increased the use of liquid biofuels strongly in recent years. The Norwegian government has pledged to increase its biofuel quota obligation (the required proportion of biofuels in annual sales of road traffic fuels) to 40% by 2030, depending on the development of technology and alternative energy carriers. In the latest National Transport Plan (2018 to 2029), the Norwegian government aims to have sustainable biofuel make up 30% all aviation fuel by 2030, and from 2020, the government wants 0.5% of all aviation fuel to be advanced biofuels. The Norwegian government is also considering biofuel requirements in shipping and for non-road vehicles and machines. All the targets mentioned above correspond to a volume of approximately 10–12m m³ timber or harvesting residue. Concerns about the indirect land use change (ILUC-effect) of conventional biofuels have resulted in highlighting the importance of increasing the production of advanced biofuels. At the same time, biomass demand from processing industries is expected to multiply over the next decades, according to the industry's own roadmap for low carbon development. In sum, the political and industrial targets could significantly raise future demand for liquid biofuels and biomass (Norwegian Ministry of Climate and Environment 2020).

In Sweden, the use of biofuels in the transport sector has increased rapidly in recent years. At present, biofuels account for about 19% of the total fuel consumption in the transport sector, whereas the share was 7% in 2011. Most of the biofuels used in the transport sector in Sweden are imported. Less than 10% of the biofuels are domestically produced from the forest biomass (Energimyndigheten 2016). In the Swedish policy context, increasing the use of biofuels in the transport sector is considered to have great potential to contribute to the goal of 100% renewable energy use by 2040.

5.3.3 Building with wood—multi-story buildings

Since construction activities cover half of the exploitation of the world's natural resources and produces 40% of global waste, minor improvements in the sustainability of the construction value chains will result in a large environmental impact. Among the three construction materials available in industrial volumes (i.e. concrete, steel and wood), wood is the only renewable one.

Building with wood has a strong tradition in the Nordic countries. Residential houses account for a large portion of the building stock. Therefore, their building and renovation activities are of great societal, political, economic, and technical importance.

Since the timber frame is already a predominant construction method used in single-family houses (>80% of the load bearing structures are wood), in attached houses (between 70 and 80%) and in summer cottages (>95%) (Pajakkala 2020), the biggest potential for increasing wood use lies in multi-story buildings, offices and other public buildings (e.g. schools, kindergartens and hospitals), industrial buildings and sports halls. However, urbanisation is affecting the building sector, and wood is not necessarily the preferred building material in cities. A lot of research and development has been allocated to develop solutions for building additional floors on top of existing concrete structures, but only few examples exist, so far. Wood is light weight, and enables such solutions without compromising the load carrying capacity of the old structures. Renovation and the energy upgrading of the façades of old medium-rise residential houses is another potential application of industrially fabricated wooden elements (Hurmekoski 2016).

The price of wood as a building material has traditionally been high compared to some competing alternatives, which has hampered the development of wood use in construction. Similarly, the lack of competence and knowledge concerning wood as a building material has contributed to the limited use of wood in buildings, particularly in urban areas. Changes are currently ongoing. Wood is getting more popular in the housing and building sector for high-rise buildings. Markets for wooden building in urban areas and high-rise buildings are changing. Markets and the building sector together are driving this development (e.g. Hurmekoski 2016).

The unit weight of wood as a structural member is clearly lower than the weight of its main competitors, concrete and steel. This fact makes it cheaper and more energy efficient to transport, handle, and assemble. Lightness also enables building extra floors on top of old concrete houses without compromising the load-bearing capacity of the existing structures. The low weight and ease of processing with hand-held tools, even non-electric ones, comprise another competitive advantage for wood in comparison to steel or concrete: if necessary, wood can be easily reshaped (sawn, split, cut or carved) or reassembled (with glue, metal plates, screws or nails) on site without consuming much energy or producing environmentally harmful or hazardous waste (e.g. Heräjärvi 2019).

Engineered wood products, such as glulam, laminated veneer lumber (LVL) and cross-laminated timber (CLT), have upscaled timber construction from single-family houses to multi-story residential buildings, offices and sports halls with over a 100-metre span (e.g. Hurmekoski 2016). Prefabricated volume elements are becoming more common in multi-story residential building construction, but Finland lacking the domestic manufacturers. The compression strength of wood is 10 to 20 times higher in the parallel-to-the-grain direction than in the perpendicular-to-the-grain direction. Therefore, LVL and glulam, which consist of members with a longitudinal grain direction, perform better in applications in which compression strength is an advantage, such as the load-bearing vertical structures of high-rise buildings. The easiness of joint and assembly techniques, as well as the presence of air tightness and high stiffness, in combination with a relatively low mass, provide these products

with interesting competitive advantages, particularly in high-rise buildings. One of the advantages is related to the lightness of the structural elements, which enables a high degree of industrial prefabrication of, for example, volume elements, which can be transported to the building site by trucks according to the optimised delivery schedule. In an ideal case, the crane can lift the almost-ready-to-live-in volume element straight from the truck to its final assembly position within a matter of minutes. This is an important asset, since construction site activities are traditionally time consuming, labour intensive and require expensive machines. Hence, using wooden volume elements can turn a construction site into an assembly site, which can cut construction time in almost half, resulting in considerable savings for the developer (Hurmekoski 2016; Heräjärvi 2019; Heräjärvi et. al. 2020).

In Finland, building multi-story wooden apartment houses has been possible for decades but mostly in theory. Fire safety regulations were updated in 1997, which enabled building houses of up to four floors with a wooden frame and façade. Another update took place in 2011, after which the building codes allowed residential as well as office buildings to have five to eight floors. Since then, it has been possible to have building of up to eight floors based on ready table design values, and even more floors are possible after a functional fire safety design and detailed computation of the fire performance of the structure. All wooden buildings with more than two floors have to be equipped with automatic fire extinguishing system, which means, in practice, sprinklers in each apartment. To avoid water damages in case of a fire, high-pressure fog systems, which require 90% less water consumption than water sprinklers, are nowadays recommended. For the time being, the 14-floor Joensuu Lighthouse is the highest wooden building in Finland. Close to 44 % of Finnish apartments are in multi-story houses, which is one of the biggest shares in the EU. This share is still increasing because of the aging population (Ministry of the Environment 2020).

Finland launched new energy efficiency regulations for new buildings in 2012, with the aim to not only produce more energy efficient buildings but also increase the use of renewable energy for their heating and cooling. More recently, the Ministry of the Environment compiled a roadmap to reduce the greenhouse gas emissions in the manufacturing of building materials. The carbon footprint of buildings will be included in building regulations starting in the 2020s, which is expected to improve the competitiveness of wood as a building material (Ministry of the Environment 2020).

Education in the field of timber construction has been prioritised in Finland because of the growing demand of timber construction experts. However, it takes years before a new crop of architects, structural designers and construction professionals can emerge and the wide potential of wood as a construction material is fully taken into practice.

In Norway, the Planning and Building Act (2008) regulates the planning and overall land use of building activities. Its purpose is to promote sustainable development. Planning pursuant to the act shall facilitate the coordination of the central regional and municipal governments and shall provide a basis for administrative decisions regarding the use and conservation of resources (Lovdata 2008).

In the 1990s, the Norwegian government initiated a program aiming to promote use of wood in construction. From 2006, the program was run by Innovation Norway, the entity supporting innovation and development in the Norwegian business sector. In 2016, the program was merged with the bioeconomy program. Evaluations revealed that the program for promoting wood had contributed significantly to the development and innovative use of wood in construction during the years up to 2016. The program supported the market-driven development of wood in construction and high-rise buildings (Røtnes et al 2017). The (current) world's tallest wooden building, Mjøstårnet (18 floors and 85.4 m), is in

Brumunddal, in the vicinity of Lake Mjøsa in Norway; it represents a new era for high-rise wooden buildings in the country.

The wood industry is small in Norway, but it is locally and regionally important. Parts of the industry are developing niche products with a high market value. Less than 6% of those employed in Norwegian industry are in the timber and wood product industry (Røtnes et al 2017).

The construction sector, represented by the building and housing sector in Sweden, is the largest consumer of sawn timber, approximately 70%, while 20% of the sawn volume are used for joinery and furniture industries (Kumar et. al. 2020). The new-house market of residential buildings corresponds to 80–90% of the timber constructions. The regulation of high-rise timber buildings changed as Sweden entered the EU in 1994. Before this, wood was not allowed in buildings taller than two stories (Regeringskansliet 2018).

Framework material, moulded construction timber, form work, windows, stairs, and impregnated wood are the main constructions for which wood is used. However, the increasing production of timber houses, together with the trend to renovate older buildings, has increased the need for timber and for employees in the sector (Kumar et. al. 2020).

Interest in multi-story timber buildings has been driven by modern building regulations as well as lower costs of building with wood compared to other building materials and increased environmental awareness. Today, in Sweden, around 10% of the multi-story buildings are constructed using timber. The majority of multi-story buildings are typically three stories high (Regeringskansliet 2018). Presently, the *Kulturhus* in Skellefteå, in northern Sweden, a 19-story (76 meters) cultural centre and hotel, is being constructed and is then going to be the tallest wooden building in Sweden (however with a hybrid construction system of wood and steel and wooden modules with concrete slabs) (Kumar et al. 2020).

The demand for housing in Sweden is constantly increasing, especially in urban areas; investments in the industrial wood building industry have increased over the past years to increase capacity, especially for multi-story buildings and for glulam segments. The government believes that this industry will contribute not only to housing but also to climate change mitigation, exporting and employment. However, stakeholders in the industry must increase their knowledge in construction, material combinations and technical solutions as well as in architecture (Regeringskansliet 2018).

5.4 Markets for bio-based products

Despite normal business cycle fluctuations, the Covid-19 pandemic and the corresponding decline in world economy, both the long-term outlook for the forest industry and for the demand in forest products seem favourable (Rikkonen et al. 2020).

The long-term operating environment of the forest sector is affected by global megatrends, such as population growth and population aging, urbanisation, climate change, changing priorities in the global economy, depletion of natural resources, declining biodiversity, increasing environmental awareness, digitalisation, networking (people, economic systems and politics), and the growth of the circular economy in response to global environmental and resource problems. Megatrends also change the demand as well as production and production opportunities for forest industry products, for example through trade, climate, energy and land use policies as well as through the consumption habits of individuals. Megatrends change the consumption of tangible and intangible assets produced by forests; they also affect the direction of trade flows in forest products and the availability of raw materials, the international competitive environment as well as the rate of transmission of market fluctuations between regions. All these changes challenge the forest sector to the forest sector's ability to adapt and survive (e.g. the Ministry of Agriculture and Forestry of Finland 2015).

Although many megatrends can have negative effects on the demand for some forest industry products, such as decreasing demand for printing and writing paper due to digitalisation, they generally support the long-term development of the demand for forest products. Efforts to increase the use of products made from renewable raw materials will increase the demand for tissue and hygiene papers and packaging boards. Efforts to mitigate the effects of climate change and the pursuit of healthy living will improve the position of wood in urban construction, where modern engineered wood products are now used more regularly alongside traditional lumber and plywood. There are also high expectations for new wood-based products for the construction, packaging, and textile industries as well as for wood-based biofuels (e.g. Regeringen 2018a; b).

The competitiveness and success of the forest sector are based on know-how, properly managed forest resources, good infrastructure and a reliable and stable operating environment. Demand for northern long-fibre softwood pulp as a basic raw material for important end and intermediate products in the forest industry is likely to remain strong in the coming years. Yet the rapid development of technology can also bring surprises.

Policy making, especially at the EU level, may also bring about surprises. Although the EU has no common forest policy, other policies—especially climate, environment and land use policies—can affect the forest sector. The EU's ambitious climate targets are reflected, for example, in the LULUCF regulation (Land Use, Land Use Change and Forestry) and the Commission's Green Deal. The carbon sink provided by forests is recognised as essential in reaching climate neutrality by 2050. Thus, increasing the forest carbon sink is encouraged. In forest-rich countries where the possibility of afforestation is limited, such as in Finland, Norway and Sweden, there are notable trade-offs between the forest carbon sink and the material use of wood. The Green Deal also includes plans to increase the amount of strictly protected forests in order to enhance biodiversity (e.g. EC 2019).

Climate change mitigation and biodiversity preservation are obviously positive policy targets. However, if the related policy measures do not consider the national characteristics of member states adequately, they will negatively affect the availability of roundwood, the competitiveness of the forest industry, employment, and national economies; in the worst-case scenario, they may create large carbon leakages and hamper biodiversity outside the EU (EC 2019).

Climate change itself is a risk for forestry. Temperature increases and the normalisation of extreme weather events, such as storms and drought, may cause forest damage in Finland, which was recently the case in Central Europe and Southern Sweden (Viera et al. 2019). It is often argued that active, ‘climate smart’ forestry operations are needed to prepare for the challenges of climate change and to increase the resilience of forests. Active forestry and the material use of wood are also needed to ensure that the level of forest sink remains high in the long run.

5.4.1 Potential market development for bio-based products

In addition to some tens of thousands of already commercialised wood-based products, there exist several new ones under development or in the process of commercialisation, and more have not even been invented yet. Inventing or developing completely new products is, however, just one side of the coin. The other side—and perhaps the more difficult one—consists of inventing new functionalities to the existing products or equipping them with smarter techniques to meet the changing requirements of the society. Megatrends and systemic changes, such as circular economy development as well as the requirements for food and beverage packaging, challenge both the existing applications and force the development of completely new ones. The cascade use of materials is such an example. Since incineration is not considered an example of material cascading, there are no effective solutions to recycle wooden construction and demolition waste (CDW), whereas the current volumetric recycling rates of concrete and steel are approximately 80 and 90%, respectively. This presents innovation challenges to the structural designers, architects, builders, and researchers working with ordinary wood products, such as structural lumber. Solutions to efficiently recycle wooden CDW are also required. Thus, developers are working to exploit this large economic potential. Many other systemic changes have similar effects and consequences (Ginga et al. 2020).

Cellulose is a chain polymer consisting of amorphous and crystalline regions. It is the most abundant organic substance on Earth. Breaking cellulose microfibrils into smaller, nanometre scale units produce nanocellulose. Nanocellulose can be applied in numerous different applications, such as additives in concrete production, thickening agents in food production, cosmetics, and the production of bioplastics for packaging applications. Nanocellulose also has potential in electronics, such as transparent screens, flexible solar panels or printed electronics (Trache et al. 2020).

If the amorphous regions are removed from the cellulose polymers, the remaining clean crystallised material is called micro-crystallised cellulose (MCC). MCC is fine white powder that has interesting properties, which can be further modified by adding other substances. Because MCC is not water soluble or toxic, there is no upper limit for its use in food, for instance as a replacement of fat or for improving the heat tolerance of food and improving its behaviour in freezing-melting treatments (Trache et al. 2016).

5.4.2 Textile revolution

Wood also turns into regenerated textile fibres, which consumes freshwater 20 times less than cotton-based fabrics. The viscose production process has been known and applied for a long time, but it has a large negative impact on environment. Alternative methods based on ionic liquids (e.g. IONCELL-F) have been recently developed, and they are about to enter the markets in the next few years. In addition to textiles, renewable, recyclable, and environmentally sound regenerated cellulose can be applied, for instance, in a variety of composite applications. These techniques are interdisciplinary and ground-breaking because they have the potential to revolutionise both chemical forest industries and those industries producing textile fabrics (Sixta et al. 2018).

5.4.3 Lignin and hemicellulose

Lignin is the second most abundant organic material on Earth. Both lignin and the third main component of wood, hemicellulose, are nowadays mostly burnt for energy. They also exhibit several possibilities for higher value-adding products, and their availability in industrial scale makes them appealing in contrast to fossil raw material.

Unlike the polymerised chain molecules cellulose and hemicellulose, lignin is a three-dimensional molecule. It works as a glue in wood matrices, and it can also be used as a binder in the manufacturing of wood products. The micro plastics in aquatic and terrestrial environments originate largely from car tires, and lignin could be used to replace the fossil oil plastics in such applications. Stora Enso's Sunila mill is the world's largest lignin producing facility; it has a production capacity of 50,000 tons per year. The Lineo™ lignin is already applied in wood adhesives, paints, paper laminates as well as lightweight components in aircrafts, wind turbines, etc. (e.g. Stora Enso 2020).

Hemicellulose can be extracted from wood using pressurised hot water extraction; it also reacts in water and makes new structures in water-oil solutions, which makes it an interesting material for stabilisation and for the structural modification of foodstuffs. Hemicellulose could also be applied as an oxygen barrier in food packages, replacing the non-renewable materials (Lahtinen et al. 2019).

5.4.4 Bark – a treasure chest of biochemicals

Bark is a side product, produced in sawmills, plywood factories and pulp and paper mills. Almost all bark is used in bioenergy production. Birch bark is very different from softwood, since the outer part of birch bark contains a considerable proportion of valuable biochemicals, such as betulin and suberin. Betulin content can be as high as 30%. Betulin is interesting from a medical point of view because it has many health effects, such as decreasing cholesterol levels. The German company Birken AG has patented the method to extract betulin from birch bark to produce emulsion cream for medical use. Birch bark waxes and fats (i.e. suberin) could be used to produce water-repellent coatings (Korpinen et al. 2019).

Softwood bark contains a lot of water-soluble tannins and polyphenols, which can replace the fossil-based, toxic substances in some extent, for example in adhesives (Lacoste et al. 2015). Spruce bark also contains stilbenes, which have applications in medicines, wood preservation agents and the in production of semi-conductors. Termites appear to dislike stilbenes; thus, they have wood protection potential in temperate and tropical conditions. In addition to protecting wood from micro-organism growth, stilbenes have anti-cancer properties (Jyske et al. 2014).

5.4.5 Resin heals

Boreal softwood trees typically live for hundreds of years. Conifer longevity is due to the bioactive compounds that protect and prevent, biotic threats. Lignans in spruce knots prevent microbes entering the trunk via the branch stub after the branch has been self-pruned. Lignans are strong antioxidants. The most common spruce knot lignan, HMR-lignan, has been observed to slow down the progress of some common cancers, such as breast and prostate cancer, osteoporosis, and cardiovascular diseases. Spruce resins also contain lignans, which can help to wounds, infections, and skin rashes (Sipponen et al. 2007). Resin acids, such as abietinic acid, are bacteriostats, meaning they prevent bacterial growth. Unlike antibiotics, they are efficient against MRSA, the severe hospital-acquired bacterial infections.

Polyphenols extracted from Scots pine knots appear to prevent the division of cancer cells, facilitating their death. Another compound originating from pine knot prevents the production

of enzymes that break cartilage. Thus, this compound has potential to prevent osteoarthritis or rheumatism (Laavola et al. 2019). Crude tall oil, a side product of sulphate pulping, contains many interesting chemical compounds, including sitosterol, which lowers cholesterol. Crude tall oil fractions are used in cattle forage to prevent infections instead of antibiotics (Aguirre et al. 2019).

5.4.6 New products in the bio-based sectors of Northern Europe

In Finland, there are several examples of new technologies and product development involving forest-based materials. For example, the Finnish companies Kotkamills and Ahlstrom-Munksjö have launched plastic-free paperboards and papers that are moisture and fat proof and do not contain detrimental fluorochemicals. Thus, they can replace plastic barrier-based materials in, for example, disposable coffee cups, muffin tins or packaging for fast food or frozen fish. Additionally, the Finnish company Spinnova Ltd. has developed a method to convert wood pulp into textile fibres without using any environmentally harmful chemicals. The company estimates that their technology could replace 20% of the world's annual cotton production by using 20–30m³ of timber, which corresponds to approximately half of the industrial roundwood harvest in Finland per year (Ahlstrom Munksjö 2020; Kotkamills 2020; Spinnova 2020).

A recent study by Samfunnsøkonomisk and the Norwegian University of Life Sciences (Røtnes et al. 2019) investigated the potential added value of new products made from pulpwood and by-products from the Norwegian sawmilling industry. This study indicates that there is a basis for relatively higher demand for bio-based products compared to expected global growth in the coming years. The demand differs substantially for different products. The growth potential seems to be highest for biofuels, pellets and some biochemical products (Røtnes et al. 2019). The study also maps the probable demand for raw wood and outlines production plans for raw wood in Norway. According to these estimates, the already announced production plans will need between 5.7–11m³ of timber. Røtnes et al. (2019) conclude that the demand for raw materials will most likely exceed the available Norwegian raw materials by a good margin, even if exports cease.

In Norway, companies are also developing a process to use biomass as a resource for animal fodder and energy pellets.

Substantial research and innovation activities, as well as investment, are needed if actors in Norway are to replace the pulp and paper industry, which disappeared after 2012. Until then, Norway will continue to export raw material to more competitive processing industries in Sweden and other European countries.

At present, around 17% of the Swedish export consist of biochemicals (including pharmaceutical and mineral oil products). Such products as starch, oil and cellulose are the main components in biochemicals, and with an addition of lactic acid and amino acids, is an important product for food industry. Most facilities producing biochemical products also develop such goods as viscose and biofuels/biogas, like the Domsjö factories (Kumar et al. 2020).

Current research is also further exploring the possibilities of making new products based on forest biomass, such as glass out of lignin (Wallenberg Wood Science Centre), bio-based pharmaceutical products (Bioinnovation), and smart packaging, like paper bottles (EcoXpac; BillerudKorsnäs Venture; Skogsindustrierna 2020c).

The Swedish government believes that the development of new bio-based products has great potential, especially given the government's renewable-energy target, to develop the biorefinery sector, as its full potential has not yet been realised. Lignin is considered to have

the greatest potential at present for making new bio-based products (Regeringskansliet 2018; Danske Bank 2020; Kumar et. al. 2020). Presently, there are between five and six companies in the Swedish biorefinery sector. The main issue for the slow development is the costly price of developing biofuel plants (Danske Bank 2020).

5.5 Key take-home messages

- The forest plays a key role in climate change mitigation in absorbing carbon, keeping carbon away from the atmosphere and storing carbon in wood-based products.
- The forest is an important provider to national and local economies in the study area, contributing to the GDP and providing employment opportunities. The number of people employed in a bioeconomy-related sector in the study area is between 5 and 7 %.
- The forest is an important provider of timber, pulp and paper in Finland and Sweden. Paper and paperboard are the most important product segments; Finland and Sweden each export paper and paperboard at an annual value of around EUR 7bn. In Norway, the pulp and paper industries mostly disappeared after 2013.
- The forest is also an important provider of bioenergy and biofuel. Bioenergy is both produced and consumed in Finland and Sweden. Both countries have high targets for the share of renewable energy; Finland aims to have 50% of its energy originating from bio-based sources by 2030, while Sweden aims to have 100% of its energy originating from such sources by 2040. For Norway, the use of bioenergy is low; only 8% of its energy consumption comes from bioenergy sources.
- Biofuel targets in transportation are high for the study area. In Norway, having a biofuel quota is obligatory, while Finland and Sweden are increasing the share of biofuel in transportation. Common challenges in the study area include the low domestic production of biofuel.
- Wood as building material has a long tradition in the study area. However, building multi-story buildings happens somewhat differently in each country. In Norway, the multi-story building sector has been supported by the government to develop the industry with the market in mind. In Finland, the possibility to build multi-story buildings has existed since 1990s; however, the use of wood in multi-story buildings has increased slowly, but recent new regulations on energy efficiency and carbon footprints are expected to increase the competitiveness of wood as building material in order to construct more multi-story buildings. In Sweden, it was not possible to build multi-story buildings (taller than two stories) until 1994; however, with modern buildings regulations and lower costs, the market for multi-storey buildings has begun to increase.
- The market for bio-based products has not yet been affected by the Covid-19 pandemic; rather, the demand for forest-based products seems to have increased.
- The market for bio-based products is affected by bioeconomy transformation strategies (e.g. exchanging fossil-based resources with bio-based ones) and by global trends, such as population growth, urbanisation, climate change and global economy transitions.
- National as well as international policy regulations, such as climate targets, LULUCF and the Green Deal, can affect the market for bio-based products.
- Apart from the traditional bio-based products, innovations and potential markets for new bio-based products have been developed in the study area. For example

- Polymer (e.g. thickening agents in food, cosmetics and bioplastics);
 - Textile fibres (e.g. textile and composite applications);
 - Lignin and hemicellulose (e.g. bioenergy, bioplastics, paint and stabilisers);
 - Bark extracts (e.g. medicines); and
 - Resin heals (e.g. substitute for antibiotics for cattle).
- In Northern Europe, new innovations include replacing plastics and single-use materials, textile development, animal fodder and energy pellets, biochemicals, bio-based pharmaceutical products and smart packaging.

6 Biodiversity and non-wood forest products

This chapter focuses on the non-wood benefits of the forest. It first discusses biodiversity and then NWFP. How is the biodiversity dealt with in forests and what NWFP are available in the three Nordic countries?

6.1 Biodiversity and ecosystem services

There is increasing concern about the ways in which habitat loss, degradation and fragmentation negatively affect the long-term viability of rare and red-listed species. Global targets, such as the Aichi Targets of the Convention on Biological Diversity (CBD) and the targets of the EU Biodiversity Strategy to 2020, have been created to halt biodiversity loss; one target, for example, aims to restore 15% of degraded ecosystems by 2020. The targets of the Strategy 2020 were not reached; hence, the ambitious EU Biodiversity Strategy to 2030 was launched.

The three key commitments in the new Biodiversity Strategy 2030 are as follows:

- Legally protect a minimum of 30% of the EU's land area and 30% of the EU's sea area and integrate ecological corridors, as part of a true Trans-European Nature Network;
- Strictly protect at least a third of the EU's protected areas, including all remaining EU primary and old-growth forests; and
- Effectively manage all protected areas while defining clear conservation objectives and measures and monitoring them appropriately (EC 2020b).

In addition, several forest-related aims are mentioned:

- A New EU Nature Restoration Plan with legally binding restoration targets;
- A roadmap for planting at least 3bn additional trees in the EU by 2030 in full respect of ecological principles;
- Develop the Forest Information System for Europe; and
- New sustainability criteria on forest biomass for energy.

To mainstream biodiversity protection in the EU, the Commission will help to build a European Business for Biodiversity movement, with this movement becoming an integral part of the European Climate Pact. The Commission will also promote tax systems and pricing that reflect environmental costs, including biodiversity loss. This should encourage changes in national fiscal systems to shift the tax burden from workers to pollution, to under-priced resources, and to other environmental externalities. The 'user pays' and 'polluter pays' principles have to be applied to prevent and correct environmental degradation (EC 2020b).

To understand why the previous biodiversity targets were not reached, the discrepancies between the policies promoting forest bioeconomy and those aiming to safeguard biodiversity must be taken into consideration.

In connection to the development of strategies for biodiversity, the concept of 'ecosystem services' was developed, and it is particularly helpful in relation to sustainability as well as biodiversity goals. The international definition of ecosystem services distinguishes between:

- Supportive ecosystem services: the basic functions of ecosystems as a basis for the other ecosystem services (e.g. soil, photosynthesis, and biochemical cycles);
- Provisional ecosystem services: goods that are produced by ecosystems (e.g. timber, water and food);
- Regulatory ecosystem services: the ecosystem function affecting environmental factors (e.g. climate change mitigation, floods, control of diseases and pollination); and
- Cultural ecosystem services: values contributing to human well-being (beauty, inspiration, and recreation) (MA 2005).

6.2 Management practices provide an opportunity for increased recognition of biodiversity and non-wood forest products

Management practices in northern European countries are dominated by the clear-cut method, leading to evenly aged forests. However, continuous-cover forestry has been discussed, and, for instance, in Finland, the method was made available by the revised Forest Act in 2014. In Sweden, the method is not allowed; however, the results of certain field trials are being discussed among researchers and foresters. The aim of continuous-cover forestry is a forest stand with a diverse age structure as well as maintaining forest coverage. The use of this method is still low, but a recent survey revealed that forest owners intend to increasingly use unevenly aged forests in future. When calculated on an area basis, 51.5% of the total forest area is used for evenly aged forestry and 25% is used for unevenly aged forestry (Juutinen et al. 2020).

The information on the impact of continuous-cover forestry on biodiversity is still scarce. However, one study states that this kind of forestry promotes ecological and social objectives better than evenly aged forestry, but it is considered worse from economic point of view (Nordström et al. 2013). It is estimated that unevenly aged management favours species that prefer shady, such as the bilberry (Siitonen 2018). It is also important to acknowledge that continuous-cover management does not improve the biodiversity unless valuable environments are also protected (Siitonen 2018).

A recent assessment on the impact of continuous-cover forestry on NWFPs concludes that uneven management can simultaneously support multiple ecosystem services when compared with traditional rotation forestry (Miina et al. 2020b). For example, the uneven forest structure is suitable to produce bilberry and reindeer lichens, the latter being crucial for the reindeer. Uneven forests are also favoured for the recreational use of forests, since felling's and soil preparation remarkably reduce the visual impact of the forest. Yet rotation forestry favours the production of lingonberry and some natural products that are collected in a certain developmental stage of the forest, such as birch sap. Moreover, mushroom production is favoured by rotation forestry, apart from the regeneration phase (Miina et al. 2020b).

6.3 Biodiversity in Finland

The Finnish Forest Strategy to 2025 (Ministry of Agriculture and Forestry 2015) supports the Convention on Biological Diversity (CBD), the EU Biodiversity Strategy and the Finnish Biodiversity Strategy 2012–2020. The strategy acknowledges that biodiversity can influence the supply of ecosystem services, where NWFPs are considered a part of the ecosystem services.

According to the Finnish Forest Strategy, the principal means to support biodiversity and NWFPs in commercial forests are nature management and the development of voluntary economic incentives, such as forest certification. The Forest Strategy points out that healthy, abundant, and biodiverse forests enable their diverse utilisation and the versatile production of ecosystem services. Forests are considered important for the recreation of most Finnish people, as forests have a positive impact on their health and well-being. Berries, mushrooms, and game are actively utilised and managed through active forest management. The strategy also points out the crucial role of forests in hosting a remarkable number of threatened species.

The strategy also reveals a trade-off between forest use and biodiversity. At the same time, when discussing the importance of commercial forest in safeguarding the biodiversity and ecosystem services, the strategy proposes felling levels to be increased by 20–30% due to increased forest growth.

Next, the Energy and Climate Strategy for 2030 indicates that the forest biomass is crucial as a source of renewable energy to replace imported fossil fuels. A background ministry report was made for the Energy and Climate strategy, in which the impacts of different forest felling scenarios on forest carbon sinks and biodiversity are evaluated (Ministry of Employment and the Economy of Finland 2017), yet forest NWFPs are not considered.

The background report summarises how increased felling's from the 10-year average of 61 m³/year can influence carbon sinks and biodiversity. The report also assesses the impact of biodiversity in terms of the structure of the standing crop, the age structure of forests and the volume of deadwood. The background report concludes that felling's of roundwood can be increased from 61 to 79 m³ per year while also safeguarding forest biodiversity (Ministry of Employment and the Economy of Finland 2017). However, this conclusion omits a crucial sentence from the original assessment, where it reports that the initial decrease of large old trees after intensive felling's may be critical for the most threatened species dependent on old trees (Korhonen et al. 2016). A precondition for improving biodiversity under increased felling levels, according to the report, is a more intensive use of nature management methods in commercial forests. Consequently, increasing felling levels is considered sustainable for biodiversity, but the message on the most threatened species in the original biodiversity assessment is omitted.

The Finnish Bioeconomy Strategy of 2012 (Ministry of Agriculture and Forestry 2014) aimed to generate new economic growth and employment within the bioeconomy as well as high value-added products and services; the strategy also aimed to reduce dependence on fossil fuels while simultaneously safeguarding biodiversity and the natural ecosystems. The strategy supported the UN SDG both domestically and in its international cooperation. Forests were considered important in reaching all aspects of sustainability, including the social, ecological, economic, and cultural dimensions. The strategy also mentioned recreation, nature tourism and well-being services as sources of NWFP. Nature management measurements along with forest certification were also mentioned to safeguard forest biodiversity (Ministry of Agriculture and Forestry 2014). The strategy did not propose any specific numbers for forest management; hence, the strategy did not mention any synergies or trade-offs between biodiversity targets.

The Finnish Biodiversity Strategy, officially called the Strategy for the Conservation and Sustainable use of Biodiversity in Finland—Saving Nature for People (Ministry of the Environment, 2012), set a target to halt the degradation of biodiversity by 2020. The strategy was drafted in direct response to the 2020 Aichi Targets and the EU's biodiversity strategy 2020. The aim was to initiate urgent measures that promote the mainstreaming of biodiversity in decision-making, reduce the pressure on biodiversity, restore degraded ecosystems and use natural resources in a sustainable way.

To safeguard biodiversity both on private and state-owned land, a government decision-in-principle was set in 2014 for the METSO forest biodiversity program to protect 96k ha of private and 13k ha state-owned forests by 2025 on a permanent or temporary basis. However, despite the generally positive attempts to safeguard biodiversity and the production of ecosystem services, the development of biodiversity in forests was negative. The reasons included the continuing human pressure on ecosystems and reduced funding to fulfil the targets of the biodiversity program (The 6th National Report of Finland 2019).

Hence, halting the loss of biodiversity by 2020 was not possible in Finland despite many steps taken in forestry to take biodiversity into account. Some of the most important of these included the renewal forest legislation in 2014 and the adoption and development of forest certification schemes (The 6th national report of Finland 2019).

The abovementioned evaluations are largely based on the newest assessment of threatened species and habitats in Finland. The red-list assessment of Finnish species indicates that forests are the principal habitat for 2,133 red-listed species (31.9%) (Hyvärinen et al. 2019). It has to be noted that also common forest plant species, such as the deciduous dwarf shrub bilberry, have decreased in number, the main reason being regeneration felling's as part of forestry operations (Tonteri et al. 2016). In peatlands, 280 red-listed species living principally in undrained mires have become red listed (4.2% of all red-listed species). The main reason for the forest and peatland species becoming threatened is forestry (Hyvärinen et al. 2019), which results in the lack of decomposing wood on mineral soils and open mires turning into forested peatlands on peat soils. Similarly, the main threats to habitats (Kontula & Raunio 2018) are forestry and forestry drainage.

6.4 Biodiversity in Norway

The Norwegian Nature Index estimates trends of Norwegian biodiversity through a selection of indicators, which represent the 44k known species found in Norway. The index consists of a total 260 different indicators, distributed over seven main ecosystems. The indicators represent species, groups of species and a few indirect indicators of biodiversity. The condition of the woodland ecosystem is described by 89 indicators, while the other ecosystems are described by indicators 22 through 46. From 2000 to 2020, there has been a positive trend in the index for the forest and freshwater ecosystems, whereas the trend is slightly negative in the mountain ecosystem. The open lowland ecosystem index has seen the most drastic and continuous decline (Jakobsson & Pedersen 2020).

According to the Norwegian Environmental Authority, 60% of the known species in Norway are associated with forest, and 48% of the threatened species live in forest ecosystems. Other activities than forest management might cause the threat, but the authority still highlights the importance of forest ecosystem management to protect endangered species (Miljødirektoratet 2020). The Norwegian government has a goal to protect 10% of forested areas. The status as of January 2020 is that approximately 5% of all forests, including 3.8% of productive forests, have been protected. (Ministry of Climate and Environment 2020).

Based on the Forestry Act, the associated sustainability regulations and the Norwegian PEFC forest certification program, a comprehensive system of environmental protection in forestry has been established. The system includes resource and environmental monitoring, forestry planning with environmental registrations, regulations on sustainable forestry, regulations on road construction and regeneration obligations, subsidies for environmental measures in forestry, updated resources as well as environmental data for forestry planning and research on forest resources and environmental considerations (Norwegian Ministries 2016).

Monitoring and research reveal that the number of endangered species in Norwegian forests has decreased since 2015. The volume of deadwood in forests is increasing by approximately 3% annually and is one of the reasons for the decrease in the number of endangered species. More research and knowledge about the different species are also a factor (Ministry of Agriculture and Food 2016).

In Norway, the Nature Diversity Act is the main legislation governing policies that protect biological diversity. Its purpose is to protect biological, geological and landscape diversity and ecological processes through conservation and sustainability. The act applies to all land as well as river systems and Norwegian territorial waters; it is also based on principles, such as the precautionary principle, the ecosystem approach and cumulative environmental effects. Furthermore, the act encompasses the user-pays principle—that is, the costs associated with preventing or limiting any damage on nature diversity should be borne by the project owner.

The Forestry Act (2006) applies to all ownership categories. It regulates managed forests and provides the objectives of the Norwegian forest policy. The central objective of Norway's Forestry Act is to promote local and national economic development and to secure biological diversity, outdoor recreation and the cultural values associated with forests. The Forestry Act also contributes to the conservation of biodiversity and the sustainable use of natural resources.

Norway's national biodiversity action plan, Nature for Life, was issued in 2016. The Aichi targets are reflected in Norway's three national biodiversity targets, which are concerned with:

- Achieving good ecological status in ecosystems;
- Safeguarding threatened species and habitats; and
- Maintaining a representative selection of Norwegian nature.

In the biodiversity action plan, the management strategies are summarised under the following headings:

1. More clearly targeted nature management;
2. Climate-resilient nature management;
3. Strengthening municipal expertise on biodiversity;
4. Safeguarding threatened species and habitats;
5. Long-term conservation of a representative selection of Norwegian nature;
6. Knowledge-based management; and
7. Adaptation of tools and instruments to the different ecosystems.

The biodiversity action plan also proposes further development of the environmental monitoring system to ensure satisfactory monitoring of all ecosystems and further development of good indicators for ecosystem services. The system is called Nature in Norway (NiN) (Norwegian Ministry of Climate and Environment 2020).

6.5 Biodiversity in Sweden

In 2012, the government initiated a policy on ecosystem services given its environmental quality goals (16 targets) and its support of the CBD. Then, in 2014, the government decided

upon policy on biodiversity (Prop. 2013/14:141) that visualised the value of ecosystem services and their relevance for the development of relevant sectors and businesses:

'The conservation of biodiversity is a cornerstone in the government's environmental policy. Biodiversity is a prerequisite for the ecosystem's long-term capacity to contribute to human's well-being. Ecosystem services is a base for economics and welfare. Both private and public sectors are directly or indirectly dependent of the services the ecosystem provides' (SOU 2013:68, p. 16).

The Forest Act of 1994 already acknowledged the importance of ecological sustainability; the act gave equal status to the production of timber and environmental considerations (which included biodiversity).

The strategy on ecosystem services builds upon the environmental quality goals, which aims *'to the next generation turn over a society in which the major environmental problems are solved'* (Prop. 2013/14, p. 27). Another goal is not to cause any further environmental or health issues internationally. The overarching goal is supplemented by several sub-targets:

- The environmental policy shall be directed to ecosystems that have recovered or are about to recover; it also aims to secure long-term ecosystem services;
- Biodiversity and natural and cultural environments are preserved, promoted and used sustainably;
- Human health is exposed to minimal adverse environmental impact, and the environment's positive impact on human health is promoted;
- The cycle is resource efficient and is as far as possible free of dangerous substances;
- There is an efficient use of natural resources;
- The share of renewable energy increases, and energy consumption has a minimal impact on the environment; and
- Consumption patterns for goods and services have a small environmental impact. (Prop. 2013/14 p. 27)

In connection with the overarching environmental goals, the 16 targets emphasise specific situations. For forests, the most relevant target is 'living forests', and in relation to forests, the goals include:

'The forest and the forest land value for biodiversity shall be safeguarded in conjunction with the preservation of biodiversity and culture environmental values as well as social values'. (Prop 2013/14, p. 28)

The 'living forests' goal includes the following elements:

- The forest's natural production ability is preserved;
- The forest ecosystem's natural functions and processes are sustained;
- Natural regeneration is used where soil conditions are suitable;
- The forest's natural hydrology is safeguarded;
- The effect of fire is preserved;
- Forests with great natural, cultural and environmental value are managed so that these values are safeguarded and strengthened;
- Forests with a large degree of unevenly aged stands and large variations in tree composition are safeguarded;
- The forests' cultural heritage is safeguarded;
- The forest's importance for outdoor activities is safeguarded;
- Threatened species are protected;
- Native plant and animal species survive under natural conditions and in viable stocks;
- Threatened species have the ability to spread to new locations within their natural area, ensuring a sustainable population; and
- Alien species and genetically modified organisms that could threaten biodiversity are not introduced. (Prop. 2009/10:155, p 182)

The strategy on ecosystem services points out that the environmental considerations in forestry are important to meet the demands of society, in which the ecosystem services are of high relevance. In connection to the international goals of the CBD, the Aichi targets, the Cartagena Protocol and the EU targets, the Swedish government set up several milestones in connection to biodiversity, in which the forest is directly or indirectly targeted, including the following:

1. Ecosystem services and resilience—systematic identification of ecosystem services;
2. Biodiversity and value of ecosystem services —understand the value of and importance of biodiversity and ecosystem services;
3. Threatened species and nature types—outline action program;
4. Invasive, foreign species—investigate the effect of invasive foreign species in Sweden;
5. Genetic diversity—knowledge overview;
6. Land use—holistic view of land use and coordination;
7. Protect land, fresh water and marine environments—protect 20% of land and fresh water and 10% of marine areas by 2020; protect forests with a high natural value; increase voluntary set-asides; and increase ecological connectivity to protect areas and biotopes;
8. Environmental consideration in forestry—increase awareness and practically implement forest environmental considerations;
9. Variation characteristics of forestry—clarify regulations to enhance variation-rich forestry; and
10. Dialogue process on developing national forest program (Prop 2013/14, p 29-30).

In Sweden, no general monitoring of biodiversity is possible, as in most parts of the world. However, because of a governmental initiative—the Species Data Bank¹², an entity within the Swedish University of Agricultural Sciences—that monitor the red-listed species, the state of the Swedish biodiversity is relatively well known. Through this initiative, the red-listed species are also monitored. Additionally, the landscape is also monitored by the national inventory of the landscape in Sweden (NILS). The species included in the EU directive on species and habitats are separately monitored every 6th year (Naturvårdsverket 2020).

In 2017, the Swedish Forest Agency (SFA) evaluated the state of forest ecosystem services, in relation to the forests’ ability to provide for ecosystem services. In the report, each of the ecosystem service category is broken down into specific benefits provided by forests. Out of the 30 benefits, seven are classified with inadequate status, hence not contributing to the environmental targets; 13 are deemed moderate, and the remaining ones have a good status (see Fig. 5.). The forest ecosystem services, found in both the supportive and regulatory categories, need immediate attention to ensure their future functioning. An intensified forestry together with climate change and changing growth conditions due to changes in annual average temperature are contributing factors. According to the SFA, there is a lack of old forests with contingent forest coverage and multi-layered forests; there is also limited to access to deadwood (SFA 2017a).

Generally, the SFA identifies a need to increase awareness of ecosystem services in the forest sector and the function of ecosystem services in forest sustainability. Furthermore, the report indicates that forest ecosystem services have to be integrated in the assessment of both company and official decision-making (SFA 2017a).

		Good	Moderate	Inadequate
Provisioning	Timber and pulpwood			
	Biomass-based energy sources			
	Game			
	Reared animals			
	Forest berries			
	Mushrooms			

¹² ArtDatabanken in Swedish

	Drinking water		Yellow	
	Fresh water fish			Red
	Genetical resource		Yellow	
	Other provisioning services			
Regulating	Climate regulation	Green		
	Prevention of storm damage and other weather-related damages			Red
	Prevention of erosion and landslides			Red
	Water flow regulation		Yellow	
	Natural control of pests and disease			Red
	Ensuring the quality and quantity of ground and surface water		Yellow	
	Air purification	Green		
Supporting	Biogeochemical cycling			
	Soil fertility	Green		
	Pollination	Green		
	Photosynthesis	Green		
	Habitats and natural environments			Red
	Biological diversity			Red
	Stability and resilience		Yellow	
	Seed dispersal		Yellow	
Cultural	Everyday recreational activities and exercise		Yellow	
	Forest and nature for tourism		Yellow	
	Mental and physical well-being		Yellow	
	Environment and aesthetics		Yellow	
	Knowledge and information		Yellow	

Figure 5. Forest ecosystem services status in Sweden (SFA 2017a)

In 2020, the latest version of the red list was made available. In Sweden, around 50% of the listed species are found in forested areas, and 43% are dependent on forests; however, a large share of the species migrates between different types of landscapes. Compared to 2015, the number of red-listed species have increased from 4,275 to 4,746. From a ten-year perspective, the number of red lists has increased, which shows a negative trend regarding biodiversity. One factor driving this negative trend is intensified agriculture and forestry, with a more monotone land use, together with expanding urban areas (SLU 2020).

6.6 NWFPs in Northern Europe

6.6.1 Berry and mushroom picking

With the increasing interest in, and the popularity of, healthy lifestyles, particularly in Asia and Europe, the business related to the utilisation of NWFPs has grown rather steadily in both Finland and Sweden during the last decade. For local societies, the NWFPs may even be more important than timber production (Shakleton & Gumbo 2010). In Norway, however, only minor parts of the NWFPs reach the market.

In Norway, more than 95% of the population participate in outdoor activities; this number has been relatively stable over the last few years (Miljødirektoratet 2020). Regular studies (three-year intervals) of the participation of Norwegians in different outdoor activities reveal, however, that the share of trips dedicated to berry and mushroom picking has declined. In 1997, the share of the Norwegian population who picked berries and mushrooms was 48%. The corresponding share in 2014 was 36% and 29% in 2020. Participation in other outdoor activities has remained stable or has increased (Statistics Norway 2020). Berry and mushroom picking for commercial activities is rare in Norway, whereas the import of berries for industrial production is common.

For example, in 2017, the turnover of the sector was EUR 530m in Finland (Ministry of Employment and the Economy of Finland, 2019). The growth of the sector results partly from the increased exports of traditional berries and mushrooms. The exports to China have increased during last decade; for example, the frozen bilberry exports exceeded 2m kilograms between 2013 and 2016 (Wallius et al. 2020). However, new products are also entering markets, diversifying the product portfolio of the sector, and offering new opportunities for

business growth. Various NWFPs can still be underutilised forest products. In Sweden, between 4–5% of berries and mushrooms are harvested each year. In Finland and Sweden, most utilised traditional NWFPs are various edible mushrooms and berries, such as the bilberry (*Vaccinium myrtillus*) and cowberry (*Vaccinium vitis-idaea*). NWFPs that are increasingly being used commercially include birch sap, pine and spruce resin, spruce shoots, wild herbs and some special mushrooms that are used for medicinal purposes, for example in Asia.

The positive developments in the NWFP sector have created opportunities for various actors throughout the value chain, in addition to the business sector. Research has provided information (e.g. Miina et al. 2020a) about the places where different NWFPs can be found and also information about sustainable harvesting levels, thus supporting business development. For forest owners, both private non-industrial and industrial ones, NWFPs offer new income earning opportunities from forests. Moreover, rural inhabitants, and citizens in general, can collect some NWFPs for commercial purposes based on the public right of access to natural areas. In Finland and Sweden, companies find opportunities to harvest berries and mushrooms by importing workforce during the berry-picking season.

6.6.2 Nature tourism

Nature-based tourism and outdoor recreation are increasing activities in rural environments, where their social and economic importance may exceed that of other livelihoods (Butler 2014). In regions with a public right of access to forest land, such as Fennoscandia, recreation is permitted widely in protected areas and commercial forests, regardless of their protection or ownership status (Juutinen et al. 2017; Stokke & Haukeland 2017; Eggers et al. 2018, Tolvanen et al. 2020). Due to the public access and well-developed road network, tourist numbers in Fennoscandia outweigh those in other areas on similar latitudes (Tolvanen & Kangas 2016).

The quality of the landscape is an important factor for rural tourism. Generally, tourists appreciate old forests with heavy timber, deciduous trees, and relatively good visibility (Tyrväinen et al. 2001). Studies on forest landscape preferences in Finland, Norway and Sweden have also shown a general preference for larger trees and forest stands of more advanced development (Gundersen & Frivold 2008). These results suggest that there is need to consider forest management methods in areas that are important for outdoor recreation and tourism.

Nature is an important attraction for both national and international tourism. The economic importance of the tourism sector has grown, and the revenue generated by tourism has in recent years amounted to about EUR 15bn in Finland (for 2017), while tourism revenue in Norway (for 2017) is EUR 18bn and in Sweden (for 2016), the sector's turnover was around EUR 29bn (MoEAaEoF 2017; NHO 2018; SOU 2017:95).

In Finland, the role of national and international tourism is especially important for the economy and employment in Lapland (MoEAaEoF 2017). The value added of nature tourism and recreation in 2019 was EUR 1.681m. and the sector employed 37.2k persons. Norwegian tourism sector, in total, employed approximately 175k people in 2018 (NHO, 2018). The share of international tourism in the northern part of Norway is approximately 30%, and it increased sharply before the Covid-19 pandemic. Winter tourism in northern Norway increased by 1,000% from 2008 to 2018 (NHO 2018). For Sweden, international tourism has a higher added value compared to domestic tourism; it contributed 2,6% to the GDP in 2018 and employed 172k persons (Tillväxtverket 2019). Furthermore, nature tourism contributes to new employment opportunities. By 2016, the number of employments in the sector had

increased by 7% (in a single year), compared to the overall increase of employment in Sweden, which was 1.7% for the same period (UNECE 2017).

In Sweden, access to nature and recreation is also a governmental strategy connected to the discussion of ecosystem services and biodiversity. Ten measurable targets are connected to the accessibility of nature, to the public right of access, to the contribution of recreation to rural development, to the rich public knowledge of nature and recreation and to the connection of recreation in school (Prop. 2013/14). An agreement has also been made on how to pursue tourism practicing the public right of access to ease potential conflicts (Anon 2020).

6.7 Key take-home messages—biodiversity and NWFPs

- As in the rest of Europe, the three Nordic countries are concerned with habitat loss, degradation, and fragmentation as well as the long-term negative effect of the loss of rare and red-listed species. International regulations are in place (e.g. the Aichi targets and the EU biodiversity strategy) and the national targets in each country support them along with individual national targets.
- When evaluating biodiversity protection, Sweden evaluates a range of ecosystem services, noting that out of the 30 evaluated ecosystem services, seven are inadequate, while 10 are good and 13 are moderate. This indicates that measures need to be taken in forest management to improve ecosystem services.
- In Finland and Sweden increased numbers of red-list species indicate that biodiversity loss has not halted. In contrast, Norway notes that the number of endangered species has decreased, most likely as a result of an increasing share of deadwood.
- Because of the increasing interest in, and popularity of, healthy lifestyles particularly in Asia and Europe, the business related to the utilisation of NWFPs has grown rather steadily in Finland and Sweden during the last decade, while this interest is decreasing in Norway.
- Nature tourism is a growing industry in the study area, contributing to both the regional and national GDP and employment. Additionally, access to nature and recreational activities are also mentioned in Finnish and Swedish government strategies, further emphasising the importance of the sector to society.

7 Concluding remarks

Forests has played an important role in Northern Europe, particularly in the Nordic countries Finland, Norway and Sweden, and it remains an important contributor to the national GDP and serves as crucial part of the bioeconomy transformation. Forests offers a multitude of services: provisional (e.g. timber, biomass and NWFPs), regulating (e.g. climate change mitigation), supportive (e.g. biodiversity) and cultural (e.g. recreation). All these services play an important role in not only bioeconomy transformation but also human well-being and climate change mitigation.

The aim of this report was to identify and describe the forest's role in the bioeconomy transformation in Northern Europe—Finland, Norway and Sweden. The report also aims at discussing policy implications of the bioeconomy transformation in the study area. In the following chapter, the main findings are discussed in the light of challenges and opportunities of northern forests, considering their ecological, economic, and social characteristics.

7.1 Bioeconomy, green transformation, and society

Bioeconomy transformation requires societies to not only replace fossil-based products but also achieve a deep transformation in the way natural resources in general are managed and utilised. In a green transition, technical innovations are needed both in research and business development. However, technical innovation is not enough; social innovation and innovative governance structures are also vital for a green transformation to take place. At the national and international level, a systemic, informed, and envisioned view of the bioeconomy-based future is needed, it should consider the ecological, economic, and social functions of forests. This entails a shift from focusing on economic growth in evaluating trade-offs and realising synergies in managing forests, and a change in policy making to enhance bioeconomy transformation and support climate change mitigation, to promote biodiversity, and improve biomass production in striving towards replacing non-renewable materials.

The transformation into a bioeconomy-based society will take time and requires long-term perspectives, as it is driven by the development of forest value chains and the innovative use of the forest-based biomass instead of fossil-based materials. The development of new materials and products depend on both financial and policy initiatives. In order to promote potential game-changing materials and products, research and development have to go hand in hand with the development of regulations, policy targets and instruments (e.g. tax or subsidies to promote renewable materials). Typically, innovations can be stalled or hindered by regulations (e.g. multi-story building regulations) that prevent markets to develop. Investments targeting green infrastructure are further important for a green transformation. However, as such investments are expensive (e.g. biorefinery or biofuel), development may be slow. Cross-sectorial connections may contribute to further enhancing the development of high-cost innovations of forest-based materials.

Furthermore, the attitudes and behaviour of consumers are relevant. Regardless of innovations, investment and the development of new materials and products depend on the attitudes of consumers, which drive the bioeconomy transformation, in addition to the bioeconomy strategies or policies used. The challenge for general consumers is to make informed decisions and choices on a mixed market consisting of both new, bio-based goods, and “old” fossil-based goods. Addressing this requires not only research and innovation for developing new materials, but also the provision of information about the importance of choosing environmentally and socially sustainable goods.

As identified by the NCoM (2020), a potential hurdle in the development of bioeconomy is urbanisation, particularly as rural areas are depleted of young people. Not only do young people make up a strong consumer group, but they are also the generation that will educate themselves and continue to develop the bioeconomy sector. Research and innovation depend on bioeconomy-related know-how of the younger generation.

7.2 More of everything—everywhere?

Forests are the major terrestrial bioresource in Europe, particularly in the northern part of the continent. Additionally, the forest is an important part of regional and national economies, contributing both to the GDP and employment opportunities. However, the bioeconomy transformation requires policy adaptation, management changes and the use of natural resources to e.g. replace fossil-based materials. The forest will, thus, be required to provide more of everything in the bioeconomy in the future.

The continuous provision of forest ecosystem services requires that forests contribute not only with biomass but also with other services. Even though forests are a renewable resource, the demands on forests are exceeding the potential supply, leading to trade-offs between different forest uses and functions (e.g. balancing biodiversity, timber harvesting and social values). Thus, choices must be made between different forest ecosystem services, and the bundle of forest ecosystem services must be well understood and monitored as well as adapted to the preferences of different stakeholders. Forest owners, managers and policymakers have a key role in making the choices about which goods or services to provide; choices that are complicated by the fact that demand for wood- and non-wood forest products are high and that most of forest ecosystem services have no monetary value. For policy making, it is important to continuously monitor these choices, to adapt policy to enable bioeconomy transformation, and to avoid limitations that hinder the full potential of forest ecosystem services. Potential synergies between different forest ecosystem services need to be realised, and given the limitations of the forest as a resource, the question is whether the goals of land use can be administrated everywhere.

7.3 Forests and the bioeconomy—a regional approach

The role of forest in the bioeconomy transformation could potentially take different shapes in different regions, given the specific combinations of forest properties, forest-based innovations, knowledge development, green investment structures and national policies. Additionally, the traditions and social values associated with forests may affect the management and use of natural resources (i.e. forests) in a region. The bioeconomy transformation, thus, must address not only economic outcomes or economic growth but also the ecological and social dimensions which must be included in future policies. Balancing the goals of land use, and forest use will create policy coherence between the forest goals, which will help them to be embraced by national, as well as regional (such as Baltic, Barents or Nordic region) and international scales.

Furthermore, given that European countries have different natural forests and different forest-based sectors, not to mention different social values, EU bioeconomy policy must evaluate these regional differences and take them into consideration. For the Nordic as well as the Baltic and Barents regions it is thus essential to collaborate and bring forward the unique features of the northern forest in bioeconomy transformation, including the potential of synergies in the provision of forest ecosystem services and the challenges related to trade-offs among them.

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