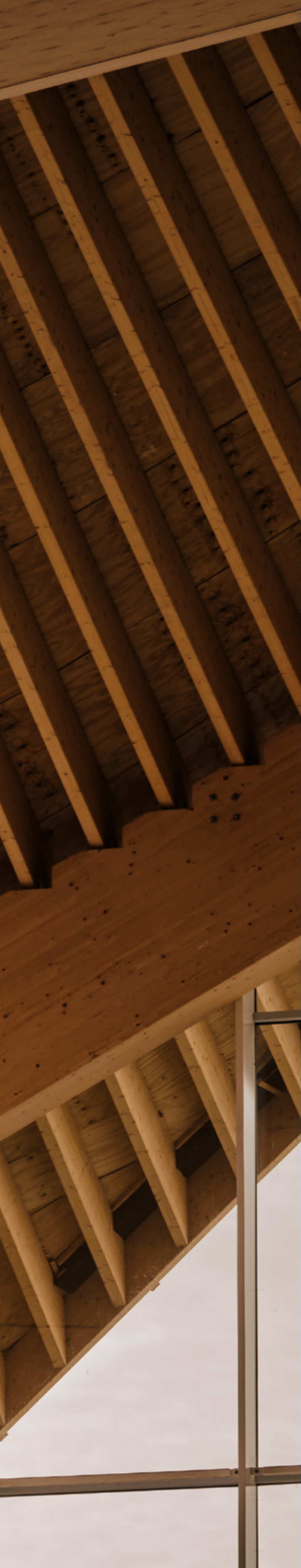

Current State of Mass Timber and Wood Product Value Chains in Europe

BACKGROUND PAPER

Prepared for TFD's Climate Positive Forest Products Scoping Dialogue in Finland

11-15 September, 2022

The Forests Dialogue

The Forests Dialogue

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ABOUT THIS PAPER

This report was developed to provide a baseline of information on the current state of knowledge related to mass timber production and construction practices for participants of The Forests Dialogue's Field Dialogue on Climate Positive Forest Products, convened in-person in Finland on 11-15 September, 2022. During the writing process, an advisory group of representative stakeholders steered the development of the paper, providing feedback and shaping the paper's direction.

The advisory group asked for this background paper to 1) Provide participants with a contextual overview of the current state of mass timber and wood product value chains in Europe (from forest management to mass timber manufacturing, construction, and policy), and 2) Build from questions and knowledge gaps identified in the 2021 Scoping Dialogue Background Paper, addressing gaps and adding new research where possible with Europe-specific content, a) specifically, the latest research in carbon accounting approaches and methodologies, and b) social and environmental safeguards. Feedback on the draft background paper was solicited from dialogue participants and incorporated to produce this final version.

ABOUT THE FORESTS DIALOGUE (TFD)

The Forests Dialogue (TFD) is an organization that designs and implements multi-stakeholder dialogues aimed at fostering social learning, building trust, and supporting processes for collaborative and adaptive land management across sectors. TFD believes that structured dialogue is fundamental to breaking deadlocks and creating meaningful change in the forest sector. Housed within The Forest School at the Yale School of the Environment, TFD's secretariat is directed by a group of 25 steering committee members representing globally significant forest stakeholders. TFD implements its mission through initiatives. Initiatives address a global forest issue identified by TFD's Steering Committee members through a series of dialogues. TFD's process includes mixing international and national perspectives, engaging the private sector in all dialogues, combining field discussions with structured meeting facilitation, and giving participants the mandate to determine outputs and outcomes. Dialogues often occur in countries where the issue is or has historically caused conflict and seek to deliver impact in-country and inform global discourse through grounded examples. Country level dialogue topics and case studies are driven by local priorities, as determined by in-country host organizations and vetted by TFD.

The statements, reports, and findings of TFD do not necessarily represent the views of YSE faculty.

Learn more about TFD's process, ongoing initiatives, and past work at https://theforestsdialogue.org/.

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The Forests Dialogue

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EXECUTIVE SUMMARY

Building upon the first scoping dialogue on Climate Positive Products, this background paper seeks to 1) Provide participants with a contextual overview of the current state of mass timber and wood product value chains in Europe (from forest management to mass timber manufacturing, construction, and policy), and 2) Build from questions and knowledge gaps identified in the 2021 Scoping Dialogue Background Paper, addressing gaps and adding new research where possible with Europe-specific content, specifically, a) the latest research in carbon accounting approaches and methodologies, and b) social and environmental safeguards. This paper focuses on the European context and uses Finland as a case study to test systems theories and discussions.

The background paper authors found that climate and the role of forests and the forest sector has become a hotbed for discussion and that a wealth of European specific information exists. Ambitious initiatives, such as the EU Green Deal and its associated policies, have broadly highlighted an important role that both forests and forest products need to play to achieve the EU goal of carbon neutrality by 2050. Specific policies, however, have started to create tension between the dual goals of transitioning to a bioeconomy and increasing the forest carbon sink. For example, the proposed EU "Fit for 55" LULUCF requirement to increase forest sink capacity by 2030 most likely cannot be achieved without reducing harvest in the short term. The public understands the appeal and benefits of the bioeconomy, especially as it relates to wood construction, but also regards forests primarily for biodiversity and carbon sequestration. The holistic connection is not apparent.

Furthermore, there are strong concerns about the growing role of bioenergy in the EU and its sourcing. Though the latest Renewable Energy Directive (RED II) has put in place strict sustainability standards for sourcing forest and other biomass materials it strongly depends on further growth of bioenergy, potentially creating market conditions in which the demand of forest biomass grows such that high prices might dampen the growth outlook for mass timber. The original goal of RED I of 20% renewables by 2020 was only (over-) achieved (22%) because 60% were sourced from biomass sources, most of them from forests. The 2030 goal set by RED II aimed at 32% renewable energy by 2030, while the currently discussed RED III aims for a much more ambitious 45% renewables by 2030 – corresponding to a doubling of its renewable energy output in less than 10 years. Even if solar, wind, and geothermal can be upscaled rapidly it still suggests an increase in the absolute demand for biomass for energy. It will be important to maintain the principle of cascading use of timber that prioritizes wood products over bioenergy, both within and beyond Europe. Minimizing trade-offs between the goals of different climate regulations and maximizing synergies instead should be a top priority moving forward.

Concurrently, carbon accounting research has made efforts to understand more systematic efforts. However, biogenic carbon accounting methods are still divergent and heavily dependent on scope and assumptions. In the past 18 months several studies have further examined the potential impact of increased demand for mass timber on forest supply. These are separated into three broad types of analyses that answer slightly different questions by 1) examining the amount existing sequestration (net growth) is available to meet increased demand, 2) incorporating global economic land models to identify use and management changes, and 3) comparing different forest strategy pathways. Many of these studies attempt to incorporate at the same time forests, forest products, and substitution. As in the past, results vary depending on 1) the displacement factors of products, 2) whether forest management feedback and disturbances are incorporated, and 3) to a lesser extent end-of-life scenarios and assumptions about future energy sources.

On the forest quality side new research has identified frameworks with which to discuss the challenges of implementing safeguards and potential solutions. More transparent and reliable data across the supply chain will help with monitoring and implementation.

Finally, what is also needed is a concurrent emphasis on demand side efficiencies, with policies in place that ensure and encourage the cascading use of wood, putting emphasis on long-lived wood products. In the building sector this includes mass timber and traditional timber methods, and also efforts to maximize the share of novel insulation materials sourced from both forest and agricultural wastes.

1. CURRENT STATE OF MASS TIMBER AND WOOD PRODUCT VALUE CHAINS IN EUROPE

1.1 Forests (Timber Supply)

1.1.1 European Forest Overview

Forests are the largest land-based natural resource in Europe covering more than 40% of Europe's land area. Representing about 5% of global forest area (not including Russia), Europe's diverse forests provide a host of ecosystem services, including wood products, water, biodiversity, and recreation. Since 1990 forest area has been expanding, and carbon stocks have been increasing between 100 and 300 million metric tons carbon per year (see Figure 1) (FAO, 2020). Sixty percent of Europe's forests are privately owned belonging to roughly 16 million landowners. The remaining forty percent are publicly owned by municipalities, regional or national governments (Mauser, 2021).

Thirty percent of Europe's forests are planted, and clearcutting is still the dominant cutting practice on these planted lands, especially in Northern Europe. The most economically important trees are Scots Pine, Norway Spruce, Oak, and European Beach (Mauser, 2021). The principal disturbances (all exacerbated by climate change) are droughts, windstorms, wildfires, bark beetle and other pest and insect infestations.

Europe's forests contribute 28% of the global supply coniferous saw and veneer logs (43% if Russia is included) (FAO, 2022). These supply a large domestic sawnwood (lumber) production, of which a fraction is currently used to produce CLT and other mass timber products (see Section 1.2.2).

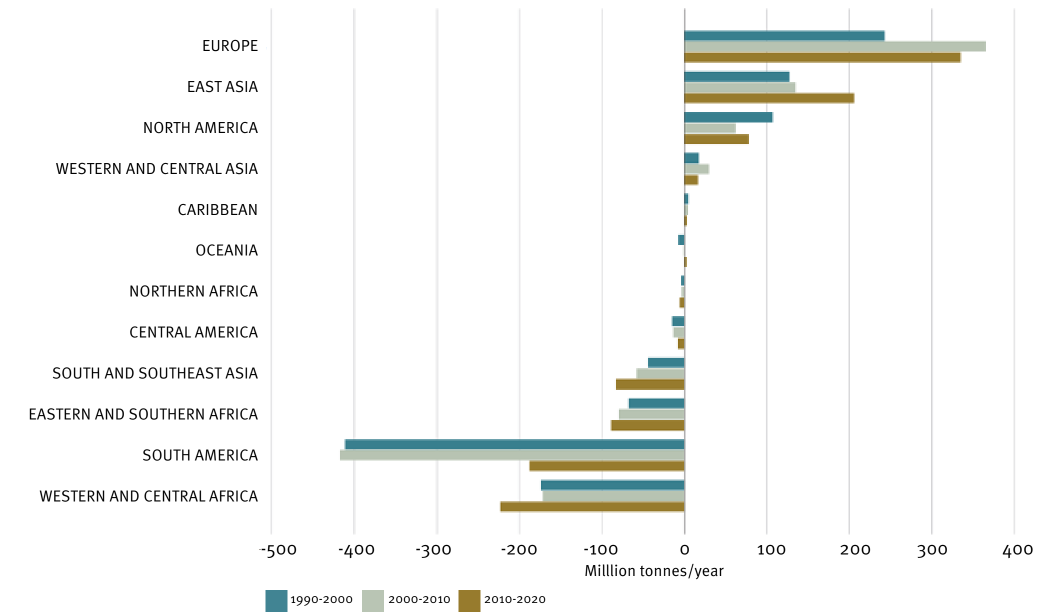


Figure 1: Change in Forest Biomass Carbon Stock, by region and subregion, 1990-2020 (FAO, 2020).

1.1.2 Future Scenarios for Biomass Use in Europe

Europe currently uses 40% of biomass for materials (e.g., wood and pulp products) and 60% for energy (Material Economics, 2021). Though much of the biomass energy are residues used to manufacture wood product materials, incentives such as the EU Renewable Electricity Directive, the Biofuels and Renewable Fuels Directive, and Members States National Renewable Energy Action Plans, have resulted in a 150% increase in biomass for energy and biofuel since 2000 (Material Economics, 2021). Current climate scenarios to transition to a low-carbon economy call for between 70 and 80% increases of biomass for energy and biofuels and with no mention of biomass for materials. If biomaterials are included total biomass use could increase by 140% over current use (Material Economics, 2021), which exceeds the current existing supply by 40-100% (Material Economics, 2021).

1.1.3 Carbon Stock Impact of Increased Demand for Mass Timber

Though still a tiny fraction of global wood use (less than 1% of global softwood lumber consumption) (FAO, 2022) there are increasing concerns about the impact increasing demand for mass timber will have on traditional lumber uses and ultimately forest supply. (Nepal, Johnston, & Ganguly, 2021) modelled three scenarios for mass timber demand between 2020 and 2060 for 12 selected countries, including seven in Europe (Austria, France, Germany, Italy, Netherlands, Spain, and UK). The model restricted mass timber construction to the individual country but allowed the raw material (or lumber) to be traded globally. By 2060, the model predicted that total harvest (softwood and hardwood) would increase by 10.5, 29, and 66.5 million m3 in the conservative, optimistic, and extreme scenarios, respectively. These increases represent 0.2%, 0.7%, and 1.6% increases from current global harvest levels (Nepal et al., 2021). Interestingly, hardwood harvest was predicted to decline slightly as the increase in softwood residues could displace some of the need for hardwood as a raw material. Europe's share of harvest was predicted to increase by a higher rate (0.7%, 1.5%, and 2.4%), due to an already established and bullish mass timber market. These increasing harvests are expected to reduce global forest stock by 0.01, 0.02, and 0.03% and in Europe by 0.02%, 0.04%, and 0.07%, which is minimal compared to the harvest increase (and the carbon removed from the forest will be stored in long-lived mass timber buildings). The model incorporates increased forest biomass growth responses (e.g., younger trees grow faster) (Nepal et al., 2021).

1.2 Wood Product Markets and Outlook

The woody biomass market is divided into wood products and forest biomass for energy as illustrated in Figure 2 (Camia et al., 2020). Following the RED II terminology, *forest biomass* refers to wood sourced directly from forests while *secondary biomass* is sourced from processes, such as sawdust from sawmills and black liquor from paper-making, including post-consumer wood.

Roundwood production in the EU reached 488 million m^3 in 2020, an increase of 21% compared to the beginning of the millenium (Eurostat, 2021). The largest roundwood producers were Germany (84 million m^3), Sweden, Finland, and France. While most industrial roundwood was used for solid wood products (sawnwood, veneers, pulp and paper) the share of wood used for renewable energy has increased from 17% in 2000 to 23% in 2020. In 2020, fuelwood dominated (>50%) the wood market in the Netherlands, Cyprus, and Hungary while it accounted for less than 10% in Slovakia and Sweden (Table 1). Coniferous trees dominate the EU roundwood market (69% in 2020), a share that has remained relatively constant over the past two decades. Sawnwood production increased by 11% from 2000 to 2020 (108 million m^3), with Germany (24%) and Sweden (17%) having been the largest sawnwood producers in 2020 (Eurostat, 2021).

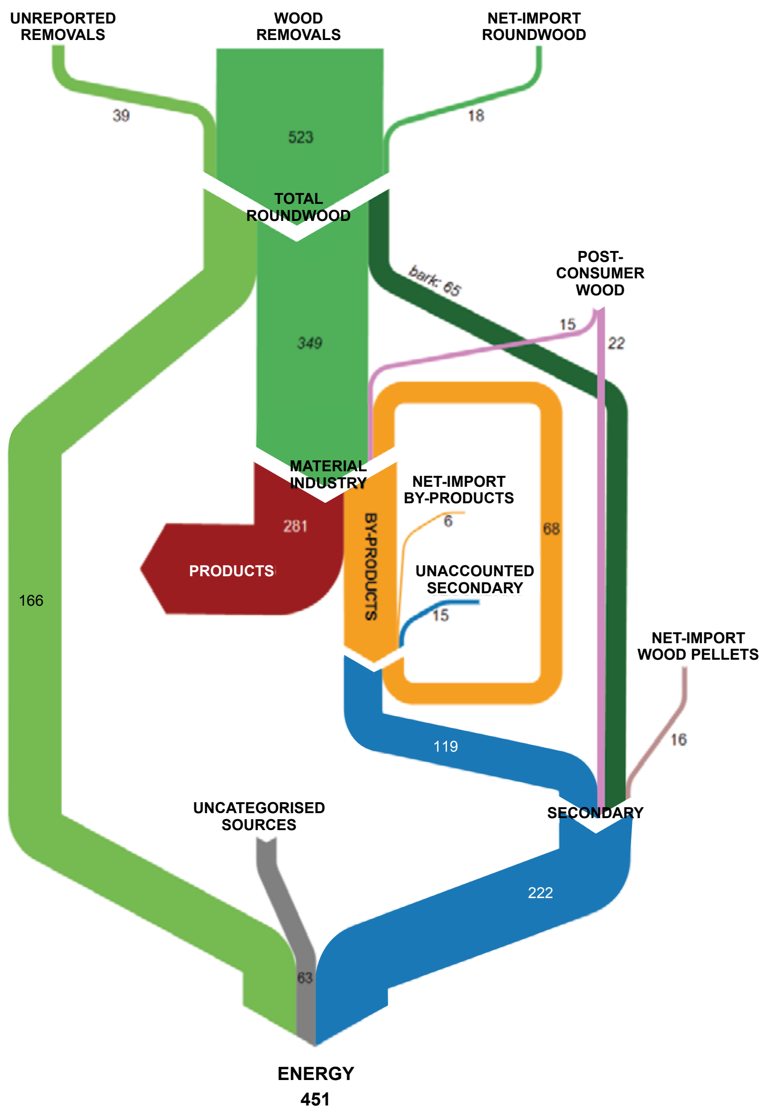


Figure 2. Woody biomass flows within the material and energy sectors in the EU in 2015 (Camia et al., 2020). Following the RED II terminology, forest biomass refers to wood sourced directly from forests while secondary biomass is sourced from processes, such as sawdust from sawmills and black liquor from paper-making, including post-consumer wood.

Most imports of wood products into the EU in 2019 (in monetary terms) originated in China, USA, Russia (23% of all wood imports); (Eurostat, 2022b)), Brazil and Switzerland, while most exports went to USA, Switzerland, Norway, and Russia (Figure 3). The EU banned the trade of wood products with Russia in April 2022, as part of its sanctions in response to Russia's invasion of Ukraine (European Council, 2022), with many of the sanctions also affecting neighboring Belarus. In 2021, Russia, Belarus and Ukraine accounted for nearly 25% of worldwide lumber trade. The three countries exported 8.5 million m3 of softwood lumber to Europe, almost 10% of the continent's total demand (Wood Resources International LLC, 2022). Two CLT plants were under construction in Russia, and one was recently completed in Ukraine (bne IntelliNews, 2021; Forest2Market, 2021).

Europe's wood-based industries include woodworking, furniture, pulp and paper and converting industry and printing, representing 19.6% of the EU's manufacturing enterprises. Tropical wood imports to the EU are limited to legally harvested timber, regulated through the Forest Law Enforcement, Governance and Trade (FLEGT) action plan (Eurostat, 2021).

Historically, wood has been an important building material in Europe. Yet, after repeated fires throughout European cities safety concerns led to a ban of wood as an urban building material. This changed with new guidance from the European Commission in the late 1980s

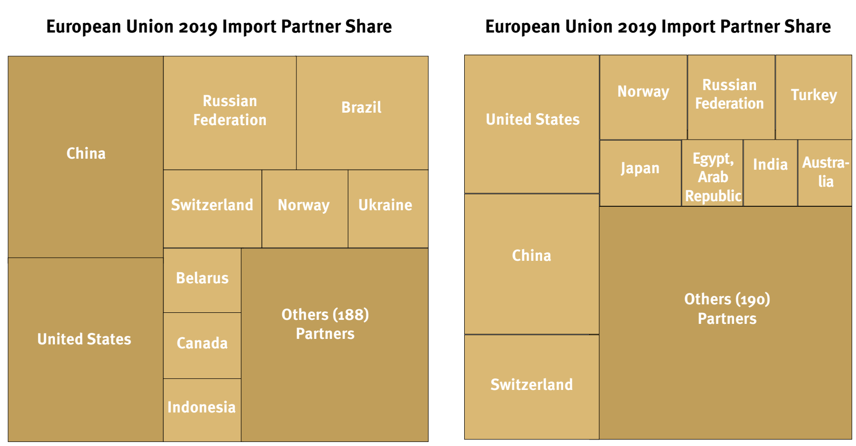
Table 1: Roundwood production, 2020

	Roundwood production		
	Total	Fuelwood	Industrial roundwood
	(1 000 m^3 under bark)		
EU (¹)	488 603	113 760	374 843
Belgium	5 351	1 237	4 115
Bulgaria	5 404	2 332	3 072
Czechia (²)	32 586	5 922	26 664
Denmark	:	:	:
Germany	84 051	22 261	61 790
Estonia	10 638	4 136	6 502
Ireland	:	:	:
Greece	:	:	:
Spain	15 496	1 615	13 881
France	47 703	23 444	24 259
Croatia	5 234	2 207	3 027
Italy	8 923	3 921	5 002
Cyprus	9	6	2
Latvia	15 347	2 620	12 727
Lithuania	6 366	1 994	4 372
Luxembourg	350	59	291
Hungary	4 972	2 516	2 457
Malta (²)	0	0	0
Netherlands	2 966	2 304	662
Austria	16 790	5 327	11 462
Poland	40 593	4 713	35 879
Portugal	13 422	1 618	11 803
Romania	18 049	6 420	11 629
Slovenia	3 891	1 074	2 817
Slovakia	7 448	524	6 924
Finland	60 233	8 937	51 296
Sweden	74 400	5 400	69 000
Liechtenstein	7	2	5
Norway	11 750	1 508	10 242
Switzerland	4 577	1 770	2 807
United Kingdom (²)	10 786	2 478	8 308

(:) not available
(¹) EU estimate produced using latest available data if a country did not report for 2020
Data for 2019 shown; data for 2020 not available
Source: Eurostat (online data codes: for_remov)

Table 1. EU Roundwood production in 2020 by country, with use as fuelwood and industrial roundwood (Eurostat, 2021).

Figure 3. European Union Wood Imports and Exports by country in US$ Thousand 2019 (World Integrated Trade Solution, 2021)



that prioritized function-based requirements for building materials, starting what some call the "renaissance of timber construction" that began in the early 1990s (Kitek Kuzman & Sandberg, 2017). Austria, for example, saw an increase in the number of buildings made from wood from 25% to 43% between 1998 and 2013 (Teischinger, Stingl, Berger, & Eder, 2015).

1.2.1 Mass Timber

Global CLT production capacity in 2020 was 2.8 million m3, of which 48% were located in Europe, 43% in North America, 6% in Oceania, and 3% in Asia. In 2019 global CLT production was 920,000 m3 of which 80% were produced in Austria, Czechia, Italy, and Switzerland (Forest2Market, 2021). By 2021, the European cross-laminated timber (CLT) market has grown to 1.4 million m3, and is further expected to grow 11.3% annually to a volume of 2.6 million m3 by 2027 (IMARC, 2022). This growth rate would be smaller than the global average, estimated at 14.5% annually by 2027 (Research and Markets, 2022), or by 13.6% between 2021 and 2028 in their latest estimate. As the world's largest manufacturer of CLT Europe is expected to continue dominating the global CLT market, driven by the UK, Germany, Italy, and France (Research and Markets, 2022). More recently, Slovenia has also become a strong market for mass timber and wood use in construction (Kuzman et al 2017). The Nordic countries (Denmark, Finland, Iceland, Norway, Sweden) launched the initiative "Nordic Wooden Cities" to promote the use of timber building techniques in residential and commercial buildings. Furthermore, with support by EIT Climate-KIC, in 2020 the digital platform NoMuWood.com was launched aimed to inspire and inform Nordic Municipalities about the possibilities and processes of wood construction (eit Climate-KIC, 2020).

1.2.2 Other Wood Products

The major groups of primary forest products are roundwood, wood-based panels, woodpulp, paper and paperboard, and others (e.g., wood charcoal; wood chips and particles; wood residues; recovered wood; pellets and agglomerates; sawnwood; veneer; other pulp; and recovered paper). (United Nations (UNECE) & FAO, 2021). Data on sawn wood production are provided by the FAO and date back to 1960 (FAO, 2022). Figure 3 provides an overview on non-fuel markets in Europe, while Figure 4 shows timber flows in the European forestry sector.

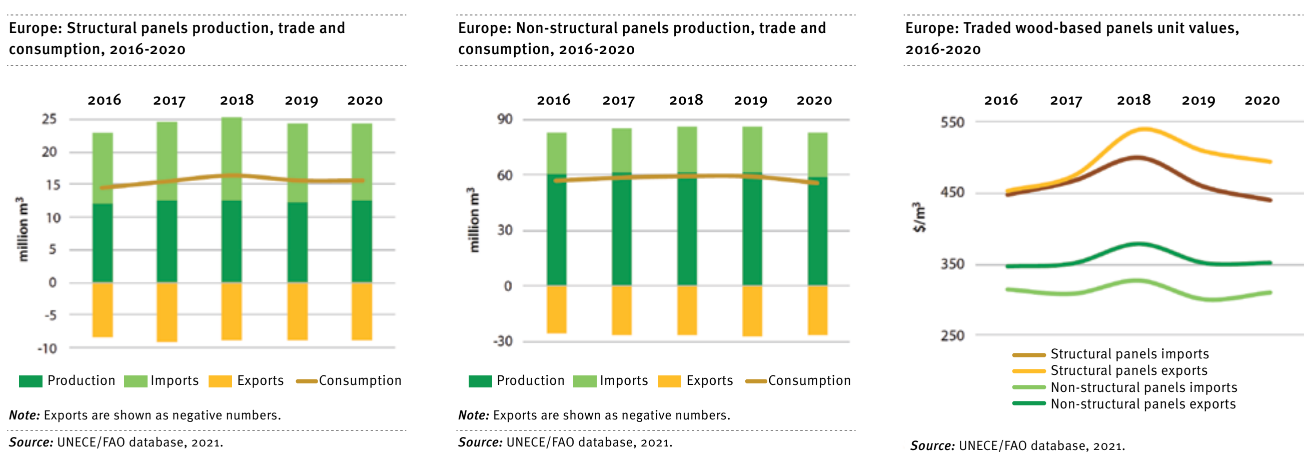


Figure 3. Overview on non-fuel wood markets in Europe: structural and non-structural panels (import, export, consumption) and traded woodpulp and paper (United Nations (UNECE) & FAO, 2021).

Within the paper and pulp industry a continuing trend over the past two decades has been a shift away from graphic paper (due to the rise in electronic communication) and towards an increased demand for packaging paper (due to the growing trade and e-commerce).

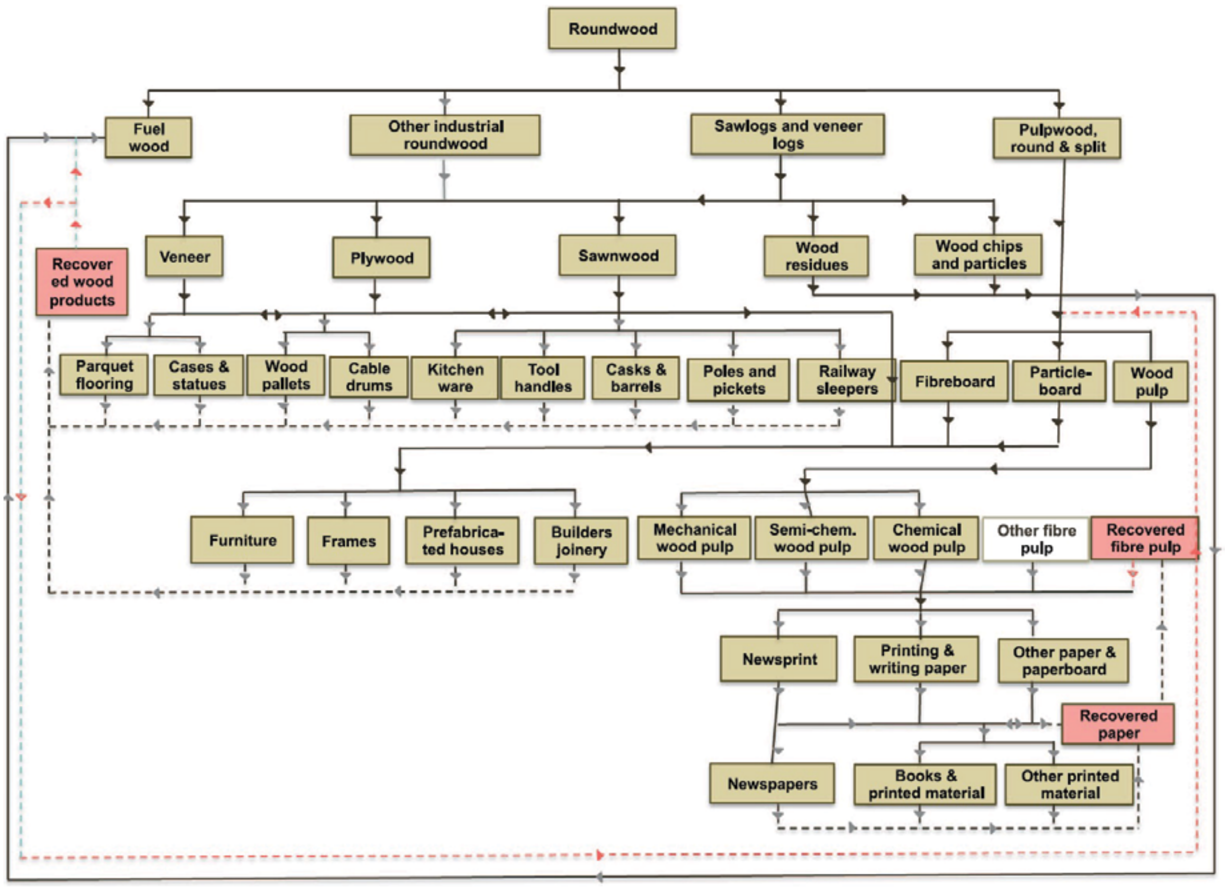


Figure 4. Timber flows in the European forestry sector. (O'Brien & Bringezu, 2018)

Emerging Wood Markets

With industries trying to meet the ambitious targets of the new low-carbon bioeconomy the substitution away from carbon intensive materials to biomaterials is a growing trend. For example, in packaging bio-based plastics will increasingly replace the traditional fossil-fuel based plastics. Though bioplastics still face challenges at end-of-life (e.g., separation from traditional plastics, carbon source in landfills) some of the newly developed materials seem able to overcome these challenges (Xia et al., 2021). Yet, it seems unlikely that the magnitude in demand for such bioplastics would affect the timber market in a major way.

1.2.3 Woody Biomass for Bioenergy

Biomass for energy (bioenergy) accounts for 60% of renewable energy sources in the EU, with the largest end user being the heating and cooling sector, using about 75% of all bioenergy (EC Joint Research Centre, 2019). Forest biomass, agricultural residues, and energy crops are the major sources of biomass for energy in the EU (Bentsen & Felby, 2012). (Sikkema, Proskurina, Banja, & Vakkilainen, 2021) found that between 2010-2018 the share of solid biomass increased from 6.1% to 8.0% of total energy consumption, corresponding to an increase of almost 300 PJ. In terms of air quality, the increased use of biomass for heating led to a 13% EU-wide increase of PM2.5 emissions and a 4% increase in VOCs emissions since 2005, highlighting the need to address the trade-offs between the transition to a decarbonized energy system and the reduction of air pollution (European Commission, 2021c).

Some facts on the market for wood pellets used in the heating and cooling sector:

- USDA/GAIN Report "EU Wood Pellet Annual" expects EU demand in 2022 to further grow to 24.3 MMT in 2022, driven by residential markets mainly in Germany (DE) and France (FR), which have been boosted by support programs for installation of biomass boilers and the high price of fossil fuels (Flach & Bolla, 2022).
- In the past 10 years, the EU demand for wood pellets has been much larger than its supply, with imports mainly originating in Russia (ended 4/22), USA, Belarus, and Ukraine.
- The residential sector uses wood pellets for heating and accounts for 25-30% of the total pellet market (highest in IT, DE, FR, AT, SE, ES), using either pellet stoves (ES, FR, IT) or pellet boilers (DE, FR, AT).
- The industrial sector uses wood pellets in large scale power plants (highest in NL, DK, BE, supplied mostly through imports).
- EU and war in Ukraine actualize disquieting scenarios on future of forest energy – researcher says: 'We really didn't expect this' - Forest.fi (Finnish Forestry Association, 2022)

In January 2021, the European Commission's Joint Research Centre (JRC) published the report "The use of woody biomass for energy purposes in the EU" (Camia et al., 2020) to assess the status of "environmentally sustainable bioenergy" and offer pathways towards a "sustainable forest bioenergy", with the goal of achieving both biodiversity conservation and climate change mitigation. As such, the findings might be used as basis for a future revision of RED II (see Section 1.3) and its treatment of the utilization of forest biomass.

The JRC report finds a 20% increase in the use of woody biomass in the EU between 2000 and 2015, with primary woody biomass contributing to 37% of wood for energy production, and an additional 14% of wood coming from undisclosed sources - suspected to originate at least partly from primary forests, possibly through illegal logging (Hurtes & Cai, 2022). The report shows that win-win forest bioenergy pathways that help achieve both climate and biodiversity goals exist but are rare (only two of 24 examined management practices are deemed 'neutral/positive': the removal of slash below locally defined thresholds, and afforestation of former arable land with mixed forest or naturally regenerating forests). In many cases, however, biomass burning leads to an increase in net carbon emissions when compared to burning fossil fuels. The report emphasizes the importance of cascading wood use where forest products are prioritized over bioenergy.

1.3 Geopolitical Context

1.3.1 Forest Climate Policy

Europe has instituted a suite of policies that impact their forests under the umbrella of the EU Green Deal (European Commission, 2022b), which aims to make Europe the first climate-neutral continent by 2050 (Runge-Metzger, 2018). It outlines broad goals and paves the way for a series of strategies, including the Regulation on Land Use, Land-Use Change and Forestry (LULUCF) (Runge-Metzger, 2018), the Amendment to the Renewable Energy Directive (RED) (European Commission, 2021a, 2022c), EU Biodiversity Strategy for 2030, and the EU Forest Strategy for 2030 (European Commission, 2021b).

The EU Forest strategy includes the following provisions for forests (European Commission, 2021b):

- promoting the sustainable forest bioeconomy for long-lived wood products
- ensuring sustainable use of wood-based resources for bioenergy
- promoting non-wood forest-based bioeconomy, including ecotourism
- developing skills and empowering people for sustainable forest-based bioeconomy
- protecting the EU's last remaining primary and old-growth forests
- ensuring forest restoration and reinforced sustainable forest management for climate adaptation and forest resilience
- re- and afforestation of biodiverse forests, including by planting 3 billion additional trees by 2030 (European Commission DG Environment, 2022)
- providing financial incentives for forest owners and managers for improving the quantity and quality of EU forests.

Implementation of policies are still being debated. For example, the EU Forest Strategy calls for protection of Old-Growth and primary forests, which are not specifically defined. A fear is that large mature high-value trees (those just reaching the culmination of mean annual increment) can now no longer be harvested, which would not only impact private landowners financially but would also remove the ability to manage forests for both carbon sequestration and products (Köhl, Linser, Prins, & Talarczyk, 2021). Even the goal to plant 3 billion additional trees has been criticized as not well thought out as there is no vision for the location of these new forests given competing land-uses and ecological constraints (e.g., soil quality, water) (Köhl et al., 2021). Similarly, the goal of restoration of forests may be difficult or impractical to achieve given a changing climate.

Public sentiments on the role of EU forests in achieving policy goals are mixed. While the public conceptually understands the need to transition to a bioeconomy[1], their perception of the value of forests are primarily for their biodiversity and ability to absorb carbon and to a lesser extent protecting

1 For further investigation see Public perceptions of using forests to fuel the European bioeconomy: Findings from eight university cities – ScienceDirect

people from natural disasters such as floods and avalanches (Mauser, 2021). In fact, there has been a recent public shift from acknowledging the multi-functional use of forests towards a focus primarily on biodiversity and nature protection (Köhl et al., 2021). (Elomina & Pülzl, 2021) found that the message of "forests are multifunctional" shows up in only one of the nine recent EU forest policy documents. However, a survey among millenials (20-29-year olds) in Austria found that they viewed timber construction as more positively than other materials, both for its aesthetics and being ecological advantageous (Petruch & Walcher, 2021).

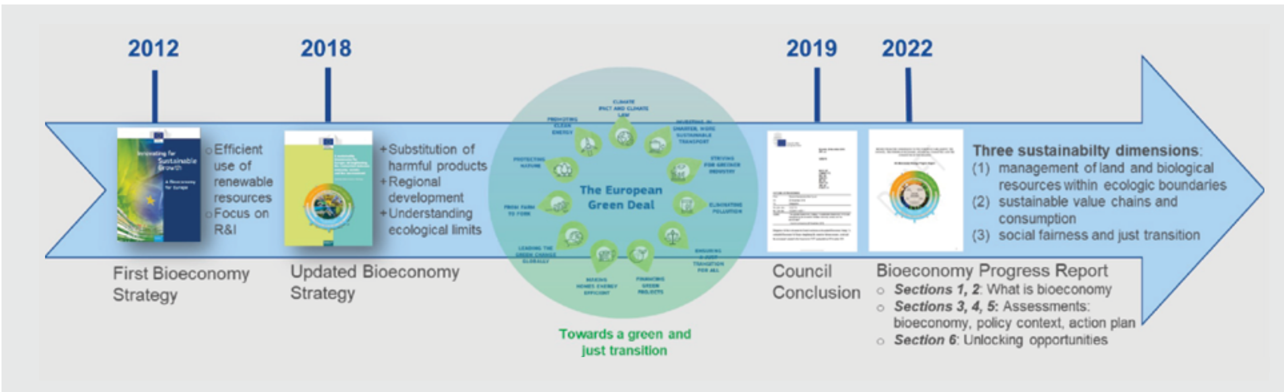


Figure 6. Timeline of the EU's Bioeconomy Strategy and the European Green Deal (European Commission, 2022a).

Two policies directly highlight the tension between embracing the bioeconomy and 'restoring forests.' The EU Biodiversity Strategy to protect 30% of land area, with 10% strict protection could reduce the area available for harvest, would directly be at odds with the need to increase harvest to promote the forest bioeconomy (Köhl et al., 2021). Even more targeted is the proposed updated LULUCF Regulation, which is part of the EU 'Fit for 55' package that aims to reduce EU GHG emissions by 55% by 2030. To meet this goal the package calls for increases in carbon removals requirements from the LULUCF sector from the current 225 mt CO_2e per year to 310 Mt CO_2e per year. Because the timeline is so short (2030), the only viable land-use strategy to guarantee short-term increases in removals is reduction in harvest (afforestation and increasing productivity, which have longer benefit accruals, would not be able to meet the removal scale needed by 2030 (Köhl et al., 2021)). However, this strategy would be at odds with the basic meeting the fiber needs of a growing population let alone embracing a bioeconomy. Discussions are underway to understand if a more holistic approach, accounting for the full value chain and leakage to other countries, can be incorporated (Köhl et al., 2021).

1.3.2 Building/Energy Climate Policy

The EU Renewable Energy Directive (RED I) as part of the EU Energy and Climate Change Package (CCP, 2010-2020) required that the share of renewable energy of the EU's total energy consumption should reach 20% by 2020. This target was overachieved, with 22% of total energy use coming from renewable sources in 2020 (Eurostat, 2022a), of which 60% came from biomass sources (European Commission, 2021c). RED was revised in 2018 ("RED II") and set a 32% renewable energy share target for 2030 with strict sustainability criteria for biomass consumed in the EU for the period 2021-2030 (European

Commission, 2022e; Flach & Bolla, 2022). Both RED I and RED II set individual targets for its member countries, with details on respective targets and renewable energy shares summarized by (Sikkema et al., 2021). Negotiations are ongoing for another revision (RED III) that aims for 45% renewable energy by 2030 and is expected to be adopted by the end of 2022 (European Commission, 2022d).

While acknowledging challenges, Sikkema et al (2021) argue that forest biomass allows the sustainable increase of bioenergy in the EU as long as harvest levels remain below 90% of net annual increment and fuelwood and harvested wood for solid products are kept separate. They also recommend a fixed ratio between forests for wood supply and forests that are protected to advance biodiversity goals.

The European Union Timber Regulation (EUTR) from 2010 lays down obligations of operators who place timber and timber products on the market so as to counter the trade in illegally harvested timber and timber products (European Commission, 2022f). The required due diligence includes information, risk assessment, and risk mitigation. The regulation covers a broad range of timber products including solid wood products and flooring, but not recycled products.

A summary of new embodied carbon regulations in the EU is provided by Stora Enso (Richards, 2022):

- Since January 2022 Sweden and France mandate consideration of embodied carbon (the carbon emissions related to manufacture, installation, upkeep, and deconstruction/demolition of building materials), with other countries expected to follow. A growing focus on embodied carbon serves as competitive advantage for wood compared to other building materials.
- Since January 2022 developers in Sweden must calculate the embodied carbon emissions for new buildings and file those with the government to receive final building permit approval (Act on Climate Declarations for New Buildings). This follows the example of the Netherlands which has mandated the assessment of embodied emissions from non-governmental buildings since 2013.
- Since January 2022 France's new RE2020 regulation mandates the analysis of embodied emissions over the entire life cycle of residential buildings, and from 2023 on also for other building types. It requires a dynamic life cycle analysis (LCA), which weighs future emissions less than current emissions. Limits on the embodied carbon will be further tightened in 2025, 2028, and 2031. Also since this year, all new public buildings in France need to be made from at least 50% wood (see below).
- At the EU-level, embodied carbon is increasingly addressed, e.g., in the proposed revision of the Energy Performance of Buildings Directive (EPBD) that requires publicly disclosed whole lifecycle LCAs for new buildings larger than 2,000 m2 starting in 2027. The EPBD also calls for national building renovation plans with information on planned strategies to reduce whole lifecycle embodied carbon emissions and uptake of carbon removals.

Detailed instructions on how to calculate "whole-life carbon" for buildings, together with a discussion of the barriers, enablers, and policy solutions within the EU context are provided by (Buildings Performance Institute Europe, 2021).

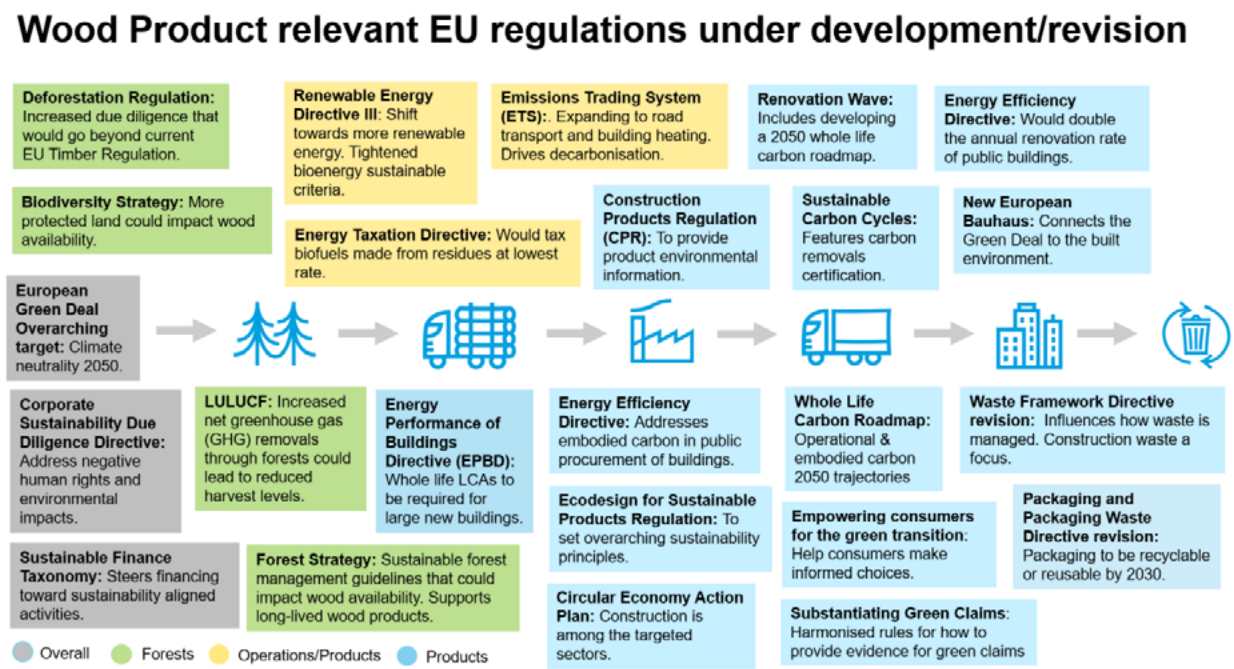
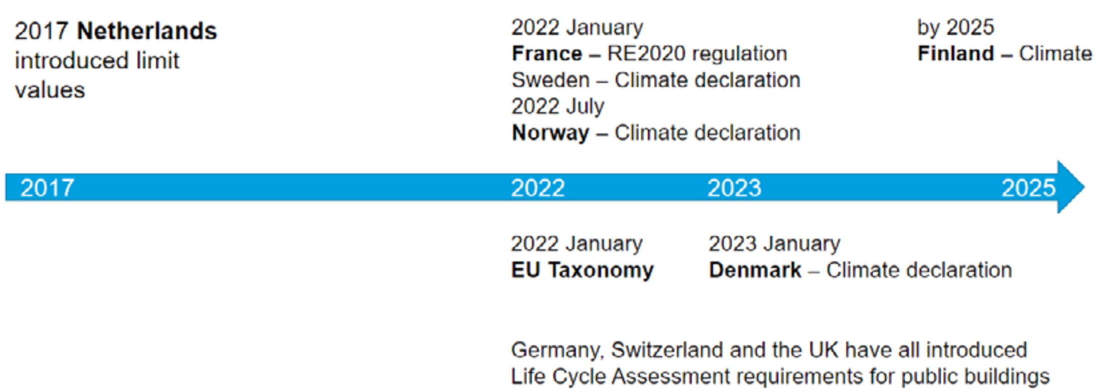


Figure 7. Wood product relevant EU regulations under development/revision (top), timeline of relevant legislation for selected EU countries (bottom).



Further information can be found in the following reports:

- In May 2022, the World Green Building Council (WorldGBC) launched a bold new policy plan for the European Union to accelerate progress on decarbonizing buildings and construction, one of the most heavily emitting sectors in the world. https://www.worldgbc.org/news-media/construction-leaders-across-europe-launch-eu-policy-road-map-towards-climate-neutral
- Bringing Embodied Carbon Upfront https://www.worldgbc.org/embodied-carbon

- Towards Embodied Carbon Benchmarks for Buildings in Europe
  https://www.worldgbc.org/news-media/new-ramboll-study-funded-laudes-foundation-towards-embodied-carbon-benchmarks-buildings
- Net-Zero Buildings: Where Do We Stand?
  https://www.wbcsd.org/Programs/Cities-and-Mobility/Sustainable-Cities/Transforming-the-Built-Environment/Decarbonization/Resources/Net-zero-buildings-Where-do-we-stand
- Decarbonizing Construction: Guidance for Investors and Developers to Reduce Embodied Carbon
  https://www.wbcsd.org/Programs/Cities-and-Mobility/Sustainable-Cities/Transforming-the-Built-Environment/Decarbonization/Resources/Decarbonizing-construction-Guidance-for-investors-and-developers-to-reduce-embodied-carbon

European examples for policies encouraging timber use in buildings:

France announced in 2020 that starting in 2022 all newly-built public buildings shall contain at least 50% wood or other bio-based building materials (3BMs), meant to support Frances's strategy to become carbon-neutral by 2050, France's Sustainable City plan (2009, "ville durable"), and having been informed by the construction of the 2024 Paris Olympics complex (Franklin, 2020). Furthermore, in the residential building sector the use of biogenic building materials has been encouraged through the new Environmental Regulation RE2020, also enforced since January 2022. RE2020 aims at reducing both the operational (through increased energy efficiency) and embodied (through selection of low-carbon materials (Rabbat, Awad, Villot, Rollet, & Andrès, 2022)) energy of buildings (Bat info, 2020).

Austria prioritized the use of wood in construction in its 2020-2024 government program, together with a commitment to strengthen research into wood-based construction technologies (Republik Österreich, 2020). The program promises to increasingly build public buildings (e.g., schools) with wood. An article published by the Austrian Chamber of Agriculture (Zwettler, 2022) warns of the potentially conflicting climate and biodiversity targets of the European Green Deal and the negative impacts this might have on the forest sector if both targets are not addressed in tandem. It argues that the active management of forests (for both material and energy use of forest products) is required in order to decarbonize the economy. In contrast, not managing large parts of forests for the sake of biodiversity and creating large carbon sinks would underestimate the risk of increased vulnerability to disturbances such as pests, windstorms, or wildfires. The article concludes that long-lived wood products should be considered as an important element of Austria's national climate strategy.

In June 2021 the Government of the Republic of **Slovenia** adopted its industrial strategy 2021-2030, which includes the goal of wood constituting at least 30% of all building materials in newly built public buildings, and that the wood processing industry should become "green, creative, and smart" (Slovenian Forestry Institute & Slovenia Ministry of Agriculture: Forestry and Food, 2021).

2. CURRENT STATE OF MASS TIMBER AND FOREST SECTOR IN FINLAND

2.1 Forests (Timber Supply)

Finland's forests cover 22.8 million hectares, about 86% of Finland's land area and 14% of the EU28's forest area (Luke - Natural Resources Institute Finland, 2019a). Productive forests (where tree growth >1 cubic meter/hectare) encompass 81.5% of the land area. Sixty one percent of production forests are privately owned by roughly 620,000 forest owners (approximate 14% of Finnish population). The remaining forest land is owned by the state (26%), companies (e.g., forest industry) (9%), and other entities (5%) (Luke - Natural Resources Institute Finland, 2019a). Though commercial harvesting occurs on all lands, a proportionally higher share of harvest takes place on non-industrial private lands (85%) (Luke - Natural Resources Institute Finland, 2019b). The state forest, Metsähallitus, has a higher proportion of protected areas (19%).

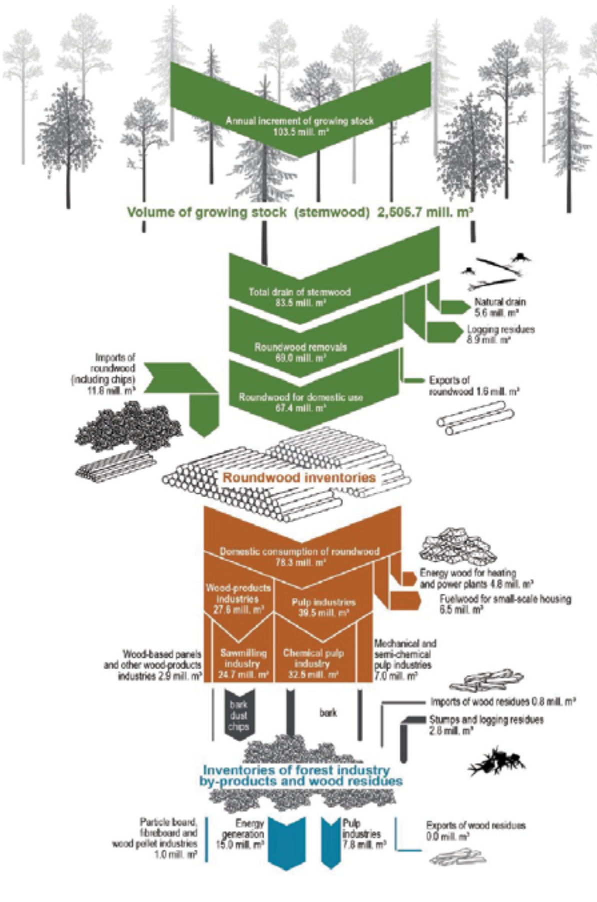


Figure 8: Infographic showing wood flows in Finland in 2020. Source: Luke (figure taken from (Kies et al., 2022).

Silviculturally, 97% of Finland's production forests consist of four species: Scots pine (~50%), Norway spruce (30%), or downy and silver birch. Forests are managed for high quality sawtimber using both even and uneven aged management. 70% of the value of timber sales comes from sawtimber (logwood); however, pulpwood represents an important market for the thinnings and tops of limbs of a sawlog cut. Prior to the development of the pulp industry in Finland, these residue materials were burned at sawmills in huge bonfires (Finnish Forestry Association, 2019a, 2019b).

Since 1960 the C stock of forestsin Finland, Norway, and Sweden have increased by 70% and timber harvests have increased by 40% (Kauppi et al., 2022). They credit this large persistent sink to forest management, including even-aged management, tree planting, fire management, in addition to CO2 fertilization.

Approximately 90% of Finland's forests are certified to PEFC and another 10% are either certified or dual certified to FSC, making a little of 90% of the forest area under a third party certification scheme (Kies et al., 2022). In addition, 2.9 million hectares (about 13% of total forest areas) are considered protected forests, with 2.4 million hectares under statutory protection and an additional 0.5 million hectares considered biodiversity conservation sites in commercial forests.

2.2 Wood Product Markets and Outlook

Finland is Europe's third largest producer of roundwood, after Germany and Sweden, harvesting 60 Mm3 in 2020 (Table 1), of which 85% were used for wood products and 15% for fuelwood. In comparison, Sweden only used 7% of its roundwood harvest for fuelwood, while 93% went to wood products.

A recent study sought to understand why wooden multi-story construction continues to remain a niche market (Jussila et al., 2022). The majority of case studies considered were located in the Nordic countries (therefore presented here) although the extensive literature study covering the past 20 years was originally designed to be global. The identified major enabling factors were cost-efficiency gains from industrialized prefabrication and perceived sustainability benefits by consumers and architects. In turn, identified key barriers included lack of experience from using wood in multi-story construction and path dependencies to use concrete and steel, rather than wood. The authors conclude that "the demand side enablers and barriers remain a great unknown, due to a gap in research", mentioning, for example, that consumer expectations for such housing are rarely studied as is the role of financial aspects such as mortgages and insurances. An earlier study had put it more bluntly (Hurmekoski, Jonsson, & Nord, 2015): that a shift towards wooden multi-story construction requires an adequate regulatory framework and an adequately structured construction industry, namely cooperation between wood product suppliers and the construction sector, and increasing competition with the wooden construction sector. However, the risk-averse nature of the construction value chain was identified as a major barrier towards these goals.

2.3 Finnish Policy Context

The Finnish Ministry of the Environment has launched the Wood Building Programme (2016–2023), which aims to increase the use of wood in construction as part of moving towards a bioeconomy (https://ym.fi/en/wood-building). The programme also aims to diversify and expand different applications for wood while creating as much value added as possible. Wood construction is promoted as part of the government's spearhead project Wood on the move and new products from forests.

The Ministry's Low-carbon Built Environment Programme offers a total of EUR 40 million in funding in 2021–2023 to support climate work related to the built environment. Support is targeted to companies, municipalities and other operators and stakeholders (https://ym.fi/en/low-carbon-built-environment).

The ministry also published guidance on how to assess whole life carbon of buildings, including the carbon footprint of materials, transportation, constructions sites, and energy (2019, https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161796/YM_2019_23_Method_for_the_whole_life_carbon_assessment_of_buildings.pdf?sequence=1&isAllowed=y). Guidance also exists for assessing the carbon handprint of buildings (https://ym.fi/documents/1410903/40549091/Raportti+-+Definition+and+methods+for+the+carbon+handprint+of+buildings.pdf). Another detailed report exists on "Carbon Footprint Limits for Common Building Types" (https://mrluudistus.fi/wp-content/uploads/2021/01/Bionova_MinEnv_Finland_embodied_carbon_limit_values_report_FINAL_19JAN2021_ed.pdf).

CASE STUDY- APPLYING SYSTEMS FRAMEWORK TO FINLAND

The climate benefits of GHG savings and carbon storage in wood buildings in Finland have been well documented (Näsänen, 2022a, 2022b; Stora Enso, 2019), Heräjärvi 2021). (Niu, Rasi, Hughes, Halme, & Fink, 2021) also investigated the GWP savings associated with cascading use- in this case recycling wooden construction materials instead of incineration and found that promising results in terms of savings, but barriers in behavior (e.g., no group wanted to take the initiative to scale new solutions) and lack of standardization of GHG quantification.

The impact of increased mass timber use on net carbon changes in Finland's forest has been the subject of much debate. (Heinonen et al., 2018) calculates that Finland can sustainably supply 73 million m3 per year for next 90 years, and intensive management can increase harvest volume to 80 million m3 per year without reducing carbon stock.

(Soimakallio, Kalliokoski, Lehtonen, & Salminen, 2021) demonstrate that over the short-term (2015-2044) increased harvest rates in Finland for any end-use (including construction wood products) would very likely result in MORE GHG emissions to the atmosphere than the reference scenario because the uncertainty of substitution is so high. Of note is that on the land side, the authors do not include any changes in disturbance risk or feedback in productivity for different levels of harvest. In the discussion portion of the article, (Soimakallio et al., 2021) point out that the studies that have smaller reductions in the forest carbon sink are explained by incorporation of forest management feedback on growth.

(Hurmekoski et al., 2020) investigated the GHG changes in different wood use scenarios over the 2016-2056 period without altering harvest levels. They found that scenarios that included shifting prior pulp and bioenergy material to textile or composite products resulted in a significant change in GHG savings (an additional savings

CASE STUDY- APPLYING SYSTEMS FRAMEWORK TO FINLAND (CONT'D)

of 8.1 Mt C over a reference scenario net GHG benefit of 9.5 Mt C (34.8 Mt CO2e). Increasing the share of sawlog production while keeping harvest the same produced only slightly higher GHG savings. The authors point out that the displacement factors for the emerging end uses of wood remain highly uncertain and there can be a lot of variation in end-of-life treatments and inefficiencies in construction.

When applying the systems framework to Finland (see Figure 2 from 2021 Background Paper) it appears that there are still debates on feedback loops in the forest even within the context of one country.

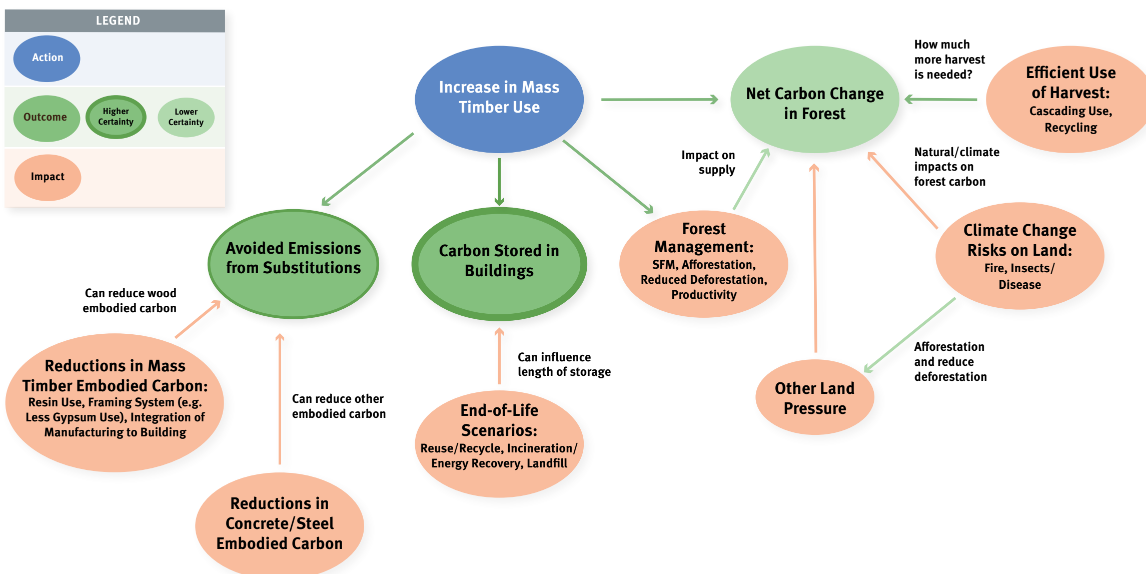


Figure 9: (Figure 2 from the 2021 Background Paper will be discussed for the Finnish context.)

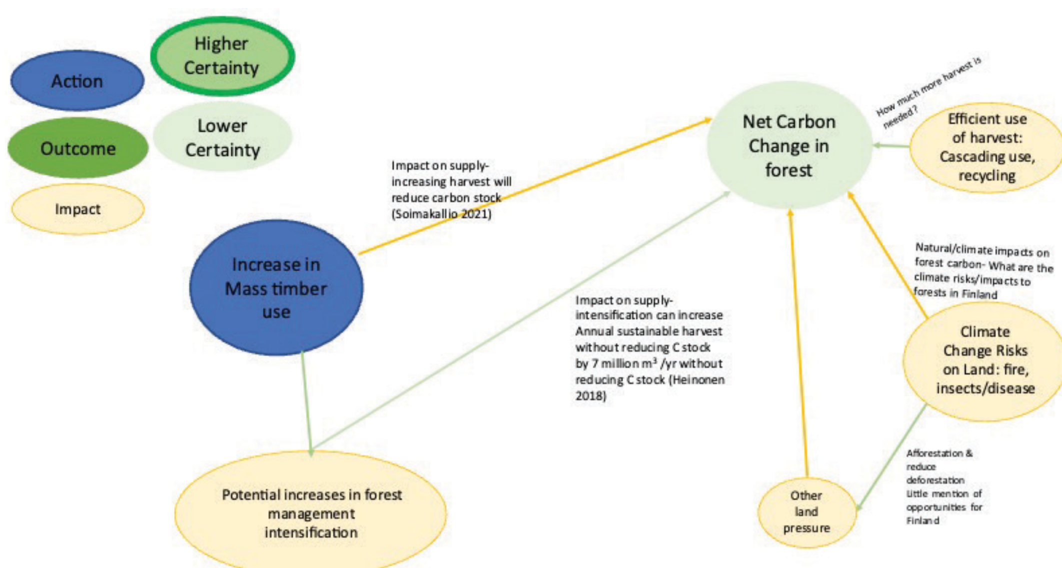


Figure 10: Discussion piece for Finland

3. UPDATE ON CARBON ACCOUNTING APPROACHES AND METHODOLOGIES (UPDATES FROM LAST TFD BACKGROUND PAPER)

3.1 Substitution (Whole Building Embodied Carbon)

Since the first TFD background paper on the *Climate Benefits and Challenges Related to "Mass Timber Construction"* was published in June 2021 additional mass timber publications have elaborated and confirmed the discussions put forward in that paper. Specifically, additional life cycle assessments have confirmed lower whole building embodied carbon in mass timber buildings compared to conventional (e.g., concrete or steel) (Allan & Phillips, 2021; Dolezal, Dornigg, Wurm, & Figl, 2021; Minunno, O'Grady, Morrison, & Gruner, 2021). Allan and Phillips (2021) found 31% and 41% GWP savings in mass timber buildings compared to steel at five-stories and twelve-stories respectively for life cycle stages A and C. (Dolezal et al., 2021), as part of the research program "Assessing the Climate and Forest Impacts of Building with Mass Timber" compared embodied carbon and primary energy in a conventional eight story concrete building in Vienna, Austria with a functionally equivalent mass timber building and found an 18% lower fossil GWP in the A1-A5 stage with the mass timber building. When all life cycle stages (A-D) are included the mass timber savings are diminished because the B stage (use stage) represents the largest share of emissions across the entire life cycle. Minunno et al (2021) conducted a literature review and meta-analysis of 73 articles on construction materials and 100 articles on building life cycle assessments finding timber buildings had a median 68% embodied carbon savings relative to concrete over the whole life cycle. (Duan, Huang, & Zhang, 2022) conducted a similar systematic review of 62 peer-reviewed articles and found mass timber buildings showed a 42.68% savings in embodied GHG relative to reinforced concrete.

(D'Amico, Pomponi, & Hart, 2021) propose that replacing steel-concrete floor systems in buildings (which are predicted to release 171-303 Mt of CO2e into the atmosphere by 2050) with wood-steel hybrid systems can save between 20 and 80 Mt CO2e without considering carbon stored in the wood building products.

Some papers provided further investigations into how to explicitly analyze biogenic carbon. (Hawkins, Cooper, Allen, Roynon, & Ibell, 2021) conducted a stand-level dynamic LCA incorporated the time it takes for forests to regrow. Even with this stand level baseline (see background paper Section 4.4) the six-story timber building designed in the UK had lower embodied carbon and exerted lower integrated radiative forcing across all time scales (20, 50, 100, and 200) than comparable steel and concrete.

3.2 Carbon Storage (Product)

Harvested Wood Product (HWP) carbon storage is influenced by production levels and by product longevity and end-of-life fates (Ganguly, Pierobon, & Sonne Hall, 2020). HWP net carbon flux (removals) will increase if there is more wood production relative to historic levels and/or if product use increases in longevity.

(Arehart, Hart, Pomponi, & D'Amico, 2021) conducted a meta-analysis of the different ways studies incorporate HWP carbon storage into LCA. They found that results vary depending on whether the assessment is static (which assesses cumulative storage and emissions over a fixed time horizon) or dynamic (which factors in the timing of emissions and storage).(Arehart et al., 2021) found analyses that showed global HWP stocks are still increasing but different countries may be declining depending on their share of wood products used relative to their historic levels.

(Heräjärvi, 2019) examined the "building sink effect" (BSE) of Finland, which is calculated by comparing the amount of CO2e stored in wooden construction products to the total man-caused CO2 emissions in the same region. BSE may indicate the impact that wood as a climate mitigation tool might have in a given region, with the caveat that neither forest impact nor substitution impact is included.(Heräjärvi, 2019) found the BSE of Finland was 0.61% and global BSE ranges from 0.12 to 1.03% depending on how much of global lumber production is found in buildings.

3.3 Carbon Impacts on Forests

As discussed in the first scoping dialogue background paper, many of the concerns with mass timber construction as a climate mitigation strategy stem from the uncertainties associated with increased harvest's impact on forest carbon stocks. Several types of analyses have attempted to further understand these uncertainties. In the last year several more papers have examined these potential impacts, building on the different types of analyses including 1) examining the amount existing sequestration (net growth) is available to meet increased demand (e.g., (Oliver, Nassar, Lippke, & McCarter, 2014)) 2) Incorporate global economic land models to identify use and management changes (e.g., (Eriksson et al., 2012; Nepal et al., 2016)) and 3) comparing different forest strategy pathways (e.g., (Law et al., 2018; Smyth et al., 2020)).

(Mishra et al., 2022) used a global multi-regional land-system modeling framework determine that 149 million hectares of additional planted forests (beyond an already predicted business as usual increase of 139 million hectares) would be needed to meet the increased demand enough to build 90% of new urban buildings with timber construction. Such a scenario would result in 102 Gt CO2 of carbon savings by 2100 due lower embodied carbon in timber buildings, additional carbon storage in buildings higher, and regrowth of younger forests. Mishra et al (2022) warn that the increased plantations may result in the loss of unprotected natural ecosystems, which will harm biodiversity, though they believe that the area of intensified plantations will not compete with ambitious land protection policies.

Kauppi used empirical analyses to examine harvest and carbon stocks in northern Europe between 1960 and 2017 and found that annual timber harvests increased by 40% at the same time that forest carbon stocks increased by 70%. They argue that such results suggests that forest management, aimed at producing more timber in existing forests, could be applied globally, which would not compete with other land uses such as agriculture.

As demonstrated in past studies, the results of recent publications examining the climate implications of different forest management pathways are highly dependent on context. (Gustavsson, Nguyen, Sathre, & Tettey, 2021) modelled three different pathways over a 201-year period: BAU, production (in which forest productivity is increased by 40% through intensive forestry) and set-aside (in which 50% of the forest land is set-aside for forest conservation in Kronoberg County in Sweden. The set-aside strategy resulted in less net CO2e emissions for the first 35 years, after which the production strategy provided the greatest sustained benefit. By the end of the 201 years the production strategy yielded about ten times greater emissions reductions compared to the initial reduction of the set-aside scenario. In addition, due to disturbances, the set-aside scenario actually had higher emissions than the BAU scenario after 80 years. (Jonsson et al., 2021) integrate a forest resource model with a global wood-product markets model to understand the impacts of increased demand for wood-based construction and/or biochemicals and biofuels may have on harvests, production, trade, carbon stock, and forest sector employment in the EU. They also found that the largest long-term savings result from increased harvest (a maximum of 85% better than BAU) for the scenario that includes increase in wood-based construction, biochemical, and biofuels. However, when examined on a short time-frame (e.g., 2030) BAU represented the maximum carbon sink. Increasing wood-based construction in all three scenarios would increase employment in the forest-based sector by 2030 relative to BAU.

(Churkina & Organschi, 2022) also point out there is little research on increasing wood in urban settings and the resulting impact on forest structure and land use may have temperature impacts beyond GHG emissions. For example, afforestation can impact forest albedo as can a shift from broadleaf to conifers.

4. SOCIAL AND ENVIRONMENTAL SAFEGUARDS

4.1 What Do These Look Like on the Ground, in Context (e.g., Biodiversity Considerations for Forests Producing Mass Timber?)

A key theme that arose from the 2021 Scoping Dialogue was the importance of social and environmental safeguards prior to wide-scale adoption of mass timber construction. Biodiversity loss has risen as an important global threat and many international efforts are underway to document, categorize, and maintain or restore including the United Nations Convention on Biological Diversity (CBD), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Millennium Ecosystem Assessment (MEA 2005) and The Economics of Biodiversity Reports (TEEB 2010) (Muys et al., 2022). Europe's forests are categorized as 94% semi-natural, 2% undisturbed by man, and 3% plantation. The broad range of management intensities and forest types favor different types of habitats. Biodiversity can be impacted by both internal (e.g., management practices) and external (e.g., climate, pollution, invasive species, land-use change) factors (Muys et al., 2022). When implementing safeguards, it is important to understand what levers are effective to manage for both internal and external changes.

(Pasternack et al., 2022) describe a framework with which it may be possible to understand the holistic impact, both positive and negative, of increased mass timber demand on forest ecosystems and the corresponding built environment, named the Global Mass Timber Impact Assessment (GMTIA). Of particular importance are the impacts on forest health and composition, which will be analyzed in Phase 4 of a 5 Phase analysis, with results due in 2023.

(Clay & Cooper, 2022) conducted a qualitative review of several existing social and environmental safeguards, which are defined "as measures taken to continually assess, monitor, and, where possible, improve the social and environmental impacts of interventions relative to the baseline, or counterfactual, scenario". Examples of existing safeguards guidances include: Core Principles of the Accountability Framework Initiative (AFi), *Buying Green! A Handbook on Green Public Procurement* from EU Public Procurement, *Verra's Sustainable Development Verified Impact Standard*. FAO Environmental and Social Management Guidelines, FSC Principles and Criteria for Forest Stewardship. Clay and Cooper (2022) identify several challenges to widespread implementation of these safeguards, including 1) lack of clarity about actor responsibilities and who has a role to ensure safeguards across a diverse supply chain. 2) lack of data availability and reliability, such as knowing fiber sourcing location 3) navigating existing guidelines that are either too broadly defined or not applicable to the specific context 4) inefficient and variable implementation and 5) lack of inclusive engagement, which results in failing to bring in the lands that are at a higher risk for poor management.

4.2 What are Some Safeguards?

4.2.1 Forest Certification

Forest certification has long been looked to as a safeguard for sustainable forest management. The total global certified area still remains about 11%, despite the fact that individual forest certification programs are growing. This phenomenon is explained by an increase in double-certified areas (Fernholz et al., 2021). Some have seen this as an indicator that those who can be certified already are, leading to the challenge of lack of inclusive engagement described in Clay and Cooper above. To partially answer this challenge, in the last decade, all major certification schemes have added mill focused certifications to provide assurances about all the wood in the supply chain, even uncertified material. For example, FSC Controlled wood standard requires a risk analysis to show that fiber is not coming from: GMO trees, land converted to a non-forest use, wood from a high conservation-value forests, wood harvested in violation of traditional or civil rights or illegal harvest. These mill-focused standards have increased assurances in wood baskets where scalable land certification is not practical.

4.2.2 Policies

Europe has broad political support to safeguard and promote biodiversity in Europe in order to help prevent species extinction reaching a critical threshold (Muys et al., 2022). For decades, Europe has been developing the Natura 2000 network of protected areas, which now covers 18% of Europe's land area. In addition, EU Biodiversity Strategy for 2030 calls for the protection and biodiversity management on 30% of EU land and to plant 3 billion "biodiversity supporting trees" to increase ecosystem health and climate resilience (EC 2020). Finally, many strategies that fall under the umbrella of Europe's Green New Deal include biodiversity goals (e.g., EU Forest Strategy, the Farm to Fork Strategy, Common Agricultural Policy (CAP), and the upcoming Nature Restoration Law). However, the implementation of these policies is still being debated with two opposing camps; those supporting land-sparing (e.g., setting aside land specifically for biodiversity separate from those providing provisional services) versus land-sharing (e.g., providing multiple provisional and non-provisional services together) (Muhs et al 2022).

4.2.3 Monitoring and Transparency

Europe's National Forest Inventory (a network of permanent plots that are remeasured every 10 years) can help monitor not only the traditional provisional services (e.g., inventory, wood production) but could be leveraged to monitor forest structural and functional diversity, which would help understand trends.

LIST OF SOURCES

Allan, K., & Phillips, A. R. (2021). Comparative Cradle-to-Grave Life Cycle Assessment of Low and Mid-Rise Mass Timber Buildings with Equivalent Structural Steel Alternatives. *Sustainability, 13*(6), 3401.

Arehart, J. H., Hart, J., Pomponi, F., & D'Amico, B. (2021). Carbon sequestration and storage in the built environment. *Sustainable Production and Consumption, 27*, 1047-1063. doi: https://doi.org/10.1016/j.spc.2021.02.028

Bat info. (2020, 14 Jan). RE2020: The Government launches simulations to define future environmental regulations. *Batinfo.com*. Retrieved from https://batinfo.com/en/actuality/re2020-the-government-launches-simulations-to-define-future-environmental-regulations_14587

Bentsen, N. S., & Felby, C. (2012). Biomass for energy in the European Union - a review of bioenergy resource assessments. *Biotechnology for Biofuels, 5*(1), 25. doi:10.1186/1754-6834-5-25

bne IntelliNews. (2021, March 30). Segezha Group launches CLT panel factory. Retrieved from https://www.intellinews.com/segezha-group-launches-clt-panel-factory-206818/?source=russia

Buildings Performance Institute Europe. (2021). *Whole-life carbonBPIE (Buildings Performance Institute Europe)*. Retrieved from https://www.bpie.eu/publication/whole-life-carbon-challenges-and-solutions-for-highly-efficient-and-climate-neutral-buildings/

Camia, A., Giuntoli, J., Jonsson, R., Robert, N., Cazzaniga, N., Jasinevičius, G.,…Mubareka, S. (2020). *The use of woody biomass for energy production in the EU* (978-92-76-27866-5). Retrieved from Luxembourg: https://publications.jrc.ec.europa.eu/repository/handle/JRC122719

Churkina, G., & Organschi, A. (2022). Will a Transition to Timber Construction Cool the Climate? *Sustainability, 14*(7), 4271.

Clay, K., & Cooper, L. (2022). Safeguarding against Harm in a Climate-Smart Forest Economy: Definitions, Challenges, and Solutions. *Sustainability, 14*(7), 4209.

D'Amico, B., Pomponi, F., & Hart, J. (2021). Global potential for material substitution in building construction: The case of cross laminated timber. *Journal of Cleaner Production, 279*, 123487. doi: https://doi.org/10.1016/j.jclepro.2020.123487

Dolezal, F., Dornigg, I., Wurm, M., & Figl, H. (2021). Overview and Main Findings for the Austrian Case Study. *Sustainability, 13*(14), 7584.

Duan, Z., Huang, Q., & Zhang, Q. (2022). Life cycle assessment of mass timber construction: A review. *Building and Environment, 221*, 109320. doi:https://doi.org/10.1016/j.buildenv.2022.109320

EC Joint Research Centre. (2019). Brief on biomass for energy in the European Union. *JRC Publications Repository.* Retrieved from https://publications.jrc.ec.europa.eu/repository/handle/JRC109354

eit Climate-KIC. (2020, 16 December). New platform inspires sustainable Nordic wood construction. Retrieved from https://www.climate-kic.org/news/norwegian-wood-new-digital-platform-inspires-sustainable-construction/

Elomina, J., & Pülzl, H. (2021). How are forests framed? An analysis of EU forest policy. *Forest Policy and Economics, 127*, 102448. doi: https://doi.org/10.1016/j.forpol.2021.102448

Eriksson, L. O., Gustavsson, L., Hänninen, R., Kallio, M., Lyhykäinen, H., Pingoud, K., . . .Valsta, L. (2012). Climate change mitigation through increased wood use in the European construction sector—towards an integrated modelling framework. *European Journal of Forest Research, 131*(1), 131-144. doi:10.1007/s10342-010-0463-3

European Commission. (2021a). *Amending Directive (EU) 2018/2001 (…) and EU 2018/1999 (…) promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652 (Proposal).* Brussels Retrieved from https://eur-lex.europa.eu/resource.html?uri=cellar:dbb7eb9c-e575-11eb-a1a5-01aa75ed71a1.0001.02/DOC_1&format=PDF.

European Commission. (2021b). *New EU Forest Strategy for 2030. COM(2021) 572 final*. Brussels Retrieved from https://environment.ec.europa.eu/strategy/forest-strategy_en, https://eur-lex.europa.eu/resource.html?uri=cellar:0d918e07-e610-11eb-a1a5-01aa75ed71a1.0001.02/DOC_1&format=PDF.

European Commission. (2021c, 26 October). Sixth Report on the State of the Energy Union - Contributing to the European Green Deal and the Union's recovery. *COM(2021) 950 final.* Retrieved from https://energy.ec.europa.eu/topics/energy-strategy/energy-union/sixth-report-state-energy-union_en

European Commission. (2022a). *EU Bioeconomy Strategy Progress Report*. Retrieved from Luxembourg: https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/adoption-bioeconomy-strategy-progress-report-2022-06-09_en

European Commission. (2022b). A European Green Deal. Striving to be the first climate-neutral continent. Retrieved from https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

European Commission. (2022c). Renewable Energy – Recast to 2030 (RED II). *EU Science Hub.* Retrieved from https://joint-research-centre.ec.europa.eu/welcome-jec-website/reference-regulatory-framework/renewable-energy-recast-2030-red-ii_en

European Commission. (2022d). Renewable energy directive. Retrieved from https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en

European Commission. (2022e). Renewable energy targets. Retrieved from https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en

European Commission. (2022f). Timber Regulation. What's new. *Environment.* Retrieved from https://ec.europa.eu/environment/forests/timber_regulation.htm

European Commission DG Environment. (2022). 3 Billion Trees Pledge. Retrieved from https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030/3-billion-trees_en

European Council. (2022, 16 Aug). EU sanctions against Russia explained. Retrieved from https://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-against-russia-over-ukraine/sanctions-against-russia-explained/

Eurostat. (2021, 13 Dec). Wood products – production and trade. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Wood_products_-_production_and_trade

Eurostat. (2022a, 19 January). EU overachieves 2020 renewable energy target. Retrieved from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220119-1

Eurostat. (2022b, 17 Aug). Russia-EU - international trade of main product groups *Statistics Explained.* Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Russia-EU_-_international_trade_of_main_product_groups&oldid=558292

FAO. (2020). *Global Forest Resources Assessment 2020: Main report*. Retrieved from Rome: https://doi.org/10.4060/ca9825en

FAO. (2022). Forest product statistics. Facts and figures. from Food and Agriculture Organization of the United Nations https://www.fao.org/forestry/statistics/80938/en/

Fernholz, K., Bowyer, J., Erickson, G., Groot, H., Jacobs, M., McFarland, A., & Pepke, E. (2021). *Forest Certification Update 2021: The Pace of Change*. Retrieved from Minneapolis, MN (USA): https://dovetailinc.org/portfoliodetail.php?id=60085a177dc07; https://knowyourforest.org/sites/default/files/documents/Forest-Certification-Update-2021.pdf

Finnish Forestry Association. (2019a). Forest Facts. Retrieved from https://forest.fi/category/forest-facts/

Finnish Forestry Association. (2019b, 12 June 2019). Silviculture. Retrieved from https://forest.fi/article/silviculture/#ae8e1001

Finnish Forestry Association. (2022, 25 May). EU and war in Ukraine actualize disquieting scenarios on future of forest energy – researcher says: 'We really didn't expect this'. *Forest.fi: News from forest & forest sector*. Retrieved from https://forest.fi/category/forest-facts/

Flach, B., & Bolla, S. (2022). *European Union: EU Wood Pellet Annual*. Retrieved from The Hague: https://www.fas.usda.gov/data/european-union-eu-wood-pellet-annual

Forest2Market. (2021, 15 March). Everything You Wanted to Know About CLT. Retrieved from https://www.forest2market.com/blog/everything-you-wanted-to-know-about-clt

Franklin, S. (2020). France mandates public buildings be built with at least 50 percent timber. *The Architect's Newspaper*. Retrieved from https://www.archpaper.com/2020/02/france-public-buildings-timber-mandate/

Ganguly, I., Pierobon, F., & Sonne Hall, E. (2020). Global Warming Mitigating Role of Wood Products from Washington State's Private Forests. *Forests, 11*(2), 194.

Gustavsson, L., Nguyen, T., Sathre, R., & Tettey, U. Y. A. (2021). Climate effects of forestry and substitution of concrete buildings and fossil energy. *Renewable and Sustainable Energy Reviews, 136*, 110435. doi:https://doi.org/10.1016/j.rser.2020.110435

Hawkins, W., Cooper, S., Allen, S., Roynon, J., & Ibell, T. (2021). Embodied carbon assessment using a dynamic climate model: Case-study comparison of a concrete, steel and timber building structure. *Structures, 33*, 90-98. doi:https://doi.org/10.1016/j.istruc.2020.12.013

Heinonen, T., Pukkala, T., Kellomäki, S., Strandman, H., Asikainen, A., Venäläinen, A., & Peltola, H. (2018). Effects of forest management and harvesting intensity on the timber supply from Finnish forests in a changing climate. *Canadian Journal of Forest Research, 48*(10), 1124-1134. doi:10.1139/cjfr-2018-0118

Heräjärvi, H. (2019). Wooden buildings as carbon storages – Mitigation or oration? *Wood Material Science & Engineering, 14*(5), 291-297. doi:10.1080/17480272.2019.1635205

Hurmekoski, E., Jonsson, R., & Nord, T. (2015). Context, drivers, and future potential for wood-frame multi-story construction in Europe. *Technological Forecasting and Social Change, 99*, 181-196. doi:https://doi.org/10.1016/j.techfore.2015.07.002

Hurmekoski, E., Myllyviita, T., Seppälä, J., Heinonen, T., Kilpeläinen, A., Pukkala, T., Peltola, H. (2020). Impact of structural changes in wood-using industries on net carbon emissions in Finland. *Journal of Industrial Ecology, 24*(4), 899-912. doi:https://doi.org/10.1111/jiec.12981

Hurtes, S., & Cai, W. (2022, September 7). Europe Is Sacrificing Its Ancient Forests for Energy. *New York Times*. Retrieved from https://www.nytimes.com/interactive/2022/09/07/world/europe/eu-logging-wood-pellets.html

IMARC. (2022). European Cross-Laminated Timber Market: Industry Trends, Share, Size, Growth, Opportunity and Forecast 2022-2027. Retrieved from https://www.imarcgroup.com/european-cross-laminated-timber-market

Jonsson, R., Rinaldi, F., Pilli, R., Fiorese, G., Hurmekoski, E., Cazzaniga, N.,. . .Camia, A. (2021). Boosting the EU forest-based bioeconomy: Market, climate, and employment impacts. *Technological Forecasting and Social Change, 163*, 120478. doi:https://doi.org/10.1016/j.techfore.2020.120478

Jussila, J., Nagy, E., Lähtinen, K., Hurmekoski, E., Häyrinen, L., Mark-Herbert, C.,…Toppinen, A. (2022). *Wooden multi-storey construction market development – systematic literature review within a global scope with insights on the Nordic region* (Vol. 56).

Kauppi, P. E., Stål, G., Arnesson-Ceder, L., Hallberg Sramek, I., Hoen, H. F., Svensson, A.,…Nordin, A. (2022). Managing existing forests can mitigate climate change. *Forest Ecology and Management, 513*, 120186. doi:https://doi.org/10.1016/j.foreco.2022.120186

Kies, U., Kouyoumji, J.-L., Rominh, P., Heräjärvi, H., Weckroth, M., Muilu, T.,…García Jaca, J. (2022). *Transformation needs of wood construction sectors in five European regions.* Retrieved from Helsinki: https://jukuri.luke.fi/handle/10024/552133

Kitek Kuzman, M., & Sandberg, D. (2017). Comparison of timber-house technologies and initiatives supporting use of timber in Slovenia and in Sweden – the state of the art. [Comparison of timber-house technologies and initiatives supporting use of timber in Slovenia and in Sweden – the state of the art]. *iForest - Biogeosciences and Forestry, 10*(6), 930-938. doi:10.3832/ifor2397-010

Köhl, M., Linser, S., Prins, K., & Talarczyk, A. (2021). The EU climate package "Fit for 55" – a double-edged sword for Europeans and their forests and timber industry. *Forest Policy and Economics, 132*, 102596. doi: https://doi.org/10.1016/j.forpol.2021.102596

Law, B. E., Hudiburg, T. W., Berner, L. T., Kent, J. J., Buotte, P. C., & Harmon, M. E. (2018). Land use strategies to mitigate climate change in carbon dense temperate forests. *Proceedings of the National Academy of Sciences, 115*(14), 3663-3668. doi:10.1073/pnas.1720064115

Luke – Natural Resources Institute Finland. (2019a). *Finland's forests 2019*. Retrieved from https://toolbox.finland.fi/wp-content/uploads/sites/2/2016/02/finlands-forests-facts-2019-en.pdf

Luke – Natural Resources Institute Finland. (2019b). *Share of non-industrial private forests of forest land and fellings*.

Material Economics. (2021). *EU Biomass Use In A Net-Zero Economy – A Course Correction for EU Biomass*. Retrieved from https://www.climate-kic.org/wp-content/uploads/2021/06/MATERIAL-ECONOMICS-EU-BIO-MASS-USE-IN-A-NET-ZERO-ECONOMY-ONLINE-VERSION.pdf

Mauser, H. (2021). *Key questions on forests in the EU. Knowledge to Action 4*. Retrieved from https://efi.int/sites/default/files/files/publication-bank/2021/EFI_K2A_04_2021.pdf

Minunno, R., O'Grady, T., Morrison, G. M., & Gruner, R. L. (2021). Investigating the embodied energy and carbon of buildings: A systematic literature review and meta-analysis of life cycle assessments. *Renewable and Sustainable Energy Reviews, 143*, 110935. doi:https://doi.org/10.1016/j.rser.2021.110935

Mishra, A., Humpenöder, F., Churkina, G., Reyer, C. P. O., Beier, F., Bodirsky, B. L., …Popp, A. (2022).

Land use change and carbon emissions of a transformation to timber cities. *Nature Communications, 13*(1), 4889. doi:10.1038/s41467-022-32244-w

Muys, B., Angelstam, P., Bauhus, J., Bouriaud, L., Jactel, H., Kraigher, H., . . .Van Meerbeek, K. (2022). *Forest Biodiversity in Europe. From Science to Policy 1*. Retrieved from https://efi.int/publications-bank/forest-biodiversity-europe

Näsänen, H. (2022a). *Comparison calculations of low-carbon construction – Multi-storey apartment building. Carbon footprint calculation report*. Retrieved from https://assets.ctfassets.net/a2tjr1gs85zs/3OyAATEX7LX-Ih7MWKcinNc/37db5c4db3f2e353bae00f99b737badc/Combient_Pure_NCC_Stora_enso_asuinkerrostal-on_hiilijalanja__lki_Loppuraportti_EN_Final.pdf

Näsänen, H. (2022b). *Comparison calculations of low-carbon construction – Office. Carbon footprint calculation report*. Retrieved from https://assets.ctfassets.net/a2tjr1gs85zs/1K2Wzaw9VZuW2DdzFgSAc-B/678fb1a4a82fcd87465b311db5878a80/Combient_Pure_NCC_Stora_enso_toimiston_hiilijalanja__lki_Loppuraportti_EN_Final.pdf

Nepal, P., Johnston, C. M. T., & Ganguly, I. (2021). Effects on Global Forests and Wood Product Markets of Increased Demand for Mass Timber. *Sustainability, 13*(24), 13943.

Nepal, P., Skog, K. E., McKeever, D. B., Bergman, R. D., Abt, K. L., & Abt, R. C. (2016). Carbon Mitigation Impacts of Increased Softwood Lumber and Structural Panel Use for Nonresidential Construction in the United States. *Forest Products Journal, 66* (1-2), 77-87. doi:10.13073/fpj-d-15-00019

Niu, Y., Rasi, K., Hughes, M., Halme, M., & Fink, G. (2021). Prolonging life cycles of construction materials and combating climate change by cascading: The case of reusing timber in Finland. *Resources, Conservation and Recycling, 170*, 105555. doi:https://doi.org/10.1016/j.resconrec.2021.105555

O'Brien, M., & Bringezu, S. (2018). European Timber Consumption: Developing a Method to Account for Timber Flows and the EU's Global Forest Footprint. *Ecological Economics, 147*, 322-332. doi: https://doi.org/10.1016/j.ecolecon.2018.01.027

Oliver, C. D., Nassar, N. T., Lippke, B. R., & McCarter, J. B. (2014). Carbon, Fossil Fuel, and Biodiversity Mitigation With Wood and Forests. *Journal of Sustainable Forestry, 33*(3), 248-275. doi:10.1080/10549811.2013.839386

Pasternack, R., Wishnie, M., Clarke, C., Wang, Y., Belair, E., Marshall, S., . . .Van den Huevel, R. (2022). What Is the Impact of Mass Timber Utilization on Climate and Forests? *Sustainability, 14*(2), 758.

Petruch, M., & Walcher, D. (2021). Timber for future? Attitudes towards timber construction by young millennials in Austria – Marketing implications from a representative study. *Journal of Cleaner Production, 294*, 126324. doi:https://doi.org/10.1016/j.jclepro.2021.126324

Rabbat, C., Awad, S., Villot, A., Rollet, D., & Andrès, Y. (2022). Sustainability of biomass-based insulation materials in buildings: Current status in France, end-of-life projections and energy recovery potentials. *Renewable and Sustainable Energy Reviews, 156*, 111962. doi:https://doi.org/10.1016/j.rser.2021.111962

Republik Österreich. (2020). *Aus Verantwortung fuer Österreich. Regierungsprogramm 2020-2024*. Vienna Retrieved from https://www.bundeskanzleramt.gv.at/bundeskanzleramt/die-bundesregierung/regierungsdokumente.html.

Research and Markets. (2022, May 20). Global Cross Laminated Timber Market to 2027 - Europe is Projected to Register the Largest Market Share *PRNewswire*. Retrieved from https://www.prnewswire.com/news-releases/global-cross-laminated-timber-market-to-2027---europe-is-projected-to-register-the-largest-market-share-301551946.html

Richards, G. (2022, 27 January). Good for wood: new embodied carbon regulations. *Stora Enso*. Retrieved from https://www.storaenso.com/en/newsroom/news/2022/1/good-for-wood-new-embodied-carbon-regulations

Runge-Metzger, A. (2018). *A clean planet for all. A European strategic long term vision for a prosperous, modern, competitive and climate neutral economy*. Paper presented at the EU Refining Forum, Brussels. https://ec.europa.eu/energy/sites/ener/files/documents/european_commission_-_a_european_strategic_long_term_vision_for_a_prosperous_modern_competitive_and_climate_neutral_economy.pdf

Sikkema, R., Proskurina, S., Banja, M., & Vakkilainen, E. (2021). How can solid biomass contribute to the EU's renewable energy targets in 2020, 2030 and what are the GHG drivers and safeguards in energy- and forestry sectors? *Renewable Energy, 165*, 758-772. doi: https://doi.org/10.1016/j.renene.2020.11.047

Slovenian Forestry Institute, & Slovenia Ministry of Agriculture: Forestry and Food. (2021). *Wood products market statement with forecasts. Market Statement 2021; Slovenia*. Ljubljijana: United Nations – Economic Commission for Europe, Committee on Forests and the Forest Industry Retrieved from https://unece.org/sites/default/files/2021-10/slovenia-country-market-statement-2021.pdf.

Smyth, C. E., Dugan, A. J., Olguin, M., Birdsey, R. A., Wayson, C., Alanís, A., & Kurz, W. A. (2020). *A synthesis of climate change mitigation options based on regional case studies of the North American forest sector using a harmonized modeling approach*. Retrieved from Ottawa, ON: https://cfs.nrcan.gc.ca/publications?id=40190

Soimakallio, S., Kalliokoski, T., Lehtonen, A., & Salminen, O. (2021). On the trade-offs and synergies between forest carbon sequestration and substitution. *Mitigation and Adaptation Strategies for Global Change, 26*(1), 4. doi:10.1007/s11027-021-09942-9

Stora Enso. (2019). *Sustainability Case Study. The Lighthouse Joensuu project*. Retrieved from https://www.storaenso.com/-/media/documents/download-center/documents/sustainability/lighthouse_joensuu_lca_2019.pdf

Teischinger, A., Stingl, R., Berger, V., & Eder, A. (2015). Holzbauanteil in Österreich? Erhebung des Holzbauanteils aller österreichischen Bauvorhaben. Retrieved from https://www.proholz.at/fileadmin/proholz/media/presse/150924_pk_vortrag_teischinger_14folien.pdf

United Nations (UNECE), & FAO. (2021). *Forest Products: Annual Market Review 2020-2021*. Retrieved from Geneva: https://unece.org/sites/default/files/2021-11/2114516E_Inside_Final_web.pdf

Wood Resources International LLC. (2022, 28 Apr). The war in Ukraine will tighten lumber markets both short and long term, particularly in Europe but also in China and the US. *PRNewswire*. Retrieved from https://www.prnewswire.com/news-releases/the-war-in-ukraine-will-tighten-lumber-markets-both-short-and-long-term-particularly-in-europe-but-also-in-china-and-the-us--wood-resources-international-llc-301535499.html

World Integrated Trade Solution. (2021). European Union Wood Imports by country in US$ Thousand 2019 Retrieved from https://wits.worldbank.org/CountryProfile/en/Country/EUN/Year/2019/TradeFlow/Import/Partner/by-country/Product/44-49_Wood/Show/Partner%20Name;MPRT-TRD-VL;MPRT-PRDCT-SHR;AHS-WGHTD-AVRG;MFN-WGHTD-AVRG;/Sort/MPRT-TRD-VL/Chart/top10

Xia, Q., Chen, C., Yao, Y., Li, J., He, S., Zhou, Y., . . .Hu, L. (2021). A strong, biodegradable and recyclable lignocellulosic bioplastic. *Nature Sustainability, 4*(7), 627-635. doi:10.1038/s41893-021-00702-w

Zwettler, S. (2022, 28 Feb). Bewirtschafteter Wald ist ein Klimaheld: Wald und Holz sind Teil der Klimaschutz-Krisenbewältigung. Die Debatte über eine Honorierung von Klimaschutzdienstleistungen ist eröffnet. *Ikonline*. Retrieved from https://www.lko.at/bewirtschafteter-wald-ist-ein-klimaheld+2400+3614617

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