What Science Can Tell Us

Towards a sustainable European forest-based bioeconomy

– assessment and the way forward

Georg Winkel (editor)

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Executive Summary

The current global economic model which relies on fossil raw materials is not sustainable in the long term. This is especially true as megatrends of demographic growth and climate change continue. This situation makes it necessary to explore alternative models that minimise the overall consumption of energy and material and maximise the share of renewable resources in the economic system.

The bioeconomy is one such alternative model. It offers both opportunities and challenges for Europe's forest resources. Forests are Europe's biggest renewable natural resource in terms of energy and material supply. At the same time, they provide much more than only biomass. They support a rich portfolio of other ecosystem services that range from protective functions (e.g. preventing soil erosion) to cultural services (e.g. recreation) and the provision of goods such as game and mushrooms.

This situation offers great opportunities for a holistic forest-based bioeconomy through the intelligent use of biomass as well as through developing innovations relating to the entire spectrum of forest ecosystem services. However, an increased use of renewable biological resources needs to consider planetary (sustainability) boundaries, e.g. by taking care of biodiversity and climate change mitigation.

This science-based study provides a synthesis of existing knowledge for policymakers on the prospects for a sustainable, inclusive forest-based bioeconomy in Europe, including:

- The importance of forests and the forest-based sector in contributing to a European bioeconomy;
- The assessment of a forest-based bioeconomy in view of innovation and economic, social and environmental sustainability;
- Future issues that may affect the development of a forest-based bioeconomy.

For more background on the arguments summarised below please see section 5.

A new policy narrative

The bioeconomy has mobilised significant investments in technology, research and innovation. New and innovative bio-products and related services have emerged, and related niche markets show dynamic growth. However, the biomass-based sectors are affected by the major 20th century transition away from the primary and secondary sectors towards services in Europe. This historic transition has been accompanied by a significant loss in relative economic importance for these sectors, despite many innovations and the dynamic growth of some branches. In this regard, the bioeconomy reality shows a mixed picture. There is much work to be done to reach the vision of the bioeconomy as a crucial pillar of a more sustainable future economy.

The starting point to better connect the vision to reality may lie in a new **policy narrative** for the forest-based bioeconomy. **This narrative should emphasise a sustainable and socially inclusive forest-based bioeconomy**. It envisions a bioeconomy that recognises and mobilises the entire spectrum of ecosystem services that Europe's forests can provide for the benefit of Europe's societies. It outlines a bioeconomy that combines responsible primary production of ecosystem services with innovative industries, and a creative and dynamically growing manufacturing and service sector.

Cross-sectoral collaboration to exploit untapped potential and synergies is needed to substantiate this narrative. It needs to tackle sustainability-related conflicts and maximise sustainability-related synergies, to green the greenest part of the bioeconomy – the forest-based bioeconomy. Substantial intellectual, political and economic investments are needed to underpin this narrative. These include:

Build upon the entire spectrum of ecosystem services

Current bioeconomy policy emphasises biomass production-related activities. However, there is a huge variety of societal demands towards Europe's forests, which correlate to various economic activities. Other ecosystem services and related products are of increasing importance, and at regional scales sometimes of primary relevance. Consequently, this study argues that a definition of **a forest-based bioeconomy should encompass economic activities relating to all forest ecosystem services**, ranging from forest biomass to tourism, recreation and non-wood products. Such a definition could be established at the **(pan-) European or EU level**.

Take a multi-level policy approach that recognises regional differences

Regional differences in Europe are crucial for the forest-based bioeconomy. Consequently, a European policy to support the development of the forest-based bioeconomy should take a multi-level approach.

- At the EU level, **the concept and basic rules for European forest-based bioeconomy markets** should be defined. The set of innovation policy tools needs to be boosted, building on existing tools such as Horizon 2020 and the European Investment Fund (EIF).
- At national and subnational levels, existing **bioeconomy strategies** provide the natural framework to set regional priorities.
- In addition, **forest-based bioeconomy clusters** in **transnational regions** could be established. These clusters could bundle activities in 'bioeconomic regions' with similar ecological and socio-economic conditions to prioritise objectives for bioeconomy development.

Become sustainable in all dimensions

A key argument to further develop the bioeconomy is the need to move from a non-sustainable economy built on non-renewable resources. The forest bioeconomy can help to contribute to this objective. However, this does not mean per se that a forest-based bioeconomy is sustainable. The entire sustainability dimension of the forest-based bioeconomy needs attention for it to be perceived as a major sustainability transition project by broader society:

- The forest-based bioeconomy must not only focus on rural communities, but also increase its legitimacy and acceptance in urbanised societies, as well as its competitiveness on world markets which serve their needs.

- A comprehensive and proactive approach to sustainability which exploits the synergies and regulates the conflicts between the different dimensions of sustainability is in the long-term the precondition for both societal legitimacy and competitiveness.

Tackle untapped synergies and resources

Developing a sustainable forest-based bioeconomy means **searching for and exploiting untapped synergies**, and developing **'win-win' development options**:

- There is significant, but regionally distinct, potential to boost a forest-based bioeconomy via tapping into **unused biomass potential**, at the same time having a positive effect on other sustainability aspects, e.g. **fire safety, employment** and **rural economies**.
- The relationship between biomass harvest and biodiversity conservation needs attention but is not black and white. There is **significant potential** to **better align forest biomass harvest** and **biodiversity conservation** through wise allocation of harvesting activities at the landscape level.
- There is significant, and often hidden, potential for forest-based bioeconomy developments focusing on **non-wood forest products**, as well as **cultural/recreational forest ecosystem services**. These often have synergies with biodiversity and the demands urbanised societies have towards forests.
- Expectations of **private forest owners** towards their forests are diverse and mirror the multiple demands of **pluralistic societies**. This could align producer and consumer interests.

Enhance cross-sectoral cooperation

The forest-based bioeconomy touches several issues that go beyond the traditional 'forest sector'. A large number of policies affect distinct stages of the forest-based value chain (and its respective sub-sectors) in different ways.

- **Cross-sectoral policy coordination** must address two types of coordination challenges: a 'silo' mentality preventing the exploitation of synergies, and conflicting sectoral interests. Actively integrating bio-based production with elements of climate mitigation, biodiversity conservation, nature-based tourism and recreation, as well as non-wood forest products, will increase the cross-sectoral support for a forest-based bioeconomy.
- **Value chain-specific assessments** are critical to address inter-sectoral policy inconsistencies and advance a more integrated policy framework.

Create a stable and level playing market and innovation policies to nurture emerging markets

A key question relating to the governance of a future forest-based bioeconomy is what an enabling policy framework should look like, specifically in the interplay with markets.

- Specific market interventions that favour the use of one forest ecosystem service over another are often problematic. Rather than subsidising specific value chains, the creation of a **level playing field** is advisable. The rationale should be to internalise sustainability effects into markets.
- **Economic instruments** at the level of the common market can incentivise sustainable production and consumption. Reviewing existing experiences at national levels and gradual implementation over the long-term would allow testing and iterative adaptation.

- **Innovation policies** are needed to kick-off and support innovations relating to the forest-based bioeconomy. **Forest-based bioeconomy clusters** in **transnational regions** can identify priorities for such policy tools.
- A **reliable and stable policy framework** is important to incentivise investments in the forest-based bioeconomy. '**Minimum durations**' could be agreed upon for policy instruments, or at least **defined criteria for evaluation and adjustment**, to provide more stability for investment decisions.

Provide better information

Knowledge is a key resource for developing the forest-based bioeconomy. Information is incomplete, or even non-existent, for key aspects such as new and innovative forest products, changing employment or many economic activities based on ecosystem services other than biomass. This may lead to incorrect assessments of forest-based bioeconomy development, including a significant underestimation of its social and economic importance. A **renewed system of indicators** for the forest-based bioeconomy could serve as the backbone for gathering this information at European level.

Encourage inclusivity

Societal inclusiveness is a crucial component for the forest-based bioeconomy in Europe. Human attitudes, interests and actions are critical for the entire forest-based value chain, from the forest owner to bioeconomy entrepreneurs to the consumer/citizen demanding forest-related products and services.

- **Environmental sustainability** is essential for approaching the urban population (c. 70% of the entire population of Europe).
- Most of the primary production and a part of the value added for products and services takes place in **rural areas**. This provides new opportunities for the inclusion of these areas in the European economy.
- **Social sustainability** requires bioeconomy politics to engage with the demands of a broader society to gain societal legitimacy. This needs to go beyond 'creating acceptance' and 'convincing consumers'.

A sustainable forest-based bioeconomy holds great promise to contribute to a transformation of the entire economic system, moving away from fossil-based production and consumption. To fully unfold its potential, a much larger transition is needed at the level of the entire society. This means expanding the bioeconomy beyond the current understanding to include a much broader vision: a **European bio-society** with sustainable consumption patterns, sustainability-related innovations, and informed participation by all citizens.

1.

Introduction

Georg Winkel

From the moment humans started generating and exchanging products and services, they have operated in the framework of a bioeconomy. Most human economic activities, whether sharing food at stone-age cave fires or participating in the virtual economy, depend, in one way or another, on biomass exploitation.

It is against the background of this bioeconomy that has evolved over the centuries that the current discussion about a future bioeconomy is unfolding. During the last two centuries, the exploitation of fossil fuels and resources has both dramatically altered and developed the world economy. Integrating fossil-based resources as a material and source of energy has enabled an unprecedented period of demographic and economic growth. At the same time, it has created severe and unwanted side effects. It is hardly disputed that the current global economic model, which relies on the mobilisation of fossilised biomass, is not sustainable in the long term. This is especially true as the megatrends of demographic and economic growth continue. This situation means it is essential to explore alternative models that, while minimising the overall consumption of energy and material, maximise the share of renewable resources in the economic system.

The "new" bioeconomy being discussed is one such alternative model. According to the European Union's strategy and action plan, Innovating for Sustainable Growth: a Bioeconomy for Europe (European Commission 2012, p3), this bioeconomy encompasses the "production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy". The main rationale behind this, and other related plans and concepts, is to advance this bioeconomy with the aim of, in the long term, at least partially replacing the harmful mobilisation of already fossilised biomass with renewable terrestrial and maritime biomass resources.

Returning to the model of material and energy supply that was dominant in the pre-industrial period but under the conditions of a (post-)industrial society and with a much greater and wealthier population and economies creates opportunities and challenges. Great opportunities relate, among other things, to the way in which a more innovative and efficient use of biomass could expand the scope of products and services for the "new" bioeconomy when compared to the traditional one. Most critical challenges relate to the question of whether an increased use of renewable biological resources is possible without neglecting planetary (sustainability) boundaries, e.g. by overexploiting soils, compromising climate change mitigation potentials and diminishing biodiversity.

This study has been designed to address both the opportunities and challenges in further developing the bioeconomy in the case of Europe's forest resources. Forests are

Europe's biggest renewable natural resource in terms of energy and material supply. At the same time, Europe's forests provide much more than just biomass. They support a rich portfolio of other ecosystem services that range from protective functions (such as preventing soil erosion) to cultural services (e.g. recreation and health related) and the provision of goods such as game and mushrooms. Building a future forest-based bioeconomy will hence happen in the framework of multiple socio-economic expectations towards these forest ecosystem services, and their provision will also be impacted by changing ecological conditions (Box 1).

Box 1: Facts about Europe's forests and the European forest sector and the bioeconomy

- Forests cover 33% of Europe's total land area. The total forest area is 215 million hectares of which 165.9 million hectares are available for wood supply, 112.95 million hectares are coniferous forest, 90.36 million hectares broadleaf forest and 47.69 million hectares mixed-species forest.
- More than 95% of the forest land in Europe is under management and around 10% of these lands are managed intensively as plantations.
- Around 80% of the forest land in Europe is available for wood supply.
- The total growing stock of forests in Europe amounts to 35 billion m^3. The average density of growing stock in forests in the European region is 163 m^3/hectare.
- 30 million hectares of forest land has been protected with the main objective to conserve biodiversity and/or landscape in Europe; within the EU around 23% of the total forest land is in Natura 2000.
- 27% of mammals, 10% of reptiles and 8% of amphibians linked to forest ecosystems are considered to be under threat of extinction within the European Union.
- More than 110 million hectares of forest land are designated for the protection of water, soil and ecosystems.
- The forest sector's gross value added is approximately €103 billion (0.8% GDP) in Europe.
- The European Union bioeconomy (as a whole) contributes to 17% of GDP and 9% of overall employment.
- From the annual turnover of the EU27 bioeconomy in 2009, 13% came from forestry and wood products and 18% came from paper and pulp.
- The share of forests that are public is less than 40% of the total forest area in the European Union while the remaining 60% of forested area is privately owned.
- Human activities and management have modified more than 96% of Europe's forests.
- The average annual sequestration of carbon in forest biomass between 2005 and 2015 reached 719 million tonnes CO_2.
- There is a large degree of variation between different European countries in most, if not all, of the above indicators.

Source: Forest Europe, 2015; EEA, 2016; The European Bioeconomy in 2030

The concept of a forest-based bioeconomy is currently understood and used in different ways, indicating distinct strategic meanings and importance (Box 2).

In this study, we aim to advance the understanding of the concept through assessing its substance and real potential for Europe. For this purpose, we use a broad and pragmatic working definition: the **forest-based bioeconomy for this report means all economic activities that relate to forests and forest ecosystem services**. Hence, we will consider not only biomass-based value chains, but also the economic utilisation of other types of ecosystem services.

Box 2: Understanding the importance of the forest-based bioeconomy concept

Within the FORBIO project funded by the Academy of Finland, 41 experts from industry, policy, science and the environmental sector were asked to define a forest-based bioeconomy. This resulted in five distinct categories of definitions, displaying diverse understandings of the concept. In the following, these understandings are presented in the order of their importance as indicated by the experts (cf Hurmekoski et al, forthcoming).

A forest-based bioeconomy was understood as:

1. A **vision for the future**: this entails a necessary or desirable paradigm shift – an economy that is built on the innovative use of sustainably sourced regenerative natural resources, as opposed to an economy based mostly on fossil resources.
2. A **concept to describe real changes**: the concept refers to observable current and expected future changes in the forest sector, such as the diversification of the end uses of wood, diminishing industry boundaries, or the commercialisation of forest ecosystem services.
3. A **synonym for the forest sector**: the concept does not mean something essentially new – it can be used interchangeably with the concept of forest sector.
4. A **useful lobbying concept**: the concept gives a new identity and critical mass for the bio-based sectors.
5. A **problematic lobbying concept**: a concept that, for instance, narrows down the perspective on forests to biomass and industrial uses.

Against this background, the study will provide a synthesis of the existing scientific knowledge, directed at decision-makers, in order to significantly increase their knowledge and capacities regarding:

- The role and importance of forests and the forest-based sector in contributing to a European bioeconomy.
- The assessment of a forest-based bioeconomy in view of innovation and economic, social and environmental sustainability.
- Future developments that may affect the development of a forest-based bioeconomy in the upcoming decades.

The study is structured as follows:

- In the next chapter, the **EU policy framework for the bioeconomy** is introduced (Section 2.1), followed by an assessment of the role of forests, forestry and the forest sector in existing **bioeconomy strategies** (Section 2.2).
- In the third chapter, the state of scientific knowledge will be reviewed for **10 critical issues that directly relate to 10 key questions for a sustainable European forest-based bioeconomy**:
  - **Biomass availability** (Section 3.1): is there enough forest biomass available to meet the demand of the forest-based bioeconomy?
  - **Biodiversity** (Section 3.2): how does the forest-based bioeconomy impact forest biodiversity in Europe?
  - **Climate change** (Section 3.3): how can a forest-based bioeconomy best contribute to climate change adaptation and mitigation?
  - **Resource efficiency** (Section 3.4): how can forest biomass most efficiently contribute to increased environmental benefits of the bioeconomy?

  - **Amenity values** (Section 3.5): how does the forest-based bioeconomy relate to amenity values?
  - **Competitiveness** (Section 3.6): what makes a European forest-based bioeconomy competitive?
  - **Jobs and employment** (Section 3.7): what are the implications of the bioeconomy for forest-related jobs?
  - **Forest ownership** (Section 3.8): how does forest ownership in Europe affect the forest-based bioeconomy?
  - **Forest (wood) products** (Section 3.9): how will forest product markets develop in the future?
  - **Non-wood forest products** (Section 3.10): what is the potential contribution of non-wood forest products to the European forest-based bioeconomy?
- In Section 4, recommendations are provided relating to **monitoring the development of a sustainable forest-based bioeconomy** in a holistic manner.
- In Section 5, conclusions for policymakers are formulated around **how to develop and govern a sustainable European forest-based bioeconomy** for the future.

In summary, the study provides an up-to-date science-based synthesis of the prospects for a forest-based bioeconomy in Europe that is sustainable and inclusive. It will support policymakers in designing a policy framework that will guide and incentivise the frequently heralded transition process.

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2.

The policy framework

2.1. The EU policy framework

Filip Aggestam, Helga Pülzl, Metodi Sotirov, Georg Winkel

2.1.1. Introduction

Many policies affect the prospects for a forest-based bioeconomy. These include policies targeting forest management (such as wood processing) as well as those governing other forest-based value chains (such as energy, paper and pulp production). The policy framework also relates to the broader societal, economic and ecological environment in which these value chains are situated. In fact, a more recent review of EU policy documents demonstrated that as many as 570 policy documents have a potential impact on the EU forest-based bioeconomy (Rivera León et al, 2016). Relevant policies cover industrial, environmental, social and international trade issues. Figure 1 provides an overview of these EU policies, relating them to areas of (exclusive and shared) competences and the existing priorities of the European Commission that have been formulated for the years 2014–2019, the seven flagship initiatives to be reached by 2020, and situates them along the forest-based sector value chain.

The complexity of the policy framework makes it very challenging to provide a concise overview. In this section we will present EU-related policies grouped into nine generic policy domains. Our selection has been informed by empirical work with the forest-based industry. It builds, in part, upon the industry's own prioritisation (Rivera León et al, 2016).

2.1.2. The EU forest policy framework relevant to a bioeconomy

2.1.2.1. Forest-focused and agricultural policy

Forest-focused policy (Pülzl et al, 2013) encompasses the forest sector policy domain. Although this has largely remained the competency of the EU member states, it has also seen repeated activity at EU level. The EU Forest Strategy sets general guidelines for EU forest policy. It also aims to coordinate other EU forest-related policies (European Commission, 2013b). The strategy recalls key principles related to sustainable forest management (SFM) and addresses a number of topics that include competitiveness and job creation, forest protection and the delivery of forest ecosystem services, striving for a multifunctional approach. The strategy is based on the notion of subsidiarity and a shared responsibility

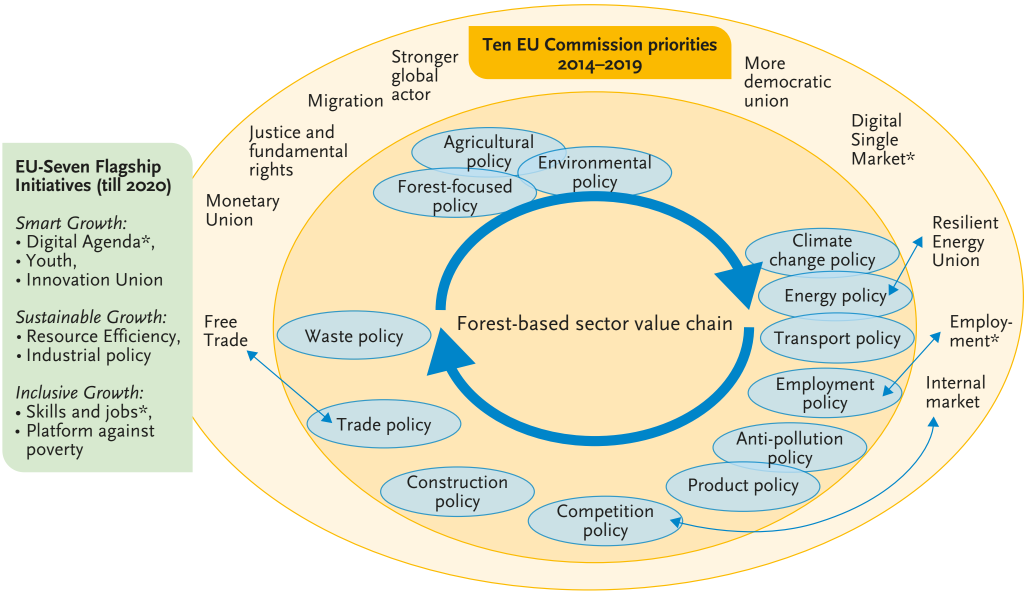

Figure 1. Forest-based value chains and EU policies relating to a forest bioeconomy (Wolfslehner et al, 2016).

between the EU and its Member States. Its impact is hampered by its lack of legal liability and direct connection to EU financial policy instruments (Pelli et al, 2012).

The Common Agricultural Policy (CAP) is divided into two pillars. Pillar 1 covers market and income support measures and Pillar 2 covers rural development. Financing for forests in the EU principally comes from the rural development pillar (Regulation, 1306/2013, 1307/2013, 1308/2013). Some of the features of the CAP 2014–2020, including the joint provision of public and private goods (e.g. payments for public ecosystem services), have increased flexibility for Member States in implementing instruments available under Pillar 1. One of the changes that may affect prospects for a forest-based bioeconomy is the introduction of greening payments under Pillar 1. The European Agricultural Fund for Rural Development (EAFRD) and the European Regional Development Fund (ERDF) offer measures that support forestry, with a strong emphasis on SFM. The LEADER approach, an instrument for rural development and forestry, may also be considered relevant for the development of a forest-based bioeconomy (Regulation, 1303/2013, 1305/2013).

Forest-focused policy constitutes a non-legally binding framework that emphasises sustainable forest management (SFM). It focuses on coordination and exchange. Its impact on the development of the bioeconomy is limited. The EU's agricultural policy provides the financial incentives for SFM, with a broad set of possible targets and discretion at the Member State level to prioritise funding. This implies that the RDP 2014-2020 will have a varied impact on the bioeconomy across EU Member States.

2.1.2.2. Climate change and energy policies

Climate change and energy policies have a significant (potential) importance for the forest-based bioeconomy. The EU climate and energy package envisages the reduction of emissions of greenhouse gases (GHG) by 20% before 2020 (Council, 2008). The 2030 climate and energy policy framework puts forward a new governance framework based on national plans to assess progress over time (Council, 2014). A binding target has also been formulated to increase the share of renewable energy and energy efficiency by 2030 (Decision, 406/2009/EC).

One cornerstone of the EU's climate policy is the EU Emissions Trading System (ETS). The ETS works on a cap and trade principle (Directive, 2003/87/EC, 2009/29/EC). It is currently in its third phase, running from 2013 to 2020. The ETS directive highlights the potential of biotechnology processes and bio-based products to enable forest-based industries to deliver climate benefits. The Land Use, Land Use Change and Forestry (LULUCF) accounting rules address a gap in the EU's GHG inventory, opening up the prospect of preserving forests as carbon sinks (Decision, 529/2013/EU). However, efforts towards using forests for carbon sequestration rest with the EU Member States. This means that the integration and valorisation of carbon sequestration under current regulations are limited. New rules that amend the legislation on biofuels, in particular the Renewable Energy Directive (which is presently undergoing review) and the Fuel Quality Directive, address the risks of indirect land use change and set the stage for a transition towards advanced biofuels (Directive, 2009/28/EC, 2009/30/EC). These amendments take into account sustainability concerns for biomass production that have been raised by the European Commission (European Commission, 2010b).

The EU's energy policy affects how the forest-based sector can produce, buy and sell energy. The Energy Efficiency Directive establishes a common framework of binding measures for the promotion of energy efficiency to ensure the achievement of the 20-20-20 targets (Directive, 2012/27/EU). It establishes a common framework for the use of energy from renewable sources in order to limit GHG emissions and to promote cleaner transport. Meeting agreed binding targets by 2020 would require large-scale changes to current land use patterns and is expected to affect the way harvested wood is utilised. The Directive also requires the development of a sustainability scheme for biofuels and bio-liquids used for transport to avoid unsustainable biomass production. In 2010, the EU issued biomass sustainability recommendations for its Member States, and the Commission considered if and whether such criteria should be made mandatory (European Commission, 2010a). The Fuel Quality Directive furthermore sets the mandatory target to reduce GHG intensity of fuels used in transport by 6% while adhering to sustainable production.

> Climate change and energy policies are based on legally binding as well as voluntary instruments. These have a direct effect on how wood is being used (e.g. timber versus energy production), which in turn influence the overall political valuation of bioeconomy activities (e.g. climate change "friendly" or "problematic"). Current incentives for bioeconomy innovations and biomass production furthermore shape future opportunities and the economic viability of the forest-based sector.

2.1.2.3. Environmental policies

Environmental policy in the EU is shaped through its Environment Action Programmes. The current Seventh Environment Action Programme (Decision, 1386/2013/EU) defines nine thematic objectives that draw on initiatives in the field of environmental policy. These include, among others, the Resource Efficiency Roadmap, the EU 2020 Biodiversity Strategy and the Low Carbon Economy Roadmap (European Commission, 2011a, 2011b, 2011c, Resolution, 2011/2307(INI)). With regard to the forest-based bioeconomy, policies affecting forest ecosystems and primary production (forestry) and industry-related policies affecting subsequent parts of the forest-based value chain are of particular importance.

The Natura 2000 network of protected areas (Habitats Directive and Birds Directives) constitutes the core of the EU's biodiversity conservation policy (Directive, 92/43/EEC, 2009/147/EC). Natura 2000 facilitates an integrative conservation approach that combines conservation goals with other land uses. Yet, given trade-offs between biodiversity conservation and biomass production, these policies have been linked to implementation conflicts (European Commission, 2015). At the same time, biodiversity conservation may have a positive impact on the provision of other ecosystem services that are relevant to a forest-based bioeconomy, e.g. non-wood forest products or amenity values. This demonstrates the varied impact of many EU policy frameworks on different parts of the forest-based sector.

Industrial policy instruments affecting the forest-based bioeconomy include the Industrial Emission Directive (IED) (Directive, 2010/75/EU) and the Best Available Techniques (BATs) reference documents (BREFs). The IED aims to minimise industrial emissions to air, water, soil and groundwater, and it sets the conditions that forest-based industries need to fulfil in order to receive permits to operate. The IED establishes performance requirements for industrial operations. These requirements will play a principal role in shaping the technical conditions for a bioeconomy (e.g. infrastructure investments needed to be in compliance with the Directive).

There is moreover a substantial body of legislation on ambient air quality and emissions to air. Among these are the Air Quality Framework Directive and the Ambient Air Quality and Cleaner Air Directive (Directive, 96/62/EC, 2008/50/EC). Together they aim to reduce national emissions of certain pollutants and limit emissions into the air. They set air quality standards, target dates and total emission limits. Greening the economy will thus not only involve a resource-efficient use of forest biomass, but also reduced air pollution as part of the wider infrastructure investments. This would consequently impose barriers (financial and technical), as well as opportunities, for forest-based industries that affect air quality, ranging from energy production to the manufacture of pulp and paper to housing.

Environmental policies affect the entire forest-based bioeconomy value chain. Established standards constrain, on the one hand, opportunities for some bioeconomy-related activities. On the other hand, they may secure the provision of multiple forest ecosystem services and set conditions that positively affect the development of “green” industries.

2.1.2.4. Employment

Employment policy is mostly the responsibility of EU Member States, yet EU legislation has an impact. For instance, the Working Time Directive protects workers’ health and safety through the establishment of minimum standards concerning working hours, including limits to weekly working hours and minimum daily rest periods (Directive, 2003/88/EC). The Strategic Framework on Health and Safety at Work 2014–2020 (European Commission, 2014) is of particular importance for the forest-based bioeconomy. It identifies key challenges and strategic objectives (e.g. prevention of work-related diseases), presents key actions (e.g. consolidating national health and safety strategies) and identifies instruments to address them (e.g. European Social Fund). Preventing risks and promoting safer and healthier working conditions is specifically relevant for those parts of a forest-based bioeconomy that are labour-intensive and/or characterised by a high-risk work environment. In essence, a healthier labour force is more productive, not to mention the value of the social dimension per se, but higher labour costs may also affect international competitiveness. Trade-offs for a forest-based bioeconomy may therefore arise specifically in situations where jobs require few qualifications and can be easily substituted elsewhere.

EU employment policies regulate only some basic standards for employment since it is mostly the responsibility of EU Member States. They are specifically relevant for forest-based industries that are labour intensive and risky.

2.1.2.5. Products policy

Many product-related policies aim to prevent threats to human health. For instance, the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (Regulation, 1907/2006) has introduced an integrated system of registration and authorisation for all chemical substances and products produced or supplied in the EU. It has shifted the responsibility for ensuring that chemicals produced, imported, sold and used in the EU are safe to the industry. REACH is interlinked with the Biocidal Product Regulation (Regulation, 528/2012) that requires authorisation for biocidal products before they can be placed on and used by the EU market. It is also linked to the Classification, Labelling and Packaging Regulation (Regulation, 1272/2008), which ensures that hazards from chemicals are clearly communicated to EU workers and consumers. These regulations set conditions for the production of bio-based products, such as biofuels, bio-based chemicals and bio-based plastics. For example, forest-based bio products need to meet the technical and safety requirements of downstream applications.

For the forest-based bioeconomy, finding innovative solutions for sustainable food packaging, including new bio-based materials, is an important responsibility. The EU has a harmonised legal framework that lays down common rules for packaging materials and articles intended to come in contact with food (Regulation, 1935/2004, 10/2011). There is also the regulation on Good Manufacturing Practice that provides for a well-controlled manufacturing process through all manufacturing stages for food contact materials (Regulation, 2023/2006). These have an impact on forest-based industries that produce packaging materials (e.g. manufacture of paper and paperboard as well as wooden packaging) as well as those involved with forest-based food products.

The EU has also laid down rules for an open market regarding public procurement and the application of rules for the award of public works, supplies and services contracts (Directive, 2014/24/EU, European Commission, 2008). There is currently no policy to facilitate the uptake of sustainable bio-based products. The existing instrument for green public procurement is voluntary. The Single Market for Green Products initiative addresses barriers faced by companies that want to market green products in different countries (European Commission, 2013a). In order to have a more standardised approach to carbon accounting, the European Commission launched a consultative process to test environmental footprint methods that may be relevant for the marketing and uptake of bio-based products. This has resulted in a draft version of the Product Environmental Footprint Category Rules, which contains a set of rules on how to measure the lifecycle environmental performance of products.

The Construction Products Regulation sets out the conditions for marketing construction products and the related use of CE marking (Regulation, 305/2011). This regulation is accompanied by a Strategy for the Sustainable Competitiveness of the Construction Sector that aims to support the construction sector in meeting its challenges as part of the Europe 2020 initiative as well as to support sustainable growth in the sector (European Commission, 2012). Rethinking construction may help to diversify forest-based production and provide long-term opportunities within a forest-based bioeconomy that have the benefit of being climate friendly.

Product policy encompasses a wide range of specific legislation that, among other things, addresses public health and safety and their environmental consequences. It provides the regulatory framework for bio-based products. Public procurement, including construction policy, may be seen as a decisive tool to incentivise the use of sustainable bio-based products.

2.1.2.6. Transport policy

Transport is a fundamental component of a functional forest-based bioeconomy. Within the EU it is significantly interlinked with climate and energy policies, such as the EU's target to reach 10% use of renewable energy in the transport sector by 2020 (Directive, 2009/28/EC). This section provides examples that have been emphasised by the forest-based industry in recent empirical work (Rivera León et al, 2016).

The Sulphur Directive regulates the sulphur content of marine fuels (Directive, 2012/33/EU). Since the beginning of 2015, EU Member States have to ensure that ships in the Baltic, the North Sea and the English Channel are using fuels with a sulphur content of no more than 0.1%. While the directive generates public health benefits, the forest-based industry has argued that it reduces the economic viability of the forest-based sector through rising transport costs. The Waste Shipment Regulation covers procedures for trans-boundary shipments (Regulation, 1013/2006). It includes a ban on the export of hazardous wastes to non-OECD countries and the export of waste for disposal. In a bioeconomy context, this regulation supports the development of renewable and circular products value chains in view of working towards a waste-free bioeconomy.

Road-haulage specifications affect the dimensions and maximum weights authorised for transport (Directive, 2015/719), common rules for certain types of carriage of goods, speed limitations and testing of exhaust emissions (Directive, 2006/94/EC). Specifications for road-haulage affect the bioeconomy by setting limitations for the logistical setups for wood supply (as well as other materials).

Transport policies affect the logistically intense stages (e.g. limiting transport volumes and haulage) of the forest-based bioeconomy value chain. They might, on the one hand, hamper global competitiveness of the bioeconomy through higher logistic costs but, on the other hand, they facilitate the development of circular economy thinking based on domestic supply of bio-based resources.

2.1.2.7. Trade policy

The EU applies trade defence instruments that affect the operations of larger forest-based companies and, by extension, the development of a forest-based bioeconomy. A general concern for the EU forest-based sector is that competition with countries outside the EU is negatively affected by unfair trading practices (Rivera León et al, 2016). The main rationale of the EU's policy against illegal logging, consisting of the EU Timber Regulation (EUTR) (Regulation, 995/2010) and the EU Action Plan for Forest Law Enforcement, Governance and Trade (FLEGT Action Plan) is to prevent the import of illegal wood into the EU and to promote SFM through international trade (European Commission, 2003, Sotirov et al., 2017). The EUTR also requires operators to apply due diligence to minimise related risks. Yet, the EUTR and FLEGT also create operational costs for the forest-based industries that hamper their competitiveness (Rivera León et al, 2016).

The EU also applies a common tariff level for all forest-based products. For most forest products, the tariff level is zero, with the exception of some manufactured goods. However, this also relates to tariff barriers and duties that apply to exports as well as protectionist subsidies. This may create an uneven playing field that restricts the trade and competitiveness of forest-based products.

Phytosanitary regulations, covering food safety as well as animal and plant health related regulations, set criteria for goods entering the EU as these must be in accordance with sanitary and phytosanitary requirements to prevent the entry and spread of diseases and pests. In this case, the forest-based sector (in particular, packaging) is affected when there are requirements for phytosanitary certificates (WTO, 1995).

> Trade policy is of increasing importance for the EU forest-based bioeconomy, in particular as it may affect international competitiveness and sustainability as regards to trade-offs between free trade as well as social and environmental concerns. Legality verification has thus become a crucial policy, combining a regulatory approach with soft incentives.

2.1.2.8. Competition policy

Competition law affects how forest-based industries can operate within the EU. Competition rules within the EU include anti-trust procedures, anti-competitiveness rules and rules on mergers and acquisitions. Also relevant to the forest-based bioeconomy are the regulations on government support. This covers national regional aid and state aid for agriculture and forestry (European Commission, 2014/C 204/01). These regulations establish general criteria to assess the compatibility of aid in the internal market. There are also guidelines on state aid for environmental protection and energy (2014–2020) that limit support to renewable energy, while making it more cost-effective to reduce actual energy costs (European Commission, 2014/C 200/01).

> Competition policy secures a free and fair market in the EU. It gives room to forest-based bioeconomy-related innovations, but may also constrain public investment in the provision of forest ecosystem services.

2.1.2.9. Research and innovation policy

There are principally two EU instruments that support research and innovation in forestry, agriculture and the bioeconomy, namely, Horizon 2020 – the EU's research and innovation framework – and rural development policy (Regulation, 1291/2013). This is relevant to the forest-based bioeconomy as it is part of the knowledge economy, in which innovation plays a key role in its future development. This includes the development of new higher-value uses for forest resources, addressing changing social and economic demands and societal challenges. Fostering knowledge transfer and innovation in agriculture, forestry and rural areas has been established as one of the six priorities for rural development policy 2014–2020 and several forest-related topics are addressed under the Horizon 2020 work programme (Decision, 2013/743/EU).

2.1.2.10. Summary

Table 1 provides an overview on the assessed policies and indicates their potential impact on the forest-based bioeconomy.

Table 1. EU policies affecting the forest-based bioeconomy (Own compilation based on Wolfslehner et al, 2016; Rivera León et al, 2016, and Winkel et al, 2015)

EU policies relating to forests and the forest-based sector	Main objectives of policies in relation to the forest bioeconomy	Governance approach	Purpose of forests	Potential impact on forest resources *(management, availability and use)*	Potential impact on the forest-based bioeconomy as a whole
Forest-focused	Multiple use of forests in accordance with principles of SFM	Strategies and action plan; subsidiarity central	Resource provider for timber and ecosystem services	Sustainable management of forests	Mainly impact on primary production of biomass and ecosystem service, limited effects
Agricultural	Focus on rural development but also addressing forests and agriculture including ecosystem services	Regulations including provision of financial means	Resource provider for timber and ecosystem services	Focus on rural development, economic competitiveness, also provision of other eco-system services, possible trade-offs	Potentially positive impact (supporting infrastructure and innovations)
Environmental	Environmental protection relating to forest ecosystem services and related value chains	Regulations, directives and strategies	Resource provider for entire spectrum of ecosystem services, trade-offs relating to maximum biomass supply	Protecting forest resources impacting on its availability as well as enhancing ecosystem services and biodiversity	Potential constraints on biomass availability, additional costs, positive for other ecosystem services to supply related demands (e.g. nature-based tourism)
Climate change	Combat global warming also through enhancing forests sinks and adapting forest ecosystems	Directives, decisions and strategies	Carbon storage, sink or source	Enhancing capacity of forests to preserve and capture CO_2	Distinct impacts possible, depending on understanding of bioeconomy as mitigation or emission strategy, also new business field
Energy	Increase share of renewable energy and energy efficiency through use of forest biomass	Directives and strategies	Resource provider for woody biomass	Producing renewable energy from woody biomass; trade off with other ecosystem services possible	Positive for energy sector, potential constraints for material uses through increased forest biomass use as an alternative source of energy
Transport	Ensure road safety and regulate sulphur emissions from ships	Directive and regulation	Resource provider for products	Incentivise local/inner European value chains, not much impact	Potential constraints through the need for investment into vehicles and an increase in vessel operating costs, but environmental benefits

Table 1. continued.

Employment	Protect workers' health and safety	Directives and strategy	Working place	Need to invest in occupational safety and health measures, not much impact	Potential constraints through the need to invest in occupational safety and health measures, but social benefits
Emissions	Minimise pollution from industrial activities to reduce emissions to air, water and land	Directives and strategies	Subject of protection	Positive, protecting them	Potential constraints through enhancing environmental protection and reducing emissions of pollutants as well as remedying environmental damage
Product	Ensure the safety of products (risk prevention)	Directives, regulations and strategy	Resource provider	No clear relationship	Potential constraints arise from higher standards, but also better products
Competition	Avoid distortions of competition and trade in the internal market	Guidelines	Resource provider for products and services	No clear relationship	Mostly positive as it creates small regulatory costs and provides space for market-driven innovations
Construction	Conditions for marketing construction products and the use of CE marking	Directive and strategy	Resource provider	No clear relationship	Potential constraints arise from the need to invest in assessment systems
Trade	Prevent unfair competition, e.g. the circulation of illegally logged timber and timber products	Regulations and action plans	Resource producer for products and services	Potentially positive for global forests as it aims to reduce illegal logging	Ambivalent: potential constraints through the necessity of proving the legality of timber (products), but also levelling the playing field for European producers
Waste	Accept and manage waste after usage	Directives	Resource provider for products and services	No clear relationship	Ambivalent: potential constraints through investments in waste water treatment and recycling, but also incentivising bio-based products and European production
Research and Innovation	Sustainable forest-based systems that address societal challenges and demand	Provision of research and innovation funding	Resource provider for research and innovation actions	Knowledge creation and innovation	Knowledge creation and innovation

2.1.3. Assessing policy impacts

Up to this point, this section has mostly reviewed the EU policy framework for the bioeconomy at EU level. In the following, we will investigate examples of the impact of this framework on a forest-based bioeconomy “on the ground”.

2.1.3.1. Varying impacts of EU policies: a retrospective look

Recent research has confirmed that financing provided through the CAP and rural development financing (pillar 2) in the 2007–2013 period was instrumental in stimulating forest-based industries (Sotirov et al, 2015c). Adopted measures were used to increase forested areas and timber resources through, for example, plantations of economically productive (fast-growing) tree species, building forest roads, mechanisation of timber harvesting and modernisation of timber processing. At the same time, EU Member States only used 13% of the rural development funding for forest-environment payments and 16% for Natura 2000 payments in the previous programming period. This reveals an imbalance between rural development and environmental policy goals in domestic implementation. Significant variations in implementing EU policies also occurred on the national level. For instance, in Northern and Central Italy, rural development funds were used for regional forest-based economic activities, whereas in Southern Italy, funds were used for the provision of public goods (e.g. nature conservation, water and soils protection).

The same study demonstrated that wood for energy was the most rapidly growing sector in the forest-based bioeconomy, mostly driven by the renewable energy and climate policies at EU and national levels during the 2007–2013 programming period. Subsidies for the forest-based bioenergy sector made, in some cases, fuelwood more profitable than the production of industrial wood. This has resulted in increased competition between the forest-based industries (e.g. pulp and paper, sawmilling and panel production) and the energy sector through its increasing demand for biomass. It has also generated an increase in timber harvesting.

Furthermore, the study highlights that balancing trade-offs between increased timber use and biodiversity conservation is a key challenge in most EU countries and, more importantly, the realisation of a forest-based bioeconomy. The implementation of Natura 2000 is seen as key policy to secure (forest) biodiversity. However, concerns have been raised regarding the extent to which Natura 2000 can achieve these objectives (see Box 3).

Similar challenges were reported for other EU policies. For instance, the implementation of the EU Timber Regulation (EUTR) varies significantly between EU Member States. It was found that, among other things, different political cultures, governance capacities and structural characteristics across forest-based industries and Member States influence domestic implementation (Sotirov et al, 2015b). This means, in practical terms, that the EUTR’s implementation varies from being effective and practically enforced to being neglected in terms of both transposition and enforcement (Schwer and Sotirov, 2014, Sotirov et al, 2015b).

Finally, a recent study has assessed the cost impact of specified EU legislation and policies on the EU forest-based industries (Rivera León et al, 2016). This study presents a unique perspective on the forest-based industries, which covers the impact of existing legal frameworks (as at the end of 2014) (see Box 4).

It should be noted that only a limited number of policies that affect the forest-based bioeconomy were highlighted here. Many more may have an impact but, for many of them, no research results are available. However, the main message is that the implementation

Box 3. Implementation of Natura 2000 in forests in EU-28

Research has shown that Natura 2000 implementation strategies differ considerably across EU Member States (Sotirov et al, 2017 building on Sotirov et al, 2015b and Winkel et al, 2015). Implementation was characterised by:

- Delays in legal transposition or practical implementation.
- Shifts from top-down, command-and-control conservation-science-based implementation to flexible approaches based on participation and negotiation with affected forest sector stakeholders.
- Distinct designation strategies ranging from smaller/pre-existing Natura 2000 sites to an emphasis on larger and new Natura 2000 sites.
- Legislative changes resulting in new management practices but also legislative changes having no impact on management practices, both with positive and negative effects on biodiversity conservation and land use.

Next to these implementation challenges, there is, moreover, evidence that the implementation of Natura 2000 is sometimes having a limited impact on forests and forest management due to lack of biodiversity management plans and guidelines, and ignorance of biodiversity goals (Sotirov et al, 2017). This poses a challenge as regards to the environmental sustainability of the forest-based bioeconomy, in particular, if timber harvesting continues to increase. At the same time, changes in forest management are insufficiently covered through compensation mechanisms, which is accelerating the implementation problems.

Box 4. Cumulative cost assessment impact of EU legislation in the forest-based sector (2005–2014)

Cost structures of different forest-based sub-sectors (e.g. woodworking, sawmilling, carpentry and pulp and paper) vary greatly and thus also the reported cost implications of different EU policy frameworks. Within sub-sectors, variability reflects the size of companies and their organisational structures, efficiency, level of integration and product portfolio. For instance, SMEs in general incur higher costs compared to larger firms, because the costs to comply with legislation is not linear and cannot be amortised by SMEs on a large volume of products. The assessment found, among other things, that the total regulatory costs of climate and energy policy (as a percentage of value added) ranged between 0.2% and 7.3%, principally covering only six legally binding regulatory frameworks (EU Emission Trading System, Energy Efficiency Directive, Third Energy Package, Renewable Energy Directive, LULUCF and the Energy Taxation Directive). The overall cost of all policies (covering 57 policy entries) on the turnover of forest-based industries ranged between 0.4% and 2.3%. These costs arise for a number of reasons, for example, due to information obligations, such as requirements for a declaration, or the application for a certificate of compliance with the standardised specifications defined in the regulations.

The variability of costs across forest-based sub-sectors is significant and reflects variations across product groups and production chains. This highlights that the impact of a policy is not uniform across the forest-based sector. The assessment furthermore demonstrates that legislation likely to create more costs for the forest-based sector emanates from the climate and energy legislation as well as from environmental legislation. However, it should be highlighted that the potential benefits that arise from the EU legislation were not considered in this assessment.

Source: Rivera León et al, 2016

of EU policies and their effects on the forest-based bioeconomy are not homogenous, but differ greatly depending on the country, region and sub-sector in question. It also shows that the overall regulatory impact on the forest-based industry is critical when considering the development of a forest-based bioeconomy.

2.1.3.2. Impacts of European policies: a forward look

The EU-funded transdisciplinary research project INTEGRAL analysed both what forest-related future scenarios ("forest futures") might unfold during the next 25–30 years and what might be their impacts on forest management as regards to ecological, socio-economic and policy aspects (Sotirov et al, 2015c). Some of the key findings from this project are presented in Box 5.

Further results from the INTEGRAL project indicate that both the importance of the European forest-based sector and societal demands for the provision of a broad spectrum of forest ecosystem goods and services are expected to rise. This reveals the need for pro-active policy and management approaches that can address trade-offs and help find a balance in order to address sustainability concerns for the European forest-based bioeconomy (Sotirov et al, 2014, Sotirov et al, 2015b, Sotirov et al, 2015c).

Box 5. Expected future impacts on the forest sector in 2040

1. The future of sustainable forest management is expected to be influenced by: (i) forest ownership, (ii) forest-related policies, laws and regulations, and (iii) timber market development.
2. EU forest-related policies are expected to continue influencing forest management at the national and local levels in the future.
3. Carbon sequestration and climate change mitigation, bioenergy use, green chemistry and green building, increase in economic competitiveness and biodiversity conservation are most likely key topics for future EU policymaking.
4. EU forest-related policies are seen as important drivers of current and future forest management. However, stakeholders at the (sub-)national level believe that they have very limited opportunities to influence how forest-related policies will develop at the EU level in the future.
5. Policy at the national level is perceived as the most relevant for forest policy implementation and for shaping the development of the forest sector.
6. Demand for and supply of forest ecosystem goods and services are expected to increase in all 10 EU countries under study in the future.

Source: Sotirov et al, 2014; Sotirov et al, 2015a; Sotirov et al 2015c.

Take home messages:

- The European forest-based bioeconomy is affected by a huge number of policy instruments. Different policies affect distinct stages of the forest-based value chain (and its respective sub-sectors) in different ways. Diversification processes, as part of a cross-sectoral bioeconomy, increase this complexity.
- Several policies address trade-offs between economic profitability/competitiveness and social and environmental sustainability. The latter is of particular importance as the forest-based bioeconomy is dependent on forest ecosystem goods and services produced on one third of the territory of the EU where many of these areas are subject to contradicting societal demands. This raises the general question in how far policies can transform trade-offs into synergies.
- Implementation (and related impacts) of policies affecting the European forest-based bioeconomy are not necessarily straightforward. Many EU policies represent conflicting goals where priorities are only defined during the transposition, implementation and enforcement by Member States.

Policy recommendations:

- The relationships between different policy frameworks, the forest-based bioeconomy and related market activities are ambivalent. The more policies intervene and set specific incentives, the more they create certain path dependencies through directing significant investments. Policy interventions, particularly those that are legally binding, may as such be risk factors for forest-based industries that wish to invest. At the same time, effective policy interventions are needed to address and accommodate diverse societal demands towards forest ecosystem services and to push for innovations. Clear, pluralistic and stable policies are thus required to support the development of a forest-based bioeconomy.
- The forest-based bioeconomy is only one policy paradigm among many others. The complex EU forest-related policy framework in place, represented by several sectoral policies, makes it more difficult to have a coordinated policy approach for the European forest-based bioeconomy. This holds particularly true given the competition with other political paradigms and the absence of a single vision for the forest-based bioeconomy. However, these processes do emphasise the need for cross-sectoral communication and coordination. Enabling policy frameworks that promote innovation are also needed. This requires accumulating scientific knowledge regarding the synergies and trade-offs that are an inherent component of the bioeconomy for informed decision-making in the future.

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2.2

The role of forests in bioeconomy strategies at the domestic and EU level

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2.2.1. Introduction

In 2012, the European Union published its bioeconomy strategy and action plan, Innovating for Sustainable Growth: a Bioeconomy for Europe (European Commission 2012). Numerous countries worldwide and in the EU have since developed similar strategies (Bioökonomierat, 2015). To date, 15 EU Member States either have explicit bioeconomy policy strategies (e.g. Germany, Finland), bioeconomy-related strategies (i.e. sectorial bioeconomy policies and strategies that are not united under a national policy strategy, such as in the Netherlands or Sweden), or are currently developing strategies that are relevant for the bioeconomy (e.g. Austria) (Bioökonomierat, 2015). However, the process has not been coordinated and many Member States have ended up producing national strategies that are rather detached from the EU strategy. What these strategies have in common is the ambition of transitioning from an economy mainly based on fossil resources to an economy where materials, chemicals and energy are derived from renewable biological resources (McCormick and Kautto, 2013). Whether and how forests are addressed in this endeavour differs between the various countries considerably.

In addition to national and EU bioeconomy strategies, some regional strategies are being developed as well, e.g. the joint Nordic strategy for the bioeconomy in Nordic countries, Greenland and the Faroe Islands is currently underway (Norden, 2016). Other strategies have been developed at a more local scale. Some of these bioeconomy strategies have even addressed forestry directly (e.g. in Finland – Northern Karelia, Central Finland, Kainuu, Satakunta; in Sweden – North Sweden, Varmland; and in Spain – Navarra regions). Other local strategies address wood processing (e.g. in Finland in Oulu and Kainuu regions) as well as more technological aspects of forestry, such as fibre production (e.g. Varmland in Sweden) and wood-based biorefineries (e.g. in Scotland) (see Errin, 2015).

The development of a bioeconomy strategy is clearly not seen as an end in itself. The main emphasis of many of these strategies is to enhance the economy and create opportunities for employment. The notion of sustainability gains increased political attention. Although many of the Global Sustainable Development Goals can be found in the national and EU bioeconomy strategies, the bioeconomy is not necessarily sustainable by itself. For example, the use of forest biomass as an energy carrier – that can be circular and zero emission in principle – still faces a series of economic, political, social and environmental challenges (e.g. Akhtari, et al 2014). Moreover, the different prerequisites of the countries adopting bioeconomy policies, as well as national political agendas, vary considerably among Member States. Hence, no one single way – or one silver bullet – towards reaching sustainable development through the bioeconomy seems to exist. How such factors materialise in the different national political and research strategies will ultimately affect the development of different national bioeconomies and their approach to sustainability. Such developments require closer attention and make up the focus of this chapter.

2.2.2. National bioeconomy strategies and country highlights in relation to forests

The meaning of bioeconomy is still "in flux" (Pülzl et al, 2014). In other words, there is no one general definition for bioeconomy adopted by all countries. Although most bioeconomy strategies display similarities such as the emphasis on economic output and a broad, cross-sectoral focus, and acknowledge the need to tackle climate change, national strategies often have different interpretations of what a bioeconomy is, and pursue different pathways as to how to promote their respective national bioeconomy (McCormick and Kautto, 2013).

Many strategies are often based on the prerequisites of the country in focus (Staffas et al, 2013). In countries like the Netherlands, well-developed agricultural, transport and chemical sectors provide a solid basis for the implementation of a bio-based economy (Langeveld et al, 2016). Forest-rich countries such as Finland and Sweden concentrate on developing higher added value from their strong forest sectors (Bioökonomierat, 2015). Other "in-between" countries, such as Germany and France, seek to develop high-tech sectors and stimulate emerging industries (Bioökonomierat, 2015). Mediterranean countries such as Spain and Italy have recently drafted bioeconomy strategies as well (BIT, 2016; MINECO, 2016). The Spanish strategy (like the Finnish one) stands out by putting emphasis on the forest sector, which is expected to benefit from an "export oriented and international" bioeconomy. The agroforestry sector, timber production, non-timber forest products, as well as other ecosystem services provided by forests are all highlighted in the Spanish strategy (MINECO, 2016). Italy applies a more production-oriented approach where forests are seen as part of a "macro-sector" grouped together with the "bio-based industry" (BIT, 2016).

Few Eastern European countries have produced explicit bioeconomy-related strategies. Rather, many countries in the region push the bioeconomy through a series of different sector policies such as agriculture, forestry, regional development, fisheries etc. (Norden, 2016). Baltic countries such as Estonia have published a draft of a dedicated bioeconomy strategy in mid-2015 (Bioökonomierat, 2015). Lithuania, for example, has no national bioeconomy strategy. However, it stands out by having had a national biotechnology programme since 2006. The forest-based sector is expected to play an important role in the national bioeconomy of many forest-rich countries in this region.

This chapter now takes a closer look at four bioeconomy strategies. These are representative of different forest regions of Europe: Finland in Northern Europe with a strong forest-based sector and a dedicated bioeconomy strategy; France in Western Europe with a newly released bioeconomy strategy that builds on its strong agricultural and forest sectors; Italy in the Mediterranean region where the forest sector is just mentioned in the first draft of its national bioeconomy strategy and has a minor relevance, despite the larger potential of forest resources in the country; and Lithuania as a representative of the Eastern Baltic region without a dedicated bioeconomy strategy, but where the forest sector plays an important role in the national economy. These are presented alongside the EU bioeconomy strategy for comparative reasons.

However, this comparison must be treated with caution as it covers only five cases from different regions and does not necessarily provide a comprehensive picture. Furthermore, the different prerequisites and complexity of the forest-based sectors in each of these countries make such generalisations fade in the face of Europe's multifaceted forest regions. As discussed above, bioeconomy approaches can vary greatly at regional, national and even local levels. It is nevertheless worthwhile to focus on a few single cases in order to make sense of this complexity, at least on a broad regional level, and get a sense of the general direction of Europe's forest-based sector under the bioeconomy. So, firstly, it is worth taking a closer look at how each of these strategies was created and what are their most important features.

(i) In the **European Union**, the European Commission launched its bioeconomy strategy accompanied by an action plan in 2012 (2012a). A related Commission staff working document (2012b) was also published at that time. This launch was preceded by an online consultation in 2011 and a number of workshops and conferences. Previously called knowledge-based (bio-)economy (European Commission 2002, 2004), the new concept replaced the notion of "biotechnology". During the German EU presidency in 2005 more attention was already being focused on the origin of bio-resources itself and less on the biotechnological engineered products (Bioökonomierat 2015). Emission reductions, better resource efficiency and an increased competiveness are expected to be reconciled with food security and the sustainable use of renewable resources for industrial and environmental purposes (European Commission 2012a: 21). Bioeconomy itself is defined as encompassing "*the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries*" (European Commission 2012b: 5). As regards forest policy, the EU Forest Strategy (European Commission 2013a) calls mainly for the sector's contribution to the bioeconomy in terms of better forestry production systems and the development of products. The forest industry sees itself as part of the bioeconomy that they call the "bio-based economy". Their vision is to replace products made from unsustainable fossil-based natural resources with those derived from biomass feed-stocks (European Commission 2013b). In the meantime, the European Commission has launched (2013) a Bioeconomy Observatory to assess and evaluate the strategy's impact and a bioeconomy panel of carefully selected experts provided related guidance (2013-2015). In July 2017, as a follow-up platform to this Observatory, the European Commission launched the Bioeconomy Knowledge Centre to better support EU and national policymakers and stakeholders with science-based evidence in this field. It will be under the responsibility of the Joint Research Centre (JRC).

(ii) **In Finland**, the final version of the "*Finnish bioeconomy strategy: sustainable growth from bioeconomy*" was published in 2014, making Finland one of the first European countries to adopt a bioeconomy strategy. Between 2009 and 2011, a number of documents prepared the ground for the forthcoming strategy, which was drafted in a project established by the Ministry of Employment and Economy with input from other ministries, researchers and many other interested parties. The Ministry of Agriculture and Forestry took part in the drafting of the strategy and is actively promoting its implementation. Various stakeholders representing the bioeconomy cluster were consulted during five workshops carried out during the drafting of the strategy. The key advocacy organisation for the bioeconomy transition in Finland has been SITRA, a think tank which operates directly under the Finnish Parliament. The strategy understands bioeconomy as referring to "*… an economy that relies on renewable natural resources to produce food, energy, products and services. The bioeconomy will reduce our dependence on fossil natural resources, prevent biodiversity loss and create new economic growth and jobs in line with the principle of sustainable development*." In a forest-rich country such as Finland, where the forest sector plays a major role in its national economy, it comes as no surprise that the forest-based bioeconomy is seen predominantly as the new path towards a sustainable green economy (Finnish Bioeconomy Strategy 2014).

(iii) **In France**, the concept of bioeconomy has long been absent from major policy documents. In 2014, the industrial renewal programme ("the new face of industry in France") promoted "green sectors" and in 2015 the government launched the National Strategy for Ecological Transition towards Sustainable Development (2015–2020). However, in 2015, a group of administrative officers from different ministries (Agriculture and Forestry, Environment and Energy, Economy, Research) – urged by some representatives of the agricultural sector – decided to work together on drafting a French bioeconomy strategy. From 2015 to 2017, they convened a consultation and organised workshops with stakeholders from the different bio-based sectors. Finally, the French government launched the national bioeconomy strategy in January 2017. According to this document, bioeconomy is "*the photosynthesis economy, and more generally the living world economy. It encompasses all biomass production and processing activities, whether in forestry, farming or aquaculture, directed at the production of food, feed, bio-based products and renewable energy*". This document includes different issues and develops a shared vision for the transition towards a bioeconomy. It should be complemented by an action plan (to be completed in 2017), which is expected to implement strategic orientations. The aim of this strategy is to define a framework shaping future developments in terms of sustainability, market development, social acceptance and research activities. Dealing with general concepts of "biomass" and "bio resources", this document does lay down specific orientations for each bio-based sector; they are supposed to establish their own orientation programme. For example, in 2015 the Ministries of Agriculture and Research launched the Agriculture and Innovation – 2025 Plan, and in 2016 the Ministry of Agriculture defined a new National Forest Programme (2016–2026). In the latter, there are a few references to the bioeconomy: it is mentioned that the forest sector is one of the pillars of the bioeconomy and that bioeconomy developments offer new opportunities for the wood-based industry.

(iv) **In Italy**, a national strategy for bioeconomy was finished very recently. A draft document titled BIT – Bioeconomy in Italy: a unique opportunity to reconnect economy, society and the environment was opened for consultation. The initiative was communicated at Ecomondo (a green technology expo) in November 2016. After the launch, "citizens and all those interested in the topic" had the opportunity to express their views by filling in a questionnaire via a website or sending written proposals of amendments. A final version of the document was presented in Rome in April 2017. However, although the final document is publicly available, the launch event was given limited visibility by the competent ministries and other interested organisations. The draft document was prepared by a working group including policymakers and technical experts, none of them with a specific expertise on forestry. No feedback on the changes eventually introduced in the document was provided to consulted stakeholders. One possible explanation for the lack of attention towards involving forest representatives is the temporary vacuum of central institutions dealing with the sector after the abolition of the State Forest Corps (Corpo Forestale dello Stato) that has been *de facto* delegated by the Ministry of Agriculture, Forests and Food Policy to deal with the national forestry strategy. The definition of bioeconomy adopted by the national strategy mirrors the one provided by Europe's Bioeconomy Strategy (European Commission, 2012). Although the final version integrates comments by stakeholders in the general part, and includes additional text on ecosystem services, wild forest products and the implementation of a cascade approach in wood production, these remain mostly descriptive and are poorly reflected in the action plan. Indeed, the latter is quite general with regards to forestry and remains mainly focused on biomass production and the energy sector. As an example, the only key performance indicator in the strategy that mentions forests is to do with "forestry biomass production".

(v) **Lithuania** does not have an explicit strategy on bioeconomy, despite some recent efforts by the Ministry of Economy of the Republic of Lithuania to take tangible steps in that direction. Accordingly, there is no formally stated or broadly accepted definition of bioeconomy. According to the Bioökonomierat (2015), programmes for the development of industrial biotechnologies (2007–2010 and 2011–2013) are the strategic documents that come closest to the concept of bioeconomy. The programmes mainly seek to develop high-tech industries. The Bioökonomierat (2015) also mentions the Programme on the Implementation of the Priority Areas of Research and (Socio-Cultural) Development and Innovation (Smart Specialisation) and their Priorities that consider the area of biotechnology as well. There are other strategic documents implicitly related to a bioeconomy, such as the National Development Programme for the Forest Sector (2012–2020) and the various strategies on the use of bioenergy, including the National Strategy for the Development of Renewable Energy Resources, adopted by the Lithuanian government in 2010; National Action Plan for Renewable Energy Resources, 2010; Act of Renewable Resource Energetics, adopted by the Lithuanian Parliament in 2011; and National Programme for Development of the Heating Sector 2015–2021, adopted by the Lithuanian government in 2015. These documents do not explicitly mention bioeconomy as such, but can nevertheless be considered to be bioeconomy "framing" documents. Whether and how an explicit bioeconomy strategy will materialise in this Baltic state remains to be seen.

All the strategies discussed were developed at different points in time, under different conditions, and involving different types of stakeholders in the process: e.g. the Finish Bioeconomy Strategy was prepared by several ministries (including the Ministry of Agriculture and Forestry), SITRA and VTT Technical Research Centre of Finland following a participatory approach involving stakeholders (including NGOs) and research institutes; the French strategy was prepared by the Ministry of Agriculture and Forestry and included representatives from the forest sector. The Italian and the EU strategy produced no clear evidence about the involvement of actors specifically belonging to the forest sector. Lithuania has yet to produce a national bioeconomy strategy. This raises the question: how are forests and the forest-based sector understood and integrated in these different strategies? Table 2 provides a brief overview of the four Member States' perceived role of forests and the forest-based sector as presented in their bioeconomy-related policy documents and strategies, compared to the EU bioeconomy strategy.

The comparison reveals that the Finnish, French and Italian bioeconomy strategies all consider the forest-based sector as one of the key sectors alongside others, highlighting biomass provision as one of the main aims. The EU strategy understands forests to be part of the primary production process and a biomass provider whereas the Lithuanian text only asserts a rather minor role for forests. Biomass availability is clearly understood to be an important aim addressed in all strategies. However, they do differentiate in terms of emphasising resource mobilisation (Finland, France), the need for increasing information as regards biomass availability (Finland, EU) and for importing biomass (Italy). Interestingly, all strategies acknowledge, in general, the importance of the notion of sustainable development, while nonetheless strongly emphasising its economic dimension. Social and biodiversity aspects are vaguely addressed by the strategies. Climate change and the role of forests are only set in the context of forest adaptation (France) and carbon sequestration (Italy, EU). Such views are predominant in the Southern bioeconomy strategies and the EU, but not in the Finnish strategy which does not explicitly address this issue in relation to forests.

In contrast, securing the competitiveness of the forest industry is presented as a main objective of the Finnish strategy, while the Italian strategy in this regard points towards the need for creating new forest supply chains. The Finnish strategy is also the only one that explicitly addresses the value added generated from forest and timber products. Both the Finnish and the EU strategies refer to employment in the forest sector. However, in contrast to the EU, the Finnish strategy does not directly emphasise the creation of new jobs through the bioeconomy with regard to forests, but addresses the value added generated from the employed people in the sector. However, since the focus of the strategy is on forests it can be assumed that the expectation to create new jobs by 2025 also applies to the forest sector. Finally, explicit references to forest owners are scarce in all strategies.

To sum up, quite a complicated picture emerges from the above comparison. The Northern point of view puts an emphasis on the need to secure the industry's competitiveness while acknowledging public access rights to forests, the valued added generated from nature-based tourism and hunting as well as the need to care for forest biodiversity. This is contrasted by a Mediterranean viewpoint that emphasises its forest sector's relevance in relation to the wood processing and paper industries and its dependence on imported biomass. Here, issues related to forest biodiversity are acknowledged (e.g. abandoned forests). The Western European perspective on the forest-based bioeconomy highlights the need for an increase in and optimisation of bio-resource production, but also the need to develop new production modes to protect forest biodiversity and to interconnect sectors. The role of forest adaptation to climate change and recreation is also addressed. The available Baltic strategy focuses around the older notion of biotechnology, still lacking a clear vision on bioeconomy and, in turn, the role of forests in bioeconomy remains undecided. Finally, the EU strategy does address forests and related products, but does not clearly emphasise their role. Forests are particularly addressed with regards to biomass demand (e.g. forestry residues) and the use of forestry residues as alternative sources of carbon and energy while explicitly acknowledging the carbon sequestration function of forests. It is also emphasised that a bioeconomy shall create new jobs in the forestry sector, something that remains unaddressed by other national strategies.

Table 2: States' perceived role of forests and the forest-based sector in bioeconomy strategies compared to the EU bioeconomy strategy

	FINLAND	FRANCE	ITALY	LITHUANIA	EUROPEAN UNION
Role of forests	Forest-based sector is a **key sector** Forests as **biomass providers** with potential to generate higher added value chains, economic growth and job creation.	Forest sector is one of the **existing filière (sector)** that already provides bio resources.	Forestry is **one of the four macro-sectors** of the bioeconomy (but the related priority is titled "Sustainable agriculture and forestry").	**Role of forests marginal** (PDIB 2006; PDIB 2011; PIPA 2014). References to forests are diminishing between 2006-2014.	Forests **part of primary production and producer of biomass** which needs certain production conditions; useful for carbon sequestration.
Role of sustainability / sustainable development	Explicitly related to **all three sustainable development dimensions; economic dimension is emphasised.**	Sustainability - core issue with **specific emphasis on environmental and social impact of bio-resources production practices**, economic consequences of the competition for raw materials, and environmental problem of closing the nutrient and water ecocycles.	Mainly understood in the context of environmental footprint, voluntary labelling and other certification schemes. "Independent Sustainable Forest Management schemes" and "existing forest certification schemes" are listed among opportunities.	None	Resources should be used and managed sustainably and pressures on ecosystems should be minimised. **Weak sustainability approach**, where substitutability of natural resource is fully assumed.
Biomass availability and forests (Section 3.1)	Strategic goal four calls for "Accessibility and sustainability of biomasses"; biomass resources as "underexploited" (p6). "Better information" about biomass availability and trends (p29). Financial exploitation of biomasses and imports needed (p29).	**Bio-resource production and mobilisation have to increase and to be optimised. None of the approaches is privileged a priori;** each approach illustrated with an example from forest sector (e.g. softwood log for construction rather than for energy).	Forest sector and its socio-economic relevance/size are presented with an emphasis on the wood processing and paper industries and their dependence from imported biomass.	PDIB (2006) and PDIB (2011) both relate to **biomass availability** (show figures of forest residues).	Acknowledges competing uses of biomass and rising global demand; asks for understanding of current, potential and future availability and **demand of biomass (including forestry residues and wastes).**

Table 2: continued.

Forest biodiversity (Section 3.2)	Asks for "**care for biodiversity in the forest** environment".	To protect and restore biodiversity, necessary to **develop new modes of production.** For the forest sector it is based on SFM principles, applied at scale of plot and at scale of landscape (territory) long term.	**(Forest) biodiversity mentioned in relation to a "problem" identified** in the challenges and action plan ("abandonment of historically managed forests with biodiversity depletion and ecosystem degradation (p41).	**None**	**Not addressed directly** *Stresses loss of biodiversity and need for habitat protection & provision of ecosystem services.*
Climate change and forests (Section 3.3)	Not explicitly addressed. *Mentioned in the strategy but the connection between forest exploitation and climate change is missing.*	**Genetic research contributes to adaptation of forest species**; **forest biomass** contributes and will contribute to **renewable energy** mix and advanced biofuels made with lingo-cellulosic materials is promising development.	"Carbon removals by managed forests covered 10% of the overall national Kyoto target for CO_2 emission reduction and that there is a quite active voluntary market of carbon sinks" (p12 and p41).	**None**	Central global challenge; **Use of eg forestry residues** and wastes as alternative sources of carbon and energy; **acknowledgement carbon sequestration function** of forests.
Efficiency and forests (Section 3.4)	**Efficiency relates to the use of raw material** (including wood and timber), indirectly to the notion of "cost-efficiency" (p15) and material efficiency.	Advocates for "a more **efficient interconnection of the main sectors**, including "forestry", "to their processing and final products exploitation" (p45).	**None**	**Not well addressed;** *PDIB (2006) to more effectively utilise the available agricultural and forest resources.*	**None**; *Efficiency notion does however come up in relation with resource efficiency.*
Social values and benefits from forests (Section 3.5)	Forests related to **public access**; value added, employment and **export figures are provided for nature-based tourism and hunting.**	Role of **forests for recreation and living environment is mentioned** but not emphasised.	**None**	**None**	**None**
Competiveness and forest sector (Section 3.6)	A cornerstone for developing the bioeconomy is **securing the competitiveness of the existing industries.**	**None**	**International competitiveness of the whole value chain (and of the socio-economic growth) is limited** (p12). "New supply chains with [from] the forestry world" are encouraged (p24).	**None**	**Not explicitly addressed;** *related to creation of jobs and innovation and market enhancement*

Table 2: continued.

	FINLAND	FRANCE	ITALY	LITHUANIA	EUROPEAN UNION
Forest and employment (Section 3.7)	**Valued added generated from people employed is explicitly addressed** (p9).	**None**	Minor references: to **generation change** in forest-wood sectors in less developed regions and **foresters**: (skills, human and social capital of farmers, etc.).	**None**	Bioeconomy to **create new jobs (including high skilled and training options) in the forestry sector**
Forest owners (Section 3.8)	Forest owners not explicitly mentioned; acknowledges **that forests in Finland are mainly privately owned** (p29).	It is mentioned that there are 3.3 million forest owners and 440,000 jobs in the forest sector.	**None**	**None**	**None**
Role of forest products (Section 3.9 and 3.10)	Valued added generated **from forest and timber products** explicitly addressed (p9); products made from wood and material use in construction, automobile and health, food and energy sectors etc.	**None**	**None**	**None**	**Not explicitly addressed** *In relation to products, product properties and standards very important where further research is needed; storage of carbon in products acknowledged.*
4. Involvement of key actors from the forest sector in drafting / writing of strategy	Ministry of Agriculture and Forestry; stakeholders in five workshops, three regional bioeconomy forums and sectoral consultations; interested persons expressed views via webpage.	13 representatives of forest sector (total 63) participated in workshops. Some forest representatives provided written contributions and were interviewed during development.	Working group of policymakers and technical experts **(none of them with specific expertise on forestry)** (p60). Additional stakeholders and citizens were consulted.	**Not stated in the document**	**Not stated in the document**

2.2.3. Research on bioeconomy strategies and forests

Recently, a growing number of reviews focused on how bioeconomy was taken up by the academic literature (e.g. Bugge et al, 2016; Golembiewski et al, 2015; Pfau et al, 2014). A recent review by Bugge et al (2016) found that scholarly literature on bioeconomy generally subscribes to one of the following three visions:

(i) "Bio-technology" vision that emphasises the importance of bio-technology research and application and commercialisation of bio-technology in different sectors of the economy.
(ii) "Bio-resource" vision which focuses on processing and upgrading biological raw materials, as well as on supply and new value chains.
(iii) "Bio-ecology" vision highlighting sustainability and ecological processes.

Most of the forest-related bioeconomy literature largely falls into the latter two categories, where research generally focuses on the choice and production of sustainable biomass resources as a means to replace fossil-based resources. However, most of the bioeconomy-related literature is dominated by natural and engineering sciences, while the social and political sciences are less visible (Bugge et al, 2016; Pfau et al, 2014).

As governments continued to produce national bioeconomy strategies and related policies, political science literature started to closely scrutinise these different developments. One of the earliest overviews of the different national approaches to bioeconomy comes from Staffas et al (2013). As different countries were still developing their national strategies and identifying bioeconomy goals, this analysis found that the bioeconomy concept had yet to be clearly defined. Not surprisingly, different strategies and policies were promoting the bioeconomy differently, dependent on the prerequisites and natural resources available to each country. Similarly, McCormick and Kautto (2013) found that the definitions of the bioeconomy in Europe are still evolving and vary depending on the actors involved. Both Staffas et al (2013) and McCormick and Kautto (2013) agree that most national strategies have a strong emphasis on economic output and a strong technical fix, whereas aspects of sustainability and resource availability are only vaguely addressed. McCormick and Kautto (2013) further call for participatory governance that engages the general public and key stakeholders in an open and informed dialogue. Such views were later reiterated by Ollikainen (2014) who, by analysing the EU bioeconomy action plan from the forest-based sector perspective, found that the EU bioeconomy strategy vaguely recognises the role and nature of the forest sector.

Some studies on bioeconomy address politically relevant questions from a rather critical perspective (e.g. Birch and Tyfield, 2013; Goven and Pavone, 2015). Birch and Tyfield (2013), for example, highlighted some of the underlying ambiguities in scholarly attempts to theorise the relationship between biotechnologies and their capitalisation. They draw attention to the fetishisation of everything being "bio". Similarly, Goven and Pavone (2015), provided a Marxist reading by describing bioeconomy as mainly a political project meant to bring about a particular set of political-institutional agendas (such as to increasingly commodify nature and knowledge). They warn scholars about the potential risks of unintentionally contributing to the legitimisation of the project.

Concerning the forest-based bioeconomy, there is less literature dealing with politically relevant questions. Pannicke et al (2015) provide some specific policy recommendations (e.g. gradual extension of existing policies that support bioeconomy products and technologies) needed to initiate a transition towards a bioeconomy in the context of

Germany. Again for Germany, Hagemann et al (2016) develop different scenarios for the wood-based bioeconomy and discuss different developments in politics, industry and society that may potentially impact on shaping alternative futures. Other studies take a more international approach to forest policy analysis (e.g. Pülzl et al, 2014; Kleinschmit et al, 2014). For example, Pülzl et al (2014) show that the bioeconomy discourse is not new but a mixed-source discourse providing a new dressing for pre-existing forestry discourses. Kleinschmit et al (2014) argue that actors stress different aspects embedded in the concept. Both Pülzl et al (2014) and Kleinschmit et al (2014) identify a rather narrow interpretation of the sustainability concept in the bioeconomy discourse and stress the need to study whether and how the bioeconomy discourse provides new policy solutions in relation to forest policy.

Studies on the role of sustainability have provided either normative-theoretical or actor-centred analyses of the various bioeconomy strategies and policies. Regarding the sustainability debate, recent contributions by Ramcilovic-Suominen and Pülzl (2017) and by Kleinschmit et al (2017) provide empirical analyses of how sustainable development is framed and integrated in different bioeconomy policy documents. Kleinschmit et al (2017) analysed and compared whether and how environmental concerns are integrated in the EU and national bioeconomy strategies in Germany, Finland, France and the Netherlands. The analysis revealed three different environmental frames: “environment understood as a challenge”, “environment understood as a standard” and “environment as benefiting from economic development”, all pointing at a weak mode of environmental policy integration. Similarly, Ramcilovic-Suominen and Pülzl (2017) describe four narratives: “production”, “efficiency”, “competition” and “sector capacity” that drive the EU bioeconomy policy discourse. Accordingly, this points at a rather weak form of sustainability, where nature is subordinated to the production of goods and services, and where it is mainly understood as a resource provider. Kleinschmit et al (2017) further argue that sustainable development is presented as an integral part of forest policies institutionalised as sustainable forest management. However, a rather technocratic and efficiency-oriented approach to sustainability is being adopted here that narrows the original idea of sustainable development (where economic, environmental and social dimensions should be balanced). Similarly, Kröger and Raitio (2017) find that the dominant pathway to sustainability in the Finnish forest policy aims to safeguard increased timber production that promotes a rather production-oriented forest policy, with less emphasis on ecological concerns.

Although research in this area is still scant, some recent scientific contributions have taken up issues related to forest stakeholders’ perceptions and citizen participation in the forest-based bioeconomy. Participatory policy processes have been applied to develop bioeconomy strategies in different European countries, yet few studies have analysed these processes. For example, Mustalahti (2017) provides an empirical case from Finland and addresses the issue of citizen participation in the bioeconomy discourse. Mustalahti (2017) argues that although citizens may not be able to create new bioeconomy innovations, key aspects of change, such as citizens’ values, interests, knowhow and environmental entitlements need to be further taken into account as the bioeconomy concept continues to evolve and affect citizens’ lives.

Regarding stakeholders’ perceptions, national empirical studies (in Sweden, Finland, Germany and Austria) have already started to investigate forest stakeholder’s perceptions and understanding of the bioeconomy concept. For example, Hodge et al (2017) have analysed the Swedish forest sector’s perceptions of bioeconomy and found that it is a broadly accepted concept, perceived as a natural extension of the Swedish forestry model. The forest bioeconomy was found to be well aligned with the key characteristics of a boundary object that serves specific interests of different forest stakeholders under a generally accepted conceptual umbrella. As stated by one interviewee "[bioeconomy] it's a buzzword, but a useful buzzword" (Hodge et al, 2017). Similarly, in Germany, Stein (2017) has analysed the acceptance of the bioeconomy concept by the German forest and wood industry. Here too, bioeconomy was found to be a generally accepted concept, "plastic enough" to adapt to the varying needs and constraints of those employing it. However, most German forest and wood industry stakeholders mentioned that the economic and social relevance of the wood sector is not sufficiently acknowledged in politics and society; many therefore felt that stakeholders should be more actively involved in the German bioeconomy discussion. This is confirmed by Giurca and Späth (2017), who found rather narrow bioeconomy actor networks, where suppliers of raw materials are at the periphery of these networks. Nevertheless, both in Sweden and Germany, most stakeholders saw the bioeconomy as an opportunity to "rebrand" themselves and re-legitimise their activities under the motto "we are the bioeconomy", implying that the bioeconomy can be a pathway for society to accept forestry as it is.

In either interpretation, most studies unanimously agree that the future evolution of the bioeconomy would have to build on a broader sustainability concept and on a more inclusive network that involves multiple sectors and actors e.g. policymakers, scientists, forest owners, industry, the private sector, citizens etc. (McCormick and Kautto, 2013; Mustalahti, 2017; Giurca and Späth, 2017). At the time, it seems that bioeconomy acts as a boundary concept that brings closer rather than divides the different forest stakeholders. However, as Hodge et al (2017) point out, such consensual, vague concepts can risk being hijacked by groups seeking to legitimise their own agendas. Kleinschmit et al (2014) expect the traditional network boundaries of the "classical" forest sector to shift and new cross-sectoral actor networks to form and in turn reveal emerging coalitions and power struggles in the bioeconomy arena. As pointed out by Kröger and Raitio (2017), the prioritisation of production over ecological concerns in Finland is already dividing classical coalitions in terms of how the pathway to sustainability is framed. How such developments will further unfold in different countries and how these developments will shape the forest-based bioeconomy remains an important empirical question.

2.2.4. Concluding remarks

"What political science can tell us" so far is that the bioeconomy concept has been taken up in the EU and in national strategies. The understanding of what a bioeconomy is, what goals should be prioritised and how these can be achieved varies between the different strategies. This holds also true when the specific forest lens is being used for analysing them. Altogether, the strategies offer a patchwork of various issues being covered and various gaps being "forgotten". This diversity is particularly explained in the political science literature by the various natural resource bases of European countries as well as by different national actors and interests involved.

Content-wise, research has shown that the bioeconomy strategies show a dominance of economic and technocratic approaches, while not enough attention has been paid to environmental sustainability considerations. In other words, environmental policy integration and sustainability have only been integrated at the surface into bioeconomy strategies. In addition, European bioeconomy strategies are characterised more by a governmental than a governance approach. Stakeholder and citizen participation are still work in progress as the bioeconomy concept evolves. Since a strong bioeconomy can completely change citizens' lives, a way to include them more strongly in the development of common goals, definitions, and the development and application of new technologies will also be in resource managers' and governments' interests. Yet, bioeconomy strategies differ across European countries. Whether and how the forest sector is integrated in these strategies depends as well on the countries and whether they are rich in forest resources.

It should be acknowledged, though, that the above observations from the political science literature are also a result of the analytical perspectives taken by the scholars concerned. It seems that critical-normative approaches to policy analysis are currently dominant in the study of European bioeconomy strategies. After all, the above overview shows a dominance of governance, discourse and political ecology approaches. Due to these critical approaches, it is no wonder that European bioeconomy strategies are considered too narrow and technocratic, and particularly serving the interests of governments and economic interest groups. An economist advocating "market-environmentalism" as an approach would probably have drawn different and more positive conclusions on how well-balanced economic and environmental rationalities are addressed in European bioeconomy strategies. However, the actors involved in the development of the strategies, and the goals prioritised independently from the lenses used in the analysis, foster the conclusion that the bioeconomy has so far been dominantly driven by economic concerns.

Take home messages:

- Most bioeconomy strategies offer different understandings of what a bioeconomy is. What goals should be prioritised and how these can be achieved is largely dependent on the different prerequisites and complexity of the forest-based sectors in each country. Hence, bioeconomy strategies of different geographical regions and the European Union do not prioritise the same aspects concerning the forest-based bioeconomy.
- Bioeconomy is acknowledged as a "boundary concept" in the forest sector. Forest actors generally accept the bioeconomy concept, as it is open enough to accommodate the varying needs and constraints of those employing it. Although forest stakeholders consider themselves an important pillar of the bioeconomy, few national strategies have actually consulted or involved forest actors in drafting national strategies. Only forest-rich countries form an exception.
- Bioeconomy strategies as such primarily focus on economic goals. In contrast, environmental and societal objectives could be better integrated in bioeconomy strategies.
- So far, the available literature in relation to bioeconomy strategies is dominated by natural and engineering sciences. Studies with a social scientific perspective are less visible. In particular, results concerning involved actors, actor networks, rules and norms are missing.

Policy recommendations:

- Since bioeconomy strategies and their relationship to the forest-based sector differ considerably across Europe, no single coherent framing of what bioeconomy means for the forest-based sector has been created. On the one side, this does allow for multiple interpretations and adaptation to local needs. On the other side, however, this vague interpretation also risks not creating political impetus. The creation of a clearer vision about what bioeconomy means for forests in the different regions of Europe reduces possible divergent interpretations and could strengthen its acceptance.
- Although forest actors acknowledge bioeconomy, most strategy processes did not include them in their development so far, thus missing the opportunity to coordinate visions and benefit from their knowhow. Similarly, citizen participation seems mostly absent in the forest-bioeconomy discussion. Their acceptance of new products and processes will be very important in the long run as political decisions on bioeconomy directly affect citizen's lives. Therefore, it would be important to move from governmental approaches to governance approaches and include forest actors and citizens within bioeconomy-related decision-making processes in order to create and strengthen their acceptance as well as to increase the legitimacy of the forest-based bioeconomy.
- Finally, as research has shown, many bioeconomy strategies do especially well in adopting a more technocratic and efficiency-oriented approach to sustainable development. This results in a narrowing down of the original idea of sustainable development where economic, environmental and social dimensions should be equally balanced. However, taking sustainability issues into account more seriously is necessary to guarantee the coherence of bioeconomy strategies with existing European regulations, national environmental orientations and sectoral policy frameworks.

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3.

Critical issues – what science can tell us

3.1. Is there enough forest biomass available to meet the demands of the forest-based bioeconomy?

Florian Kraxner, Sabine Fuss, Pieter Johannes Verkerk

3.1.1. Introduction

For centuries, forests have been used as a source of timber and fuel. The demand for wood products has increased in the 20th century, driven to a large extent by population and economic growth. Between 2000 and 2016, the world consumption of roundwood has increased by 8% compared to the last one and a half decades of the past century where the increase was 5% (FAOSTAT, 2017). The demand for wood is expected to increase in the coming decades (UNECE-FAO, 2011), although future developments are uncertain due to observed structural changes in wood markets (Hurmekoski, Hetemäki, 2013; 2014) (see also section 3.9). While globally the demand for wood for material use increased steadily during the 20th century, the importance of forests for fuel decreased dramatically due to the availability of fossil fuels. At the same time, the roundwood consumption in Europe has stayed stable during the past three decades. According to FAOSTAT (2017), European consumption declined from 710 million m^3 in 1984 to 700 million m^3 in 2000, and then increased again by 3% to 722 million m^3 in 2016. However, and particularly in Europe, forests are also regaining their importance as a source of fuel. Globally, biomass for bioenergy received special attention due to the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC 2014). In the report, bioenergy, together with carbon capture and storage (BECCS), has been highlighted as a realistic option with probably the highest potential for creating negative emissions. In that way, BECCS would be crucial for achieving ambitious climate mitigation targets (i.e. global average warming limited to 1.5-2 degrees Celsius) by the end of this century (see also Fuss et al, 2014; 2016; Smith et al, 2016). A large-scale employment of BECCS would inter alia increase the global demand for biomass feedstock substantially and hence put further pressure on the sustainability of biomass production systems as well as on the wider bioeconomy sector. Therefore, a key question is how much biomass is available to support these developments.

Biomass from forests and wood industry can be categorised into primary biomass production (stemwood from final fellings, thinnings), primary residues from forests (logging residues, stumps), and secondary forest residues from the wood processing industry (e.g. sawdust, woodchips, bark). This chapter focuses on these three biomass categories, although woody biomass can also come from landscape maintenance and post-consumer wood (e.g. demolition wood, discarded wood products).

Societal challenges at global level, such as climate change mitigation, on which the European Commission has taken a leadership role (see section 3.3), could stimulate demand for forest-based biomass for carbon sequestration, bioenergy substituting fossil energy, and further substituting for fossil-based products such as in construction, textile, chemicals and plastics sectors. In this chapter we will synthesise the currently available information on potential forest biomass availability within Europe and globally. Finally, possible impacts on forests in Europe and abroad will be discussed as an important dimension of sustainability.

3.1.2. Potential biomass availability from European forests and wood industry

European forests currently supply approximately 407 million m^3 of roundwood per year excluding bark, as of 2010 (Forest Europe, UNECE, FAO, 2011). However, large differences exist in the amount of wood that is harvested within Europe as each country's forest resources vary in size, and the harvest is often concentrated on easily accessible areas with productive tree species (Levers et al, 2014; Verkerk et al, 2015) (Fig 2). Looking at the amount of wood that is felled annually in relation to the annual increment gives a rough indication of how intensively forests are used. It also indicates whether there is potential to increase harvest levels. The current felling intensity in European forests is approximately 64% (average over EU28, in the period 2000-2010) of the annual increment (Forest Europe, UNECE, FAO, 2011), which is a rough indication that harvest levels could be raised.

European forestry has a long history of estimating the sustainable supply of wood. Nowadays, the potential sustainable supply level, or availability, is often based on resource information derived from national forest inventories. Tools such as EFISCEN (Verkerk et al, 2011; Nabuurs et al, 2007), G4M (Kindermann et al, 2013), EFDM (Mubareka et al, 2014) use the results of these inventories to estimate forest biomass availability under different management assumptions at the European level. Many countries have now started to develop their own tools (Barreiro, 2016). Indeed, many resource assessments have been carried out over the last decade to quantify the potential availability of biomass from forests (e.g. UNECE-FAO, 2011; Verkerk et al, 2015; Mola-Yudego et al, 2017; Lauri et al, 2014; de Wit and Faaij, 2010). These assessments indicate that, in Europe, generally more biomass could be mobilised compared to current utilisation levels.

The assessments typically estimate a theoretical biomass potential, which is then reduced by considering the constraints that reduce biomass availability. They use different types of constraints, which complicates the comparison between them, as well as the comparison of biomass availability from other sectors. To address this issue, the S2Biom project recently provided a comprehensive assessment of biomass availability

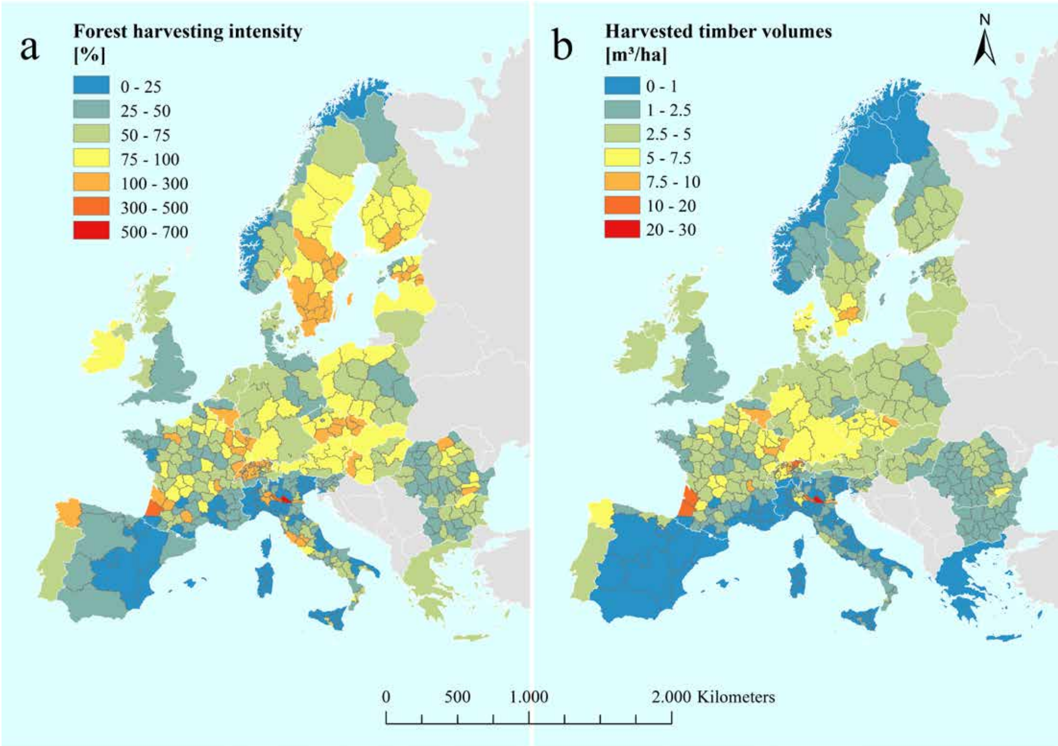

Figure 2. Average harvesting intensity (A; %) and harvested timber volumes (B; m^3/ha) for the period 2000–2010. Source: Levers et al, 2014.

in Europe. The project assessed ligno-cellulosic biomass availability from forests and the forest sector, as well as for the agricultural and waste sector, for the 28 EU Member States and nine neighbouring countries (Montenegro, Macedonia (FYROM), Albania, Bosnia and Herzegovina, Serbia, Kosovo, Turkey, Moldova and Ukraine) (Dees et al, 2017; Panoutsou, 2017). The project estimated biomass availability for the following typologies:

- *Technical potential*, defined as the absolute maximum amount of ligno-cellulosic biomass potentially available assuming the absolute minimum of technical constraints.
- *Base potential*, representing the potential most closely aligned to current guidelines of sustainable forest management. This also covers legal restrictions such as restrictions from management plans in protected areas, e.g. Natura 2000.
- *High potential*, which is a potential with less constraints compared to the base potential, assuming a strong focus on the use of wood for producing energy. It includes a strong mechanisation of harvesting across Europe. Biomass harvesting guidelines are less restrictive, e.g. stumps are included in this potential for all countries.

The S2Biom project estimated the potential biomass availability from forests in the 37 countries at 379 million tonnes dry matter per year (or 817 million m^3 per year) (including bark) for the base potential in 2012[1]. The potential is estimated to stay rather stable over the coming decades with only a slight decrease to 370 million tonnes dry matter per year overbark by 2030. About 88% of the total biomass potential was in stems, while

1 All results of the S2Biom project are available from: http://S2Biom.alterra.wur.nl/

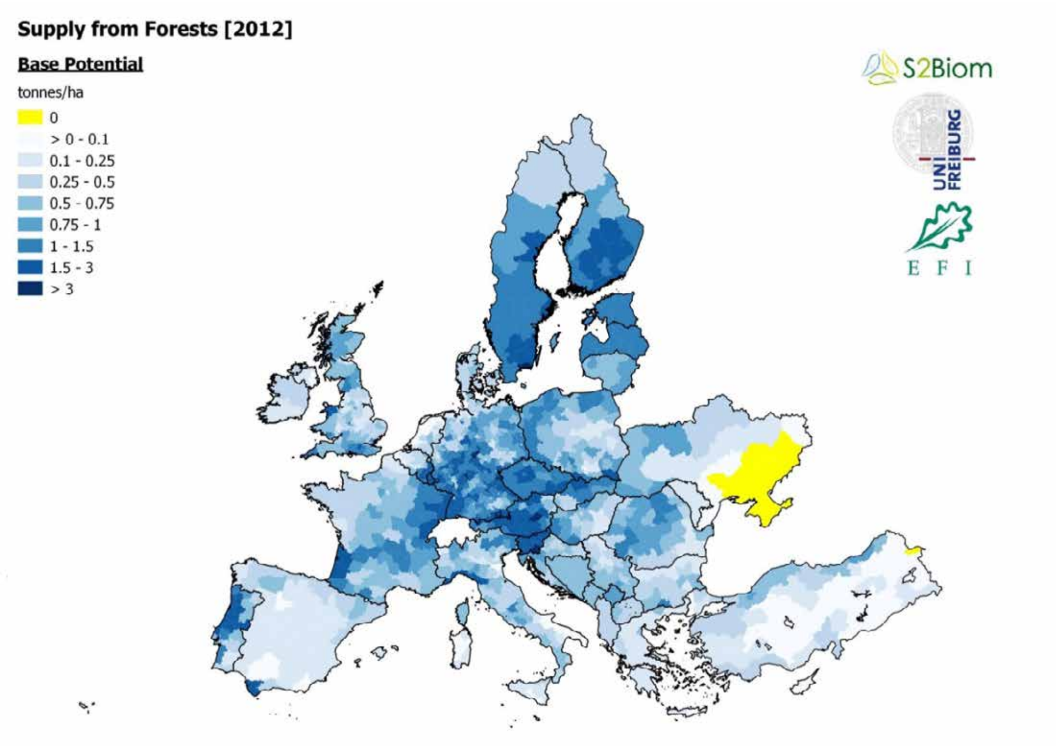

Figure 3. Distribution of potential forest biomass availability (biomass production and primary residues from forests) per ha of land for the base potential in 2012. No data are available for regions marked yellow. Source: Dees et al, 2017 and Panoutsou, 2017.

primary residues represented 12%. The regional availability of biomass varies widely across Europe. The forest biomass potential per unit of land is generally highest in Central and Northern Europe, due to higher forest productivity (mainly Central Europe, southwest France and Portugal) and a higher forest cover ratio (mainly Northern Europe) (Fig 3). Comparing Figures 2 and 3 suggest that regions with high potential availability already have higher levels of wood production and tend to have more limited potential to increase wood production beyond current wood production levels.

Future forest biomass availability is likely to be affected by climate change. A review of climate change impacts on productivity suggests that productivity may increase in the northern part of Europe and that there are mixed projections for other parts of Europe (Reyer, 2015). According to Shvidenko et al (2017), countries of the mid-latitude ecotone and the xeric belt (Moonil et al., 2017) – which includes southern and south-eastern European countries such as the Ukraine – will be particularly vulnerable, with water stress becoming the major limitation factor. While changes in productivity have been considered within the S2Biom project, natural disturbances (e.g. storm, wildfire, bark beetle outbreaks) have not been taken into account. Such disturbances are estimated to increase in the coming decades (Seidl et al, 2014) and may even cancel out climate change-induced productivity gains (Reyer et al, 2017). Furthermore, natural disturbances may lead to strong disruptions of timber markets and may affect biomass availability in the long term through its impacts on forest (age) structure (Gardiner et al, 2010). Climate change caused forest threats require urgent counteractions through a broad portfolio of managerial, silvicultural and technical measures to increase forest landscape resilience (see section 3.3).

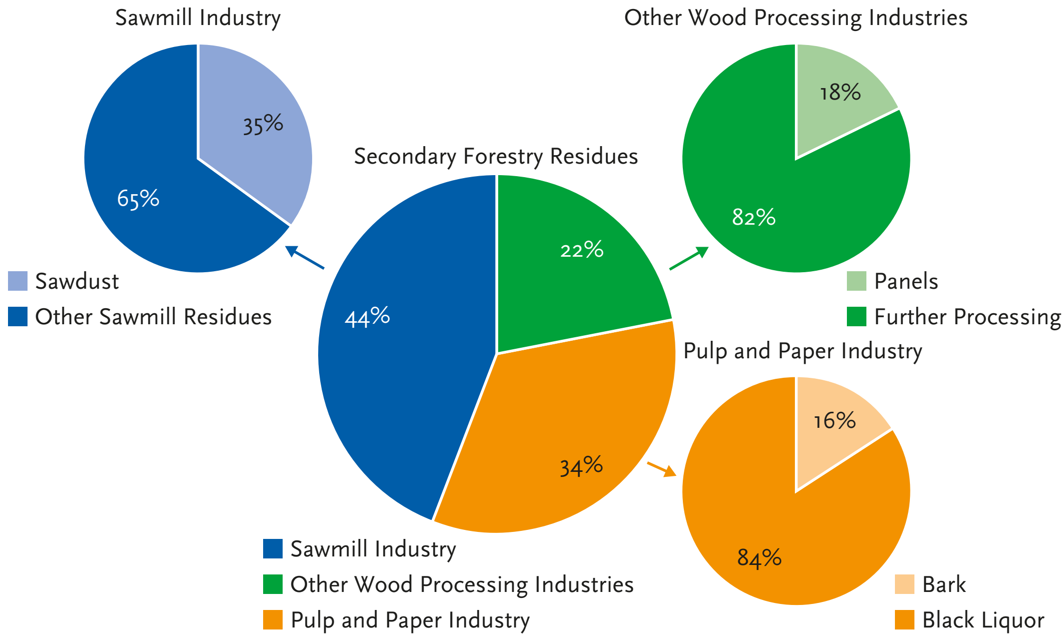

Figure 4. Composition of supply from secondary forest residues for the base potential in 2012 for 37 European countries. Source: Dees et al, 2017.

In addition to climate change, a key issue for forest biomass availability is whether private forest owners can be activated to bring their wood to the market. It is unclear, however, if private forest owners are interested in mobilising more wood as they might have very different objectives for their forests. For instance, a survey carried out in Germany, Portugal and Sweden suggests that European private forest owners may not be able to contribute to mobilising large amounts of stemwood for energy purposes (Blennow et al, 2014). However, the survey did not address the attitude of forest owners to supplying logging residues and stumps. The results are also in contrast with findings from the South-Eastern European countries showing a relatively high degree of willingness on the part of forest owners to manage their forests for producing woody biomass for energy purposes (Stjepan et al, 2015, see section 3.8).

Once wood is processed by the forest industry, some of it becomes available as secondary residues. Such secondary forest residues comprise residues from saw mills, from the pulp and paper industry and from other wood processing sectors. The S2Biom project estimated the total biomass potential of secondary forest residues from the forest industry at 91 million tonnes for the base potential in 2012 (Dees et al, 2017). The composition of this potential is shown in Figure 4. Residues from saw mills dominate at over 40%, followed by pulp and paper residues at over 30% whereas other wood processing residues form the smallest, but still considerable, element at over 20%.

3.1.3. Global biomass availability and trade

The European bioeconomy's demand for biomass could also be met by imports from other parts of the world and biomass trade within Europe. According to the latest Forest Resources Assessment (FRA) by the United Nations Food and Agriculture Organisation

(FAO), forests cover around four billion hectares of the world's surface, and are the largest contributors to the global biomass supply. When it comes to availability of biomass, it is assumed that, globally, approximately 57% of forest biomass is growing in managed forests, accounting to some 360 billion m^3 (FAO 2015).

According to the World Bioenergy Association (WBA), one third of the global forest area is located in Russia and Brazil, with the majority of primary forests concentrated in Russia, Brazil and Canada (WBA 2017). Following FAO's FRA (FAO 2010), the total biomass (growing stock) of these forests amounts to roughly 530 billion m^3. Most of this biomass is found in South America (177 billion m^3), and Europe (including Russia) (112 billion m^3). These areas are followed by North and Central America (86 billion m^3), Africa (77 billion m^3), Asia (54 billion m^3), and finally Oceania hosting the smallest global forest biomass share (21 billion m^3). While regions with tropical forests show the highest biomass density (e.g. South America with an average density of 205 m^3 per hectare; Western and Central Africa 189 m^3 per hectare), European forests have an average biomass density of 156 m^3 per hectare (without the Russian Federation) and 111 m^3 per hectare respectively (including the Russian Federation).

Regions with larger bioeconomy sectors increasingly tend to import additional biomass in order to supply their demand. Global biomass trade hence increased nearly five times (from 600 million m^3 to 2.8 billion m^3) between 1962 and 2010. One reason for the increase of biomass demand is bioenergy. In 2012, five out of six billion m^3 biomass converted into energy originated from forests. Globally, the fuel wood share of the total roundwood production was 50% in 2016 (1.87 billion m^3), most of which is produced in Asia and Africa. In Europe, the fuel wood share was 20% of the total roundwood production in 2016. However, Europe's fuel wood production increased by 57% between 2000 and 2016, whereas its production shrunk in Asia by 10% during the same period (FAOSTAT 2017). According to Lamers et al (2014), net woody biomass trade volumes for energy alone increased sixfold (from 32 million m^3 to 190 million m^3) between 2000 and 2010. Over this period, demand for wood pellets increased most strongly, making them the dominant commodity on international markets, whereas trade with wood waste, roundwood, and wood chips for energy remained much smaller and was pretty much limited to Europe.

It is estimated by WBA (2016) that by 2035, the annual global bioenergy potential from forest-based feedstock will be 78 exajoules (EJ). This roughly corresponds to 8 billion m^3 biomass (including wood fuel, forest residues and by-products of forest industry) and is based on the assumption that – given good policies – by 2035, about 5% of the agricultural area (240 million ha) can be used for growing dedicated energy crops for biofuels and solid biomass for energy. However, the literature offers a large variation in estimates of future global bioenergy potential from (forest) biomass. For example, Lauri et al (2014) estimate that the available woody biomass resources for energy conversion in 2050 will be between 11 and 43 billion $m^{3,}$ which could cover up to 40% of the world's primary energy consumption in 2050. The Global Energy Assessment (GEA, 2012) presents a range for the total global technical bioenergy potential for the year 2050 of between 17 and 29 billion m^3, while Canadell and Schulze (2013) and Haberl et al (2010) offer more conservative global estimates ranging from three to 17 and three to 29 billion m^3 respectively in 2050. Lower estimates are mostly due to environmental safeguards such as the protection of primary forests or the consideration of sustainability criteria for the biomass production. Clearly, the actual production (and consumption) levels of forest biomass for bioenergy in the future will depend heavily on policy measures supporting bioenergy and the development of alternative renewable energy forms.

More accurate estimates for biomass availability require improved data from modelling and remote sensing and need to include calculations for biomass accessibility. One of the challenges in providing better information on biomass availability is that – on a global level – the geographic extent of forests is still not yet accurately determined. Another issue is that information on the exact amount of biomass stocking in global forests is not yet available for vast areas – such as in Africa and the tropics, but also in Europe (cf Fritz et al, 2016; Schepaschenko et al, 2015. Furthermore, there is no exact data on the geographic extent of managed forest versus non-managed or primary forest areas (Kraxner et al, 2017).

Globally, the biomass trade (exports) growth has significantly slowed in this century. From 1984 to 2000, it grew by 41%, but only by 11% from 2000 to 2016 (FAOSTAT). However, the continuing growth is an indicator of the fact that some countries cannot meet their biomass demand by domestic supply. To what extent this trend will continue will also depend on future policy goals. For example, the move towards more ambitious climate mitigation under the Paris Agreement could imply an even larger reliance on biomass for decarbonisation (Rogelj et al, 2015; Luderer et al, 2013). To achieve the necessary emissions reduction by the end of this century, a ramping up of bioenergy production would need to be combined with carbon capture and storage (BECCS), the mitigation of aviation emissions through biofuels, and the substitution of other materials with forest biomass (e.g. in construction, textiles, chemicals) (Rockström, 2017). However, at the same time as this increasing demand, some of the traditional demand for industrial roundwood has been declining, especially for graphics paper production in many OECD regions (e.g. EU, North America, Japan). As a result, the EU production of industrial roundwood, for example, has increased only 4% from 2000 to 2016 (FAOSTAT), and has actually declined from the historical record of 382 million m^3 in 2007 to 355 million m^3 in 2016. Thus, the challenges of the different increasing demands for forest biomass are to some extent balanced by declining demand for some of the traditional products in Europe (Solberg et al, 2014). Moreover, Favero and Massetti (2014) show, using an integrated assessment model, coupled with a global dynamic forestry model, that trade in woody biomass for bioenergy can also help to achieve increasing demand. Building on this methodology, Favero and Mendelsohn (2017) estimate an increase in the world demand for woody biomass from 3.7 to 5.2 billion m^3 per year. However, this would come with environmental and socio-economic tradeoffs e.g. increased pressure for deforestation and shrinking farmlands leading to a potential food security conflict.

3.1.4. Impacts on forests within Europe and globally

Mobilising more wood will represent an intensification of forest utilisation and could result in trade-offs with other forest functions (Verkerk et al, 2014). The extraction of logging residues and, especially, stumps could have adverse impacts on forest soil carbon stores and greenhouse gas emissions. Increased soil erosion, soil compaction, depletion of soil nutrient stocks and changes in nutrient cycling could impact future productivity and lead to loss of valuable habitats (Walmsley and Godbold, 2010; Achat et al, 2015). Indeed, there are concerns that the use of wood for wood production would involve trade-offs, notably with biodiversity (Peters et al, 2015) (see also section 3.3). To what extent these trade-offs would occur depends on how the forest biomass-based bioenergy is advanced, and what measures are taken to safeguard environmental sustainability.

With respect to sustainability, specific criteria and indicators for an ecologically, socially and economically sound forest management have been introduced to national and regional forest-related policies. The majority of these sets of criteria and indicators have been developed by pan-European institutions such as Forests Europe and the United Nations Economic Commission for Europe and the Food and Agriculture Organisation, along with the United Nations Forum on Forests and by forest certification schemes (see e.g. Rametsteiner and Simula, 2003; Linser and Wolfslehner, 2015). In view of developing a sustainable forest-based bioeconomy, these indicators possibly need to be updated (see section 4). The Sustainable Forest Biomass Network of the International Union of Forest Research Organizations (IUFRO) develops forest biomass harvesting guidelines to ensure sustainable management of forest sites, which helps to build social support for the bioeconomy. Such guidelines would also help to define criteria by which potential biomass availability – assessed through inventories – can be reduced to that which is environmentally sustainable.

Box 6: Sustainability safeguards

In order to strengthen sustainability safeguards, some of the latest achievements are high spatial resolution maps of sustainable forest management that allow for corrective online feedback by involving citizen science technology. The land use mapping and open-access visualisation tool Geo-Wiki[2] hosts an interactive global map of certified forests at a 1km-resolution (Kraxner et al, 2017). This online tool can support the identification of forest-based feedstock and other harvested wood products (HWP) of sustainable origin within a country or a region, while creating improved and corrected hybrid maps in the background, based on the user feedback (Fig. 5).

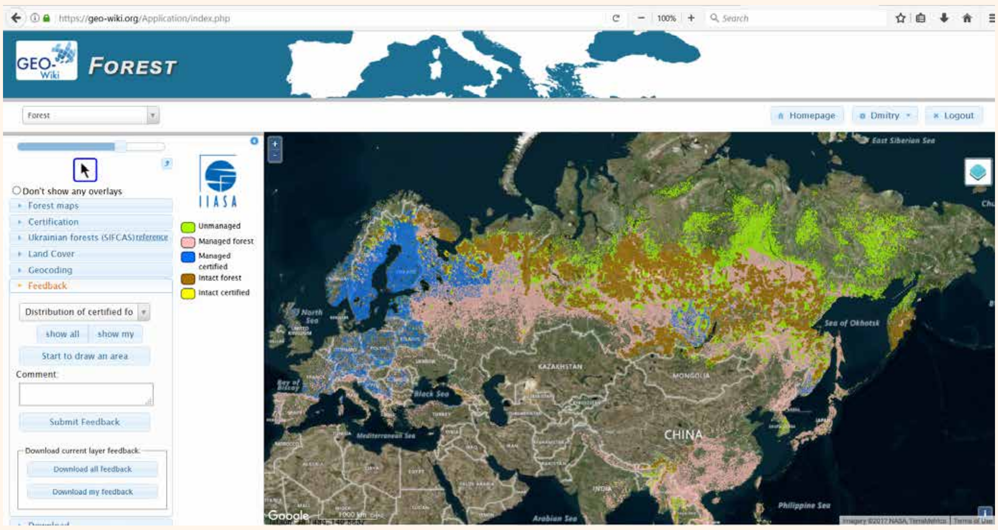

Figure 5. Global map of certified forests. Eurasia-snapshot from Geo-Wiki, Forest Branch[3]. Colour key: green = unmanaged forest; pink = managed forest; blue = managed and certified forest; brown = intact forest; yellow = intact and certified forest. The left part of the screen shot shows the interaction panel including the feedback options. Source: modified after Geo-Wiki (2017) and Kraxner et al (2017).

2 Geo-Wiki is a platform that provides citizens with the means to engage in environmental monitoring of the Earth by providing feedback on existing spatial information overlaid on satellite imagery or by contributing entirely new data. Data can be input via the traditional desktop platform or mobile devices. Resulting data is available without restriction (www.geo-wiki.org).

3 For instructions on how to use the Geo-Wiki tool and how to provide feedback in order to improve the global certification map, please see: https://geo-wiki.org/archive/manual/feedback_forest_certification.pdf.

3.1.5. Conclusions and policy recommendations

The limited biomass availability – with respect to their goals to develop a bioeconomy – in some European countries such as Germany and the United Kingdom, implies that they already have to import biomass to meet their demand. Further growth in demand, e.g. to meet ambitious renewable energy targets, could intensify this situation. However, the declining demand for some traditional forest products, such as graphics paper, balances the situation, and the *net* increase is lower. Hence, for policymakers, the situation implies the need to pay special attention to the environmental sustainability of imported and domestic biomass resources. Yet, by 2016, the European region was a net exporter of both roundwood and fuel wood, meeting the demand from domestic forest biomass resources, and imports from outside Europe only playing a minor role. Nevertheless, there is a clear need to frequently update information and research on the assessment of the European forest biomass supply and demand outlook.

After all, it is important for Europe to be part of the global community seeking to strengthen efforts to implement international sustainable forest management certification. It is most important in the tropics, the entire southern hemisphere and vast areas of northern-hemisphere-Asia (i.e. Siberia) to avoid indirect land use change and adverse environmental consequences (Havlik et al, 2011; Frank et al, 2013; Kraxner et al, 2017). This should be accompanied by supporting international programmes such as Reducing Emissions through Avoiding Deforestation and Degradation (REDD+) and restoration activities under The Bonn Challenge (IUCN, 2011). Successfully implementing these programmes will be part of a solution to meet the future biomass needs of an environmentally sound global bioeconomy – together with global trade of sustainable biomass and accompanying measures such as adequate policies for forest monitoring and (forest) law enforcement with special emphasis on the countries with highest biomass productivity.

Take home messages

- Expert calculations say that by 2035 about 8 billion m^3 of forest biomass will be needed for the global bioenergy sector annually – potential estimates indicate a global availability between 3–43 billion m^3 annually.
- Globally approximately 57% of forest biomass is growing in managed forests with the highest biomass availability in tropical forests.
- European forests currently supply approximately 407 million m^3 per year. Most wood is available and harvested in easily accessible areas with productive tree species – particularly in central Europe and the southern parts of Sweden and Finland, as well as in the Baltic countries.
- Existing studies suggest it is possible to significantly increase the availability of forest biomass beyond the current level of wood use in Europe. However, mobilising this potential would imply significant changes in the current management in many European countries.
- A key issue in mobilising the potentially available wood is whether private forest owners can be incentivised to bring their wood to the market.
- Intensification of forest use could result in adverse impacts on forest soil functions, and as such, impact future productivity and lead to loss of valuable habitats.
- It is unclear to what extent there will be increased wood production in Europe in the future, due to the opposing demand trends. There is no recent and systematic demand assessment available. Indeed, there is a need for a new assessment of the European forest biomass supply and demand outlook.
- If there is to be a significant increase of future forest biomass supply in Europe, it is important to pay attention and implement policy measures to safeguard environmental sustainability along with the increasing production.
- Future forest biomass availability is likely to be affected by climate change. Productivity may increase in the northern part of Europe and is likely to decrease in southern and eastern parts of Europe due to e.g. increased water stress.
- Global biomass trade can also help to meet the future demand, although currently Europe is a net exporter of forest biomass. For example, strongly increasing European demand in forest biomass-based bioenergy could lead to increasing imports to Europe.
- There is a need to search for synergies and decrease trade-offs between increased wood production and other forest ecosystem services in Europe, and globally. That means, for example, that domestic protection of biodiversity cannot come at the risk of higher biodiversity loss outside Europe.
- New and transparent online tools can help identify forest biomass from sustainable origins and in that way promote and support sustainable biomass availability and trade.

Policy recommendations

- The Paris Agreement implies a large reliance on biomass for decarbonisation, e.g. through BECCS and substitution of fossil materials in construction, textiles, chemicals, etc. In order to avoid negative environmental and socio-economic tradeoffs from increased biomass demand, appropriate policies for biomass production, harvesting, trade and use need to be put in place.
- Environmental safeguards need to penetrate related policies to ensure sound development of Europe's bioeconomy.
- In view of developing a sustainable forest-based bioeconomy, attention needs to be paid to updating sustainability criteria and indicators and to the development of forest biomass harvesting guidelines, to help build social support for the bioeconomy.
- European policymakers are encouraged to strengthen efforts in implementing sustainable forest management certification internationally with special emphasis on the southern hemisphere and Asia to avoid indirect land use change and adverse environmental consequences.
- International programmes such as REDD+ and the Bonn Challenge need to be strongly supported by European policies to ensure that the future biomass needs of an environmentally sound global bioeconomy are met.
- Global trade in sustainable biomass needs to be supported and accompanied by adequate policies for forest monitoring and law enforcement.
- Climate change-caused forest threats require urgent counteractions through a broad portfolio of managerial, silvicultural and technical measures to increase forest landscape resilience.

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3.2

How does the forest-based bioeconomy impact forest biodiversity?

Jürgen Bauhus, Jari Kouki, Yoan Paillet, Thomas Asbeck, Marco Marchetti

3.2.1. Introduction

Forestry, as the first stage of most forest-based bioeconomy value chains, has always produced biomass that has been used by society in many different ways. More recently, the mitigation of climate change through the replacement of fossil fuels and energy-intensive materials with renewable woody biomass, timber, and new biomaterials made from wood and bark has become an important focus. The manipulation of forest structure and composition for the production of biomass can alter forest ecosystems and the habitats of forest-dwelling species and can thus have a considerable negative impact on biodiversity[4], in particular if it leads to an intensification of biomass removal. Therefore, these forestry activities are the focus of this chapter. Other activities that may also be regarded as elements of a forest-based bioeconomy, such as the collection of non-timber forest products, hunting, or the use of forested landscapes for nature-based tourism, will not be covered here. By helping to mitigate climate change, which is a major threat to many species and ecosystems, the forest-based bioeconomy can also benefit biodiversity. However, this indirect effect of the bioeconomy on biodiversity has not been quantified and will therefore not be discussed here (but see section 3.3).

The influence of forest management on biodiversity has been debated and researched intensively for many decades. As a result, we have now a much better, though still rather incomplete, understanding of the influence of forestry activities on biodiversity.

Forestry practices have been improved and changed considerably to reduce this impact and to conserve biodiversity in production forests, subsequently called "forest available for wood supply" (FAWS). The removal of woody biomass through harvesting affects biodiversity in several ways. Most importantly harvesting leads to a decline in those forest structures and habitats that are typical for unmanaged forests (e.g. old large trees, large

4 According to the convention on Biological Diversity (CBD) "Biodiversity" refers to all the variety of life that can be found on Earth (plants, animals, fungi and micro-organisms) as well as to the communities that they form and the habitats in which they live.

Box 7: Selected biodiversity-related indicators for Europe's forests (Forest Europe, 2015)

- The area of forests and their growing stock continue to increase since 1990
- Atmospheric deposition of nitrogen continues to be high
- 30% of forests consist of only one tree species (mostly conifers)
- 87% of forests are classified as semi-natural, ca. 12% are protected with the main objective of conserving biodiversity, 1.5% are strictly protected with no management interventions
- Tree species that are considered invasive currently occupy 0.5% of Europe's forests
- The mature phase of forests (> 90% of the recommended rotation ages) contributes to 13% of the forest area
- The amount of dead wood per ha increased slightly in most regions but is still significantly lower than in natural forests
- Landscapes with highly connected forests were either stable or decreased in most countries. Landscapes with poorly connected woodlands represent over 60% of the EU territory

quantities of dead wood) and a decrease in the number of red-listed[5], forest-dwelling species (Stokland et al, 2012). Many species that have the highest threat levels depend on completely unmanaged forests because they require specific habitats or resources that are hard to maintain in intensively managed areas. Yet, in practically all European countries, networks of protected areas are unlikely to maintain forest biodiversity alone given their limited size and share of the landscape. Thus, managed forests and the intensity of their use are critical for biodiversity conservation in the European context.

The majority of forest-dwelling species can also maintain viable populations in managed forests, assuming current levels of management and harvest intensity. This comprises thousands of species associated with dead wood or mature forests. They thrive in the biomass fractions that remain in the forests during harvests or that can maintain their populations as long as there are relatively mature, closed-canopy forests in the landscape. These currently mid-abundant species are likely at risk if the intensity of biomass harvest increases substantially. Whereas rare species seldom have a major influence on functional aspects of forest ecosystems – due to their numerical scarcity – mid-abundant (or subordinate) species may play major roles for key functional processes, such as decomposition of soil organic matter and cycling of energy, carbon and nutrients. However, while theoretical considerations support this statement, there are no verified cases of significant impairment of ecosystem processes through a loss of mid-abundant species from European forests (Mori et al, 2017), possibly because these mid-abundant species have so far been able to maintain their viable populations. While we apply a functional perspective here, we acknowledge that all species have a value per se.

Here we will address the question how the growth of the bioeconomy might affect the balance between risks and opportunities for biodiversity conservation. We therefore focus on the influence on biodiversity of those changes in European forestry and land use that may be driven by the bioeconomy. These comprise:

5 "Red-listed" refers to those forest-dwelling species that are under a threat of becoming extinct. Assessment of red-listed species is usually done at a national level. A species can be under threat due to its declining population trend, small population size, or restricted or diminishing geographical range. Red-listing includes several levels of threat (such as critically endangered or vulnerable), depending on how the quantitative criteria are met for each assessed species.

- Changes in management systems to increase biomass removals from existing forest resources:
  - Shortening of production cycle lengths.
  - Systematic use or clearing of successional forests that have developed in recent decades on abandoned farmland.
  - Changes in tree species composition to provide woody biomass with specific properties for specific production chains.
  - Increasing biomass harvestings from forests that are already used for production purposes (e.g. wood mobilisation and removal of residues such as branches, stumps, etc.).
- The expansion of the forest resource through:
  - Conversion of agricultural land to short-rotation coppice systems, or afforestation of plantations and other types of forest.
  - Conversion of peatlands to forests.

3.2.2. Possible influences of bioeconomy production systems on biodiversity

Change in management systems

Around 25% of forest-dwelling species depend on dead wood and senescent trees for at least a part of their lifecycle. This encompasses a wide variety of organisms including insects, fungi, bryophytes, birds and bats (Stokland et al, 2012). Large amounts of dead wood and senescent trees, as well as tree cavities, are typical of mature and over-mature stages of forest development and are typically found in higher quantities and qualities in unmanaged forests. Conversely, forest management tends to truncate successional forest development cycles and to eliminate such elements. Shorter rotation lengths are likely to have the same – amplified – impact on forest biodiversity. For example, younger oak stands in French forests displayed less dead wood-dependent beetle species and a different species composition when compared to older stands. A higher diversity of this species group was found in older, over-mature stands where structural heterogeneity was also high. The importance of forest age as a key parameter for the occurrence and abundance of species has been confirmed for several taxa including birds, lichens and invertebrates. This is not to say that only old, closed-canopy forests are optimal for forest biodiversity. All successional stages with their typical communities of plants, animals and microflora should be represented in the landscape.

In many European regions, current landscapes are very different from historical ones. Frequently, the growing stock in forests has increased over recent decades and forests are much denser now than in the past. Traditional land use forms that provided for gradual transitions between agricultural land and forests (e.g. grazed forests, silvopastoral systems, trees outside forests etc.) are disappearing and with them the species that were dependent on them. Extensive agricultural practices have been replaced by more intensive systems, and marginal agricultural land has been reclaimed by forests, in particular in southern and eastern Europe (Angelstam et al, 2013). In these regions, more intensive harvesting to maintain open forests in some places and an overall mosaic of land uses might be beneficial for many threatened species.

Increasing use of mechanised harvesting may cause damage to forest soils through compaction and disturbance, which in turn may modify vegetation composition and affect soil biota. However, the effect of mechanisation on biodiversity in general may be manifold and remains poorly understood. In many jurisdictions within Europe, harvesting machines are restricted to the extraction system (forest roads and skid tracks) to avoid soil damage in the rest of forest stands, spatially confining any negative effects. However, where machines are not confined to skid tracks, e.g. where they operate on frozen ground, they may damage or destroy significant amounts of dead wood logs. In this case, intensive mechanisation of harvests may considerably affect some key measures taken to maintain forest biodiversity.

Finally, the use of fertilisers in forest ecosystems is currently not widespread. However, replacement of nutrients that have been removed with biomass may become more common in intensively managed forests, notably through the use of sewage sludge, wood ash or lime. The impact of fertilisers highly depends on the type and quantity applied. Those containing nitrogen may lead to further eutrophication of forests, which is already a key threat to species richness of vascular plants over large parts of Europe, because a large proportion of threatened species are associated with nutrient-poor habitats. Application of lime or wood ash to reduce soil acidification may also affect plants that are restricted to acidic soils.

Change in tree species composition

Above and below ground biodiversity, as well as many primary consumers, symbionts, parasites and pathogens, have a more or less strict preference for certain tree species. Through specific trophic interactions in ecological networks, this species preference has cascading effects on the level of secondary consumers and so on. This does not mean that a partial or complete change in tree species composition reduces biodiversity. For example, adding individuals or tree groups of an exotic species such as Douglas fir to a stand with a matrix of native species such as European beech provides additional habitat niches (e.g. smooth bark v rough bark, leaves v needles). The main question is to what extent a matrix of native species can be diluted, at the stand or landscape level, before negative impacts occur for populations of native species. In the case of mixtures of European beech with widely spaced Douglas fir, the specific broad-leaved tree-related fauna can be maintained. However, where most or all native tree species are being replaced, populations of native species that are dependent on these will also be impacted or even lost. The greatest negative impact on forest biodiversity has been observed in forest systems where native forests have been replaced by plantations of non-native tree species (Paillet et al, 2010). However, a growing forest-based bioeconomy might also lead to an increased use of native species, if new product chains with valuable products provide incentives to landholders to cultivate these species. Currently, in central Europe, there is an economic disincentive for forest owners to replace secondary conifer forest in Europe with native broadleaved or mixed forests. In most cases, it is more profitable to cultivate the conifers that typically produce a higher wood volume over a shorter time span and fetch a higher average product price than comparable native broadleaved species. Hence, the development of new, more valuable products from native tree species may promote biodiversity and also facilitate the adaptation of forests to climate change.

Increasing removal of conventional and residual biomass

There appear to be many countries in Europe where harvest levels are well below current wood increment and where more intensive forest use might be possible (Fig 7, see also Fig 2 in Section 3.1). However, from the perspective of biodiversity conservation, deriving a harvesting potential from the current forest net growth is not straightforward. For example, most net growth may occur in young and middle-aged forests, whereas harvests take place in mature forests, where impacts on old-growth-associated species are larger. A comparison of unmanaged and managed forests that were conventionally harvested (mostly stem wood) has shown that species richness in a range of taxonomic groups (e.g. dead wood-dependent species) is typically negatively affected, although it can increase in other groups (e.g. vascular plants) (Paillet et al, 2010). The increasing demand for wood for energy has led to the additional harvesting of residues (harvesting slash and stumps) or whole trees. Removal of branch material affects the deadwood-dependent species that have specialised on this small diameter substrate. The piling of residues for drying purpose in the field may also create traps for early colonisers when the material is extracted. Following harvesting, stumps represent an important dead wood source, in particular after clear-felling when there may be little large-diameter dead wood left. The species assemblage in stumps can be rich and contain many specialist species. Stumps are therefore a key habitat to buffer the effects of above-ground biomass removal on dead-wood-dependent species. In addition, branch residues and stumps also constitute a habitat for many species that do not feed on the wood and they are important for the recycling of nutrients and maintenance of soil structure. Hence their removal is likely to have negative effects on biodiversity and ecosystem functioning and should thus be confined to fertile sites with low conservation values (Bouget et al, 2012).

Short-rotation coppice systems

Short rotation coppice (SRC) represents a more specialised and intense practice dedicated mainly to producing biomass for energy purposes. SRCs are characterised by management practices (soil preparation, weed control, planting, fertilisation, harvest, etc.) that are similar to those used in agriculture. The species currently used in commercial SRC plantations in Europe are fast-growing species with good coppicing ability that achieve high biomass yields, such as willows (*Salix sp.*), poplars (*Populus sp.*), *Eucalyptus sp.*, black locust (*Robinia pseudoacacia*). Establishment and use of SRC has both positive and negative effects on the biodiversity of the initial ecosystem. These depend largely on the landscape context and on the land-use system that is being replaced. If SRC are established on former arable land or intensively managed grasslands, the effects on biodiversity could be mostly positive. If they are established on extensively managed grasslands, the effects are predominantly negative. Regarding above-ground biodiversity, the number of plant species increases initially for the first two or three years after the establishment and slowly decreases with the age of the SRC owing to the increasing shade near the ground. In poorly structured landscapes, SRC also harbour many animal species, e.g. invertebrates and birds, which would otherwise not find suitable habitat. These benefits typically increase where the SRC are connected to remnant forests. Other management practices such as rotation length, application of herbicides and fertiliser can also influence their biodiversity (see Dimitriou et al (2011) for a coverage of environmental effects of short rotation coppice systems).

Conversion of peatlands to forests

A growing forest-based bioeconomy may also initiate processes where land use and cover are permanently changed to increase the supply of wood-based products and materials. For example, the conversion of peatlands to forests is technically feasible, in many cases, through draining. While such measures may increase the cover of forests, they almost always have a concurrent detrimental effect on the biodiversity of the original habitat, with possible detrimental side-effects on greenhouse gas emissions and adjacent ecosystems. Also, the emerging forests are probably different from the corresponding natural forests. In northern Europe, and in Finland in particular, draining peatlands for forestry purposes has been widely practised. The side effect has been that several peatland habitats and their biodiversity are currently under serious threat (Janssen et al, 2016). Additionally, large areas, estimated to be around 0.5–1 million hectares in Finland, which were initially drained have proven to be unsuitable for timber production but yet have lost their natural characteristics. Thus, further conversion of peatlands to forests may have serious negative impacts on biodiversity. Discontinuation of drainage and restoration of peatlands, including those currently used for agriculture, may be employed to reverse these negative effects of land-use change.

3.2.3. Options to mitigate the influence of biomass harvesting on biodiversity

Spatial segregation of forest management intensities

The information presented above indicates that intensively managed forests that are characterised by a simple structure (even-aged and mono-specific), non-native tree species, a high level of external inputs such as fertiliser or energy, frequent disturbances through harvesting and site preparation are the worst option for the conservation of native biodiversity. However, the opposite may actually be true: if these intensively managed and highly productive forests are confined to a small proportion of the landscape, the management intensity in the remaining semi-natural non-reserved forests can be reduced, for example to retain more habitat trees or deadwood, and more forest area can be set aside for conservation without necessarily reducing the overall harvest levels (Côté et al, 2010). Hence, a higher level of biodiversity could be maintained over a large area. Unfortunately, in Europe we have no results from landscape-level experiments that could confirm this theoretical landscape management model. Also, we do not know which model would have a higher impact on biodiversity: further intensifying management in already intensively managed forests, or intensifying it in forests where the current level of management intensity is quite low. In other words, we do not know the shape of the relationship between forest use intensity and the impact on biodiversity at the stand or landscape scale (Fig 6).

Retention forestry

In practical forest management, the negative effects of an intensive use of forests on biodiversity may be alleviated with measures that aim at maintaining sufficient levels of key structural forest elements that are of importance to biodiversity. In the so-called retention forestry approach, some structures and features such as old trees, unusual tree species, dead wood and special habitats are retained at the time of harvest and kept in the long term (Gustafsson et al, 2012). While the approach was originally associated with clearcutting practices in northern Europe, it is increasingly also applied in selectively managed forests in other regions. Key sustainability indicators across Europe that can be linked to this approach include the amount of dead wood, the occurrence of old trees, and a native tree species composition. Whereas the general effectiveness of the retention approach has been well documented, the specific levels of structural elements to be retained and their optimal spatial pattern are far from clear. More research is needed to evaluate retention thresholds for different taxonomic groups in different forest types.

3.2.4. The potential for intensive forest management in Europe

Current forest harvesting – measured as the proportion of annual increment that is harvested – represents about 66% across Europe but with remarkable variation (40–80%) (Fig. 7). Although this harvesting ratio is probably not an accurate indicator of what is

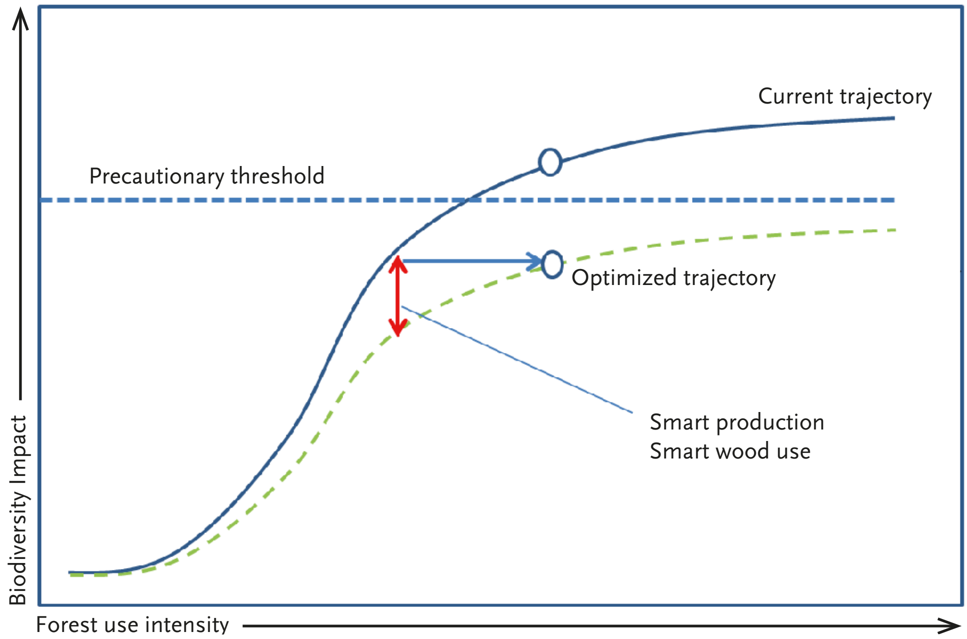

Figure 6. Hypothetical relationship between forest use intensity and its influence on biodiversity. At high level of forest use intensity, characterised by high removals of biomass, substantial cultivation of non-native tree species, use of fertilisers etc., the impact may exceed a threshold that defines undesirable effects such as loss of species, weakening of populations, or reduction in ecosystem functions. To avoid crossing this threshold, alternative, smart forms of forest management may be employed. This may include, for example, the use of mixed-species forests to increase the productivity of stands, or the intensification in selected parts of the landscape to facilitate a higher level of habitat retention in the forest matrix. Using the wood resource more efficiently may also contribute to reducing the biomass removal or the area that is affected by harvesting.

happening with regards to forest biodiversity, it nevertheless indicates the overall pressure that a forest-based bioeconomy imposes on forest ecosystems. For example, the harvesting ratio is neither related to the average amount of dead wood, a key component for forest biodiversity and indicator of forest naturalness, nor to forest age (Fig. 7).

Recent analyses of biomass production potentials in European forests have suggested that there are theoretical opportunities to increase biomass production from the current levels (Verkerk et al, 2011). However, the scenarios indicated that taking technical, environmental and social aspects into consideration – including 5% of forest area to be set aside for biodiversity conservation purposes – reduces the theoretical potential supply in 2030 considerably (by 50%) while still remaining above the current harvest levels for the EU. This indicates that strong intensification of biomass extraction from forests is likely to be in conflict with high environmental standards for forest management. However, different European countries are in different positions, as indicated by high variability across countries between the current and theoretical maximum in the intensities of forest use (see Section 3.1). Further increases in harvesting intensity in countries where the level is already very high may be more critical than in countries where current intensity is low and where increased harvesting may help to maintain desired landscape conditions. In any case, it is evident that the goal to conserve forest biodiversity may substantially reduce theoretical harvesting potentials. This does not take into account, however, the possibly enormous and still largely untapped potential to increase biomass production with biodiversity benefits through afforestation of agricultural land, in particular in areas where agricultural use has been abandoned.

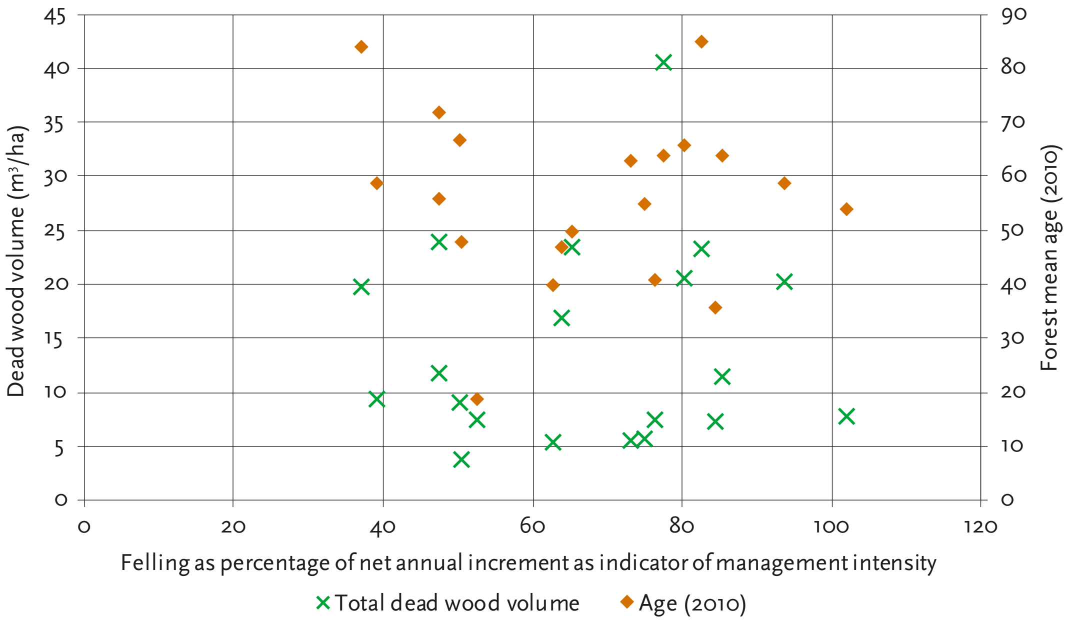

Figure 7. Relationship between harvesting ratio, the removed proportion of the net annual increment, versus average amounts of dead wood and stand age in forests of 20 European countries (data from State of Europe's Forests 2015). Dead wood and stand age are important determinants of forest biodiversity. The lack of a clear relationship between these variables indicates that the current harvest ratio is not directly related to dead wood amounts or the average forest age. Historical factors as well as other key forest characteristics – such as the current forest age class distribution – likely play an important role in shaping this relationship. Obviously, the potential to increase biomass removals is most likely for countries that have a low harvesting ratio and high stand age but there is an urgent need to verify how the intensification may influence forest biodiversity.

Take home messages:

- High levels of biomass removals can alter the composition of communities of forest-dwelling species and may also lead to the loss of certain species. Particularly sensitive and well documented cases are those species that directly depend on dead wood for parts of their lifecycle. However, so far there is no evidence that these changes have also impaired the functioning of forest ecosystems, e.g. regarding decomposition, nutrient cycling, pest control etc., where forest cover and native tree species composition have been maintained.
- Other taxonomic groups and species benefit from more frequent or more intensive disturbance of forests associated with harvesting.
- The different response patterns of species to a gradient in forest use intensity suggests that a variety of management intensities could be applied at the landscape scale, including strict reserves.
- An important challenge for a sustainable forest-based bioeconomy is to match forest types and individual forest patches with potentially sustainable forest use intensities. This task is complex because: a) we often do not know the shape of the relationship between forest use intensity and its impact on biodiversity (Fig. 6), b) the effectiveness of compensatory measures such as the retention of habitat trees or dead wood has not been quantified in such a way that necessary thresholds are established, and c) the influence of the landscape matrix is unclear.
- It is essential to observe that bioeconomy is based on biodiversity since biodiversity is the basis for the goods and services that forests may provide. Thus, in general terms, the choice is not between biodiversity and bioeconomy but rather on developing principles of a bioeconomy that also maintain biodiversity.

Policy recommendations

- Managed forests with high conservation value (e.g. Natura 2000 areas, ancient forests, biodiversity hot spots) should be least considered for more intensive biomass harvesting.
- More intensive biomass harvesting should be applied where it benefits biodiversity, for example through maintenance of traditionally open forests or open landscapes, e.g. intensive management of successional forests on former agricultural land.
- Land use changes to expand the forest resource should not target peatlands or grassland with high conservation value.
- Where biomass is required for energy, dedicated systems such as short rotation coppice, which may add to biodiversity at the landscape level, are to be preferred over the harvesting of forest residues (branches and stumps).
- The development of new, valuable products from forest biomass should focus on native tree species to promote their future cultivation.
- To enable the development of a sustainable bioeconomy, "biodiversity-smart" forest production systems need to be elaborated, which either reduce the current impact on biodiversity or facilitate intensification without further increasing the impact (Fig. 6).
- There is a need to include scientifically based biodiversity policy, including measurable actions and targets, into the further development of the bioeconomy. European countries have widely different initial situations affecting how they might address the bioeconomy and biodiversity. However, national policies should be connected to a larger European perspective that takes into account large-scale regional aspects of biodiversity maintenance.
- Given the advancement of a forest-based bioeconomy, there is an increasing need to find policy measures that promote synergies and reduce trade-offs between bioeconomy and biodiversity. It is not at all self-evident that the bioeconomy is good for biodiversity and that all its effects are positive in this respect. Rather, it is evident that well-justified and relevant policy measures are urgently needed to guide the development of a bioeconomy that maintains biodiversity for future generations.

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3.3

How can a forest-based bioeconomy contribute to climate change adaptation and mitigation?

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3.3.1. Introduction

Climate change, including extreme events and associated increasing forest disturbances, is already affecting the growth and stability of forests in Europe and constitutes a major challenge for future forest management. In addition to impact on resources, the changing climate could have severe consequences for forest ecosystem services and the forest sector as a whole. Rapid environmental change and increased climate variability imply that traditional management experience is no longer sufficient to guide future management practices. As long-lived ecosystems, forests need to adapt to climate change, because trees regenerated today will experience significantly different conditions in the future than in the past. Even if global warming can be limited to below two degrees by implementing the Paris agreement of December 2015 through ambitious international policy and drastic technological and behavioural changes, it is unavoidable that changes in climate features, such as more frequent and intensified droughts and changed disturbance regimes, will impact on species suitability and silvicultural choices. Evidence shows that already now, with average temperatures about one degree above pre-industrial levels, there have been noticeable changes in the vitality and productivity of species close to their distribution limits. Moreover, increases in insect, storm and fire damage can at least partly be attributed to climate change.

Forests are not only affected by climate change; because of their important role in global biogeochemical cycles, forests and the way forests are managed and used influences how strongly the global climate is changing. Forest ecosystems and wood products are currently sequestering approximately 13% of the anthropogenic greenhouse gas emissions in the EU, thereby mitigating climate change. Thus, forests are not only part of the climate change problem; they can also be part of the solution through a number of mitigation strategies that will be described in the next section. Reaching the Paris 2015 targets could require negative emissions, which are possible to achieve with forest-based climate change mitigation measures and carbon capture technology (Gasser et al, 2015; Tokimatsu et al, 2017).

3.3.2. Climate change mitigation strategies

3.3.2.1. Four levers of mitigation strategies

Internationally, the most important forest-related climate change mitigation strategy is **conservation management**. Deforestation is a major contributor to global greenhouse gas emissions and significant efforts, particularly in tropical countries, are directed to reducing emissions from deforestation and forest degradation (REDD+ policy). Efforts directed at forest conservation in tropical countries have rarely been successful, especially where they focus mainly on conserving high biomass stocks in primary forests. The economic interest in generating income from land and the overall shortage of natural resources to supply an increasing world population implies that forest conservation policies are often in conflict with other sectoral policies and market forces. Land conversion to industrial cash crops (e.g. palm oil) or mining are incompatible with sustainable forest management and a forest-based bioeconomy as the cleared land is rarely reverted into forest, at least not in the short term. On the other hand, sustainable forest management has the potential to decrease forest degradation, thereby feeding a forest-based bioeconomy.

The second mitigation strategy consists of **sequestration management** with the focus on **sequestering carbon in forests**. Secondary forests, as well as intensively managed forests, have low average growing stocks and when such forests are allowed to replenish previously depleted carbon stocks, they remove carbon dioxide from the atmosphere. European forests are in the process of recovering from past exploitations and large-scale fellings following the second world war and harvest rates have been significantly lower than increments for several decades. In addition, the forest area has increased through active afforestation and natural succession on abandoned lands no longer used for agriculture. Consequently, carbon has accumulated in both forest biomass and forest soils. The sequestration of carbon in forests can be increased through a reduction of harvest removals, with the largest short-term effects created through forest protection: letting forest stands mature and return to a more natural state with large carbon stocks in the ecosystem. Sequestration of carbon in forests occurs at a lower rate when management continues with reduced intensity, resulting in prolonged rotation length and increasing average age in the managed forest. However, as disturbance risks increase with age, height and volume of forest stands, carbon sinks resulting from decreased utilisation are not permanent and can, for example in the case of large-scale storm damage or forest fires, relatively quickly turn into carbon sources (e.g. Lindroth et al, 2009). A second trade-off of forest protection and reduced harvest intensity is the locally reduced biomass supply to society, which also means less feedstock for the bioeconomy. Another option to enhance the sequestration of carbon in forest biomass that avoids this trade-off is to increase the sequestration rate of forests through increased productivity, for example through selection of faster growing genotypes or species, fertilisation and other means of site improvement (Rytter et al, 2016).

A third strategy focuses on **increasing carbon storage in wood products**; another mitigation strategy that can support the bioeconomy development. Life spans of wood products can vary from zero to one year in the case of direct energy conversion, one to four years for paper products, a few decades for wood-based panels, and more than 100 years in durable wood construction. Promising opportunities to expand wood product carbon sequestration include the development of innovative wood products with long lifespan such as cross-laminated timber products that are increasingly used in the construction sector (Tollefson, 2017). Bio-textiles produced from dissolved pulp are another example of products with a longer average lifetime compared to traditional paper products. The cascading use of biomass, where discarded wood products are recycled and converted into another product, is another option to extend the lifespan of wood fibres, delaying the point in time when the carbon contained in these products is released back into the atmosphere, either through decomposition or, better, through its use for energy generation (Keegan et al, 2013).

The fourth climate change mitigation lever based on forests and their use is **substitution management**: when wood products or forest bioenergy substitute for fossil fuels and fossil fuel-intensive materials, such as concrete, steel or plastics, greenhouse gas emissions can be reduced in other sectors. A meta-analysis carried out by Sathre and O'Connor (2010) quantified displacement factors of wood product substitution. The displacement factor quantifies the amount of emission reduction achieved per unit of wood use. In most cases emissions of the competing materials are significantly higher. On average, Sathre and O'Connor found that using a ton of wood products instead of cement results in GHG emission reductions of 2.1 t C. Sathre and O'Connor and more recent studies indicate that the substitution effect is strongly case dependent and that, with increasing contribution of other renewable energy sources, the fossil fuel substitution effect generally declines (Rüter et al, 2016).

The costs of different climate change mitigation strategies in the forestry sector can vary substantially. In certain situations, costs can be even negative as benefits can outweigh costs, for example in the case of selecting more productive genetic plant material in regeneration. On the other hand, potential measures can also be extraordinarily expensive, effectively preventing the uptake of the measure. A recent comprehensive study for the Canadian forest sector (Lemprière et al, 2017) indicated that average mitigation costs varied from -7 Canadian $ per ton of CO_2 for an improved wood utilisation strategy, to 70 and 72 Canadian $ per ton of CO_2 for a longer-lived forest products strategy and improved site preparation and planting, respectively. The costs showed huge spatial variability as well. For example, while reduced harvesting had an average cost of 43 Canadian $ per ton of CO_2, the values in different spatial units ranged from 4 to 884 $ (Lemprière et al, 2017). The study underlined that such economic analysis should use cost curves associated with various quantities of emission reductions and that strategy portfolios should be compared for different time horizons. A one-size-fits all approach does not yield optimal results. Recent studies in Germany also estimated the costs of climate change mitigation scenarios (Bösch et al, 2017; Wissenschaftlicher Beirat Agrarpolitik Ernährung und gesundheitlicher Verbraucherschutz und Wissenschaftlicher Beirat Waldpolitik beim BMEL, 2016). The latter study included an increased use of introduced coniferous species in the most ambitious mitigation strategy, which would likely provoke resistance from societal interest groups and could also increase the risk of natural hazards. These studies illustrate the importance of scenario assumptions and the methodological choices for the cost assessment. Such economic evaluations of alternative mitigation strategies are therefore difficult to generalise and need to be interpreted with caution.

3.3.2.2. Complementarity and trade-offs of mitigation strategies

The mitigation strategies focusing on enhanced carbon storage in wood products and the substitution of fossil fuels and energy-intensive materials require biomass removals, which in most cases will decrease the carbon sequestration in the forests – unless afforestation or management changes are applied which increase the available forest resources. In countries with substantial afforestation (such as Ireland) it is possible to combine the sequestration of carbon in forest ecosystems with a larger use of wood for various wood products and subsequent substitution of other more energy-intensive materials. The situation is different within an existing forest area. If management intensity is reduced with larger area of protected forests or increased tree retention, this comes with the direct trade-off of reduced biomass availability for the production of wood products and the generation of bioenergy, consequently reducing substitution potentials (or even generating the need to use more energy-intensive materials to substitute wood products). In line with this, and also from an economic point of view, the highest trade-offs occur between managing sequestration in forests in the form of increased retention and reduction of the harvesting potential and the increase of sequestration in wood products. An increase in the area of highly productive species (such as Douglas fir in Central Europe) may, on the other hand, have positive effects on carbon sequestration in forests simultaneously with enhanced economic output of forest management and material substitution. Enhanced carbon storage in HWP usually also generates material substitution effects. However, in the case of cascaded use of biomass instead of incineration of discarded wood products, the enhanced HWP sink may reduce energy substitution potentials. Wood material use and bioenergy result in different substitution pathways and these are sometimes in direct competition. On the other hand, as integrated value chains for material and energy use prevail in Europe, energy substitution can also be enhanced through stimulation of high-value wood product use, which increases the availability of residues for energy uses as a side effect.

Whereas cascade use and material substitution offer, in the long-term, larger mitigation potentials than sequestration in the ecosystem, there are situations where, in the short-term, fossil fuel emissions may even increase. Recognising such temporal dynamics is important and balancing short- and long-term impacts is perhaps the most challenging task in climate change mitigation through forest management measures. When different mitigation strategies are compared for a short time horizon, maximisation of carbon sinks in the forest seem to generate the largest reductions of emissions. However, these benefits are short-lived (two to three decades possibly), as forest carbon sinks saturate and mature stands become more vulnerable to natural disturbances. Moreover, without wood harvesting there are no wood products and other more energy-intensive materials need to substitute renewable wood products. Therefore, when comparing alternative resource use strategies, it is essential to apply a wide system boundary that includes not only the forests, but entire economic sectors, including the substitution effects outside of the Land Use Change and Forestry sector. It is also important to consider that drastically reducing harvest implies creating shortfalls in resources for the wood industry, with consequent negative economic and social impacts in rural areas with limited alternative economic activities. Trade-offs may also occur at the global scale if reduced wood use from European forests leads to larger imports from other world regions, which could trigger carbon leakage through indirect land use change and deforestation or degradation of currently carbon-rich tropical forest ecosystems (O'Brien and Bringezu, 2017).

3.3.3. Adapting to unavoidable climate change

A wide variety of adaptation strategies exist, including selection of suitable species or provenances that are well adapted to the changing climatic conditions (for example more drought tolerant), changes in forest regeneration techniques and management practices, disturbance risk mitigation and many more (cf Kolström et al, 2011). A specific challenge for adaptation to climate change in forest management is the very long planning horizon in forestry. Due to the long lifespan of trees, common management cycles in European forests range from 20–40 years in plantation forestry, 60–100 years in coniferous-dominated forest types, and up to 120–180 years in some broadleaved forest types. Once a forest stand is regenerated, for several decades there is only very limited flexibility to change its species composition – meaning that trees regenerated today will be exposed to potentially very different climatic conditions later this century. Consequently, the most important forest management decision is the selection of species and provenances in forest regeneration. Where close-to-nature forest management is practiced with natural regeneration, it is critical to evaluate if the existing forest genetic resources are also appropriate under changing climatic conditions. In the case of planting, there are more choices, but an important question remains over whether to select plants that are well adapted to the current or the expected future climatic conditions.

There will always be considerable uncertainty about the most likely climate change that will take place in the region (cf Lindner et al, 2014), but as this is strongly affected by future political and socio-economic developments, this uncertainty will remain in the future, even if climate science is going to strongly improve the reliability of scenario projections. One way of managing the uncertainty is to diversify adaptive management strategies at the district/landscape level. While some adaptation strategies can be combined at stand scale, certain choices cannot be avoided at stand level. However, different strategies can be selected in neighbouring stands to increase the diversity of forest types and management regimes at district level.

An important element in adaptive forest management strategies are measures aimed at improving the resilience of forest ecosystems to extreme weather events such as droughts, forest fires, storms and heavy snows. For example, managing mixed species stands instead of monocultures provides a fall-back option in case one species is failing. Generally, fostering genetic diversity is crucial to enhance the intrinsic adaptive capacity of forest ecosystems.

Active management usually facilitates adaptation to climate change, and there is a much more limited capacity to adapt if there is no economic incentive to manage the forests. In managed forests there are opportunities to affect species composition through harvesting and subsequent regeneration measures. These are considered common production costs and are covered through timber revenues. Increased mortality in unmanaged forests leads to an accumulation of dead wood, which is positive for forest biodiversity but also represents a substantial fire risk, especially in Mediterranean and Continental climates. Large public expenditure is needed to prevent the development of devastating wild fires that could destroy homes and threaten lives, besides also causing negative impacts on ecosystems such as enhanced soil erosion. Communities and state budgets often have to pay these costs without any support from timber sales. Adaptive forest management decisions strongly depend on the awareness of forest owners and forest managers of the impact of expected climate change and available response strategies. Therefore, it is critically important to communicate state-of-the-art scientific understanding on climate change to practice and to expand the capacity for mitigating climate related risks and decision-making under uncertainty.

3.3.4. Interactions between adaptation and mitigation

There are close interrelations between climate change adaptation and mitigation. Managing forests for mitigation necessitates adaptation to climate change. Sequestration management should be optimised with suitable species and provenances to ensure the highest possible level of productivity under climate change. Adaptive management strategies that minimise disturbance risks help to avoid associated emissions and protect carbon stocks in forests (Reyer et al, 2017). However, there could be trade-offs between proactive adaptation and mitigation as adaptation might imply a shift in species towards more drought tolerant species that are less productive. This may create short-term losses in productivity, motivated by less growth decline / mortality under the expected future dryer climate.

The costs of forced adaptation, where highly productive species may have to be replaced by slow-growing species due to the changing environmental conditions, could lead to high economic losses (Hanewinkel et al, 2013). From an economic point of view, there might be an opportunity to replace productive species from Europe with better climate-adapted species from other growth regions outside Europe that may then even contribute to mitigation. However, such non-native species are potentially harmful to native forest biodiversity. Furthermore, investments in tree breeding and the introduction of new species and genotypes in forest management require commitments that will only later return benefits compared to business as usual. Such adaptation costs can only be covered through incomes generated from mitigation measures to a limited extent. Biomass revenues from fuel wood reduction measures motivated by the mitigation of fire risks is one of the few examples of an economic contribution from mitigation management. However, just as with other early thinnings, the revenues are unlikely to cover the full costs. In the recovery following large disturbance events, economic and ecological impacts vary a lot case by case. For example, after storm damage, most biomass can be salvaged and marketed. Without soil exposure, major carbon releases can be avoided, unless damaged trees are left on site to decay. In the latter case, negative emission impacts are balanced by more positive ecological impacts as room is given to natural forest dynamics, leading to a diversification of forest structures and improved biodiversity.

3.3.5. Bioeconomy development affects climate change adaptation and mitigation

Forests provide renewable wood production besides many other valuable ecosystem services. Developing a forest-based bioeconomy with more intensive use of forest biomass can support climate change mitigation, especially if the mitigation focus is focused on the enhanced production of long-lived wood products, such as through wider use of wood construction, substituting the energy-intensive materials concrete and steel (Tollefson, 2017). In Europe, sustainable forest management has a strong tradition and, after several decades with increments substantially above fellings (although with considerable regional variation), growing stocks have increased in almost all European countries. Exceptions to this overall trend occurred temporarily under two circumstances: in the aftermath of major disturbances and as a consequence of socio-economic changes with large-scale forest restitution in Eastern Europe. Large-scale storms have, in several cases, blown down multiple times the regional annual harvest volumes (e.g. in Southwestern France and Southeast Sweden; (Gardiner et al, 2010; Lindroth et al, 2009). Following the collapse of the Soviet Union and other socialist regimes, restitution of forests created incentives for immediate clear cuts (Olofsson et al, 2011). As the forest carbon sink strength of European forests nears saturation (Nabuurs et al, 2013) – at least with the current level of forest resource utilisation, the climate change mitigation potential of forests should no longer rely only on carbon sequestration in the forest ecosystems, but should concern the whole value chain. Forest-based climate change mitigation should increasingly also use the management of carbon sinks in harvested wood products and substitution (Nabuurs et al, 2015). In this context, bioeconomy development can support mitigation by ensuring that forests are kept productive, sequestering carbon from the atmosphere, storing carbon in harvested wood products and creating substitution effects (Kurz et al, 2016).

As active management is also a prerequisite for high adaptive capacity, bioeconomy development will also support climate change adaptation. Through regular management it is easier to replace species which are increasingly maladapted under the changing climate. Several tree species with major economic importance are projected to be negatively affected by climate change. Norway spruce is particularly sensitive to climate change and is expected to decline in several regions. Bioeconomy developments need to recognise this threat to the most common European tree species and aim to also identify innovative uses for other species, which might expand their distribution in a changing climate. Particularly important would be a wider use of broadleaved species, which constitute the majority of underutilised biomass resources at present and might get even more abundant in the future. Another synergy lies in disturbance risk mitigation through biomass removals in fire-prone regions where enhanced biomass utilisation helps to avoid emissions from wild fires. The term Climate-Smart Forestry describes a management that tries to find such synergies with local issues to combine forest conservation, adaptation and productivity in regionally different ways (Nabuurs et al, 2015).

Take home messages:

- Climate change, including extreme events and associated increasing forest disturbances, is already affecting the growth and stability of forests in Europe and constitutes a major challenge for future forest management. Adaptation to climate change should not be delayed, because trees have long lifespans and will be exposed to changing climatic conditions over the next decades.
- Forests play a key role in global biogeochemical cycles and can mitigate climate change in different ways. In Europe, the most important mitigation options are carbon sequestration in forests, carbon storage in harvested wood products and substitution effects through enhanced use of wood products instead of more energy-intensive materials and the use of bioenergy to replace fossil fuels.
- Carbon sequestration in forests can be enhanced with reduced management interventions, but also through forest expansion (afforestation) and through various measures that stimulate forest productivity (e.g. improved genotypes and optimised management regimes).
- Enhanced carbon sequestration in harvested wood products and the substitution of more energy-intensive materials can go hand in hand, but are incompatible with large-scale forest protection to maximise sequestration in the forest in the same region.
- The most critical trade-off between bioeconomy development and climate change mitigation is a narrow mitigation strategy focusing on maximising forest carbon sinks through reduced management interventions, which cuts off the resource supply for the bioeconomy.
- Climate-Smart Forestry combines forest conservation, adaptation and productivity according to regional conditions.
- The largest overall mitigation effects in the mid- and long-term can be achieved through substitution effects supported by sustainably managed productive forests. These mitigation strategies can be supported through bioeconomy developments targeting increased use of forest products and bioenergy and they also benefit from adaptive forest management strategies.

Policy recommendations:

- Forest mitigation strategies differ strongly in their temporal effects. The strategies with largest short-term benefits are often less efficient in the long term. To balance existing trade-offs, a policy mix of different mitigation strategies is better than only one strategy.
- There is a potential trade-off between forest protection and bioeconomy developments. Whereas protection contributes to short-term climate change mitigation, it constrains the biomass resource basis for the bioeconomy, reduces the possibility for mitigation in a broader system perspective, taking harvested wood products and substitution into account, and limits mid- to long-term mitigation potentials.
- Careful spatial planning can minimise conflicts. Forest carbon sinks could be maximised in habitats of lower value for the bioeconomy and on sites with low disturbance risk and long-term mitigation potential. Forest expansion and increased productivity of managed forests could create opportunities for simultaneous sequestration in forests, harvested wood products and mitigation through substitution.
- Sinks in harvested wood products and substitution effects can benefit through bioeconomy developments such as expanding innovative wood product use in the construction sector.
- Mitigation strategies and associated policy incentives need to be evaluated, including their cross-sectoral effects such as sustaining rural economies and offering employment in disadvantaged regions, while also considering their long term and global consequences.
- The mitigation potential of bioenergy is generally less efficient than expanded material use of biomass, but decision-making needs to consider local circumstances. In specific cases, achieving long-term benefits could imply temporarily enhanced emissions. Forest biomass is heavily used to achieve renewable energy targets. To fulfil the Paris agreement, bioenergy is needed alongside solar and wind and plays a key role in integrating the latter renewable energy sources in a stable and reliable renewable energy supply. Inefficient ways of using forest biomass should be avoided; a smart use of forest products and bioenergy reduces fossil GHG emissions.
- It is recommended that bioenergy is produced as a side product in combined material and energy use value chains. Direct use of biomass for energy should not limit material use as this creates longer-term carbon sequestration and larger substitution benefits.
- Climate change adaptation and mitigation and bioeconomy developments can best be aligned through measures that support active management and sustainable use for forests. Win-win solutions are enhanced biomass removals in fire-prone regions, diversification of stand structures and management regimes, and carefully planned species and genotype selection to ensure that forests remain stable and productive.

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3.4

How can forest biomass most efficiently contribute to increased environmental benefits of the bioeconomy?

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3.4.1. Policy context and definitions

(Resource) efficiency is a key concept when talking about the sustainability of a forest-based bioeconomy. At the broad level, *resource efficiency* tends to be defined as "doing more with less" or "minimising waste" and a general ambition to ensure that resources – specifically material and economic resources – are put to as good use as possible (Thonemann and Schumann, 2016). As an overarching principle, there is agreement on the importance of resource efficiency, but disparities arise as discussions close in on more exact definitions of the concept and concrete policy measures and instruments (International Resource Panel, 2017).

In this chapter we will focus on resource efficiency as a means to reduce negative impacts on the natural environment from human activities. In this context, much of the discussion tends to be centered on *reduction of material volumes* but it is important to note that, from the perspective of environmental aspects, this is not the full picture. Reduction of material use does not automatically lead to an environmentally advantageous outcome, nor to an economically optimal use of resources (Lifset and Eckelman, 2013). Thus, for the sake of policy design, focus should not be on volumes per se but on the minimisation of the *actual environmental impacts* from natural resource use (Söderholm and Tilton, 2012).

This view is echoed by Sfez et al (2017) who define resource efficiency *as the ratio between benefits obtained from resources and the impacts from the resources used*. We base our discussion on this, but further narrow it down to "the ratio between the environmental impacts and the environmental benefits from different forms of wood utilisation".

We discuss the following questions:

- How can wood-based products and solutions have the most environmental benefits from a lifecycle perspective, especially pertaining to climate change?
- What is the role of policy in this?

3.4.2. Substitution effects from using wood

In the general discussion of, and enthusiasm over, the potential of the wood-based bioeconomy, it is important to separate ends and means. Introducing wood-based solutions *can* lead to a substantially reduced environmental impact over the product lifecycle (Suter,

2016) but increasing the share of wood-based solutions in societal applications should not be seen as an end in itself. A key aspect to consider here is *the substitution effect*, i.e. what is being replaced by wood (see also section 3.3.2). This will have substantial consequences for the overall assessment of the environmental balance sheet, but it will vary greatly both between and within different areas of wood utilisation. For example, there is broad consensus on the potential to reduce lifecycle environmental impacts in the construction sector by use of wood frames instead of steel and/or concrete. The latter materials tend to have a significantly higher impact in terms of lifecycle greenhouse gas (GHG) emissions. Not only is the actual production process less GHG-intensive for wood than for steel or concrete, wooden frames also store carbon for decades before it is released back into the atmosphere. Furthermore, the production of wood frames yields plenty of by-products that can be used for other materials or energy (Gustavsson and Sathre, 2011).

In other cases, it is a lot more difficult to determine the substitution effect. It is often helpful to think not only in terms of one material replacing another, but instead focus on the actual function or service provided. Wood may, for example, very well be the best raw material for the production of printing paper, but the function – information dissemination – can be provided in a completely different way (electronically). This makes it immensely complicated to do assessments of whether performance of the wood-based solution (i.e. paper) is superior to the alternative (Bull and Kozak, 2014).

Finally, it is of key importance to take into account the effects of time and technological developments when discussing the substitution effect. In the energy sector, wood-based bioenergy often replaces fossil fuels. This comes with substantial gains in terms of climate change mitigation. However, let us assume that a specific piece of wood is first used in a bookshelf and then for energy at the end of the bookshelf's life in say, 10–20 years. With current trends in the global energy system, the share of renewables is likely to be a lot higher in 2030 than today, with the consequence that the substitution effect would be smaller (Höglmeier et al, 2015).

3.4.3. Synergies or trade-offs between different wood usages

A much-debated issue in the broader discussion of how wood can best contribute to reduce negative environmental impacts is how to find a balance between wood as an industrial raw material and wood as an energy source. In the EU this issue has been debated in the context of the so-called *cascade use* principle (Olsson, 2017). Though a concept used with different meanings in different contexts, the research literature primarily refers to cascade use as the sequential re-use and recycling of wood for one or several different material purposes and eventually as energy (Thonemann and Schumann, 2017).

Cascade chains, where wood is repeatedly re-used and recycled, can be very beneficial in terms of reducing environmental impacts in different applications, as the wood at several stages can replace more GHG-intense materials and fuels (Sathre and Gustavsson, 2006). However, the cascade use principle is often interpreted to mean that material use should have preference over energy use (European Commission, 2013). It is important to emphasise here that prioritisation of material use over energy use is not by default the best choice. In reality, this verdict will be context-specific and vary both geographically and over time (Thonemann and Schumann, 2017; Hanssen et al, 2017).

In the EU policy debate, some have argued that the growing demand for bioenergy will crowd out other sectors and constitute a threat to development of the bioeconomy at large (e.g. Eickhout et al, 2012), but this question is overly simplified. Especially in forest industries, synergies abound between the use of wood as an industrial raw material and as an energy source. Bioenergy is, in many cases, a central component of industrial infrastructures for manufacturing products for the wood-based bioeconomy. Notably, in both Sweden and Finland, the forest industry is the largest domestic user of wood-based bioenergy, through its use of industrial by-products for generation of process heat and electricity[6].

3.4.4. Policy recommendations

While we have hitherto focused on resource efficiency from an environmental perspective and played down the economic aspects, the latter become a key component of any discussion related to policy. In short, to ensure that wood can contribute effectively towards climate change mitigation, improvements in environmental benefits should be closely correlated with economic benefits. Striving towards this should be a central objective of environmental policy. However, policy frameworks to achieve this are not likely to be simple. Rather than a single specific policy instrument, a mix of policy measures will be necessary because the issues at hand touch upon separate policy areas and address a long list of institutional and market failures (Ekvall et al, 2016; Rogge and Reichardt, 2016).

A central component of this policy mix will be to ensure that, to a greater extent, economic actors have to pay the costs of activities that result in negative environmental impacts. This might be through, for example, taxation of greenhouse gas emissions. Variations on this theme (such as a more effective EU Emissions Trading System) are necessary to even out the uneven playing field between fossil and renewable resources in material as well as energy applications.

Policymakers also have a key role to play in supporting innovations that can realise underutilised potential for improved environmental performance in wood product lifecycles. For example, raw material losses along the supply chain of wood can be considerable (10–20%) due to handling of biomass and – more importantly – decay of biomass during storage. Here, there could be a need for public R&D support in the development of logistics systems that minimise losses and create business opportunities from the minimisation of supply chain waste. Conversely, there are likely improvements to be made in the development of so-called reverse logistics systems that make material reuse and recycling of wood more cost-efficient. Incentives to design products and packaging to simplify material recycling also contribute towards this.

When it comes to bioenergy, projected costs of electricity generation up until 2030 indicate that biobased electricity is, in most countries in the EU, unlikely to be competitive with solar and wind on a per kWh basis. This could mean that projections of mid- to long-term bioenergy expansion in the EU could be overestimated (Warringa et al, 2016; Frankfurt School-UNEP Centre/BNEF 2017). However, wood-based electricity generation does have important advantages compared to other renewables, in that bioelectricity is dispatchable and could be used to balance electricity grids in a future characterised by more variations in electricity generation (Arasto et al, 2017). This is a property that could prove quite useful in the efforts to decarbonise the European energy system. However,

6 The forest industry in Finland accounts for more than 60% of total Finnish wood energy use (Karhunen et al, 2014) and the Swedish forest industry's share of total Swedish wood energy consumption is slightly above 50% (Swedish Energy Agency, 2016).

there is a need for policy supporting innovation that can help wood reach its potential as an energy source in applications where other renewables have shortcomings. In addition to grid balance and energy storage (where incentives and market design need to reward provision of grid balancing services), aviation fuel (where there is a lack of effective international policy frameworks that support renewable fuels) and process heat are key examples. In space heating, however, wood-based energy is competitive especially in Northern Europe without heavy subsidies or other incentives.

Finally, it is important to focus on further developing synergistic relationships between different wood product streams. Here, public procurement policy support for wood-based construction could play an important role. Not only are there significant opportunities in terms of substitution effects but increased demand for long-lasting wood products such as building structures also increases the volumes of by-products suitable for fibre, chemicals and energy.

Take home messages:

- There is currently no consensus about what resource efficient use of wood actually is. We define it as the ratio between the environmental impacts and the environmental benefits from different forms of wood utilisation.
- Key to determining this is the substitution effect, i.e. what does wood replace in a specific application.
- Wood is used in a vast array of functions in society, which makes it untenable to provide many specific suggestions for how wood should be used to provide the most environmental benefits.
- The use of wood in cascade chains – through repeated re-use and recycling – can be very beneficial in reducing GHG emissions through the substitution of fossil materials and energy at several stages over time.
- Cascading is sometimes interpreted as meaning that material use should hold priority over energy use, but this is a simplified and potentially misleading statement.
- The use of wood frames for construction is one example where the substitution effects are large because of the comparatively high environmental impacts of alternatives such as steel and concrete.

Policy recommendations:

- The complexity of the issue of how wood is best used to support reduced environmental impacts is such that no individual policy measure will suffice and, instead, a policy mix is needed.
- The policy mix should include instruments such as more effective emissions trading systems or taxes on greenhouse gas emissions, public R&D support for design that favours recycling and waste reduction in wood product supply chains, as well as public procurement policies for applications where lifecycle assessments have shown wood to be an especially beneficial alternative.
- Policymakers should aim for a pragmatic stance and not have increased use of wood-based products as an end in itself. Instead, focus should be on applications where wood-based solutions are superior to others.

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3.5

How does the forest-based bioeconomy relate to amenity values?

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3.5.1. Introduction

The growth of a forest-based bioeconomy is expected to lead to rising demands for the tangible goods that forests provide to society, in particular for biomass and timber. At the same time, the intangible values of forests, also termed amenity values (Tyrväinen, 1997), are increasingly demanded by society as well (Smith et al, 2010). The wide range of nonmaterial benefits from forests, which can be also called Cultural Ecosystem Services (CES) (Plieninger et al, 2013), includes opportunities for recreation and tourism, health and wellbeing benefits as well as for nature and aesthetic experiences, spiritual enrichment and cognitive development (Millennium Ecosystem Assessment, 2005).

Although the amenity benefits of forests have always played an important role in supporting quality of life in Europe, their benefits to societies are increasingly acknowledged due to social and demographic changes and changing lifestyles. Approximately 75% of European Union populations live in urban areas and the numbers of people directly dependent on traditional rural livelihoods such as forestry continues to decrease (European Union, 2016). Moreover, concerns about the health impacts of modern lifestyles in urban areas, such as lack of exercise, obesity and mental health problems linked to stress, are well recognised. Correspondingly, issues of access to nature and the potential wellbeing benefits of outdoor recreation have climbed higher up the policy agenda. Moreover, key social and demographic drivers affecting the demand for the amenity benefits of forests include an aging society, multi-cultural populations, raised environmental awareness and health and wellbeing trends (Bell et al, 2008; Nilsson et al, 2011; Carrus et al, 2017).

This subchapter discusses the role of forest amenity benefits in Europe, the relation of these benefits to bioeconomy strategies and the need and possibilities for enhancing their provision. Amenity benefits are often not included in bioeconomy strategies, although they contribute increasingly to urbanising societies. Their direct and indirect economic values for European societies and bioeconomy are substantial, and, regionally, their support for livelihoods, such as tourism and employment, can be significant.

3.5.2. Demand for forest amenity benefits

Some amenity values have long been considered in forestry (Pistorius et al, 2012), in particular recreation and tourism (Bell et al, 2008) and aesthetic values (Gobster, 1999; Gundersen and Frivold, 2008). Outdoor recreation refers to the activities that people undertake in places where they can access nature or green areas, mainly as part of their daily or weekend routines. Nature-based tourism as a term covers activities that people enjoy outside their permanent residence, while on holiday, and that focus on engagement with nature (Bell et al, 2007). Typically, this means travelling to and staying overnight in locations close to or in national parks, forests or the countryside and participating in activities that build on the natural qualities of these sites.

In North European countries, for example, outdoor recreation and particularly visits to a forest are a very common leisure activity. In Denmark, Finland, Norway and Sweden national outdoor recreation surveys show that 76% to 91% of the adult population pay visits to forest annually, and even more participate in outdoor recreation in nature areas in general. The average frequency of forest visits varies greatly even between Nordic countries, from 38 times/year/person in Denmark to 120 times/year/person in Finland. However, forming a comprehensive view about the economic importance of forest-based recreation and tourism is difficult due to the lack of comprehensive statistics. Visitor monitoring of outdoor recreation, for example, is not conducted in a homogenous way throughout Europe (Edwards et al, 2013). In addition, nature-based tourism lacks a common definition and comprehensive statistics (e.g. Fredman and Tyrväinen, 2010) although some countries, such as Finland, are aiming to improve the statistical databases in the near future.

The cultural and regional differences in Europe are also reflected in the use and demands for forests (e.g. Grilli et al, 2016). Nature-based tourism, for example, is an important sector in Central Europe and a well-acknowledged growth area in northern Europe. It also has high potential in forest-rich countries in Eastern Europe. In fact, the sector is often claimed to be the fastest growing branch of tourism (e.g. Hall and Boyd, 2005; Bell et al, 2008). In Finland, Norway and Sweden, the potential for new tourism business models based on forests and other natural resources is included in current bioeconomy and tourism strategies. The growth prospects of the sector rely strongly on increasing the number of foreign visitors, including from outside Europe. Nature-based tourism has a growing importance in Southern Europe as well. For example, in Italy, nature-based tourism reached 11.9bn Euro and 102 million days in 2014, mainly in the protected areas network.[7]

Nature-based tourism firms are typically located in rural regions, they are often small scale and they interact with other resource users (e.g. forestry and agriculture, mining, industrial fishing) as well as landowners. The sector provides a complement to more traditional resource uses such as farming, forestry and fisheries, as well as to large-scale tourism and hospitality businesses. In that way, the sector plays an essential role in diversifying rural livelihoods and supporting rural areas to be populated (Lundberg and Fredman, 2012).

Moreover, non-timber forest products such as game, mushrooms or berries provide values – beyond supplying food – that are related to recreation benefits, sense of place,

7 http://webitmag.it/ecotur-il-turismo-natura-supera-i-100-mln-di-presenze-in-italia_75838/

inspiration, education, and traditional knowledge. A recent European synthesis demonstrates that a large variety of game (38 species), mushrooms (27 species) and vascular plants (81 species) is collected and consumed in member states of the EU. Overall, more than 100 million EU citizens consume wild food. Forests and other wooded lands are of outstanding importance for this cultural ecosystem service but regulations over use and limited access are common features in many countries (Schulp et al, 2014). For example, mushrooms and wild asparagus are wild foods that people appreciate in Southern Spain. However, most woodlands where these are found are in private ownership and thus not accessible to the public. Marketing and using these products has further potential, for example, in the tourism sector or to support citizens' everyday healthy diet. These products, mainly edible mushrooms, forest berries and medicinal plants, have important cultural and socio-economic meanings in some European countries (e.g. Sizsak et al, 2016; Guarrera and Savo, 2016; see also section 3.10).

However, the majority of the amenity benefits of forests are "consumed" in urban and peri-urban forests, because of their nearby location and easy accessibility to citizens (Tyrväinen et al, 2005; Tu et al, 2016). Forests within and around urban environments create attractive green townscapes and contribute, at the local level, to the quality of working and housing environments, and their benefits are reflected in property values (e.g. Tyrväinen et al, 2005). Forests are an important part of urban green infrastructure and also promote tourism and indirectly enhance economic development (Terkenli et al, 2017). Scientifically documented health-enhancing qualities of urban and peri-urban forests are a result of multiple benefits that reinforce each other. Well-managed forests, for example, provide health promotion environments through their ability to reduce wind speed, abate noise, improve air quality and provide opportunities for contact with nature and stress recovery. Safeguarding biodiversity can also play a key role in urban forest management and is appreciated by users.

The health benefits of forests and nature at large have been increasingly recognised as a valuable support to the health of European populations suffering increasingly from health problems caused by stress, obesity and inadequate physical exercise (e.g. Carrus et al, 2017; Ten de Brink et al, 2016). In recent years, research has identified opportunities to engage health policy interests, identify information gaps and to develop a network of researchers and research institutions in forestry, health, environment and the social sciences (Nilsson et al, 2011; Pearlmutter et al, 2017). Recent results show the positive role of biodiversity upon perceived restorative properties and self-reported benefit for urban and peri-urban green spaces (Carrus et al, 2015). Specifically, in highly urbanised countries, forests have considerable and still growing potential in enhancing public health, although its economic values are not yet fully understood.

On the one hand, heavy land-use pressures in urban growth centres across Europe have reduced the availability and quality of forests and other types of nature areas for public use. Rapid expansion of urban built-up areas during the past decades has led to significant changes in urban and peri-urban landscapes, resulting in the fragmentation of formerly continuous green corridors (European Union, 2016). On the other hand, the latest report on the state of forests in Europe (Forest Europe, 2015) shows that from 1990 to 2015 the area of forests has increased by 17.5 million hectares, with an average growth of 700,000 hectares per year, accounting for one third of the European territory. The availability of new forest areas may contribute to changing the economic and social asset by a transition from a rural to a touristic and handicraft economy (Fedrigotti et al, 2016). Moreover, changes in land ownership through the privatisation of formerly public land around cities and towns, in particularly in Eastern parts of Europe, have closed or substantially reduced the availability and access to former recreation forests for local use. These type of changes have also raised public concerns and land-use conflicts. In consequence, the need to address the loss of nature spaces and to safeguard forests has led to new policies and laws in many countries to improve the supply and quality of forests for social uses, for example, through afforestation, collaborative planning and community forestry projects.

People also enjoy private amenity benefits from owning forests. For example, woodland owners in Spain and Portugal enjoy values such as having a good place to raise a family, leaving legacy values, welcoming friends and visitors to one's place, and enjoying a "country way of life". The fact that rural real-estate prices are frequently above those that can be justified by cash returns from primary production alone confirms the substantial private amenity values that landowners consume (Campos et al, 2009).

Moreover, forests, especially including large old trees, are appreciated, maintained and protected for *spiritual and religious values* in many parts of Europe (Blicharska and Mikusinski, 2014). For example, oak and pine trees have been used in Greece since antiquity to mark and protect sacred groves and springs, and are often located near churches and chapels (Kizos, 2014). A societal trend exists in Germany (and other countries) toward more "natural" forms of funerals outside the traditional cemetery settings, in forests (called "funeral forests"). These forests often managed by private companies have distinct features and are often very aesthetic forests, comprising open stands of ancient trees. Although spiritual and religious values remain understudied in Europe, this phenomenon can be considered as a valorisation of the cultural ecosystem services of forests.

3.5.3. Amenity benefits within the forest-based bioeconomy

Urban forests are often owned by municipalities or other public bodies and are managed to meet people's environmental expectations, frequently through new models of governance (Lawrence et al, 2013). Multi-objective management is typically applied to enhance biodiversity, recreation and landscape values that are highly appreciated by the users. Moreover, national parks and other designated areas are key environments for nature-based tourism across countries, and their local and regional economic value generated through nature-based tourism for the rural societies in which they are based is significant and continues to grow (Kajala et al, 2012).

However, in many countries, commercial forests are also important in delivering some of the amenity services of forests. The possibility of recreational services in forested areas varies between countries depending on the landowner structure and the use rights of nature. In the Nordic countries, for example, free access to all nature areas, independent of the landownership, is an important asset. There is, however, a significant share of forests in private ownership across Europe, even around population centres and nature-based tourism destinations, that allow limited public access to nearby users. In these areas, deeper knowledge of the demand and the overall value of forests for society is needed in order to find ways to improve provision and meet various types of societal demands, including the amenity benefits. In consequence, new solutions such as market-based mechanisms in private forests are needed to provide compensation for the landowners for the use of, or enhancing the quality of, their forests for tourism and recreation (e.g. Thorsen et al, 2015b).

In principle, multiple-use forestry offers great potential for fostering sustainable forest management. Amenity values are directly experienced and intuitively appreciated by people (Daniel et al, 2012), and they are typically enjoyed in "bundles" of multiple ecosystem services. Therefore, they may guide forest management towards multi-functionality. However, incorporating amenity values into forest management requires better knowledge of the many types of forest owners, including their level of ecological knowledge, their attitudes, and their management strategies and practices. There is some evidence that changed motivation of forest ownership can translate into changed management practices and subsequently changed forest patterns. For example, studies in Germany (Schaich and Plieninger, 2013), France (Bergès et al, 2013), Poland (Żmihorski et al, 2010), and Latvia (Rendenieks et al, 2015) found substantial differences in biodiversity, stand structure and composition between privately and state-owned forests. Typically, species richness (often stamped by nutrient-, light-demanding and urbanophilic species), structural diversity of stands and density of habitat features were found to be higher in private forests.

Although amenity benefits are often regarded as secondary to financial concerns, they can have a critical influence on forest owner decisions and forest user attitudes. For example, 37% of private forest owners in the Southern Black Forest, Germany, are motivated by lifestyles that enable the enjoyment of experiencing nature rather than by economic considerations (Bieling, 2004). In England, up to 47% of woodland owners are driven by concerns for amenity values such as public and private recreation, scenery, or wildlife watching (Urquhart and Courtney, 2011). At least 17 studies in Europe identified forest owners that are influenced by amenity values (Urquhart et al, 2012). In addition to forest owners, we also find a strong demand for forest amenity benefits among wider urban and rural communities, resulting in manifold types of community-level engagement with forests (Plieninger et al, 2015).

Moreover, in countries and regions with intensive wood and biomass production, short rotation tree species, new methods to produce bioenergy and a larger size of management units (including regeneration cuttings) are applied. Research shows, for example, that large-scale even-aged forestry has clear impacts on the visual and recreational quality of landscapes. The forest preference studies mainly conducted in Northern Europe conclude that, for recreational use, people appreciate mature forests with good visibility, some undergrowth and a green field layer with no strong visible signs of forest management (e.g. Lindhagen and Hörsten, 2000; Ribe, 2009; Tyrväinen et al, 2017). Forests that are thought to be in their natural state, or that look natural and bear no visible traces of human activity, are usually preferred. In contrast, the large size of the regeneration area and direct traces of cutting, such as signs of soil preparation and logging residues, have a negative impact on the recreational quality of forests. Ultimately, preferences towards forest management depend to some extent on personal characteristics and previous forest experiences (e.g. Tyrväinen et al, 2017, Kearney and Bradley, 2011; Edwards et al, 2012) along with the outdoor activities performed. Thus, it is important to understand the landscape and environmental expectations of the actual users through research (e.g. Gundersen et al, 2015). These findings suggest that adapted management methods, particularly large-scale forest regeneration methods, should be avoided in forests that are in active recreational or tourism use, in particular along trails and paths and in nearby population centres.

In areas where timber income from forests is high, social and economic benefits from amenity values can still be significant although they are not always reflected in market prices. In privately owned forests, in particular, the economic incentives for producing amenity values for public use for landowners are lacking and, therefore, the impact of timber-oriented management measures on recreation and landscape values are not taken into account when making decisions on forest management. This means that provision of these services is too low compared to the provision of marketed goods such as timber (Thorsen et al, 2014a). This notion calls for new models for funding provision of cultural ecosystem services in private lands and also compensation mechanisms that would bring economic income, for example from recreation and tourism sector, not only to entrepreneurs but also to landowners (e.g. Tyrväinen et al, 2014; Thorsen et al, 2014b).

Take home messages:

- The amenity value of forests represents a broad set of intangible values, including scenic, recreational and tourism values, health and wellbeing benefits as well as spiritual and religious values that are increasingly demanded by urbanising and ageing societies in Europe.
- Taking amenity values into consideration in the development of a forest-based bioeconomy is important as they largely influence and promote the acceptability of the whole forest sector. Forest amenity values are typically public goods without markets and therefore their provision is too low compared to the demand. When developing policies, management measures or the spending of public funds for European forests, it is important to obtain a wider understanding of the demand for these services and their support by the general public. In this discussion, awareness raising about the role and contribution of forest ecosystems to the wellbeing of the society at large is important.
- Urban forests are an important part of green infrastructure that have been identified as an essential consideration in strategic urban planning. Forests form a network of natural and semi-natural areas providing a wide range of ecosystem services for urban societies, improving citizens' health and quality of life. They also support the green economy.
- There is a substantial potential for conflict between the growing demands for forest biomass (provisioning ecosystem services) and for forest amenity values (or cultural ecosystem services). Although small-scale forest management often supports landscape and recreation values, intensive and large-scale biomass production, in particular regeneration practices in even-aged forestry, has negative impacts on landscape and the recreational quality of forests. Economic incentives for landowners to produce amenity values for public use are mostly lacking and, therefore, recreation and landscape values are not adequately taken into account when making decisions on forest management aiming at wood production.

Policy recommendations

- In the future, forest-based bioeconomy strategies and practices need to address comprehensively sustainability targets covering not only economic and environmental values but also a broad and diversified range of social and cultural forest values that are directly consumed and enjoyed by diverse European populations.
- Policy measures are needed to enhance the provision and use of amenity benefits in different social contexts across countries. Also, sound decision-making depends on better information about the relative importance of ecosystem services and different stakeholder groups' preferences for their provision. Improving knowledge about the economic value of these benefits is crucial to support decision-making and help in assessing the economic impacts of alternative actions/policies.
- Strategic urban forestry plans should be adopted in collaboration with stakeholders by municipalities and other governmental bodies to meet the growing public demand for forest amenity values for the benefit of nearby users. Urban and peri-urban forests should be safeguarded and their role in providing public benefits should be acknowledged in land-use planning and decision-making.
- Existing or arising conflicts between growing demands for biomass and forest amenity values may be resolved either through integration strategies (such as integrated landscape management or multiple-use forestry), or through segregation strategies (e.g. through identification of key forest areas or regions with high demand for amenity benefits combined with their good accessibility and suitability of such use within the urban – peri-urban – rural gradient). In principle, small-scale forestry or multiple-use forestry enables management for multiple objectives, in particular when inclusion of users' values is well integrated within the planning process.
- Novel policies, business models and funding mechanisms such as payment schemes for cultural ecosystem services are needed to enhance the adequate supply of amenity values.
- Forest extension services should be developed to provide more comprehensive support in amenity-led management for forest owners.

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3.6

What makes a European forest-based bioeconomy competitive?

Anne Toppinen, Jaana Korhonen, Elias Hurmekoski, Eric Hansen

3.6.1. Introduction

For a forest-based bioeconomy to be viable, it must prove that it is both sustainable and competitive and that it can provide economically and environmentally superior goods and services (see section 3.9 and 3.10). Competitiveness is a relative measure defining how a firm, industry or country performs in comparison to competitors. The timescale, geographical location, institutional settings of the operational environment and choice of strategy each impact competitiveness (Korhonen et al, 2017). Maintaining competitiveness requires responding and adjusting to changing conditions over time. Often, value creation potential in the short run is tied to costs whereas in the long run it is more tied to the capability to innovate (Fig 8) (Korhonen, 2016; Roos and Stendal, 2016). Competitiveness in the forest-based bioeconomy calls for a shift from being identified as

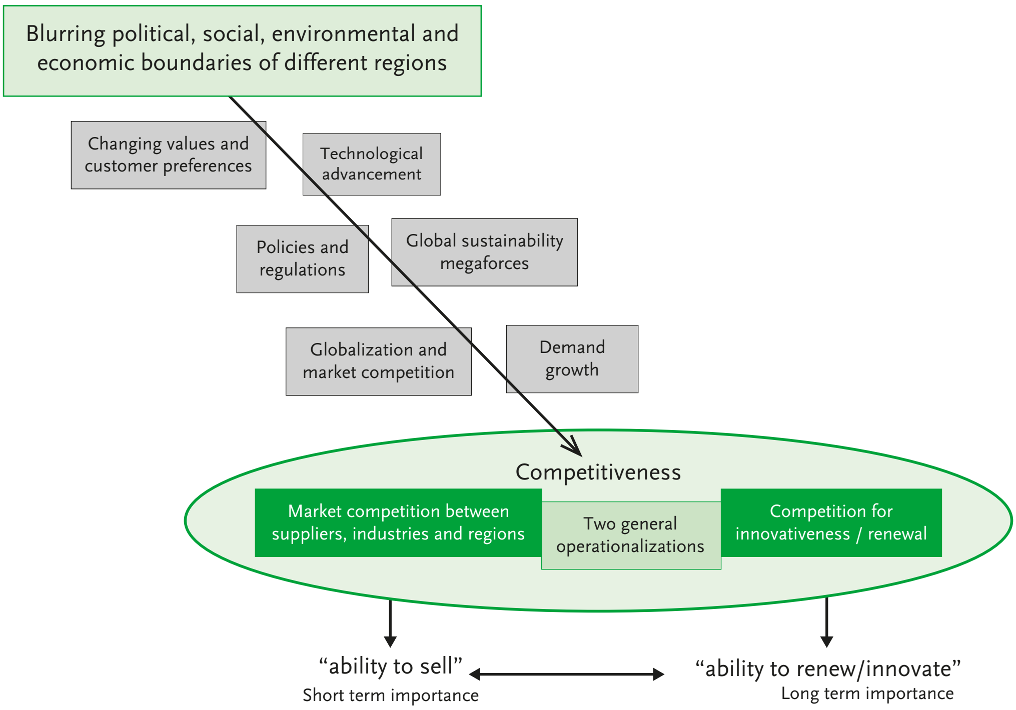

Figure 8. Conceptual lens for viewing competitiveness and its macro-economic drivers in the European forest bioeconomy.

an "extractive" sector to an "attractive" sector by environmentally conscious global consumers (Bugge et al, 2016; Hansen, 2016). This implies an enhanced focus on innovation, improved industrial management processes, and addressing increasing customer needs for forest bioeconomy products and services (Näyhä et al, 2015).

3.6.2. Europe in the global context

Global megatrends such as demographic and social changes, shifts in global economic power, rapid urbanisation, climate change, resource scarcity and technological breakthroughs are drastically re-shaping business and society now and will continue to do so in the future (Bugge et al, 2016; Pätäri et al, 2016). The economic, political, social and environmental boundaries of different regions, industries and sectors are blurring due to ubiquitous connectivity and the rise of the private sector in the global political agenda. The development of the bioeconomy in different geographical regions is driven by both internal and external factors linked to global megatrends. Internal factors can be, at least partly, controlled by firms and industries, whereas external factors transpire in the global economic and natural environment.

The scientific literature base on competitiveness of the bioeconomy is increasing but, typically, not dealing with the firm or consumer-level questions (Korhonen et al, 2017; Kleinschmit et al, 2014). It is important to pay attention to these issues in order to realise the potential related to bioeconomy development. For example, one major question is whether corporate cultures are sufficiently open to changing the business logic and engaging in deeper inter- and cross-sectoral collaboration (Korhonen et al, 2017; Hansen, 2016). Taking the example of the role of services, the importance of tourism and activities relying on the ecosystem services is growing, while the importance of many traditional material-based manufacturing businesses is stagnating or even declining. In comparison, the leading European pulp and paper companies seem to be ahead of North American ones in terms of addressing the bioeconomy as a business opportunity (Hansen, 2016).

Table 3 presents some of the most important internal and external factors affecting – either positively or negatively – the competitiveness of the European forest-based bioeconomy compared to global competitors, based on the extant economic and business literature (see also Boons et al, 2013). The role of subsidies and taxes is an issue shaping market competition and competitiveness, though it is not explicitly addressed in Table 3. In addition, production scale also matters, and different factors are emphasised in large companies than in the small and medium-sized firms which dominate, especially in wood products-based industry (sawmilling, panels or, at a more value-added level, carpentry or wooden furniture) (Husso and Nybakk, 2010).

3.6.3. Competitiveness of the European forest-based bioeconomy

The ongoing structural changes in the global forest products industries are only partly related to increased competition from emerging economies. It is obvious that an export-driven model where competitiveness relies on cost-based factors such as cheap labour and raw materials will not apply to all the players in a changing strategic environment. This holds particularly true in the Nordic countries with relatively high labour and raw material costs (slow tree growth) (Korhonen, 2016). Therefore, measuring competitiveness

Table 3. Important internal and external long-term factors affecting the competitiveness of European bioeconomy.

Internal	External
+Abundance of intellectual, educational, scientific and technological capabilities	+Global societal demand for sustainability if forest industries achieve/maintain accepted level of sustainability
+Well-established bio-based firms	-+Structural changes in global demand
+Relatively high sustainability standards	-/+Emerging laws and regulations at EU or national level
+Good governance of natural resources, solid land tenure system	-/+ Rising production costs in Europe/competing countries/regions (also due to exchange rate appreciation)
-/+Productivity growth in competing regions/Europe	-Global financial crisis
-Fragmented business networks	-Market uncertainty
-Slow adaptation of technologies and business models	-Protectionism and rise of nationalistic perspectives
+/- Company policies and culture	-/+Decline in oil price

of high-value-added products and services should be better tied to customer satisfaction, credibility within the value chain and innovation rather than costs.

Services are typically associated with traditional services-as-products such as nature-based tourism. However, services also link directly to the value added to goods through knowledge-intensive work, for example in developing and maintaining sustainability driven substitutes for fossil-based products (Roos and Stendal, 2016; Pätäri et al, 2016). The case of emerging modular building elements based on massive engineered wood products serves as an example (See Box 8, Nähyä et al, 2015).

3.6.4. Diversification of the sector requires updating strategies

The future strategic orientation of the European forest-based sector will be based on increasing diversification of products and services. The traditional definition of sectoral boundaries will change, and many experts believe that the variation between individual firms within the sector will exceed the variation between different sectors. The key will be finding the right strategy in the right place at the right time – calling for managerial capability, as well capacity to absorb new knowledge in a digitalised world. It is essential to note that different strategies and business models are possible and also necessary for a thriving European forest-based bioeconomy (Hansen, 2016; Boons et al, 2013).

One topical example is the Finnish Metsä Group's Äänekoski mill where traditional high-volume, low value-added products (pulp), and an array of low-volume and high-value-added products (e.g. chemicals and, for example, biocomposites used in music instruments) are produced in an industrial ecosystem of firms operating within the same facilities (Palahí and Hetemäki, 2017). The key for success in this kind of context is to align mass producers and niche players side-by-side along the value chain. A different example is the Norwegian Borregaard sulphite pulp-based biorefinery (established in 1889 to produce cellulose and paper), where the focus today is on specialisation in

Box 8: Modular building elements.

To give an idea of the complexity of the factors affecting competitiveness, we consider the case of modular building elements, which has grown at a double digit rate in the past few years. The main competitive advantages can be attributed to the physical properties of wood, namely the beneficial strength-to-weight ratio, which allows industrial prefabrication of entire room modules on a conveyor belt. The modules are then transported over reasonable distances, thus making the manufacturing process more efficient, standardised, safe and convenient, and more predictable compared to traditional on-site construction practices. The significant productivity gains coming from the reduced on-site construction time imply that the overall building costs can be equal, whether using the prefabricated wood elements or the established practices, even if the wood material would be more expensive. On top of the various possible technical benefits of wood-frame building, substituting wood for Portland cement reduces the CO_2 emissions of construction and may imply additional health benefits for the residents, owing to the moisture-buffering property of bare wooden surfaces. However, for a typical construction professional that is in charge of making the decisions on the construction process, none of the above features are decisive. Instead, the perceived risks related to the uptake of untried new practices are given the most weight, typically making the new practices unattractive. Due to this significant inertia in changing the established perceptions, it may take several decades to introduce new construction practices on a larger European scale, although they may already be important in the near future in some regions (such as Austria and Nordic countries). Over time, the most common competitive building materials will develop in terms of technical and environmental performance (Roos and Stendal, 2016), thus maintaining a highly dynamic competitive situation. Nonetheless, one can expect the new practices to begin gaining increased credibility and cost competitiveness through an increasing number of positive examples and “learning by doing”. The case also serves as an example of how it may be easier in the short-term to maintain the competitiveness of mass-produced products by incremental product changes and resulting cost reductions, while radical innovations involving organisational and process changes require more resources, skills and time. In the wood products industries, cost reductions are increasingly difficult to gain, suggesting a need for rapidly developing products, whose demand is determined by attributes other than price. This, in turn, requires a long-term commitment to innovation.

high-value-added and low-volume niche products such as high-level expertise in lignin, vanillin and fine chemicals. In this case, the company must be capable of competing with high R&D investments, superior products and expertise.

When looking at realised firm-level competitiveness based on profitability margin and reinvestment ratios among mass producers, the leading European forest sector companies (SCA, UPM-Kymmene and Stora Enso) maintain their status within the top 10 largest forest, paper and packaging companies. However, their operational profitability, measured before interest, taxes, depreciation, and amortisation divided by total revenue (EBITDA margin), has remained lower compared to Latin American, American and emerging Asian companies (Fig 9). European investment has been perking up during the last few years, strengthening faith in the competitive future of European forest-based companies. This also becomes evident when looking at the reinvestment ratios in Figure 9. European investment has been largely driven by demand for long-fibre pulp from boreal forest resources in global markets, and the growing demand in global markets due to population growth and the rising and ageing middle class, particularly in Asia. The comparison of small-scale producers is difficult due to the lack of reported information, even though their role in terms of employers and value-added have a growing importance (see Sections 3.5 and 3.7, and Husso and Nybakk, 2010).

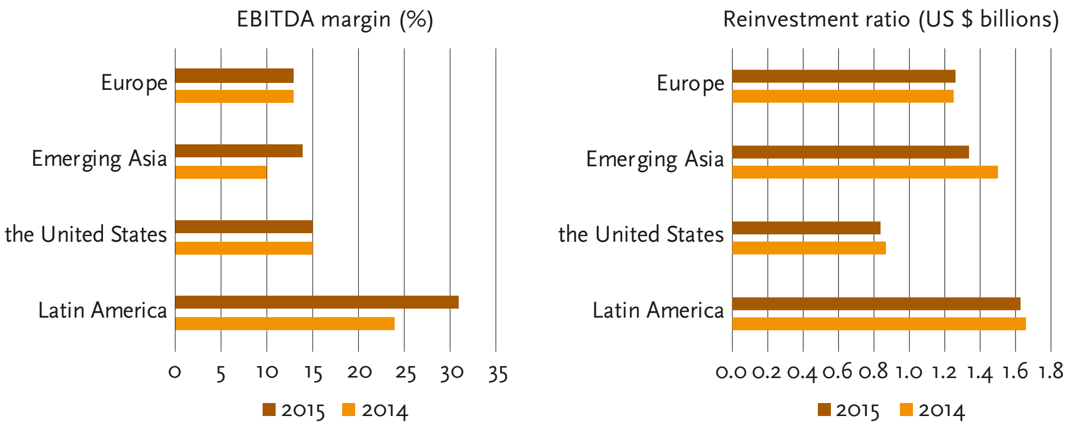

Figure 9. EBITDA margin by region (%) and reinvestment ratio (US $ billions) (data from PWC, 2016).

3.6.5. Conclusions and research gaps

As more weight in the forest bioeconomy will be on services (including branding) and innovation, more attention must be paid to customer value-added and R&D collaboration with other sectors. These include those that are facing increasing pressure to detach from oil, including chemicals, fertilisers, textiles and construction solutions. One significant aspect is also the improving utilisation of byproducts from primary production, most of which have traditionally been used as energy or for wood-based panel production. In particular, the Nordic forest sector has relatively long experience of coordinating complicated industrial processes, as well as monitoring and addressing the sustainability of the sector. Adapting new technologies or processes for converting the side streams into higher value products may even help in securing the operation of high-volume primary products (see also Porth et al, 2016). However, it is also conceivable that, for example, the petrochemical industries will take an increasing interest in wood-based feedstock material, leading to changes in forest ownership, rather than the existing forest sector penetrating other sectors.

It is important to note that direct support of one sector within the forest-based bioeconomy (e.g. energy subsidies) can have adverse impacts on the competitiveness of other sectors due to pressure for a price increase resulting from the competition for the same raw material (such as pulp and paper industries and thereby also a variety of bio-based chemicals based on the pulping byproducts) (Kangas et al, 2011; Moiseyev et al, 2014). Indirect methods that aim to create a level playing field such as a carbon tax and R&D support may better encourage healthy competition and innovation in the long term. In the future, a social license to operate from communities and countries where internationalised European-based companies operate also becomes an increasingly important competitiveness factor for the sake of reputation and risk management (Toppinen et al, 2014).

More empirically oriented research is required to better understand the scalability and market potential of new forest-based products and services. Moreover, while one can aim to raise awareness of sustainable choices, the sector itself also needs to adapt to societal views and create new industrial ecosystems for expanding utilisation of forest biomass. This puts emphasis on an emerging circular forest bioeconomy.

Take home messages:

- Competitiveness that relies only on cost-based factors will diminish in importance in a changing strategic environment of new industrial ecosystems towards the expanding use of forest biomass. Finding and exploiting synergies between high-value products and services and established value chains is necessary.
- Innovation is needed for industrial renewal, but you cannot have innovation without risks, and for that you need risk capital.
- Aligning sustainability and economic competitiveness at the organisational level will have less impact in the short term but will grow in importance over time due to global sustainability challenges.
- Managerial capabilities and the capacity to absorb new knowledge in a digitalised world are pertinent.
- The development of databases to assess small business competitiveness is needed to support policymaking.

Policy recommendations:

- Creating a level playing field (such as a carbon tax and in the form of R&D) is superior to subsidies for encouraging long-term healthy competition and innovation.
- Increasing investments in R&D, and forest-based bioeconomy-related educational systems, is of utmost importance. In practice, innovating entails risk, and hence, requires risk capital. Measures such as pilot project support and public procurement are important.
- Local sourcing can help control the risks related to sustainable supply chain management.

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3.7

What are the implications of the bioeconomy for forest-related jobs?

Anna Lawrence, Raffaele Spinelli, Anne Toppinen, Eftimiya Salo

3.7.1. Introduction

Forest-related work is by its nature very diverse, and includes forestry professionals (including forest managers and planners, forest engineers, and public forest services), contractors and entrepreneurs, as well as self-employed workers and the informal workforce. In relation to the bioeconomy, forest-related work is even broader, and includes those who develop and depend on ecosystem-based services, harvesting non-timber products, supporting ecotourism and forest-based education, in addition to the focus on industries producing goods and services from forests (e.g. forest, chemicals and textile industries). Global trends in the nature of work, including computerisation, efficiency savings, the transformation of big industry, and the growth of small-scale entrepreneurs, all affect forest-related work. In this section we examine the information available about forest-related work. We also look at wider trends and consider the implications for future employment in a transforming bioeconomy.

In reviewing these issues, we are dependent on the availability of data and research. As we show, employment statistics are incomplete and not always reliable in relation to the bioeconomy. Furthermore, research is sparse, so that issues are examined in certain geographical contexts. For example, the role of gender in forest decision-making (including corporation boards) is well understood in Nordic countries; the diversification of small scale contractor companies is comprehensively studied in Italy; the poor conditions of undocumented workers are documented in Turkey. These issues are not unique to these places, and there would be great value in researchers turning their attention to the wider range of forest-related work.

3.7.2. Forest-related work trends

Forest-related work is summarised in global statistics which indicate trends in employment in three sectors: forest work, wood products, and pulp and paper products. So, as conceptualisations of the sector shift from “forest industry” to “forest bioeconomy”, information becomes less complete. The statistics do not include employment related to processing biomass for energy, nor newer “service jobs” in forest-related education, the environmental sector and tourism.

Statistics provide information on the size of the workforce, age and gender composition, wages, and frequency of fatalities (for example, see Figures 10, 11). Concerns are

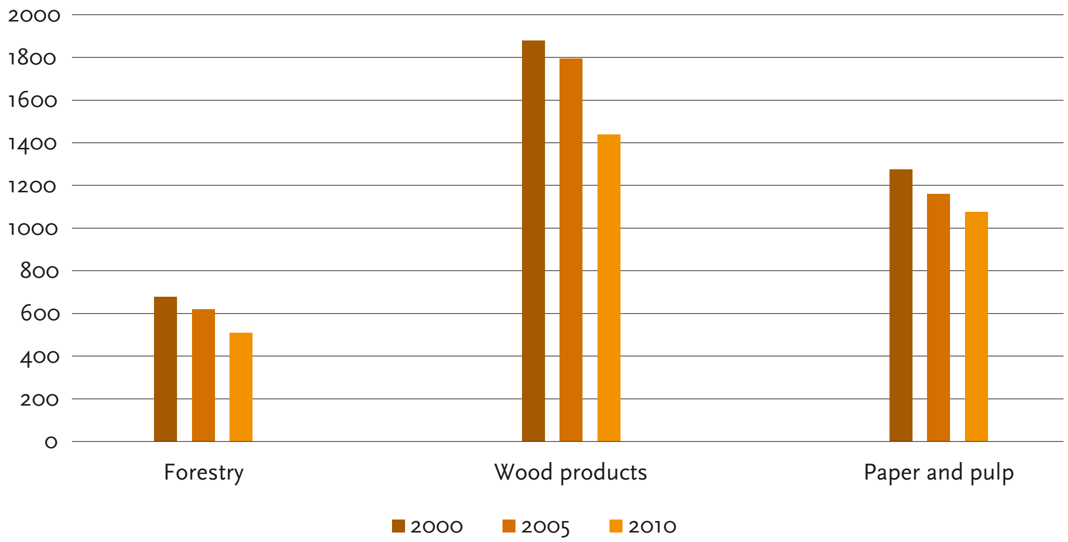

Figure 10. Change in reported totals employed in forestry wood products and paper / pulp in Europe. Totals are based on data for those countries which reported in all three years (2000, 2005, 2010) so do not represent all of Europe but indicate trends in employment.[8]

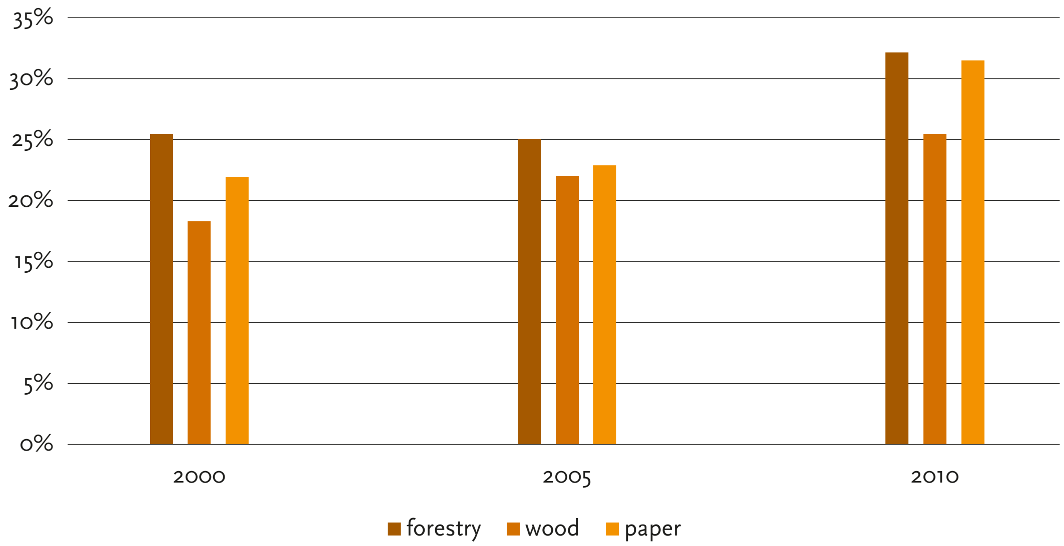

Figure 11. Change in reported percentage of workforce aged 50 and older.[8]

8 Source: Original analysis based on UNECE Statistical Database (http://w3.unece.org/PXWeb2015/pxweb/en/STAT/STAT__26-TMSTAT1/. Totals are based on data for those countries which reported in all three years (2000, 2005, 2010) so do not represent all of Europe but indicate trends in employment. Insufficient data was reported in 1990.

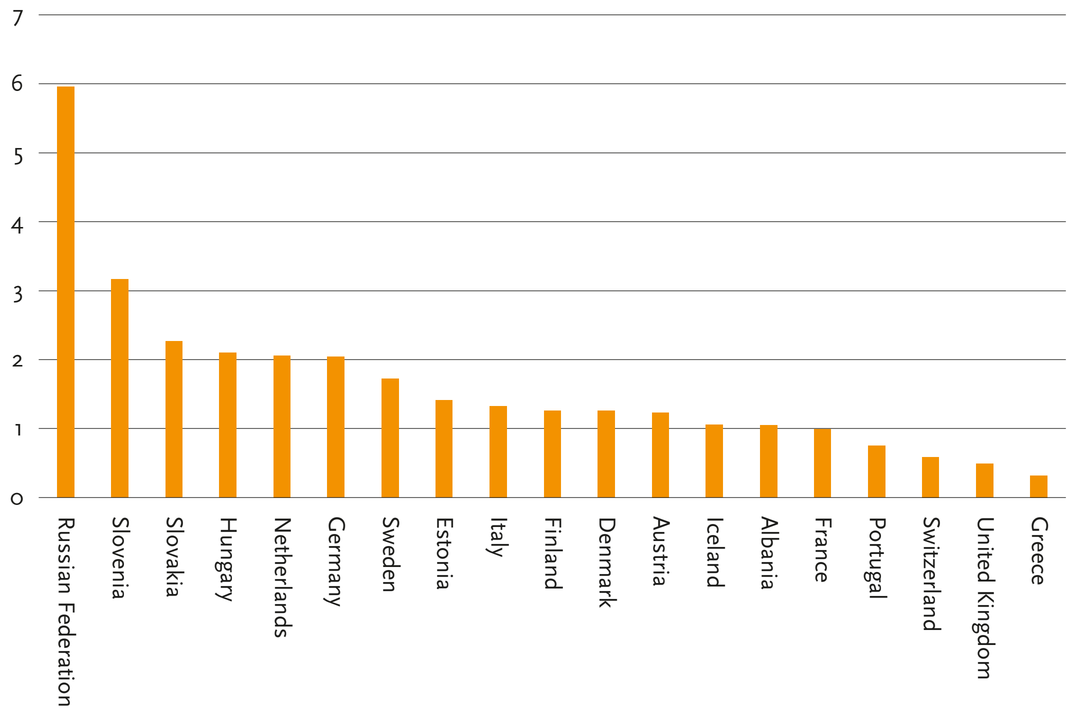

Figure 12. Ratio of forest sector income 2010: 2000 for a range of European countries. A ratio of 1 implies that forest sector income has not changed between 2000 and 2010. A ratio of 6 indicates that the sector's income has grown six-fold. Negative ratios indicate that the sector's income has shrunk. All figures are based on reported data and subject to the same potential errors as any national statistics.[9]

often expressed about the quality and consistency of these statistics but they do indicate some clear trends. Even these employment figures are underestimates as seasonal workers, the self-employed and contractors are often not included.

Based on the same European data, the percentage of women employed in the forestry, wood product and pulp / paper sectors is respectively 17%, 17% and 32%. This proportion has not changed significantly or in a constant direction through the period 1990–2010.

It is not easy to summarise changes in the forest-related workforce simply from the statistics. While national statistics indicate that the traditional workforce is declining and ageing, the sector as a whole may be growing in some countries. For example, data on "total forest sector income" in 2010 compared with 2000 (again from Eurostat) shows that, in most countries, the ratio of 2010 income: 2000 income is more than 1, i.e. that income has grown (most notably in Russia).

These indications of growth in the sector, which contrast with statistics about declining workforce, may reflect the fact that the workforce is becoming more hidden, innovative, outsourced or diverse. It illustrates the difficulties involved in understanding forest work based on available statistics. To put these figures in context, we turn to wider research into the changing nature of work, and social studies of changing issues in forest-related work itself.

9 Source: Original analysis based on UNECE Statistical Database (http://w3.unece.org/PXWeb2015/pxweb/en/STAT/STAT__26-TMSTAT1/.

3.7.3. The changing character of work

3.7.3.1. Work in general

Globally, work in general is evolving, in ways that require workers to have more ability to process data, more analytical and vocational skills and higher education levels. It has been predicted that artificial intelligence and big data will replace some skills and jobs, and as this happens costs will go down, outcomes will improve, and our lives will get better (Brynjolfsson and McAfee, 2014). However, predictions that these trends would lead to less time spent working have not been fulfilled (Stewart et al, 2015). Time previously spent with tools and machinery is now spent on computers and "smart machines". Production *in general* has become increasingly complex and knowledge-intensive, with consequences for employment relations, as work contracts must increasingly rely on self-motivation rather than line management and control. This links to the issue of computerisation and robotics. In developed countries, forecasts range widely, but suggest that high-skill and high-wage occupations are the least vulnerable (Arntz et al, 2016). The more optimistic interpretations suggest that certain *tasks* rather than *jobs* will disappear, and new skill-requirements will appear, such that diversification and greater productivity may in fact result (see chapter 3.8 on forest-sector structure and outlook).

Changes in population, politics and economy have seen a move away from secure lifelong employment, and from industrial unions with strong collective bargaining power. The "employment contract" has evolved greatly in 200 years, and increasingly relies on internal commitment and motivation rather than authority and obedience. Furthermore, as the complexity and knowledge intensity of production processes increase, there is a premium on education and knowledge-intensive skills. Without investment in education and minimum wages, it is predicted that we will see growing inequality (Hodgson, 2016).

3.7.3.2. Forest-related work types

As discussed above, forest-related work is largely represented in policy discourse through official statistics. However, these represent the traditional sector more than the more diverse niches of the emerging bioeconomy. In this section we reflect on the evidence available for changes in forest-related work, and its relationship with the global work trends mentioned in the previous section. There is no doubt that the forest as a focus of industry will continue to thrive; indeed the importance of wood-based products is increasing in the bioeconomy (see Section 3.9), but within and alongside this traditional base, we see both shifts towards the private (and particularly entrepreneurial) sector; and a diversification of the "product" to include many new products and ecosystem services. Four trends in particular characterise this:

1. A diversification of the value chains based on forest biomass to include new applications in energy, chemicals, packaging, textiles and the construction sector, which brings new skills and job opportunities to the forest sector; indeed skills shortages can constrain the growth of this sub-sector (Domac et al, 2005; Pezdevšek Malovrh et al, 2016).
2. The diversification of public sector forest-related work which increasingly relates not only to forest management, production and processing but also to rural development, urban forestry, the economy of ecosystem services, community and public engagement and the knowledge economy. Public forest employees can experience considerable pressure and conflict in their resulting roles (Maier and Winkel, 2017; Lawrence, 2017).

3. The emergence of a large number of small contracting firms in response to the decline of public sector engagement and the transformation of the private sector; and new opportunities as small-scale forests are brought into production (Spinelli et al, 2014; Spinelli et al, 2016).
4. The emergence of recreation and nature-based tourism as increasingly important entrepreneurial activities. Demographic changes, consumer behaviour and the increasingly mobile and connected lifestyles of European citizens have contributed to outdoor recreation preferences and broadening travel horizons. The sector is growing, but there is a lack of statistics to describe that, and it is difficult to separate a "forest" component from the wider benefits of nature-based tourism (Mononen et al, 2016).

This combination of factors creates a growth area of new forest-related work requiring different abilities such as innovativeness, networking and learning skills.

3.7.3.3. Technology and society

The last decades have witnessed the rapid mechanisation and computerisation of forest harvesting, in an attempt to maximise productivity, reduce supply costs and increase operator safety. Even where motor-manual harvesting techniques are still competitive due to cheap labour, there is a general objective to introduce mechanisation in order to streamline production and anticipate future labour shortages. Mechanisation multiplies operator productivity and achieves an overwhelming superiority over traditional technology, which makes it a better choice even when utilisation rates and labour cost are comparatively low. These advantages have led to adoption rates ranging from 25% in Italy to 95% in Fennoscandia. However, such shifts require much capital, with implications for forest-related work, and entrepreneurs. Much of the burden is carried by the machine contractor, who invests his/her own capital in the machine or borrows such capital from a bank – provided he/she can prove future solvency. In Europe, part of the burden is shared by governments, who release subsidies for modernisation of the agricultural and forestry machine fleet.

The radical mechanisation of forest work, particularly harvesting and thinning, has profoundly affected not only the economics of forestry but also the social relations and quality of forest work, including changes in the division of labour, and the way that different types of work are valued and remunerated. A countervailing trend, which is much smaller and poorly documented, is the development of small scale and portable machines for access and harvesting, to enable the inclusion of a wider range of forest owners in the bioeconomy.

3.7.3.4. Innovation

The shift to a bioeconomy perspective highlights different types of work within both new and traditional sectors of forestry. Research into innovation in the forest sector highlights its potential for employment, and finds that the value for job creation comes from new products and services (rather than new processes which are more likely to reduce employment) (Kubeczko et al, 2006). It is clear that the wider approach to developing the bioeconomy, for example through the carbon economy, requires innovation and that this in turn will bring new types of employment (Nijnik and Miller, 2013).

3.7.3.5. Health, safety and wellbeing

The forest-related sector suffers from high accident and fatality rates and compares unfavourably with agriculture, construction and manufacturing[10]. Although accident rates have decreased over the past 30 years as a result of increased awareness, aggressive safety programmes and widespread mechanisation, forestry work remains a dangerous occupation. Occupational accidents are highest in countries that are characterised by difficult topography (FOREST EUROPE, 2015), but apply across the sector including forestry work, processing and service industries. Mechanisation has been shown to be a much more effective factor in reducing accident rates and severity than have training and company policy statements.

Forest-related work also suffers from a risk of isolation and depression as a result of working in solitary and remote places. Workers' wellbeing relates to perceptions and experiences of health, safety and security, but also to experiences of conflict (e.g. with landowners or members of the public over environmental issues), status of the work, and promotion prospects (Mylek and Schirmer, 2015). Even jobs in the "green" sector, working with sustainable woodworking skills, for example, show higher risk of isolation and depression.

3.7.4. People in forest-related work

The efficient organisation of labour and technological development is leading to higher labour productivity, the other side of which is lower labour intensity in all branches of the forest sector. While forest sector salaries are often described as "poorly paid" (Strehlke, 2003; Kastenholz, 2015; United Nations, 2015), the situation varies enormously between roles, and between countries (contributing to growing trends of cross-border migration for forest-work). Gender, ethnicity, age, sexual orientation and beliefs all contribute to workforce diversification, which in the forest sector is generally low. The UNECE and FAO statistics do not record ethnic diversity, nor national origin, of the workforce, but this aspect of workforce diversity is receiving increasing attention, particularly in North America. Diverse conditions e.g. "wage slavery" conditions for ethnic minorities and industrial reorganisation serve to highlight how conditions are tied to context.

Female leadership potential has been recently emphasised as a source of untapped potential in the forest industry, even in Nordic countries which are at the forefront of gender equality (Hansen et al, 2016). Female members represent only 16% of board of directors or top management teams (TMTs) in the global forest industry (as represented by PPI Top100 companies). More strikingly, 84% of the companies have only two or fewer female representatives on their TMTs.

Women and ethnic-minority professionals in forestry are associated with a more ecosystems-based approach, and can help with the shift towards more participatory and multi-functional forestry (Brown et al, 2010). Higher diversity is also associated with better sector image, retention of much required talent pool, innovation and better reflection of customer and stakeholder needs, all of which are significant sources of market and financial benefits over the longer run. Conversely, the prevailing masculine culture in forestry

10 National Institute for Occupational Safety and Health. 2012. Logging Safety. https://www.cdc.gov/niosh/topics/logging/. Accessed on 5 Jan 2017.

can exacerbate health and safety problems (Coen et al, 2013). One solution under discussion to promote better gender balance has been setting quotas for female board members. Norway introduced quotas for women in 2003, requiring that public companies fill at least 40% of their board seats. More recently, quotas have been introduced in public companies in many other European countries as well, but their effects have not been analysed in the forest sector context.

3.7.5. Employment structures in industrial forest-related work

While the bioeconomy emphasises new kinds of work, the importance of industrial production and manufacturing is not going to disappear. However, there are some important changes in its characteristics, which affect the types of work available in both the more traditional areas, and in emerging niches such as small-scale forest management.

3.7.5.1. Reorganisation of corporations

Big changes have been seen in the industrial, productive side of forest-related work: large companies have merged, downsized, out-sourced, relocated, restructured or disappeared, often with drastic consequences for workers and communities. Unions do not have the power, nor offer the security, that they once did in many countries. Much of the former work of corporations, particularly harvesting, has been out-sourced to a rapidly growing number of contractors who have different work cultures, and need new management and communication skills to do well. In some countries, and in non-certified forests, forest work is largely done by insecure and unprotected informal workers, including migrant, student and seasonal workers.

3.7.5.2. Challenges for small to medium enterprises

Forest owners generally sell their timber as standing stock or as logs stacked at the roadside, but they seldom perform harvesting with their own employees. Before 1990, most public owners in Europe supported large logging crews, but the new decade saw a massive shift towards the outsourcing of logging services. In some cases, former employees were encouraged to set up their own logging service enterprises, with privileged access to public grants. Today, timber harvesting and transportation are mainly performed by specialised contracting firms, separate from both the forest owner and the timber processing plant. The number of such firms operating in Europe is estimated at 50,000, with a total workforce of around 250,000 (Ambrušová and Marttila, 2012).

These conditions result in weak negotiating power for the numerous small firms, especially when they find themselves squeezed between a relatively static forest ownership and a highly dynamic wood industry, both much more powerful and less flexible than they are. In many countries, legitimate contractors suffer from unfair competition by irregular operators, i.e. those who do not pay taxes, insurance, registration, minimum wage etc. These are fly-by-night operations that can offer a logging service for a much lower rate than a regular contractor, and are common wherever a non-industrial market exists, as in the case of firewood (Spinelli et al, 2017).

This makes forest extraction an unattractive business which may constrain the growth of the bioeconomy. For all the diversification of roles which the bioeconomy brings, an increased reliance on wood materials and energy will require a focus on the harvesting sector and the problems experienced by contractors.

Despite the radical business model changes that have occurred in the past 20 years, the sector is still rooted in tradition, with a large proportion of forest entrepreneurs inheriting the trade from their parents, although succession and retention problems are occasionally reported. It is often noted that such enterprises most need support in business and financial management. Other areas of support include associations as platforms for networking and to influence policy.

These issues apply surprisingly widely across the European sector. Contractors from Italy, Sweden, UK and Slovakia identify the same needs: guidance on business management, support for continuity and innovation (Sterbova et al, 2016; Spinelli et al, 2016; Eriksson et al, 2015; Sääf et al, 2014; Erlandsson, 2013; Hallongren and Rantala, 2012; Penttinen et al, 2011).

3.7.6. Skill needs

The evidence reviewed suggests that needs in forestry education include: the general challenge of attracting students from a wide range of socioeconomic groups into forestry education; mechanisation, computerisation and advanced technology; multipurpose forest management; entrepreneurship and business skills for nature-based tourism and other ecosystem services; communication and management skills; embedding safety and health cultures and practices; communication technologies, and organisational structures and management.

The advent of mechanisation has increased the need for complex technical skills. The availability of training courses is quite variable, and the content of courses diversified. Vocational schools offer comprehensive multi-year courses, but shorter-duration ad-hoc training courses are also available, and are administered by certified instructors at professional training centres. Over the past decades, efforts have been made across Europe to raise the formal qualification of forest operators, overcoming the limitation of informal on-the-job training.

Take home messages:

- Forest-related work in the bioeconomy relates to both conventional forest production of wood, and newly emerging sectors including a wider range of niche wood production, wood-based energy, and ecosystem services such as recreation and tourism.
- Workforce statistics focus on the traditional forest industrial sector and highlight low employment of women, the ageing workforce and poor safety record across all parts of the sector (forestry and processing). However, these statistics do not represent the full range of changes in types of work and conditions emerging with the growth of the bioeconomy.
- In the last 30 years the dominant trends in forestry have been mechanisation and a shift to private-sector and small-scale contracting.
- Mechanisation, computerisation and robotisation of work affects the quality of work (improved safety) and the demand for knowledge-intensive jobs.
- In recent decades the shift to small-scale contracting has been mainly in the forest harvesting sector but the bioeconomy is further supporting this trend, as much of the work in new niches such as bioenergy, community-owned or worker-owned businesses and nature-based tourism, is developed entrepreneurially.

Policy recommendations:

- The value of the sector is poorly represented by incomplete statistics and research. The emergence of new types of work (such as ecotourism) and innovation (such as new machinery for different forest products) requires a coherent understanding of change in the sector. The needs of the sector would be better understood if statistics were more consistent and included workers across all related sectors.
- Low workforce diversification is a key concern in the transition to bioeconomy and should be addressed in education, recruitment and training.
- Support is needed to develop the small business sector both in conventional aspects of forest-related work (such as forest harvesting), and in innovative sectors incorporating more value-added activities. Ensuring decent payment schemes and socially sustainable working conditions are a concern for social sustainability.
- Supporting small-scale contractors to develop alternative business models, for example by combining contracting with trading, and offering support in business development and financial management, is a high priority.

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3.8

How does forest ownership in Europe affect the forest-based bioeconomy?

Gerhard Weiß, Anna Lawrence, Liviu Nichiforel

3.8.1. Introduction

The availability of forest biomass and other forest ecosystem services for the products and services of the bioeconomy critically depends on forest landowners – their goals and preferences and capacities to manage their land. National statistics, in many countries, show that while larger, industrial-scale forest holdings tend to regularly utilise the yearly allowable cut, small-scale owners often underutilise their timber resources. Therefore, it is important to analyse what motivates different types of forest owners to supply wood and non-wood ecosystem services for bioeconomy purposes.

In dominant forest policy discourses, forest owners are seen as being interested, first of all, in income and profit from their forests and in producing timber for the market. Research has repeatedly demonstrated that these are highly simplified assumptions which are typically valid for larger or industrial forest holdings, but apply much less to small-scale or non-industrial forest owners who hold a large portion of the privately owned forest land in Europe. A major trend is that the share of traditional owners is decreasing but non-traditional owners without income preferences are increasing across Europe, so their interest in managing and providing forest products and services becomes increasingly important.

In this section we aim to illustrate the ongoing trends of ownership changes in Europe, and to show how policies influence ownership and owners in ways that are relevant for the provision of forest biomass and other ecosystem services for a forest-based bioeconomy.

3.8.2. Forest ownership in Europe – diversity and trends

Forest ownership across Europe is highly diverse. This diversity is expressed in the legal forms of ownership, socio-demographic and social characteristics of the owners, and their goals and attitudes for forest management. The following table presents a mixed classification using the legal form as a basic distinction, but adds further institutional characteristics connected with the property size or form of company (e.g. industrial v non-industrial). This scheme shows some of the most common ownership categories. The often used category of non-industrial private forest owners (NIPFOs) is here divided further into traditional farm and non-traditional urban forest owners (Table 4).

Table 4: Important types of forest ownership in Europe.

Public	Semi-public	Private
State forests	Common forest ownership	Industrial large-scale forest owners
Municipal forests	Third sector organisations	Traditional farm forest owners
		Non-traditional urban forest owners

From the legal perspective, the most basic distinction is between public and private forest ownership forms. This may appear straightforward but in fact there are different understandings of what actually is public or private. Related to this, we find a range of special, semi-public or intermediary types which differ significantly from pure public or pure private in terms of constitutional basis and objectives, including municipal forests, common forest ownership, third sector organisations and investment companies.

Box 9: Special or intermediary types of forest ownership

- Municipal forest ownership: although it may be argued that this is a sub-category of public ownership, it is often claimed to be distinct because of the closeness of the management (communes) to the multiple local beneficiaries (citizens). More than 10% of all public forests in Europe are in municipal ownership.
- Common forest ownership (common property regimes): such types of ownership exist in many European countries and in various forms, including traditional commons with a history of several hundred years (typically to be found in Austria, France, Italy, Romania, Slovenia, Spain and Switzerland) or community-owned or -managed forests established through land reforms in the 18th and 19th centuries (e.g. in Poland, Hungary, Slovakia and Sweden, and also very recently in the UK).
- Third sector ownership: social, environmental or other non-profit organisations increasingly acquire forests for special management objectives that are in the public interest. Religious institutions are also expanding their land holdings because of restitution, e.g. in Romania, Serbia, and Slovakia. We see this category as semi-public when the owning organisations (which may be private or specifically regulated as third sector, non-profit, charity or semi-public institutions) are regarded as having the stewardship over the forests in a form of "public trust". However, the availability of data for these diverse types of ownership is patchy.
- Forest investment companies: these are purely private, profit-oriented companies although they offer single persons or organisations the possibility for joint investments. Since they often invest in other countries, they are sometimes under special observation by civil society organisations and, in order to prove their sustainable management practices to their investors and the public, they often have their forests externally certified for sustainable management.

Source: Weiss et al, 2017; Weiss et al, forthcoming

The diversity of forest ownership categories and the high number of individual forest landowners are important characteristics of European forestry. In total, it is assessed that there are some 16 million forest owners in Europe. Some 60% (around a billion hectares) of all the forest land is privately owned, but this proportion varies greatly from country to country. While private ownership predominates in northern and central Europe, Mediterranean countries and France, higher shares of public ownership are found in many former socialist countries in eastern and south-eastern Europe and in some parts of Germany and Switzerland. The proportion of private forest land that is owned by individuals and families (in contrast to companies) also varies. For instance, only 30% of the Slovakian private forest area is owned by this group, but the figure is 100% in Lithuania, Macedonia and Serbia. Related to this, the forest holding sizes vary considerably. Across Europe as a whole, 61% of all private forest holdings have an area of less than one hectare, while only 1% of owners have forest units over 50 hectares. Large holdings may be owned by public entities such as national states or provinces, by churches or by private persons or companies. There is a trend towards increasing investments in large forests areas, often in the form of forest investment companies, particularly in former socialist countries (e.g. in Romania or Czech Republic) but also in western and northern Europe. Investment companies are the subject of contrasting opinions for, on the one side, introducing efficient management practices and thus supporting rural development, but on the other side, driving prices up and hindering local development.

While industrial owners have a professional and commercial focus on their forest resources, farm forest owners usually have their agricultural land at the centre of their strategic decisions, and give their forest land a secondary role in serving the farm and family with timber and fuel wood supply, other products and services, or as a savings bank for irregular investment needs, etc. All this affects the style and intensity of their forest management, the types of products, and strategic decisions or innovations (Rametsteiner et al, 2005).

Non-traditional, non-resident, absentee or urban owners often have smaller parcels, lower expectations of deriving income from their forest, consumption- rather than production-oriented preferences, and often less knowledge, skills and capacities for the management of their forests. They are typically seen by policymakers as rather passive managers of their forests, but this view is sometimes based on assumptions rather than fact. In some cases they have been found to be more open towards alternative products or services. Furthermore, so-called urban owners should not be mistaken for passive owners even though they are less income-oriented. What is clear is that smaller-scale owners, and non-traditional owners, have different priorities and concepts of management. These owners and their characteristics vary widely across Europe, and it is important to get to know them in each policymaking context, so that suitable services, including incentives and advisory services, can be developed for them. For instance, messages and communication channels that are able to connect to urban instead of rural owners' goals, values and lifestyles would help to attract the interest of this growing group of land owners.

Currently, the share of traditional types of forest owners is shrinking. With the decreasing number of farms in Europe, farm sizes are growing, but forests are often divided up among inheritors that have other professions. Other demographic and social changes in Europe add to this, altogether stimulating a growing diversity of private owners' interests, values and demands towards their forests and forest management types. This trend of changing lifestyles of owners towards "urbanisation" has been described as one of the major trends in European forest ownership (Figure 13).

3.8.3. Forest policies addressing diverse ownership structures

Because forests are of high public interest, governments have defined legal frameworks for forest management that prescribe, prioritise or encourage desired management objectives in public as well as private forests. Countries differ in how far their policies aim to influence the ownership structure and the forest management. Such policies include the following diverse kinds of measures (Weiss et al, 2017; Weiss et al, forthcoming):

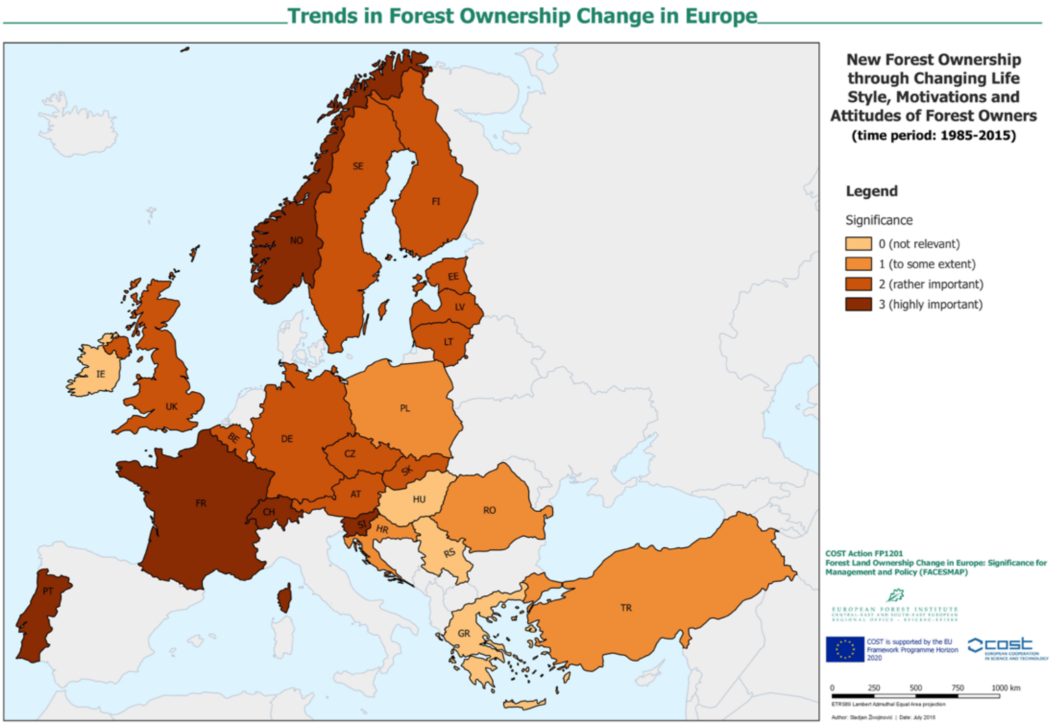

Figure 13. Significance of forest ownership change through changed lifestyle, motivations and attitudes of forest owners in European countries (data source: FACESMAP Country Reports; map based on country expert assessments; published in: FACESMAP Policy Paper, Weiss et al, 2017).

- Restitution and privatisation of state forests. The restitution of forests has been the major recent change in eastern and southeastern Europe, but was carried out to different extents and in very different ways in different countries (for example, no restitution of forest land in Poland). It caused the share of non-state (private or municipal) forest owners to rise from zero to around 50% or more in countries such as in Lithuania or Romania. In some eastern European countries, former state forests were also privatised (e.g. Lithuania). Privatisation of state forests has also taken place in other European countries, but to a much smaller degree (Norway, Sweden, UK).
- Defragmentation policies: various restrictions relate to inheriting, buying or selling forests, e.g. pre-emptive rights for neighbouring farmers (e.g. Austria, France, Lithuania, Slovenia), limits for splitting forest (e.g. Austria and Sweden) or required education or training of the buyers (e.g. Austria and Estonia). For balancing out the negative effects of fragmentation, many countries support the formation of cooperatives or associations and a few countries have specific regulations for joint ownership (e.g. Belgium and Finland). Germany and Finland are examples for countries with official land consolidation programmes.
- Policies that impose forest management, independent of ownership type: as shown in the map of property rights distribution, below, the eastern and south-eastern European countries in particular strongly prescribe forest management goals through legal provisions and official forest management planning. Active forest management is also prescribed in some western European countries such as Finland, although the Finnish forest policy was considerably liberalised recently, e.g. by also allowing uneven-aged management practices that were forbidden before.

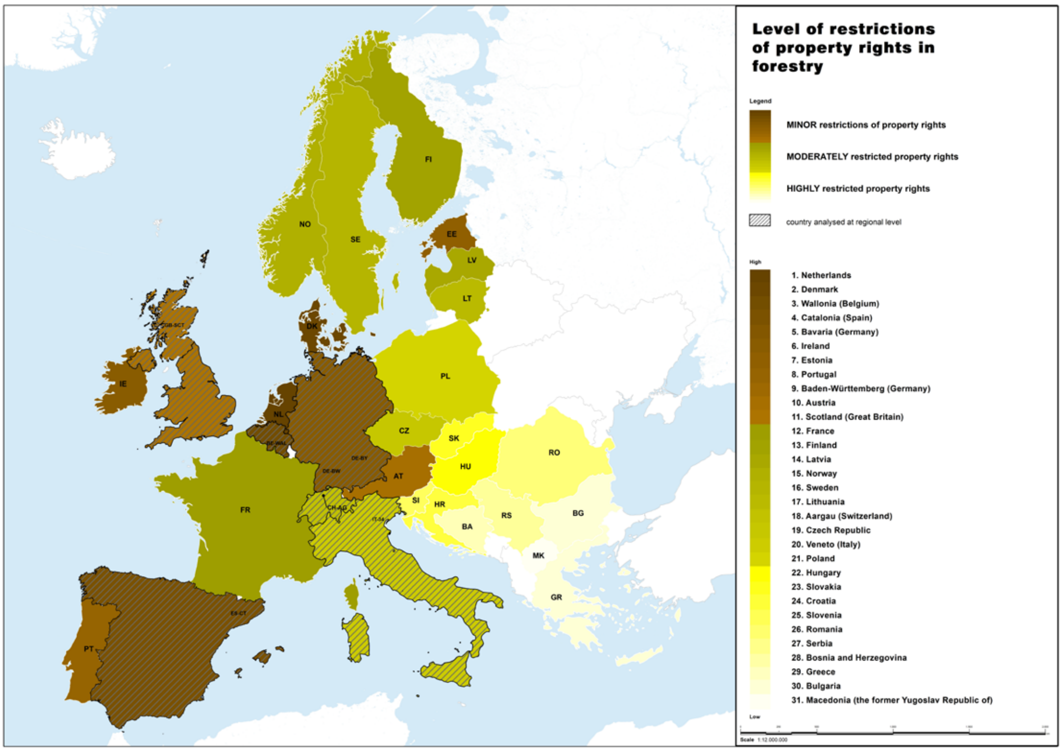

Figure 14. Level of restrictions in private forest management identified across Europe: the assessment is based on expert analysis of legal provisions applying in 31 jurisdictions, for a number of 37 indicators characterising five categories of owner's rights (access, withdrawal, management, exclusion and alienation). The methodology used for the assessment is described in Nichiforel et al, forthcoming.

The diversified picture of property rights distribution in European private forestry was recently analysed by a study which compared the existing forest legislation in 31 European countries (Nichiforel et al, forthcoming). Forest laws, as the main legal instrument of forest policy, usually protect forests and define goals and limits for forest uses; the primary purpose has often been timber production, but multiple other uses (or conservation goals) have been added over time. The regulatory frameworks of European countries differ greatly with respect to the extent of property rights granted to private owners, despite the fact that most of the analysed countries are members of the European Union. Some countries provide more freedom to the owners to decide on how much, when and how to use their forest resources, while others strongly prescribe goals and measures of forest management (Fig. 14).

Timber provided by private forests always belongs to the owner but only two countries grant full freedom to forest owners to decide on the amount of timber to be harvested (Finland and the Netherlands). In 11 countries, general silvicultural restrictions apply, such as maximum harvesting amounts, minimum harvesting age or the mandatory requirement of felling licences. In countries with less freedom in decision making, owners have no or only limited opportunities to influence the amount or time of timber harvests (Bosnia and Herzegovina, Croatia, Hungary, Greece, Macedonia, Poland, Romania, Serbia, Slovakia, Slovenia).

The owner always has the right to use non-timber products (such as mushrooms and berries), but in eight jurisdictions specific certificates or approval are required if the owner wants to sell the products on the market (Bosnia and Herzegovina, Bulgaria, Bavaria, Croatia, Czech Republic, Romania and Serbia). In most countries the forest owners have limited capacity to exclude the general public from using non-timber forest products. Although in 24 jurisdictions owners have the legal right to restrict the public's use of mushrooms and berries for commercial use, in practice the harvesting and picking of non-wood forest products is very hard to control. This is also because in 21 countries forest owners have to allow the public access into the forests while in four countries (Finland, Sweden, Norway, Scotland) even camping in private forests is legally allowed for the general public.

In contrast, hunting rights and the ownership of game are much more strongly regulated in most of the countries. In 29 jurisdictions the game belongs either to nobody (*res nullius*) or to the state. Only in Wallonia and Bosnia Herzegovina are hunting associations granted the ownership of the game. In 18 out of the 31 jurisdictions the owners cannot influence the quota set for hunting and only in nine jurisdictions can the owner decide if and who is allowed to hunt on their property, regardless of the size of the forest (Wallonia, Estonia, Finland, Ireland, Latvia, Norway, Portugal, Sweden and Scotland).

The major factor differentiating the regulatory frameworks employed in the European context refers to the freedom of owners to decide and implement forest management objectives. Some strict rules regarding forestland management are found all over Europe, e.g. restrictions for changing forests to other forms of land use or the obligation for reforestation after final fellings. Yet, very big disparities exist in respect to how the elaboration and implementation of Forest Management Plans (FMPs) is regulated. While in countries with less restrictive legal frameworks, FMPs are not compulsory or only requested for specific purposes (e.g. qualification for financial subsidies, forest certification, large scale clear-cuts), in countries with highly restrictive legal frameworks, FMPs are mandatory or even prescribed by public authorities. Such strict regimes are typically found in the former socialist countries in East and South-East Europe, with the exception of the Baltic countries.

With regard to landowners' property rights, there seem to be two opposing trends: while forest policies have tended to become more liberal in productive forests, nature conservation policies have tended to restrict forest owners' room for decisions. The liberalisation trend is visible in the western countries as well as in some former socialist countries, most notable in the Baltic ones, where the restitution of forests has been followed by a deregulation of private forest management. Nevertheless, in many of the post-socialist countries, the change in the ownership structure has not been followed by a change in the forest management rules, which are still similar to the ones applicable for state forests. In the EU countries, the main restrictions in the property rights occurred as an outcome of the many norms and standards imposed in the environment field during the 1990s, in particular due to the implementation of environmental directives promulgated at European level through the Natura 2000 policy.

The identified variations in the legal frameworks used to regulate private forestry in Europe has implications for how to reach the goals of any bioeconomy policies:

- In countries where the property rights of the owners are more restricted, governments have more direct opportunities to define forest management. However, this is at the expense of the entrepreneurial and innovative inputs of the owners for efficient forest management. When assuming the bioeconomy will work through market mechanisms, the consistent forest policy would be to grant owners more freedom in forest management.

- Countries with fewer restrictions can rely on forest owners' own interests in their market-oriented forestry. Here, policies need to make sure that market signals direct the management decisions of forest owners, and if those market signals are lacking the policies would need to provide for appropriate policy instruments such as awareness raising or financial incentives.
- While for timber and other forest biomass commodities markets are usually established, this is not always the case for non-timber or non-wood forest products. Here, two strategies are used, either to grant the property rights to the owners or to the public. It can hardly be generalised which is better as it seems that this often depends on the specific product as well as country-specific cultural traditions and institutions.

Forest management in western countries is commonly addressed by financial incentives, such as for ecologically oriented management (e.g. close-to-nature management practices) or for supporting investments to improve efficiency and competitiveness (e.g. forest road construction). Many countries offer specific support for joint management of fragmented forest parcels or for joint marketing of their timber. All in all, the impact of price incentives on the timber and pulp wood markets are quite limited, particularly in the long run, since the amounts of wood offered on the market is rather stable. Wood mobilisation measures to increase the participation of owners of fragmented forest parcels on the market depend strongly on the regions, varying market conditions and forest owner types. Consequently, a mix of instruments is recommended, including improved information, cooperation, infrastructure, legal frameworks and technologies. The limited effect of financial incentives goes along with the findings from research on forest owners suggesting that their motives of ownership are manifold, and profit-oriented motives often rank least among diverse values such as ownership pride, family tradition, maintaining capital, conserving nature or providing recreation and amenity services.

Take home messages:

- Forest ownership in Europe is more diverse than usually assumed and goes beyond a simplistic division into public and private ownership.
- The type of ownership has significant implications for the provision of forest biomass and ecosystem services.
- The share of non-agricultural, urban forest ownership with non-traditional management goals is growing across Europe.
- Forest owners' property rights differ greatly across European countries.
- While there is a trend for liberalisation of forest laws and advisory services across Europe, nature protection policies bring substantial restrictions of the property rights for forests located in protected areas.
- Forest policy has only partially been successful in influencing the behaviour of forest owners.

Policy recommendations:

- For a better knowledge of the goals, motivations and behaviour of different forest ownership types there is a need to improve statistical information and surveys across all forms of ownership.
- In order to improve their effectiveness, policy instruments and advisory systems need to be diversified and adapted to the diverse needs and preferences of different ownership types.
- Bioeconomy strategies and policies should address the different forms of ownership by combining policy instruments, including information, incentives and legal and institutional frameworks.
- The formulation of forest-related objectives for a European bioeconomy strategy needs to consider the diversity of the regulatory frameworks impacting on forest management in the European countries.
- Forest owners have a key role to play in the future forest-based bioeconomy. Policy will need to take their values and behaviours into account in influencing owners' behaviour.

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3.9

What is the current state of forest product markets and how will they develop in the future?

Ragnar Jonsson, Elias Hurmekoski, Lauri Hetemäki, Jeffrey Prestemon

3.9.1. Introduction

Forest-based industries – pulp and paper, solid wood products, and a number of downstream value-added wood-based manufacturers – have received limited attention in the pursuit of a successful implementation of EU and national bioeconomy strategies. According to Eurostat, the pulp and paper and solid wood products industries accounted for about 4.4% (€277 billion) of the production value and 5.4% (1.61 million) of total EU employment in manufacturing in 2013. The importance of the sector is far greater if one were to include forestry and logging and downstream wood-based industries (furniture, energy, chemicals, etc.).

The global and European forest-based industries are undergoing major structural changes (Hansen et al, 2013). Most notably, the consumption of graphic papers has been declining in most OECD countries and increasingly also in non-OECD countries, such as China, due to the increasing use of electronic media. Moreover, the consumption and production of wood-based products is increasingly shifting from the previously leading forest industry regions of North America, Western Europe, and Japan to the rapidly growing large economies of China, Brazil, and India. Furthermore, with emerging new biobased products, such as biofuels and bioplastics, the boundaries with other sectors, such as energy, chemical and textile industries, are expected to become increasingly blurred. These changes are producing a growing diversity and complexity in the forest sector, presenting what are likely to be ever greater economic and policymaking challenges in Europe and worldwide in the future.

The outlook for European forest-based industries depends on the perspective. In terms of market growth, looking only at large volume *traditional products* (sawn wood, wood-based panels, pulp and paper) may yield a different picture compared to one that considers also *new or emerging wood-based bioproducts*. The aim of this section is to assess ongoing trends and likely future developments of European forest-based products markets, considering the most recent research, expert assessments, and available data.

3.9.2. Large volume forest-based products

European forest-based industries have been facing major changes in the 2000s compared to the period 1960–2000, which was characterised by stable market growth for all large-volume forest products (Hetemäki and Hurmekoski, 2016). The trends from this century are likely to continue to shape the traditional forest-based industry over the next 10 to 15 years.

Economic globalisation has led to increased trade and a global market for wood-based products. Focal points of forest products manufacture have become progressively more spatially separated, with companies placing manufacturing plants at different geographic locations along the value chain from the forest to the consumer. Intensively managed forest plantations in the southern hemisphere are gradually replacing temperate and boreal forests as the predominant raw material resource for the manufacture of wood products, not least wood pulp, where production has increasingly been moved to Latin America. Furthermore, while demand for traditional forest-based products is growing quickly in China, India, and other developing countries – in line with their rapid growth in income – demographic and economic development is not supporting sustained growth in Europe. It should be noted that growth is higher in Eastern Europe than in Western Europe. Europe is a net exporter of most large volume forest-based products, and is expected to remain so in the medium term (UNECE/FAO, 2011).

The progress in digital information and communication technology (ICT) is having a negative impact on the demand for graphic paper (Pöyry, 2015). The decline of newsprint consumption started in the USA in the late 1980s, and the substitution impact of digital ICT has gradually spread to other graphics paper products and markets, including emerging economies such as China. Packaging and hygiene paper consumption, on the other hand, continues to increase in Europe and globally.

EU renewable energy targets continue to stimulate an increasing demand for energy wood, thereby also influencing the markets for many established forest-based products (Solberg et al, 2014). Bioenergy provides opportunities for new markets for forest and industrial residues and for post-consumer wood. Selling chips, sawdust, bark or pellets to energy firms provides income for the sawmill industry. Chemical pulp producers may also profit from growing bioenergy markets by producing bioenergy (heat, power, biofuels) as a side stream of the pulping process. On the other hand, particleboard and pulp and paper industries tend to suffer from the development of bioenergy markets, due to higher prices for wood raw material (Johnston et al, 2016; Jonsson and Rinaldi, 2017). This suggests a need for improved forest management to increase timber growth rates, advances in harvesting and technical efficiencies in manufacture, and acceleration in cascaded uses of woody biomass to avoid further crowding out of material uses by energy uses. There is still considerable uncertainty related to future EU climate and energy policies, though. A crucial consideration is to what extent, and in which form, the support for wood-based energy will continue. Moreover, there is uncertainty as to the extent and timing in the emergence of economically feasible alternative renewable energy technologies.

All in all, there are signs that economic development and demand for traditional, large-volume wood products in Europe has become decoupled from GDP growth, as is apparent from Fig. 15. The decoupling results from declining graphic paper markets due to digital ITC and stagnating solid wood products market as a consequence of demographic developments, while the climate and energy policy environment is favouring the use of wood fuels.

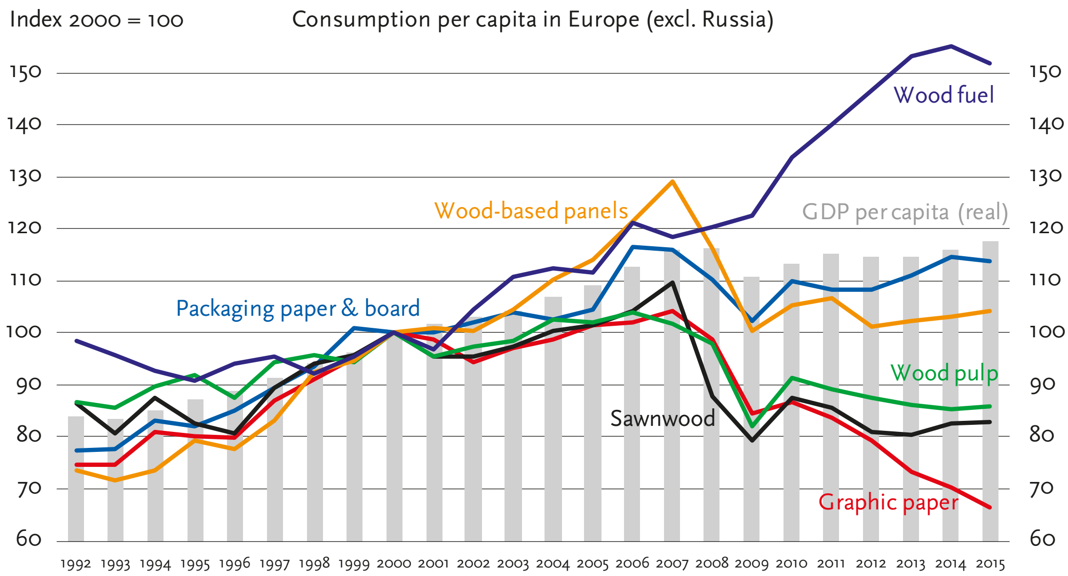

Figure 15. Consumption per capita of forest-based products and GDP growth in Europe (excluding Russia) (Data: FAOSTAT, World Bank).

3.9.3. New forest-based products

The concept of "new forest products" or "innovative bioproducts" has been increasingly on the policy and industry agenda in the 2000s (Philippidis et al, 2016; Cowie et al, 2014). There are two reasons for this. Firstly, there is a clear desire by policymakers and others to reduce the fossil fuel dependency of the global economy. Secondly, the forest industries seek to diversify their businesses, due to stagnant or declining markets for a number of traditional products. As there is no established definition for new products, it is useful to distinguish the following categories:

1. Old products with newly increasing demand due to changes in the operating environment. For example, dissolving pulp for the textile industry due to the need to find substitutes for cotton, as its production competes for land with food and feed production and consumes scarce water resources for irrigation.
2. Old products with incremental improvements, such as lighter weight or lower production costs. For example, paper and packaging coatings and fillers based on nanocellulose.
3. Novel products or products with radical improvements. For example, the use of nanoscale organic matter in electronics.

In the future, the relative importance of new products can be expected to grow further. It is conceivable that, beyond 2030, there will be a large number of product categories, none of which dominates the sector to the extent that paper and wood products did in the past century, particularly in terms of value (see Figure 16). However, currently it seems that there will be only a few individual product groups whose annual production volume in the EU will exceed one million metric tons or a million cubic meters per year by 2030, such as biofuels, dissolving pulp (for textiles, etc.), and engineered wood

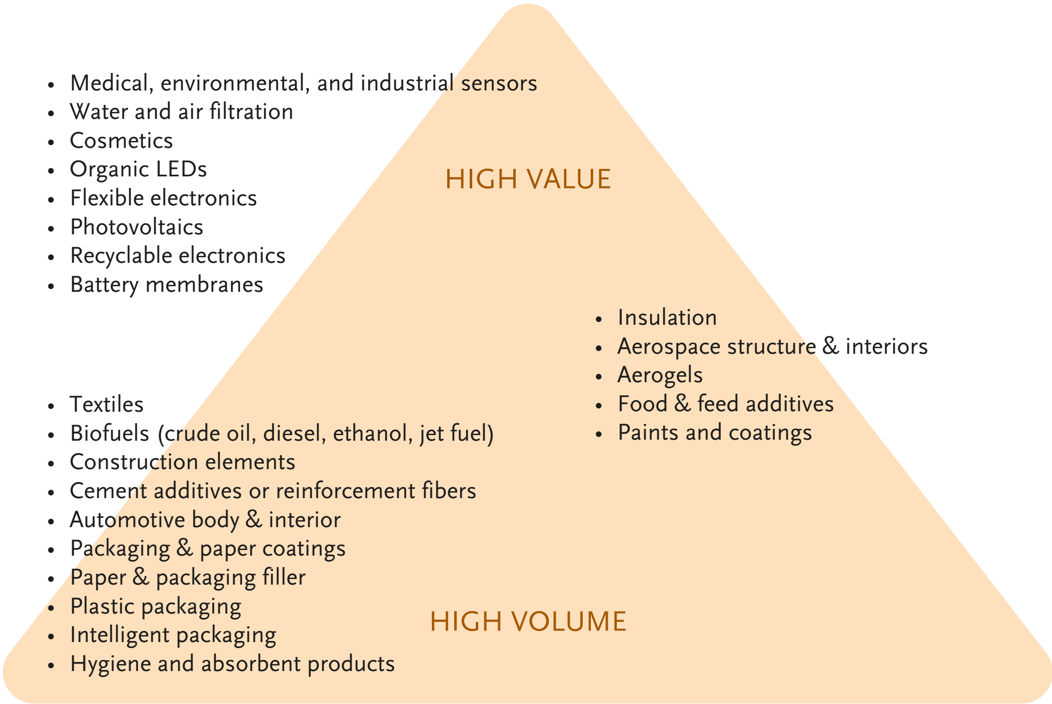

Figure 16. Examples of the possible end uses of new wood-based products (Cowie et al, 2014; Pöyry, 2016).

products (notably cross laminated timber). This would be in the face of around 105 Mm^3 sawn wood production and 37 Mt of pulp production in the EU in 2015.

The long-term outlook for other product categories appears more uncertain at the moment. For example, there is no policy pull for bioplastics like that experienced in biofuels, which is why the production of biofuels is expected to reach seven million metric tons in the EU by 2020, compared to less than one million metric tons of bioplastics (Pöyry, 2016). The majority of these volumes are based on agricultural feedstock, yet wood-based feedstock can be significant in regions with a high dependency on forest industry. Yet, the increasing political commitment for a circular economy (European Commission, 2015), and the problems caused by plastic waste (e.g. ocean pollution), may change this trend in the coming decades.

Although small in terms of volume, the new products are often expected to provide high value. The secondary wood products sector (joinery and carpentry, prefabricated wooden buildings, etc.) already exceeds the sawmilling sector in terms of production value in the EU, despite an estimated 10 times lower production volume. If forest biomass-based production was to capture only 1% market share of the global fuels and plastics markets, it would create new turnover of €40 billion for the forest-based sector (Pöyry, 2016). However, very little independent research exists to judge the likelihood or possible impacts of such developments, partly because data on the emerging products are elusive. Nonetheless, the unit value of biofuels or bioplastics is not necessarily high, compared to some of the established forest products, such as sanitary papers.

The interdependencies between forest product markets may play an even stronger role in the future, as the residues from the production of intermediate wood products (most notably sawn wood and pulp) account for a significant source of raw material for the production of energy, wood-based panels, and chemicals that can substitute for oil-based products. For example, the global forest industry produces annually 50 million metric tons of lignin. In the absence of other uses, lignin is typically used directly for energy production; however, in the future it could be used for a various assortment of fuels, platform chemicals and plastics (Pöyry, 2016). The profits from current products may provide the funding for investments in new products, or the new products will help to sustain the production of established products, through improved utilisation of side-streams. For example, the profitability of sawn wood production is to some extent dependent on the ability to sell mill residues for energy production or wood-based panel manufacture. Furthermore, with shrinking demand for electricity in some regions, due to declining energy-intensive industrial activity and increasing energy-efficiency, investments in further processing of by-products into higher value-added products may guarantee the continued operation of sawmills.

The interdependencies may also pose challenges, such as in the case of increasing pulp production capacity in Finland and Sweden. Due to integrated pulpwood and log procurement – i.e. the important role of sawmills as suppliers of chips for pulping – the investments in pulp capacity also necessitate a major increase in sawmilling, yet the demand for sawn wood may not grow at the same pace as the demand for market pulp.

Take home messages:

- On a global level, continued growth in the production and consumption of forest-based products – with the exception of graphics paper that competes with electronic ICT – is expected. However, in the EU, sawn wood, pulp and paper markets are likely to experience stagnation until 2030, because of unfavourable demographic developments, slow economic growth, increasing global competition, and a number of market-specific drivers, notably progress in digital ICT.
- The outlook for the forest-based products sector in the EU contrasts with 20th century experiences, when production and consumption of all forest-based products followed economic development and population growth. The changing situation is due not only to the long-lasting economic downturn, but also the result of numerous structural changes.
- Global trends, notably demographic developments and progress in electronic ICT, will likely continue for many decades. The outlook for major forest-based product markets outlined above thus provides a reasonable baseline for future developments of the sector. However, there are a number of uncertainties around future developments.
- A prominent uncertainty concerns the evolution of climate and energy policies, as they have been shown to exert a strong influence on forest-based products markets.
- Yet another uncertainty regards growth prospects of emerging forest-based products. Even though they may not turn out to be very important in terms of volume, they may provide significant economic value by 2030.
- Finally, the trend analysis outlined above does not consider potential game changers or wild cards, such as technological breakthroughs or, for example, the introduction of a strong support scheme for negative emissions.
- Given the importance of global forest products markets to the economy, employment and forests, and the changes taking place in the markets, the overall scale of independent, transparent academic market research is alarmingly low. There is also a need to better connect market developments to wider sustainability concerns.

Policy recommendations:

- It is important to understand various interdependencies between material and energy uses of wood, as well as between existing and emerging markets. Policy decisions, particularly those directed at the scale and scope of renewable energy standards, targets and incentives, are likely to markedly influence future developments of traditional forest-based industries due to these various dependencies (synergies as well as competition) between forest products markets.
- To promote synergies and reduce as much as possible any undue crowding out of material uses of wood through lop-sided support to energy uses, measures to enhance material efficiency, such as cascading, should prove useful.
- Increasing diversity and complexity of forest products markets implies difficulties for monitoring the development of the sector. It also makes the design of regulation more complicated. Therefore, there is an increasing need for policy coordination across different policy sectors, as well as a long-term stable policy environment that helps to reduce uncertainties and, consequently, makes the investment environment more predictable.

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3.10

What is the potential contribution of non-wood forest products to the European forest-based bioeconomy?

Irina Prokofieva, Marko Lovrić, Davide Pettenella, Gerhard Weiß, Bernhard Wolfslehner, Jenny Wong

3.10.1. Introduction

In a bioeconomy based on natural resources, understanding the full spectrum of available forest resources, including non-wood forest products, as well as identification of their current role and future potential is paramount. The FAO defines non-wood forest products (NWFP) as "products of biological origin other than wood derived from forests, other wooded land and trees outside forests" (see Figure 17). This definition specifically excludes woody raw material, such as chips, charcoal, fuelwood, etc., and products collected in tree stands in agricultural or agroforestry systems, but includes such products as gum arabic, rubber/latex, resin, Christmas trees, cork, bamboo and rattan (FAO, 2015).

The consideration of NWFP as part of the bioeconomy is definitely not new. For example, before the advent of petroleum refining in the late 18th century, pine resin was extensively used in industrial processes as the main source of oil-based solvents, turpentine, tars and pitches. Thus pine resin was used to manufacture paints, varnishes, waterproofing for wooden ships, dye, lubricants, paper size, polish, glues, soap, face cream, medicines and chewing gum. Likewise, oak and chestnut bark were traded in large volumes as the main source of industrial tannin. These tree-based products were incorporated into forestry either as a by-product of timber production or as the primary product, e.g. the oak bark coppice systems used in Wales (UK) for tannin production and cork oak silvopastoral systems of Portugal and Spain. The domestication of tree species in response to the increasing scale of demand for these industrial materials resulted in specialised silviculture, forest management and plantation development. However, the production of these natural products declined as they were substituted with manufactured, synthetic alternatives such as chromium salts for leather tanning. Much of this substitution, especially that replacing pine resin, was based on mineral oil as a raw material. The emergence of the bioeconomy, which seeks to reduce the dependence on non-renewable and fossil-based raw materials, is stimulating a resurgence of interest in the use of forests as a source of industrial raw materials, such as resin, tannin, cork, rubber, gum and as a chemical feedstock. This in turn offers new opportunities for European regions where timber production is not profitable or where alternative forest management regimes are more attractive.

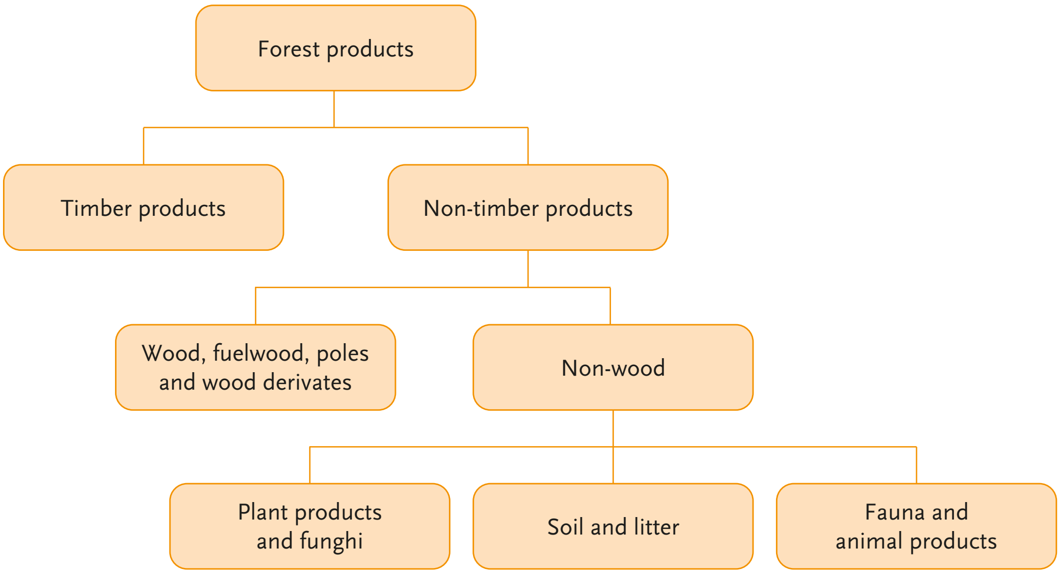

Figure 17. Non-wood forest products. Source: own elaboration based on FAO (1999).

3.10.2. Economic and societal importance of NWFP in Europe

According to the Millennium Ecosystem Assessment report, more than 150 NWFPs are represented in international trade. The latest report on the State of Europe's Forests (FOREST EUROPE, 2015), estimated that the total value of NWFP in the Forest Europe region was €2.2 billion representing around 10% of the value of roundwood. Considering the scale of data gaps in this domain and the fact that many NWFP are not even included in the official statistics, this is a significant figure and will underestimate the present role of NWFP to Europe's economy.

The STARTREE project (www.star-tree.eu) explored the economic importance of NWFP by estimating the volumes and values of a selection of NWFP in international trade using the UN Comtrade database. The products that were examined were tannins, cork, nuts, mushrooms, foliage, berries and honey. The global trade value of these commodity groups amounted to 12 billion USD in 2011, of which some 4.69 billion USD can be attributed to wild harvested NWFP (Pettenella et al, 2014), while the rest predominantly comes from agricultural production.

The EU has a strategic role in the international NWFP market, accounting for half of the total export value of commodities based on raw or processed NWFP at world level. It is a global leader in the supply of cork (85% of it is produced in Europe), cork-based products and chestnuts; and it is also leading in processing and exporting some other NWFP, such as vegetable tannins and wild mushrooms (see Figures 18 and 19, and Table 6). Apart from these products, the EU is a net importer of NWFP and it accounts for almost half of the total global NWFP import (Table 5).

The high internal demand and the EU's strong position on international markets for several NWFP represent a significant opportunity for a European bioeconomy, and offers a chance to enhance internal NWFP supply and maintain industrial processing as well as local and traditional know-how of NWFP value addition. While it is unrealistic to supply

Table 5. Global EU trade values of selected commodities which include NWFP in the year 2011 (million USD). (Source: Pettenella et al, 2014)

		Trade values in 2011 [USD millions]				
Code	**Product**	**World**	**EU-Exp.**	**EU-Imp.**	**Bal.**	**%***
040900	Honey	1906	616	1019	-403	32.34
060410	Mosses	58	33	37	-4	55.98
060491	Fresh foliage	1210	729	887	-157	60.29
060499	Dry foliage	367	170	231	-61	46.33
070951	**Fresh Agaricus**	1302	1102	972	129	84.63
070959	Fresh mushrooms	785	414	480	-66	52.69
071151	**Preserved Agaricus**	101	32	53	-21	32.07
071159	Preserved mushrooms	119	17	85	-68	14.45
071231	**Dried Agaricus**	116	41	58	-17	35.52
071232	Dried Auricularia	196	4	16	-12	1.95
071233	Dried Tremella	55	1	2	0	2.30
071239	Dried mushrooms	1370	71	170	-100	5.17
200310	**Prepared Agaricus**	1179	572	568	4	48.48
200320	Prepared truffles	29	24	17	6	82.02
200390	Prepared mushrooms	228	84	87	-3	36.77
080221	**Hazelnuts**	180	25	41	-17	13.61
080222	**Shelled hazelnuts**	1782	296	1342	-1046	16.60
080231	**Walnuts**	987	164	308	-144	16.61
080232	**Shelled walnuts**	1545	219	678	-459	14.15
080240	Chestnuts	299	153	121	31	51.05
080250	**Pistachios**	3013	524	1287	-763	17.38
081010	**Fresh strawberries**	2579	1604	1533	71	62.18
081020	**Fresh raspberries**	1173	410	442	-32	34.97
081030	**Fresh currants**					
081040	Fresh cranberries	1428	345	488	-143	24.14
081090	**Fresh other**	2948	713	914	-201	24.19
081110	**Frozen strawberries**	1090	479	706	-227	43.95
081120	**Frozen raspberries**	951	416	694	-278	43.72
081190	Frozen fruits and nuts	2530	1033	1484	-451	40.82
320110	Quebracho	85	7	32	-25	8.27
320120	Wattle	130	4	24	-19	3.37
320190	Other tannins	195	92	57	35	47.05
450110	Natural cork	147	140	132	8	94.88
450190	Cork in pieces	93	79	69	10	84.94
450200	Cork squared	72	63	42	21	87.82
450310	Cork Stopper	743	705	406	299	94.92

Notes: The World-EU28 percentage is calculated as fraction of EU28's export with regards the global trade in 2011. The export and import values consider also the intra EU trade. Commodities marked in bold are mostly generated from agricultural land.

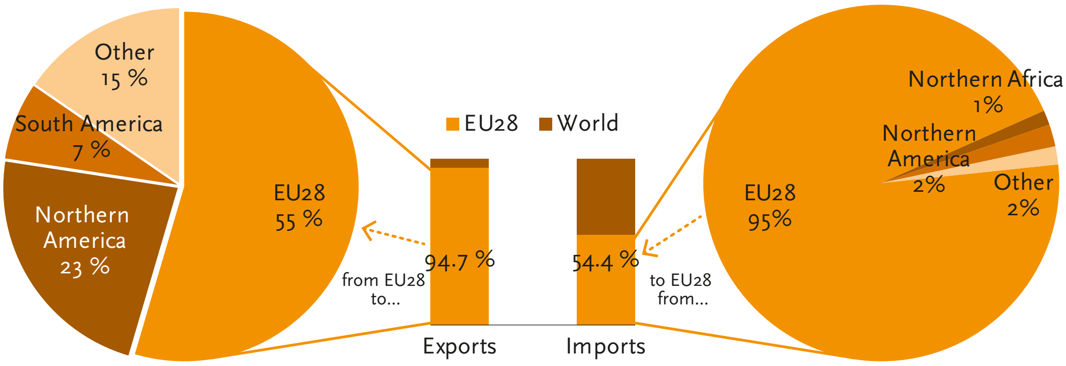

Figure 18. EU28 import and export partners for cork stoppers in 2011 with respect to global trade (percentage based on USD).

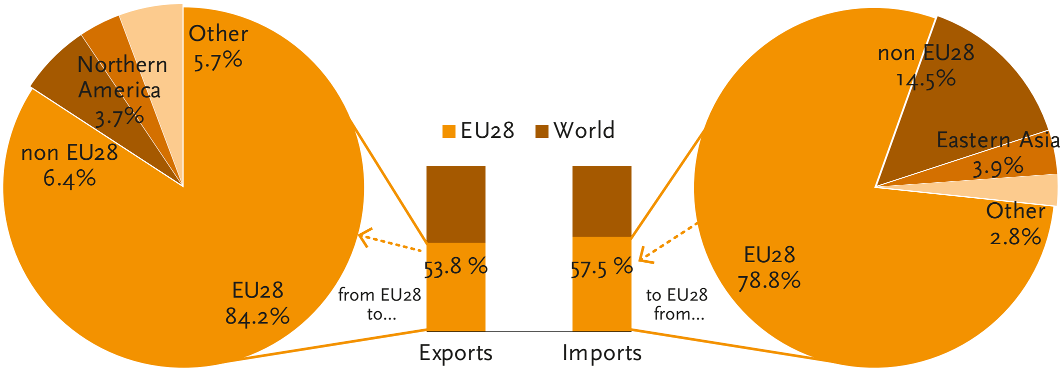

Figure 19. EU28 import and export partners for fresh mushrooms in 2012 with respect to global trade (percentage based on USD).

Table 6. Global export and import top five countries of fresh mushrooms in million USD.

Exports (million USD)					
2005		2010		2012	
China	139.1	China	145.1	China	163.7
Netherlands	48.0	Netherlands	77.5	Poland	93.8
Poland	44.5	Poland	75.5	Netherlands	69.4
Romania	25.0	Italy	49.6	Italy	54.4
Russian Fed.	24.3	R. of Korea	44.7	R. of Korea	37.9
Imports (million USD)					
2005		2010		2012	
Japan	152.9	Japan	99.1	Germany	100.1
Germany	75.4	Germany	95.4	Japan	97.8
Italy	61.8	France	83.8	France	90.9
France	51.7	Italy	61.2	Italy	51.9
UK	34.5	UK	58.7	USA	51.1

internal EU demand for all NWFPs from European forests, the enhanced production of NWFPs could be a key aspect of future forest policies in order to reduce dependency on international trade and re-establish economic bridges between largely urban NWFP consumers and producers located in remote rural areas. This can be done by fostering process-related, technological, organisational and institutional innovations that span from forest management through harvesting to the processing and marketing of products. With a few exceptions, the most notable of which are pine resin and cork, currently most NWFP are generated as a side product of normal forest management and no formal actions are taken to enhance their production. The specific integration of NWFP production into forest management may range from small interventions (such as the use of forest thinning regimes to enhance production of mushrooms or berries) to the selection of specific tree species (such as cherries, nuts or other fruit trees), agroforestry systems (such as the Portuguese *montado* system with cork production and grazing), or the establishment of orchards of native fruit trees and shrubs (e.g. chestnuts, hazelnuts, elder, sea buckthorn, etc.). Innovations in harvesting or processing may reduce costs or improve the product quality – for instance, the availability of natural ingredients or the shelf life of the products. More attention can also be given to the enhancement of different environmental and food standards that address the overall quality of the internal supply in order to differentiate the market and capture high-quality segments and hence higher prices. In the EU, strict requirements for food traceability – also affecting edible NWFP – are being introduced on a compulsory basis. A more transparent market in terms of origin identification can enhance the preferences towards European NWFP and can support the parallel process of transforming informal activities into formal ones.

3.10.3. NWFP opportunities in the bioeconomy era

From the bioeconomy perspective, the key feature that is more prominently visible with NWFP than with wood-based products is their potential to bring socio-economic wellbeing and redistribution of wealth to both urban and rural areas, thus contributing to “inclusive growth” in Europe. A prominent recent development in this regard is a trend towards greater appreciation and use of natural, traditional and wild resources. This is evident in the proliferation of popular culture around “wild foods” and “foraging”, the resurgence of interest in traditional crafts and also in the emergence of “back to nature” lifestyles which are consciously chosen. For example, many traditional wild forest products such as chestnuts, mushrooms, forest herbs, fruit juices etc. are no longer seen as subsistence food but are part of healthy “superfoods” and stylish gourmet food served in the finest restaurants. Home-made, hand-made or one-of-a-kind artisanal products based on NWFP, such as natural soap, speciality liqueurs, berry jams, etc., produced by small manufacturers that incorporate the use of traditional methods and materials, successfully capture growing consumer segments who are willing to pay high prices for high-quality, unique, organic or locally produced goods. New marketing channels, internet platforms and social media networks allow even small producers to reach distant clients. At the same time, regional or quality certification schemes testify to the specific product’s qualities. Horizontal cooperation of small producers under a common brand allows for joint marketing and can facilitate growth e.g. year-round sales through supermarket chains or in their own shops. Traditional NWFP can also be used as an image and *genius loci* for marketing clusters of local products and services (e.g. mushroom roads, chestnut trails, truffle weeks) that can connect different actors and services of the same territory. Vertical integration or cooperation

Box 10: NWFP harvesting and consumption in Europe

A household survey of NWFP picking activity across 28 countries in Europe – including EU28 members (with the exception of Malta, Cyprus and Luxemburg) as well as Serbia, Turkey and the European part of Russia – gathered nearly 15,000 completed questionnaires and this body of data represents the first comprehensive overview of the scale of NWFP activity in Europe. The results of this survey indicate that nearly 25% of European households reported picking NWFP at least once in 2015 (see Figure 20). The variation in harvesting activity among countries is rather dramatic – ranging from 5% in the Netherlands to 68% in Latvia reflecting national differences in traditions and culture surrounding NWFP. Wild berries and mushrooms are the most frequently harvested groups of NWFP (game and fish were not included in the survey), with 20% and 19% of European households engaged in these activities, followed by forest nuts (14%), wild medicinal and aromatic plants (12%), and tree foliage, flowers and moss (11%). The survey also revealed that the majority of the collected NWFP are used within the household for its own consumption or as gifts. Only around 30% of the reported NWFPs (on average) were reportedly sold to appear in formal supply chains.

The numbers of people engaged in picking NWFP suggest that this is a component of everyday life which represents a personal connection with nature and forests for many Europeans. Much of this activity is based on the exercise of ancient rights to wild natural products intended for subsistence purposes and most directly benefiting poorer people. It also illustrates the significance of these products both in terms of the recreational value associated with harvesting them and the economic value obtained from their consumption, which is remarkably higher than the formal statistics suggests.

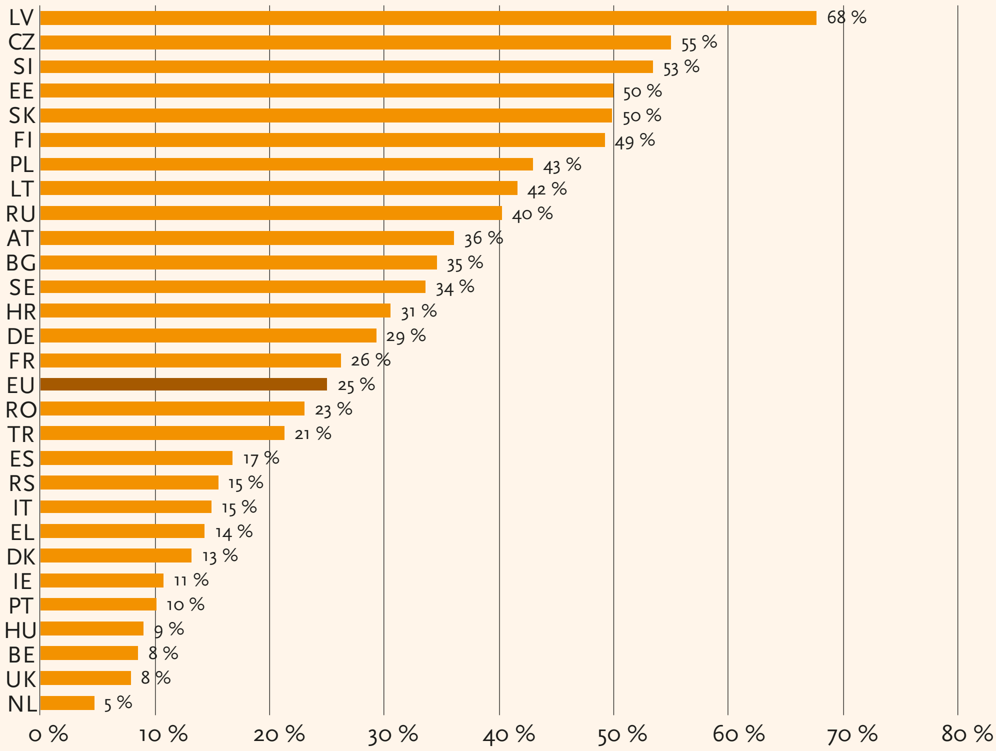

Figure 20. Percentage of households engaged in NWFP harvesting activity in 2015 (Vidale et al, 2015).

may secure a higher value added for the primary producer (farmers' direct marketing of processed products) or may allow for a traceability of the product chain (e.g. high quality game meat or other products from natural production).

Another trend which is growing in importance is the experience economy. The core of the business offer is the experience of the product – e.g. consumers' feelings, fun, fantasies – and not the product itself. Conventionally, forest experiential services include guided tours, eco-tourism, cultural or sporting events. In many instances, NWFP are marketed together with or through these services. In the last decades we observe the expansion of experiential services related to NWFP, such as foraging or mushroom collection tours, wild fruit cooking courses, or different types of production workshops (e.g. "weave your own basket", "make your own herbal salt", "cut your own Christmas tree", etc.). The market for such products is potentially large given that 25% of EU households already engage in NWFP harvesting and use.

The opportunities awarded by NWFP are not limited to small-scale entrepreneurial activities, as the advances in R&D, technology and innovation, coupled with imagination, continuously result in new uses of traditional products, such as, for example, cork. Today, this natural raw material is used not only for bottle stoppers, but also in construction, heritage, decoration, fashion as a leather substitute for clothing, plastic arts and aeronautics. Cork fabric, cork paper and cork wire are already a reality, and new uses and applications are continuously emerging. In addition, a huge silent potential for medicinal or pharmaceutical products is hidden in wood, bark, fruits, leaves from a broad range of forest plants. Traditional medicinal knowledge has gradually decreased over the past few centuries due to the emergence of formalised medicine. However, an increased interest by society in herbal medicines for self-medication and as a complement to the conventional medical approach heralds renewed demand for herbs while the pharmaceutical industry turns again to NWFP as a source of promising chemical substances. Black cherry (*Prunus serotina*), for example, has been shown to contain a significant amount of amygdalin, which is currently being used in cancer research with harvest field trials already being conducted in Germany. Another example is bog myrtle in Scotland, which is used as a substitute for tea tree in skin preparations, including palliative use for skin complaints.

Take home messages:

- Non-wood forest products play an important role for human societies for both household use and as a commercial product. NWFP relate to green space and regional identity, and link personal and societal wellbeing, all of which is not sufficiently quantified, and is not part of current political debate.
- Nearly 25% of European households report collecting NWFP, with a wide variation in activity at national level. Aside from the use of NWFP for subsistence purposes by certain segments of population, their use as natural heritage product, as natural foods and as leisure activity, especially among urban dwellers has been growing in popularity.
- Informal and non-market activities substantially contribute to livelihood and wellbeing, as well as to maintaining local and regional identities, which is an important carrier of rural development in Europe
- The EU has a strategic role in the international NWFP market, which has been increasing due to a growing demand for these products. As net importer, the scope of sustainability assessment of NWFP needs to be taken into perspective vis-à-vis local products.

Policy recommendations:

To fully benefit from the opportunities and potential offered by NWFP, several factors need to be better considered:

- Optimised forest management concepts that seek synergies and minimise trade-offs are needed to balance multiple claims on forest resources to ensure that they are not prone to overexploitation, an essential element to secure sustainability of NWFP use in a bioeconomy.
- NWFP monitoring is currently inadequate both for production, trade, and consumption to properly document the full dimension of NWFP in Europe as well as imports and exports. A new product classification scheme for NWFP alongside minimum common standards for data collection is needed to give visibility to the sector and support the policy process.
- More research is needed on defining sustainable harvesting limits for wild NWFP in Europe. The experience from tropical countries demonstrates that overharvesting resulting from commercialisation can be a significant threat to many species especially those used as medicinal and aromatic products.
- Harvesting, management and exploitation rights need to be clearly defined and understood. This is to guarantee, first of all, that the forest owners benefit from enhancing NWFP production on their land and incorporate NWFP-related objectives in their forest planning decisions; and secondly, that harvesting and exploitation is done in a legal manner, allowing for traceability of products and ensuring healthy employment conditions of the people involved in all the processes on the one hand, and respecting traditional use rights by local populations on the other.
- The variety of NWFP and their uses, alongside the diversity of production systems, results in a complex institutional framework, which encompasses multiple policy domains and involves multiple stakeholders at different spatial scales. Policies and legislation affecting NWFP-related value chains need to be coherent, consistent across scales (EU, national and sub-national) and domains (e.g. forest, agriculture, nature protection, food, trade, etc.) and strategically developed in consultations with stakeholders in order to avoid placing contradictory demands on value chain actors and support innovation at all the stages of NWFP value chains.
- The enhancement of domestic production by fostering innovations along the value chain, from forest management all the way to product marketing, may be a key aspect of future forest policies.
- Bolstering the NWFP economy requires alliances with sectors as varied as the materials industry, health, personal care, art, tourism, nature protection and immigration. Biochemistry and bioengineering can help to unlock the potential of NWFP properties to launch bio-based solutions tackling pollution, or global change adaptation.
- For effective support of innovations in NWFP there is a particular need for open and flexible support programmes that can offer systemic structures for tailor-made support. A variety of support mechanisms should be made available for NWFP-related activities in order to promote networking, cooperation, education and training of different actors and professionals involved or related to NWFP value chains, enhance R&D and entrepreneurship activities and raise awareness of NWFP both among the civil society and decision-makers. Such support is rare but examples do exist, such as rural development agencies, LEADER local action groups, cluster organisations or other regional cross-sectoral platforms.

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4.

Monitoring and assessing the sustainable forest-based bioeconomy

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Towards an integrated forest-based knowledge base

The "critical issues" reviewed in Section 3 have revealed that information needs on a forest-based bioeconomy go beyond the classical instruments so far employed by the sector. These requirements are by nature multi-sectoral, interconnected and integrative across value chains. Against this background, new modalities of a forest-based knowledge base need to be developed that facilitate a broader approach towards knowledge management, information exchange and further utilisation (e.g. for communication, assessment). Even so, while value chain implantation, inter-sectoral connecting points, compliance of different data sources and system thinking (e.g. life cycle analysis) are still not fully developed in current information and data instruments, the principal tool, i.e. indicators, has been substantially shaped by forest-related processes.

In general, indicators are tools alongside the political agenda of a variety of national, regional and global policy processes. They are part of the core discussions of sectoral processes and proposed EU assessments (e.g. sustainability criteria for bioenergy, European core health indicators, European tourism indicators, sustainable forest management (SFM) criteria and indicators for the new EU Forest Strategy, etc.). They build a central element of the framework to assess the implementation of the UN Sustainable Development Goals (SDGs).

SFM indicators have so far been used for monitoring and reporting, for communicating SFM content to a wider audience, for policy formulation in national forest programmes and, to a certain extent, for performance assessment (see EFI, 2013; Prins, 2016; FOREST EUROPE, 2015 and 2011; EEA, 2016). The *Pan-European Indicators for Sustainable Forest Management* have been referred to in many political debates and have proved useful for forest monitoring and reporting at both national and European level.

The transition towards a bioeconomy has big potential for an expanded and diversified use of forest resources. The contribution of the forest sector to the bioeconomy builds on the presumption that sustainable development is a necessary condition for a forest-based bioeconomy. Sustainable development needs to be at the heart of the bioeconomy concept, and has to take account of local and regional conditions, as also addressed by the SDGs. Consequently, there is a need for a realistic understanding of the potential capacity of forest resources to contribute to a sustainable bioeconomy. Also, many new forest products are emerging, and it will be important to monitor their whole value chain sustainability. Forest-related indicators hold great potential to become functional instruments for a forest bioeconomy, contribute to a general bioeconomy monitoring, help to assess and inform about the desired sustainable development paths, and can become a useful tool for policymaking and natural resource planning.

A forest-based bioeconomy implies that a lot of objectives and also (potentially contradictory) targets have to be addressed and clarified: how wood is grown and used, how ecosystem services are managed and valued, how climate change can be integrated, where and how forests and biodiversity are protected, how resource efficiency can be tackled, how competitiveness impacts jobs and societal welfare, and how all this is integrated into dynamic land use and societal development in Europe. In this context, indicators are highly relevant as tools to inform policy makers, as tools to synthesise complex matters, and as tools for decision support.

Indicator use for sustainability assessment

Over the past 25 years, indicators became prominent in evaluating sustainable forest management and were used in both political processes and certification initiatives (FRA, MCPFE/Forest Europe, UNECE, FSC, PEFC, cf e.g. EFI, 2013). The forest-based sector brings ample experience of indicators as the tools for measuring, monitoring, and assessing sustainability progress, while new trends will require a more comprehensive touch on the whole value chain.

In Europe, FOREST EUROPE is *the* pan-European forest policy process for the continent's forests, joining efforts with UNECE and the FAO Forest Resource Assessment (FRA). Its 46 member states (including the European Union) aim at developing policies on how to protect and sustainably manage forests. The FOREST EUROPE process has developed a pan-European criteria and indicator (C&I) set for SFM, which consists of six criteria and 34 quantitative indicators (describing the forest status and changes) as well as 11 qualitative indicators (describing national forest policies, institutions and instruments towards SFM).

Other global and regional forest policy processes and initiatives, such as the Montréal Process, international organisations such as ITTO organisations but also certification processes (e.g. FSC, PEFC) are applying indicators. Parallel to the work carried out in the forest sector, sustainability indicators have been developed and used by many others. For instance, the OECD, the UN Commission on Sustainable Development and Eurostat monitor sustainable development by indicators. Conventions and agencies such as the Convention on Biological Diversity and the European Environment Agency monitor and assess biodiversity conservation by indicators, and the Convention to Combat Desertification monitors desertification by indicators. Furthermore, the UNECE and FAO developed indicators as a basis for regular and harmonised Forest Resource Assessments that cover all regions globally. In the light of the recently developed UN Sustainable Development Goals (SDGs), indicators are an essential element in monitoring global progress towards reaching sustainable development. However, in this regard, forest resources-related information will play a rather subordinate role.

Consequently, forest-related indicators have been developed on different levels of government. In pan-Europe (FOREST EUROPE) in particular, these indicators helped to operationalise sustainable forest management along the lines of criteria (i.e. essential elements or conditions by which SFM may be assessed). Forest-related indicators nowadays are mainly used for international and pan-European reporting purposes to monitor forest resources and the sustainable management of forests. Accordingly, this set-up demands national implementation, hence we find derived national indicator sets, as well as examples of derived local indicators (EFI, 2013).

Lessons learned from indicator science

While the demand for forest-related indicators as data carriers is potentially manifold, there are certain areas of application where indicators have been particularly used. A recent EFI study on the implementation of SFM indicators identified **five major applications of indicator use** in Europe (EFI, 2013):

(1) *Reference framework* for dialogue and communication to provide stimulus and support for communication within the forest sector, especially in terms of setting and streamlining the forestry debate.
(2) *Tool for monitoring and reporting* on the progress towards sustainable forest management, which helps to improve the availability, quality and comparability of forest information among European countries.
(3) *Reference framework* for the development and adaptation of national policy instruments and/or forest-related policies.
(4) *Assessment tool* for measuring progress towards sustainable forest management, i.e. by adding interpretation and value information to monitoring data, and identify emerging issues.
(5) *Information tool* for creating links to outside the forest sector and other global initiatives.

Compared to further scientific indicators, it can be summarised that indicators with reference to the forest-based sector contribute essentially to:

- Agreeing to *shared definitions* (e.g. finding a common understanding of what constitutes sustainable forest management).
- Shaping *monitoring and reporting* activities.
- Facilitating *unambiguous communication and learning efforts* among stakeholders.
- Fostering *education and capacity-building* through participatory decision-making and decentralised policy implementation.
- Supporting *participatory modes of decision-making, knowledge generation and exchange*.
- Reaching a *global convergence for indicator implementation*.

The development of indicators for the forest-based bioeconomy should make use of existing sets of national, regional and global indicators, in particular the ones developed for monitoring and assessing sustainable management and use of forest resources.

One challenge in the context of the forest bioeconomy is that the forest-centred activities remain quite sectoral. The contribution of forests to the bioeconomy should present/indicate how to utilise their full potential for the forest bioeconomy, overcoming sectoral boundaries. In addition, developing forest bioeconomy indicators might create the opportunity to circumvent shortcomings that have been reported from the existing indicator framework (cf EFI, 2013; Grainger, 2012), such as:

- *Missing conceptual fundament* to unravel the full potential of indicators.
- *Unclear reference* to political goals and objectives.
- *Limited operational design and data availability*.
- *Lack of assessment features* providing diagnosis, warning signal, and guidance.
- *Unbalanced indicator sets* that are particular weak in terms of socio-economic indicators.
- *Weak harmonisation* as regards terms and definitions on forest information hampers reliable indicator interpretation.

For defining a reliable and fit-for-purpose set of forest-related bioeconomy indicators, conceptual, technical and procedural aspects need to be taken into account.

Major elements of a bioeconomy knowledge base

An important knowledge base for the forest bioeconomy is readily available as part of the FOREST EUROPE process. An analysis of current forest indicators as implemented by FOREST EUROPE, strongly in line with other indicator initiatives worldwide, shows there is a strong focus on the early stages of the forest-based value chain, i.e. forest resources and primary production. The Pan-European indicators (34) for SFM mostly cover the first part of the forest-based sector value chain, with three exceptions: wood consumption, trade in wood, and energy from wood resources (Figure 21).

This forestry-centred indicator set creates a valuable core when talking about the sustainability of forestry production, but it has been designed for a different purpose than informing about the entire forest-based bioeconomy: safeguarding the sustainable management of forests.

Hence, for monitoring the bioeconomy, a broadening of the knowledge base is required. A recent EFI analysis of the EU Bioeconomy Strategy (Wolfslehner et al, 2016) identifies the forest-relevant topics contained in the strategy and gives guidance on the topics to be addressed by indicators. It shows that classical SFM indicators can cover a significant range of issues, but will need to be complemented by further indicators along the value chain, ranging from biomass to other ecosystem services, also as a response to the key issues identified in this study.

An analysis of currently available data also revealed that there is already a lot of relevant information available, but it is fragmented in different data sources, which makes comparison, integration across sectors and scales and compliance with international reporting standards sometimes difficult.

For the aforementioned EFI study (Wolfslehner et al, 2016), a set of possible data sources have been explored in view of extending the SFM indicators towards the monitoring of a forest-based bioeconomy:

- EC Resource Efficiency Indicators Report, 2015
- EC Good Practice Guidance in the Sust. Mobilisation of Wood in Europe, 2010
- FAO Global Bioenergy Partnership (GBEP) Indicators for Bioenergy Report, 2011
- Material Use Indicators for Measuring Resource Productivity and Environmental Impacts, WS Report, 2010

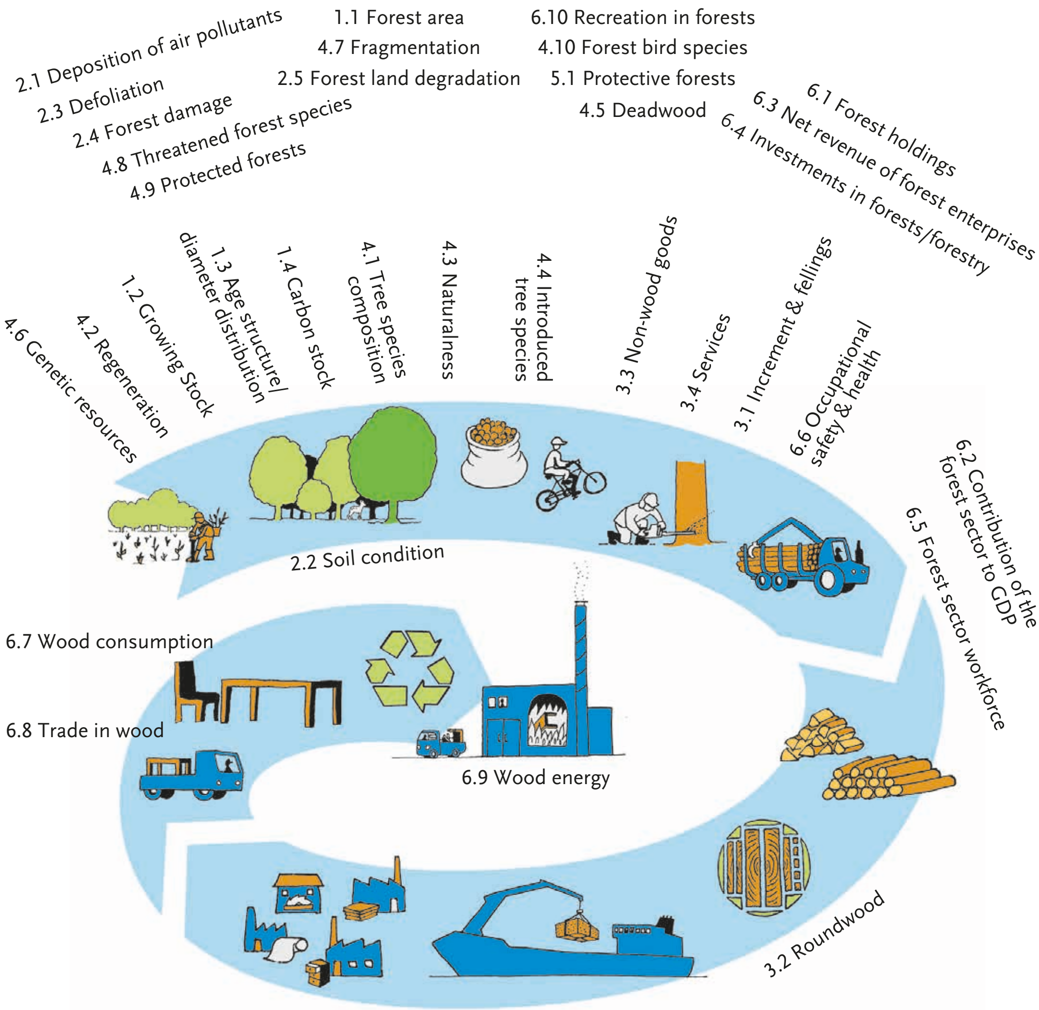

Figure 21. Current Pan-European indicators for sustainable forest management in relation to the forest-based sector value chain. Source: Wolfslehner et al, 2016.

Table 7. Potential forest-related topics addressed by the EU Bioeconomy Strategy

Bioeconomy criteria	Forest-related topics
Ensuring food security	Role of forests in watershed management and the provision of water for agriculture and fisheries to secure sustainable food production
	Edible non-wood forest products
	Forage and feed for livestock
Managing natural resources sustainably	Using existing SFM criteria and indicators for SFM
	Forest ecosystem services
	Social services like health/wellbeing
	Desertification
	Illegal logging
	Green infrastructure
Reducing dependence on non-renewable resources	Low carbon society: carbon sequestration, carbon footprint, carbon neutrality
	Renewable goods and substitution of fossil products: bio-based products, bioenergy, carbon in wood products
	Resource efficiency
	Biomass availability
	Energy security, independence from non-renewables
	Indirect land use change, displacement effects of EU biomass demand
Mitigating and adapting to climate change	Compliance with climate policy goals
	Resource efficiency
	Carbon accounting
	Climate change effects: diseases, pests, fires
	Resilience and risk
Increasing competitiveness and creating jobs	Jobs in rural and in urban areas
	Forest sector workforce Income generation
	Green jobs, services to/from the sector
	Innovation and start ups
	Diversification of forest-related bio-based products
	Emerging societal trends and new markets

- EEA Core Set of Indicators
- EU Resource Efficiency Scoreboard
- Eurostat SDI
- FAO C&I for Sustainable Woodfuels
- OECD Green Growth Indicators
- Pan-European Indicators for SFM
- United Nations Sustainable Development Goals

For a comprehensive forest bioeconomy framework, additional information collection efforts will need to be started, depending also on how the forest-based bioeconomy is understood and politically defined. Relevant indicator gaps along the forest-based value chain relate to topics such as:

Table 8. Indicator gaps along the forest-based value chain

Topics related to forest management	• Forest ecosystem services • Social services regarding health and wellbeing • Illegal logging • Certification • Carbon storage in wood products • Carbon footprint
Topics related to the forest-based sector and secondary production	• Environmentally sound processing • Innovation in processes and products • New markets • Diversification of forest-related products • Secondary or value-added forest products • Bioenergy, biorefineries • Forage and feed for livestock • Green jobs • Sustainable construction • Recycling • Green public procurement
Topics related to logistics	• Sustainable transport from the forest road to the factory • Sustainable transport from the factory to the consumer • Green infrastructure

A broadened approach can look like Figure 22, which can be directly referred to Option 1 in the subsequent chapter. "Broadened" normally means larger sets of indicators and data needs, which makes handling more complex, in particular when originating from different instruments and sources. In the next section, three options looking at how to address this dilemma are explored.

Pathways towards integrated indicator-based monitoring

In the context of an EU bioeconomy, there are particular opportunities for further developing forest-related indicators that address (a) the *challenges voiced by the EU bioeconomy strategy*, that define (b) *intersectoral tools* that seek compliance with other sectors and initiatives, and that (c) *strengthen assessment features* that will allow estimating the sustainability impacts of moving towards a bioeconomy.

A recent EFI study (Wolfslehner et al, 2016) demonstrated three optional pathways that can – stepwise – lead to a more integrated forest bioeconomy monitoring. Starting from the summary that current forest-based indicators are sectoral and confined mostly to the early stages of the forest-based bioeconomy value chain, and additional relevant information is scattered across very different sources, an updated approach for forest bioeconomy monitoring was proposed for a pragmatic evolution from current sets to new, innovative solutions.

Option 1: Complement the pan-European indicator set for SFM with additional bioeconomy-related topics

This option takes a pragmatic approach, recognising that around 25 years of investment and experience are gathered in the current pan-European indicator set for SFM, and further expert work is currently ongoing.

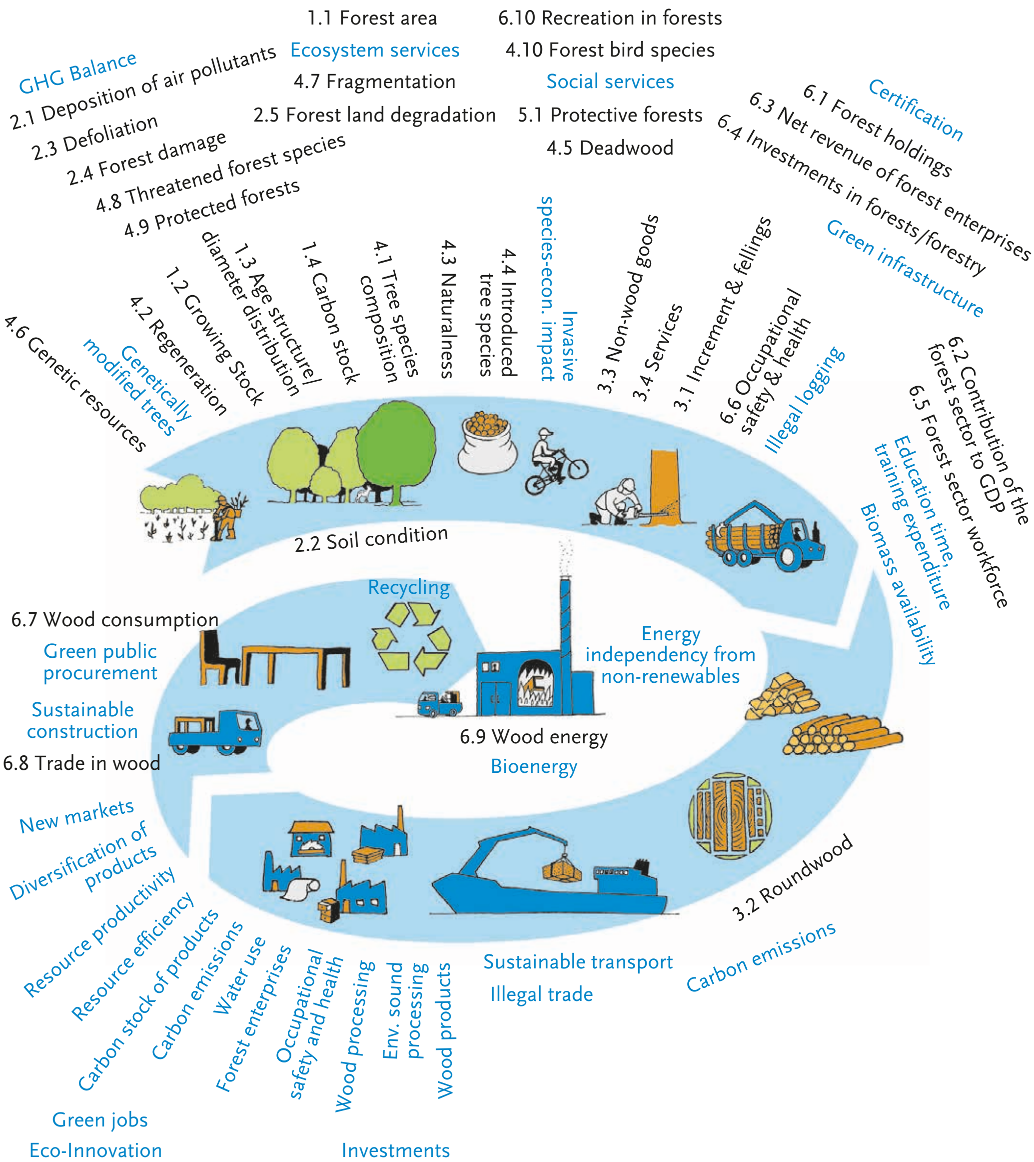

Figure 22. Current Pan-European indicators for SFM and complementing additional indicators (in blue) along the forest-based sector value chain. Source: Wolfslehner et al, 2016.

This option defines the pan-European set as a starting point to initiate a process where identified gaps along the forest-based value chain are successively closed by complementing the current indicator set with references to the bioeconomy and the respective EU forest-relevant policy framework.

This approach has the advantage of building on a well-proven institutional framework and capacities (including national data collection). It thus implies a form of evolution rather than revolution. This solution also means that the long list of current indicators is expanded, which increases the efforts for data collection. It also requires a response to the shortcomings of current statistics, such as a redefinition of the sectoral boundaries.

Option 2: Develop a new forest bioeconomy indicator set with thematic subsets of indicators

This option implies a conceptually more advanced approach than Option 1. It comprises some of the pan-European indicators for SFM, but is intrinsically meant to be a process for developing new, additional indicators, following a new thinking. The central objective is no longer SFM, but is shifted towards the sustainability of the *whole* forest-based sector value chain, not just focusing mainly on the forest management part.

The EU Bioeconomy Strategy could provide the basis for the new indicator framework and relevant criteria for it. More specifically, in line with the five societal challenges of the EU Bioeconomy Strategy, five subsets of indicators should be developed referring to (i) Ensuring food security, (ii) Managing natural resources sustainably, (iii) Reducing dependence on non-renewable resources, (iv) Mitigating and adapting to climate change, and (v) Creating jobs and increasing European competitiveness. This approach will require more time and resources in setting up a related cross-sectoral indicator process, but will be more tightly linked to the EU Bioeconomy Strategy. It offers the opportunity for sectoral harmonisation and synchronised methods of data and information management but, of course, should avoid a new form of thematic-sectoral encapsulation within the subsets. This approach requires a cross-sectoral dialogue on the sub-topics which are part of a forest bioeconomy. It will create a new picture of business services and ecosystem services, which relate to the sector and beyond.

Option 3: Design a cross-sectoral key indicator set

This is option is based on a new trend in indicator development and use, for example applied by Eurostat (Europe 2020 strategy headline indicators) and the European Environment Agency (Core set of indicators). It builds on a limited number of key, core or headline indicators which aim to deliver a short, understandable picture of sustainability aspects in a bioeconomy. This would allow communication to a broader audience, decrease data collection and reporting burdens, and support a concentrated discussion on what are the key information needs for decision-making.

This approach could run in parallel to, or be backed up by, larger sets which can be used to synthesise (sub)indicators or composite indicators (e.g. a footprint). Such key indicators are ideally designed in a way that supports cross-sectoral application, and might require an adapted institutional framework where this discourse is facilitated. This could be existing bioeconomy fora, expert panels, or observatories, or new instruments respectively.

Recent experiences show that selection processes and the simplification of information are very demanding, both in terms of rigidity and acceptance of stakeholders. On the other hand, selection could build on Options 1 and 2, and the outcomes of other processes that employ key indicators. It could be seen as an evolutionary step, following a consolidation of bioeconomy indicators.

While these indicators address key aspects of a bioeconomy development, it is important to maintain holistic and systemic elements for analysis, i.e. how these measured phenomena interact, and what are the causal relationships behind them. A novel approach in land and natural resource use science is to address synergies and trade-offs of socio-economic activities. This concept would lead to the uptake of synergy and trade-off indicators that explain systemic patterns. These can be used to demonstrate positive effects of the bioeconomy as compared to a fossil-based economy, but also help to avoid adverse effects and perverse incentives in a European bioeconomy. Synergy and trade-off indicators can be designed to clearly demonstrate the positive and negative effects of action and policies. These indicators, and proper metrics, could monitor critical issues related to examples such as:

- Land use competition and indirect land use effects *(EU, regional and globally)*.
- The effects of intensified management and conservation.
- The relationship between biomass use and biodiversity.
- Balance between material and energy use of biomass.
- The cross-implications of increasing use of biomass on carbon sequestration.
- Effects on urban and rural development.
- A holistic view on technological rationalisation and its social effects.
- Effects on natural and social capital.

This instrument is deemed to demonstrate both potential positive and negative effects of shifting European economy, and help safeguard a sustainable development in this context.

Take home messages:

- Accepting sustainability as a lead concept underlying a forest-based bioeconomy requires instruments for measuring and assessing developments of the sector: indicators are proven tools to do so, but need further development for safeguarding sustainable development and highlighting synergies and trade-off of an emphasised natural resource use.
- The forest-based sector has rich experience in indicator work as primary tools for providing metrics and communication tools to address forestry issues. However, in a forest-based economy, the scope needs to be broadened towards a value-chain approach, where forest products and forest ecosystem services are equally considered "from cradle to grave".
- A further emphasis on the forest-based bioeconomy needs a more balanced approach of economic, environmental and social aspects. Hence, indicators need to reflect such a balance and give impetus to the bioeconomy debate in the light of sustainable forest management and sustainable development.
- Modern development of indicators implies that key or headline indicators can help unravel essential, comparative, and benchmarking aspects of bioeconomy value chains. There are at least three pathways on how to carry on from the existing wealth of indicator work. It should be emphasised that data generation is not sufficient but also requires knowledge brokers to make proper use of data and information.

Policy recommendations:

- Indicators should be designed for bioeconomy monitoring so as to show and assess sustainability effects of the bioeconomy, but also to capture the possible synergies and trade-offs among the different societal demands for forest resources, and between forest sector and other sectors.
- Forest monitoring would benefit from being harmonised and its instruments made comparable with other sectoral instruments. Initiatives such as the recently installed Bioeconomy Knowledge Centre (BKC) can help to streamline data collection, assessment and interpretation of the effects and perspectives of the bioeconomy in the future. Support from the forest science community is needed for this purpose.
- It is recommended that the experience and lessons learnt from forest-related indicator development and processes (e.g. FOREST EUROPE) is taken up and to further update and develop these indicators to fit the whole forest-based bioeconomy as well.
- A cross-sectoral political forum could debate the priorities, metrics of assessment, choice of targets, and the acceptance of trade-offs, while targeted science-policy exchange instruments support these processes. With the EU Bioeconomy Panel and the European Bioeconomy Alliance there are already fora which enable cross-sectoral dialogue and cooperation.
- It is important to consider national strategies and approaches, and their role in the EU bioeconomy as a whole. Bioeconomy monitoring has to feed into the discussion and planning of appropriate land use in Europe, the optimal use of our resources, and an awareness of possible leakage effects of European policies into the rest of the world.
- Monitoring results could be used to communicate and provide information to a broader public, as well as supporting new forms of information sharing and citizen science. New approaches such as key or headline indicators and indices should be tested to satisfy these needs.
- Indicators form the structural and methodological backbone of an integrated bioeconomy monitoring. A common platform for EU data providers and national data collectors requires consensus and agreement on procedures, goals and targets.

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5.

Policy conclusions

Georg Winkel

The bioeconomy concept has developed dynamically since entering the political arena. It has followed the path of other visionary policy paradigms: a rapid growth in importance accompanied by investment in policy strategies, research and think tank narratives; continuous debates on the content and operationalisation of the concept; increasing complexity but also the first signs of erosion of importance as new and complementary concepts emerge.

The bioeconomy is currently at a crossroads. It has mobilised significant investments in technology, research and innovation. New and innovative bio-products and related services have emerged, and related niche markets show dynamic growth. However, the biomass-based sectors are affected by the major 20^{th} century transition away from the primary and secondary sectors towards services in Europe. This historic transition has been accompanied by a significant loss in relative economic importance for these sectors, despite many innovations and the dynamic growth of some branches of the bioeconomy. In this regard, the bioeconomy reality shows a mixed picture. There is still much work to be done to reach the vision of the bioeconomy as a crucial pillar of a better and sustainable future economy.

This study indicates that the starting point to better connect the vision to reality may lie in a new **policy narrative** for the forest-based bioeconomy. **This narrative should emphasise a sustainable and socially inclusive forest-based bioeconomy**. It envisions a bioeconomy that recognises and mobilises the entire spectrum of ecosystem services that Europe's forests can provide for the benefit of Europe's societies. It outlines a bioeconomy that combines responsible primary production of ecosystem services with innovative industries, and a creative and dynamically growing manufacturing and service sector. Cross-sectoral collaboration to exploit untapped potential and synergies is needed to substantiate this narrative. It needs to tackle sustainability-related conflicts and maximise sustainability related synergies, to green the greenest part of the bioeconomy – the forest-based bioeconomy.

Substantial intellectual, political and economic investments are needed to underpin this narrative. This study brings together evidence from multiple science perspectives to assess the development opportunities. A significant policy push will be needed to capitalise on them. In the following, key points for such policymaking are outlined.

Build upon the entire spectrum of ecosystem services

Current bioeconomy policy emphasises biomass production-related activities. This study shows, however, that there is a **huge variety of societal demands** towards Europe's forests, which correlate to various economic activities. While **biomass production** and related products and services are economically the most easily quantifiable and in many cases the most significant, **other ecosystem services and related products** are of increasing importance, and at regional scales sometimes of primary relevance.

At the same time, there is **no agreed definition** of a (forest-based) bioeconomy. An open definition is possibly helpful to maximise political support, as many interest groups can use the concept even though they would not operationalise it in the same way. But the vagueness of the concept comes with the price of limited impact. Therefore it is suggested to **define the forest-based bioeconomy as encompassing economic activities relating to all forest ecosystem services**, ranging from forest biomass to tourism, recreation and non-wood products. This definition could be established at the **(pan-) European or EU level.** It would provide the basis for policy measures that support the development of economic activities and innovations relating to the entire spectrum of forest ecosystem services.

Take a multi-level policy approach that recognises regional differences

This report has repeatedly shown that regional differences in Europe are crucial for the forest-based bioeconomy. These differences are already partially mirrored in current national or regional bioeconomy strategies. They relate to:

- The **biophysical conditions** of the forest resources, which determine their use options;
- **Socio-economic factors** (e.g., demographic developments, the overall economic situation, degree of urbanisation, unemployment rates, cultural values/traditions) determining the demand for forest products and services;
- The **sustainably usable forest biomass** resource potential;
- The **industrial infrastructure** and **bioeconomy entrepreneurship**, and competitiveness of the regional bioeconomy;
- The **institutional setting** (e.g. relating to forest property rights) and **political culture** (e.g. relating to the implementation of EU policies).

Recognising these regional differences, a **multi-level approach to bioeconomy policy making is needed**. At the European (EU) level, **the concept and basic rules for European forest-based bioeconomy markets** should be defined. The set of innovation policy tools needs to be boosted, building on existing tools such as Horizon 2020 and the European Investment Fund (EIF).

Given regional differences, these policy tools will have to be tailored at the regional level. Existing bioeconomy strategies at the national or subnational level provide the natural framework to set regional priorities. In addition, **forest-based bioeconomy clusters** in **transnational regions** could be established. These clusters could bundle activities in 'bioeconomic regions' (similar to the concept of biogeographical regions used in EU biodiversity conservation policy) with similar ecological and socio-economic conditions to prioritise objectives for bioeconomy development. Crossing national boundaries within the European single market, they could facilitate economic integration and strengthen Europe's bioeconomy competitiveness globally.

These clusters could set regional priorities within the broad European policy framework to support bioeconomy innovations on the ground, assessing **regional innovation potential** as a first step. Subsequently, regionally specific bioeconomy profiles could be developed through flagship projects. Focus could be put on regions with *high bioeconomy innovation potential* (world market leader regions), and regions with a *specific development potential*, e.g. through exploring synergies such as biomass production in fire-prone

Mediterranean forest in regions with high unemployment rates and rural abandonment. The flagship projects could aim to bundle policy tools, e.g. relating to innovation policy and the future Common Agricultural Policy to strengthen and explore regional forest-based bioeconomy portfolios.

Become sustainable in all dimensions

A key argument to further develop the bioeconomy is the need to move away from a non-sustainable economy built on non-renewable resources. This study confirms that there is substantial scientific evidence for this argument. More specifically, a forest bioeconomy based on biomass production can be **one major strategy to mitigate climate change in the long term**, through the **sustainable use of renewable forest biomass**.

However, this does not mean per se that a forest-based bioeconomy is sustainable. The review of the European policy framework has indicated that there are trade-offs between biomass production and social and environmental sustainability, which should be better taken into account in policies. Sustainable land management is decisive here given that the **land base for a forest-based bioeconomy covers more than one-third of Europe**, and many of these areas are subject to potentially contradicting societal demands. This report has further assessed different aspects of sustainability ranging from biomass availability, biodiversity, resource use efficiency, climate change mitigation potential and employment to the relationship between competitiveness and sustainability in general. A key message is that the **entire sustainability dimension of the forest-based bioeconomy needs attention** for the concept to be successful and engaging for a broader society. For a future forest-based bioeconomy to be perceived as a major **sustainability transition project**, it needs to demonstrate its environmental, social and economic sustainability in a credible manner.

This requires **proactive engagement** of policymakers and bioeconomy actors to maximise synergies and minimise trade-offs between biomass-based value chains and other forest-related ecosystem services:

- There is the possibility to **increase harvesting of forest biomass** at the European scale, but the **implications for other forest ecosystem services** and **social acceptability** need to be carefully investigated.
- The relationship between biodiversity conservation and (increasing) forest biomass use is not black and white, but depends on the (local) situation. '**Biodiversity smart**' approaches to forest management could exploit synergies and minimise trade-offs.
- There is a need to **adapt forest management** to a changing climate and utilise synergies between bioeconomy development and climate change adaptation, e.g. through active management to facilitate species conversion towards **climate resilient forests**.
- The **employment situation** in the forest-based bioeconomy is one key aspect of social sustainability that needs greater attention, specifically relating to workforce diversification and ensuring attractive employment conditions.
- There is a need to continue and extend engagement with a **diverse range of forest-related interest groups** beyond the traditional forest sector to increase credibility and legitimacy, and improve the responsiveness of the concept to the demands of pluralistic societies.
- Taking the entire portfolio of forest ecosystem services into consideration may help to leverage **bioeconomy diversification** and alignment with **societal demands** at regional level.

Consequently, to sustain a holistic bioeconomy narrative, it is necessary to:

- **Explore synergies**, but also determine **thresholds and standards for sustainability**, e.g. relating to biodiversity or greenhouse gas emission reductions.
- Establish and further develop sustainability standards for international trade beyond Europe and make **social and environmental sustainability a key issue in trade** relating to the forest-based bioeconomy.
- Engage strategically in **cross-sectoral alliances** to demonstrate and solidify the sustainability dimension of the forest-based bioeconomy, e.g. a 'bioeconomy for biodiversity alliance' with the conservation sector.
- Explore **new sustainability markets**, e.g. relating to lifestyle-oriented high value wood and non-wood forest products.

The connection between the environment, society and economy is critical for future support for the forest-based bioeconomy. The forest-based bioeconomy must not only focus on rural communities, but also increase its legitimacy and acceptance in urbanised societies, as well as its competitiveness on world markets which serve their needs. A comprehensive and proactive approach to sustainability which exploits the synergies and regulates the conflicts will in the end also benefit the competitiveness of the forest-based bioeconomy in Europe (see Section 3.6).

Tackle untapped synergies and resources

Developing a sustainable forest-based bioeconomy means **searching for and exploiting untapped synergies**. This report presents ample evidence:

- There is significant regional potential to boost a forest-based bioeconomy via tapping into **unused biomass potential**, at the same time having a positive effect on other sustainability aspects, e.g. **fire safety, employment** and **rural economies**.
- There is **significant potential** to either reduce the current impact of forest biomass harvesting on biodiversity or facilitate intensification without further increasing the impact through wise allocation of harvesting activities at the landscape level (see Section 3.2).
- Nearly **25% of European households** collect non-wood forest products, and Europe is the key global market. There is significant, and often hidden, potential for forest-based bioeconomy developments focusing on **non-wood forest products**, as well as **cultural/recreational forest ecosystem services**. These often have synergies with biodiversity and the demands urbanised societies have towards forests.
- **Wood-based construction** is a part of the forest-based bioeconomy with substantial economic and environmental benefits, including efficient **mitigation of climate change** through enhanced carbon sequestration in wood products and substitution of fossil fuel intensive materials.
- Expectations of individual **private forest owners** towards their forests are diverse and mirror the multiple demands of **pluralistic societies**. This could **align producer and consumer interests** in the exploration of the amenity and recreational values of forests (forest owners as providers of 'nature').

It is imperative to develop these **'win-win' development options**. Political obstacles (e.g. a lack of cross-sectoral cooperation) or economic obstacles (e.g. substantial transaction costs, for instance when building up new value chains across sectors) frequently prevent this exploitation. Policies to overcome **cross-sectoral obstacles** and (initial) **transaction**

costs by supporting innovative business models in their initial stages could help to exploit untapped development potential for the forest-based bioeconomy.

Enhance cross-sectoral cooperation

The forest-based bioeconomy touches several issues that go beyond what one would normally label as the 'forest sector'. A huge number of policies affect distinct stages of the forest-based value chain (and its respective sub-sectors) in different ways (see section 2.1). Diversification processes, as part of a cross-sectoral bioeconomy, will increase this complexity.

Enhanced cross-sectoral policy coordination is already frequently called for in the EU and national policy arenas. Such calls are also mirrored in the policy recommendations in some sections of this report. Yet, the call for a more consistent bioeconomy policy should not disregard the nature of cross-sectoral policy conflicts: a lack of coordination between different sectoral policies might be the result of 'silo' mentality that prevents the use of cross-sectoral synergies. In other cases, however, contradicting policy objectives represent conflicting societal interests in forests. Cross-sectoral policy coordination must address both types of coordination challenges. Actively integrating bio-based production with elements of climate change mitigation, biodiversity conservation, nature-based tourism and recreation as well as non-wood forest products will increase the cross-sectoral legitimacy, and developing potential, of a forest-based bioeconomy.

Value chain-specific assessments are critical to address inter-sectoral policy inconsistencies and advance a more integrated policy framework. The assessments require close collaboration of both different value chain actors and concerned policy sectors, as well as scientific knowledge which can contribute to identifying the synergies and trade-offs.

Create a stable, level playing field and innovation policies to nurture emerging markets

A key question relating to the future governance of the forest-based bioeconomy is what an enabling policy framework should look like, specifically in the interplay with markets. This report suggests that:

- **Failure to address negative or positive external effects of economic activities on the environment** or the **value of non-market goods and services** can be an important disincentive to invest in the bioeconomy. This includes disregarding the carbon balance of products and services, or their larger environmental and social impacts, and excluding the value of many ecosystem services (natural capital). Internalising and valuing these aspects calls for **economic instruments** at the level of the common market to incentivise sustainable production and consumption. These instruments would require the quantification of environmental impacts, e.g. via lifecycle assessments and footprint assessments, and agreement/compromises about the important environmental aspects to be covered, including their relative importance. Reviewing existing experiences at national levels and **gradual implementation over the long term** would allow testing and iterative adaptation.
- **Specific market interventions** that favour the use of one forest ecosystem service over another **are often problematic**. For instance, subsidising forest biomass use for energy, and vice versa prescribing a preference for a certain use of forest biomass (e.g. cascading hierarchy order), are evaluated rather critically in this report. Specific interventions risk perpetuating path dependencies relating to technol-

ogy and economic development that might not be sustainable in a system perspective, or in the long term when conditions change. Rather than subsidising specific value chains, the creation of a **level playing field** is advisable. This encompasses the **internalisation of external effects**, but also the **establishment of sustainability objectives** to guide innovation or public procurement policies, as well as the regulation of **social and environmental minimum thresholds**. These instruments should also guide the development of **international forest and trade governance**, to expand the level playing field beyond the EU. This may include the option to introduce sustainability-oriented tariffs, which should follow the same principles as the instruments applied on the internal EU market.

- **Innovation policies** are needed to kick-off and support innovations relating to the forest-based bioeconomy. There are significant opportunities for high and medium value wood-based bio-products and related services, as well as economic activities relating to the broad spectrum of forest ecosystem services beyond biomass. Many of these innovations span traditional policy or industry sectors. They may face high initial costs related to R&D and to transaction costs for product development and market entry. **Forest-based bioeconomy clusters** in **transnational regions** (see above) can identify priorities for innovation policy tools to support these innovations, but may not prevent competition for support at the larger European scale.
- A **reliable and stable investment environment** is important to incentivise investments in the forest-based bioeconomy. The future development of policies is one critical uncertainty relating to the future of forest bioeconomy markets (Section 3.9). Possible significant policy changes may create uncertain conditions for investments. This uncertainty cannot be diminished as policymaking needs to be able to respond to new societal demands. Yet, '**minimum durations**' and timelines could be agreed upon for policy instruments, or at least **defined criteria for evaluation and adjustment**, to provide more stability for investment decisions.

Provide better information

Knowledge is a key resource for developing the forest-based bioeconomy. This study shows that information is incomplete, or even non-existent, for some key aspects. This may lead to incorrect assessments of forest-based bioeconomy development, such as a significant underestimation of its social and economic importance. To avoid this, there is, specifically, a need for better information regarding:

- **New and innovative forest (wood) products** and related services;
- **Non-wood forest products**, and specifically innovative business models relating to them;
- Innovations, including new business models, relating **to other forest ecosystem services**, e.g. cultural forest ecosystem services such as nature tourism or funeral forests;
- **Job opportunities** beyond the traditional forest sector (e.g. relating to forest-based chemicals, textiles, services);
- Attitudes, perceptions and interests of **key societal groups**, including forest owners and citizens (as consumers and clients for forest ecosystem services-based products and services);
- **Synergies** and **trade-offs** between **different products and services** of the forest-based-bioeconomy.

A **renewed system of indicators** for the forest-based bioeconomy could serve as the backbone for gathering this information at European level (see Chapter 4). The imperative is to develop an up-to-date, timely and realistic understanding of the current and future development potential of the forest-based bioeconomy in a European context, including its global interdependencies through international trade.

Encourage inclusivity

Societal inclusiveness is a crucial component for the future development of the forest-based bioeconomy in Europe. Human attitudes, interests and actions are critical for the entire forest-based value chain, from the forest owner to bioeconomy entrepreneurs to the consumer/citizen demanding forest-related products and services. Consequently, policy needs to make the bioeconomy more responsive to, and inclusive towards, distinct societal demands.

Environmental sustainability is critical for approaching the urban population (c. 70% of the entire population of Europe). This study shows that there are opportunities to connect the forest-based bioeconomy to environmentally conscious consumer groups dominating urban milieus through value chains relating to the entire spectrum of forest ecosystem services. At the same time, most of the primary production and a part of the value added for these products and services takes place in (rural) forest areas. This provides new opportunities for the inclusion of these areas in the European economy. The promise holds for innovative wood-based products and non-wood forest ecosystem services-based business, as well as for classical forest biomass products. For the latter, demonstrated environmental sustainability can help to improve the position of European producers in competition with emerging economies outside Europe.

Social sustainability requires bioeconomy politics to engage with the demands of a broader society to gain societal legitimacy. This needs to go beyond 'creating acceptance' and 'convincing consumers'. Forests are different from a cornfield or an industrial plant. They are the focus of many societal demands. It is imperative to proactively engage with these demands and develop them into business opportunities, thus diversifying the forest-based bioeconomy. Social sustainability may also mean accepting limitations on economic activities in forests, e.g. relating to the provision of public goods.

In conclusion, a sustainable forest-based bioeconomy holds great promise to contribute to a transformation of the entire economic system, moving away from fossil-based production and consumption. To fully unfold its potential and mobilise the necessary support, a larger transition is needed at the level of the entire society. This means expanding the bioeconomy beyond the current understanding[11] to include a much broader societal vision: a European **bio-society** with sustainable consumption patterns, sustainability-related social innovations, and informed participation in bioeconomy-related value chains. Europe's forests with their rich and diverse portfolio of ecosystem services can be one important fundament to build this society.

11 In a much-recognised recent publication, Bugge et al., 2016 have differentiated three bioeconomy visions: a biotechnology vision emphasising the importance of biotechnology, a bio-resource vision focusing on processing and upgrading of biological raw materials, and a bio-ecology vision highlighting environmental sustainability (see section 2.2).

Key messages

- Policies must support the entire spectrum of forest ecosystem services-based economic activities, from biomass production to activities relating to non-wood forest products or cultural ecosystem services.
- The European forest-based bioeconomy is regionally diverse. Policies to boost bioeconomy development should set regionally different priorities. As well as national bioeconomy strategies, forest-based bioeconomy clusters in transnational regions ('bioeconomic regions') could enable priority setting and the implementation of regionally adapted bioeconomy policies.
- A forest-based bioeconomy needs to be sustainable with regard to its economic, environmental and social dimensions. The creation of a level playing field with respect to sustainability related externalities at the level of the European market is one key demand; the exploitation of currently unused synergies between the sustainability dimensions is another.
- Cross-sectoral interlinkages are critical for the forest-based bioeconomy. This requires policy coordination to explore cross-sectoral development potential, and the updating of sectorally based information and monitoring tools to not underestimate its economic, societal, and environmental importance.
- A sustainable forest-based bioeconomy which capitalises on the entire spectrum of forest ecosystem services can play a central role in the sustainability transformation not only of Europe's economy, but of the whole of society towards a European bio-society.

Reference

Bugge,M., Hansen, T., Klitkou, A., 2016. What is the Bioeconomy? A review of the literature. Sustainability 8:691-716.

What Science Can Tell Us

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