Evaluation of the climate benefits of the use of Harvested Wood Products in the construction sector and assessment of remuneration schemes

Final Report

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Evaluation of the climate benefits of the use of Harvested Wood Products in the construction sector and assessment of remuneration schemes

Final Report

EUROPEAN COMMISSION

Directorate-General for Climate Action
Directorate C – Climate Strategy, Governance and Emissions from non-trading sectors
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Abstract

The aim of this study is to evaluate the climate benefits of harvested Wood-based Construction Products (WCP), and to explore the role of policy in encouraging the use of these materials. In particular, this study explores the opportunities and challenges of incentivizing an increased uptake of WCPs, as well as the ways in which policy can successfully support this transition, by remunerating market actors that employ WCPs in construction projects.

Based on the analysis of the construction market and of the wood value chain, and of the regulatory environment surrounding WCPs in the European Union, the study identifies barriers and opportunities for an increased deployment of these products. It then performs a critical review and comparison of existing methodologies for the calculation of embodied emissions and biogenic carbon content.

The study then proposes the design of a method, usable by practitioners, to assess the climate benefits of using WCPs. The method values the fact that WCPs delay the release of GHG by several decades (long-term carbon capture). Based on this method, a remuneration scheme is proposed to encourage the usage of WCPs, targeting beam manufacturers and project developers.

Executive Summary

The aim of this study is to provide the European Commission, DG CLIMA, with an evaluation of the climate benefits of harvested Wood-based Construction Products (WCP). In particular, this study explores the opportunities and challenges of incentivizing an increased uptake of WCPs, as well as the ways in which policy can successfully support this transition, by rewarding the use of these products in the construction sector. This task requires an understanding of the current state of the market for wood construction products, but also the development of a methodology to quantify the climate benefits of WCPs and translate that into a remuneration scheme. This study articulates along three parts: the first part (A) is concerned with providing an overview of the current market share of WCPs, the barriers and opportunities to increase that share, as well as the policies and market-based schemes in place in Member States to address the uptake of wood products. The second part (B) provides a critical review of existing methodologies and standards to measure the embodied carbon and biogenic carbon content of WCPs. Finally, the third part (C) brings together the findings from the previous tasks, by, on the one hand, testing the proposed methodology to measure the embodied carbon of WCPs, and on the other, proposing a remuneration scheme based on that methodology to reward the uptake of wood in construction.

Part A provides an overview of the current market share of Wood-based Construction Products (WCPs) used in the Europe, as well as the main barriers and opportunities to increase that market share. The Wood-based Construction Products studied include timber, but also engineered wood products with a capacity to sustain the structure of buildings such as glulam and Cross-Laminated Timber (CLT). The main findings indicate that there is potential to increase the material flow of woody biomass towards production of solid wood products. The study finds that in almost all Member States of the EU, the consumption of wood comes primarily from local production, about 85% of total consumption at EU, but there are substantial differences between MS ranging from 0% in Malta to 99.5% in Bulgaria.

WCPs have an average market share of 2.4% in the EU (representing a total EU consumption of 26.2 Mm^3, or 15.7M tonnes), whereas non-metallic minerals (at the base of concrete, bricks and glass) constitute the bulk of materials used in the construction sector (market share of 93%). The remainder is made up of metal ores (notably steel and aluminium). This market share of WCPs in the materials used in construction varies widely between Member States: front-runners such as Finland or Sweden reach a market share above 10%, while most MS display a market share lower than 2%. Based on an extensive review of literature at EU and at Member State level, and on engagement and consultations with stakeholders, the study points at a relatively limited potential of EU forests to increase supply (+10 to 15%, with large variations per MS). Our results agree with orders of magnitude and patterns found in other studies, but uncertainties remain in the identification of areas available for wood supply, current felling and increment levels, and the influence of the identified constraints on the potential wood supply.

Besides increasing harvest in the EU to match future demand for WCPs, the study identifies additional ways to increase the biomass inflow into this sector. The study also investigates the potential for increasing demand of WCPs, with barriers to demand identified as the main factors currently limiting the growth of the market share of WCPs.

Moreover, Part A provides in Chapter 2 an in-depth analysis of public policies set up or decided (but not yet implemented) to support the uptake of Wood-based Construction Products in case studies in the European Union: Finland and France. These two Member States were chosen because, based on the analysis of their National Energy and Climate Plans (NECP) and of their Long-Term Strategies (LTS), they have placed a significant level of political priority on the promotion of wood-based construction.

These two case studies lead to the following conclusions regarding the transposition across the European Union of policies supporting the uptake of Wood-based Construction Products. In order for a policy supporting the demand of WCPs, e.g., via regulation, to be effective, the supply side must have the technical and industrial capacity to meet this demand. This capacity was well advanced in Finland, but nevertheless needed strong public support (e.g., in Research & Innovation, in demonstrators). It has taken much longer time to develop in France (more than 20 years), but seems now to have reached fruition. As described in Chapter 1 “Market Analysis”, this build-up of capacity is necessary across the whole value chain: forest management, sawmills, manufacture of engineered wood products (e.g., glulam, Cross-Laminated Timber – CLT), architects, civil engineers, construction companies.

Furthermore, considering the low ratio of new construction compared to the exiting stock of built environment, regulation could be made more effective in addressing climate change by extending its scope to renovation works. Finally, the two areas of regulation where public policy appears to have been, or is foreseen by our interviewees to be, most effective are (1) fire safety, using simple rules to allow multi-storey buildings with a wooden frame – with no compromise made on the safety level; (2) the construction code, by attributing building permits only to the buildings with a demonstrated low environmental impact over their life-cycle.

Finally, Part A identified and analysed in its Chapter 3 the market-based schemes that incentivise the use of low-carbon, and in particular wooden, materials, by affecting the economic incentive structure of market actors. The landscape of Market-Based Schemes to reduce the GHG emissions associated with the construction of buildings can be summarised as follows:

A significant number of initiatives define and certify the overall sustainability performance of a building over its lifecycle. Among these, Level(s) is the recent EU-based and EU-sponsored holistic initiative, competing with the global, privately-managed BREEAM scheme set up a decade earlier. In addition to these two trans-national initiatives, several have been developed at national level, such as HQE Bâtiment Durable in France, BES 6001 in the United Kingdom, Greencalc+ and GPR Gebouw in the Netherlands;

Two initiatives (Label Bas-Carbone and BenchValue) focus on the quantitative evaluation and certification of the benefits in terms of saved GHG emissions of a broad range of actions (Label Bas-Carbone) and more specifically of the substitution of mineral-based construction materials with wood-based alternatives (BenchValue). These two schemes create the technical base for a market in carbon credits, but do not develop such a market;

Two initiatives (Puro.Earth and Carbomark) have moved to the ultimate stage of establishing an exchange market for carbon credits, whereby they create a platform to match the supply of carbon credits by companies that remove GHG emissions with the demand by companies eager to compensate theirs.

The Part B of this study analyses and reviews existing standards and methodologies for measuring embodied carbon through the entire life cycle and to examine whether and how biogenic carbon content of wood products used in construction is incorporated into the selected methods and standards. More specifically, the objectives are:

to provide an overview of existing standards and methodologies for measuring embodied carbon and biogenic carbon content of wood products used in construction;

to provide and analyse a complete calculation for a selected wood construction product, based on at least two different methods and/or standards, using their most up to date version;

to make recommendations for a single methodology that transparently and credibly quantifies the net carbon storage in wood construction products.

The analysis reveals that none of the reviewed methodologies is perfect for measuring the embodied GHG of wood products used in construction and that different methodologies can bring to significantly different results. Nevertheless, a good methodology can be created by taking the good elements that already exist and using the LCA standard EN 15804+A2, the de-facto LCA standard used in the construction sector as starting point, adaptable to specific needs.

As a general recommendation, the methodology should take into account the impact of both biogenic and fossil GHG fluxes. To ensure that the sink effect of forest and their sustainability is safeguarded, but that at the same time the methodology is kept relatively simple and applicable, a tier-based approach is proposed. This approach foresees the use of a reduction factor expressing the risk that the wood credited is harvested using practices that do not take into account carbon effects in the forest. The higher the guarantees of safeguarding the carbon functioning of the forest, the lower the reduction of the generated credits to be received.

To take into account the benefits of temporary (biogenic) carbon storage in wood products and crediting them, the use of a simplified dynamic LCA approach is suggested, one that does not follow the carbon neutrality assumption. This method also allows to take into account the effect of lifetime extending practices.

To calculate the GHG benefits of using wooden construction and estimate the relative carbon credits generated, the building against which the wood-based one is compared has to be identified. It is suggested to identify representative benchmark buildings for (macro) regions and building typologies (residential, commercial, industrial etc.), for which the life cycle impact per square meter is pre-calculated.

The way to deal with the assessment of the impact of the building end-of-life is a point which needs to consider several aspects, since it is not easy to assess today the impact of what will happen in several decades time. Evaluating the end-of-life stage based on the current situation has the advantage of being based on accurate figures, but might not properly reflect the impact/benefits of that material building in the future. Using projections brings with it the inherent uncertainty of the assumptions/forecasts made. Long-term projections made by Member States might be used, although this is an approach not used in the LCA standard and generally in LCA accounting practices which is based on the status-quo assessment of impacts.

The final Part C of this study is concerned with identifying the policy options to incentivise the use of wood in construction by focusing on the material's climate benefits. It does so by comparing various schemes for the development of a market-based scheme and an accompanying methodology that quantifies and remunerates the volumes of carbon emissions savings by employing WCPs. The mechanism here developed intends to be a stepping stone to progressively moving to a larger and fully-fledged market for carbon removals and emissions, for the built environment and beyond, in a situation of overall climate neutrality (planned for 2050 and beyond). This requires an approach that takes into account the complexities involved with determining the net climate benefits of wood-based construction products (WCPs). Most critically, with the issues revolving around sustainable forest management and products' end-of-life. This approach shall involve, first, a solid and feasible methodology for the calculation of the tons of carbon stored for specific building types, the guarantee of origin from sustainably managed forests, and the development of a process that creates value for the quantity of carbon saved.

First, this Part C provides in Chapter 9 an application of the methodology proposed to quantify the volumes of carbon emissions savings, to accompany the market-based scheme for the promotion of WCPs in construction. The latter is therefore tested in light of its intended use by construction sector practitioners that choose to apply it for certification and remuneration of their effort to reduce GHG emissions by using WCPs. Specifically, an LCA using the proposed methodology is carried out that assesses the greenhouse gas emissions of different structural versions of a multi-storey office building (with conventional techniques based on mineral-based materials, and with WCPs), and to assess the feasibility and accuracy of using this method. After this test of the proposed methodology in a concrete case, it is concluded that its application is straightforward and simple, as long as the requirements for data collection – namely access to a life cycle database and to a software/tool that would calculate the life cycle inventory – are guaranteed.

Following this assessment, this Part C delves in Chapters 10 and 11 into the development and design of a scheme that applies the proposed methodology within a policy framework. Direct remuneration from the scheme, in the form of a price mechanism dependent on the quantities of CO_2 stored in the wooden material has been explored as a viable option for the objectives of this study. However, based on the assessments performed in the elaboration of the quantification methodology, and the testing of that methodology, it was found that the magnitude of emissions saved in wooden buildings is of a limited level, and likely not enough to give a strong enough price signal for the project developer.

Nevertheless, as described in Chapter 12, a remuneration scheme providing other forms of incentives based on the carbon saved by using WCPs is still a viable and achievable policy option in this context. In particular, the methodology for quantifying volume of carbon removed would work on two levels: on the one hand, remunerating the beam producer for participating in the scheme by certifying their WCP, representing the point of entry of the scheme; on the other, supporting the project developer in carbon reduction claims for labels, marketing or public authorities.

The proposed scheme comprises the following fundamental elements:

Guaranteed sustainability of forest management: based on the considerations from the Part B of this study, the scheme would involve a four-tier system. This system comprises four options for the qualitative assessment of the origin of wood. Each option is associated with a reduction factor that reflects the quality of the information on the wood;

Remuneration for the beam producer: although the financial renumeration for the carbon saved is limited for the project developer compared to the overall investment in the building, it is a much more substantial contribution for a beam producer, and could therefore trigger a desired change in behaviour at this level towards sourcing from reliably sustainable sources. The estimates show that it will largely cover the administrative costs as well as potential additional remuneration, as an incentive to change the behaviour. The certification body will then give the WCP producer the right to sell a certain amount of carbon credits on the voluntary market, based on the volumes of carbon saved, as well as on the origin of the wood;

Remuneration for the project developer: using the scheme to feed tax benefits and incentives can be envisaged in coordination with national/local authorities that want to promote green buildings and less carbon emissions from construction materials. This would take the form of tax benefits or lower levies for permits when the certified carbon removal is proved;

A standard setting and accreditation body: this body will have to perform several key tasks to enable the system to function, such as deciding the methodology to be used to calculate the carbon emissions; deciding on what is accepted as sustainable source of wood; designing the accreditation criteria; accrediting certification parties; promoting and communicating about the label options.

A certification party: a certifying party is necessary to ensure the consistency and integrity of the system. However, this can take a variety of forms. A certification party can be a company or an NGO that meets the criteria as set by the accreditation body. They are only allowed to certify against the standard after being accredited. They are the ones that in the field have to fulfil the certification and who will check the calculations.

The proposal for a carbon credit scheme, in light of the low volumes of carbon claims available, should not limit the search for other regulatory frameworks. This study constitutes a significant first step in the development and incorporation of LCA methodologies remunerating the long-term storage of carbon into policy frameworks for the building sector. While this study designs a remuneration scheme targeting beam producers and project developers, it principally offers a methodology that can be employed in a variety of policy instruments and contexts. Integrating this methodology within a system of building permitting, hence requiring compliance to the scheme, is regarded as a potential option to explore.

Moreover, the previous Parts of this study informed on the several barriers, particularly with regards to building codes and regulations, as well as the unavailability of scientific / technical knowledge and of professional skills, that inhibit the development of WCP. Regardless of the market-based scheme, these barriers will persist, unless addressed by means of further integration of and harmonisation of national rules and guidelines, and of appropriate support and funding.

Résumé exécutif

L'objectif de cette étude est de fournir à la Commission européenne, DG CLIMA, une évaluation des avantages climatiques des produits de construction à base de bois (PCB). En particulier, cette étude explore les opportunités et les défis de l'incitation à une utilisation accrue des PCB, ainsi que les moyens par lesquels l'intervention publique peut soutenir avec succès cette transition, en récompensant l'utilisation de ces produits dans le secteur de la construction. Cette tâche nécessite une compréhension de l'état actuel du marché des produits de construction en bois, mais aussi le développement d'une méthodologie pour quantifier les bénéfices climatiques des PCB et les traduire en un système de rémunération. Cette étude s'articule autour de trois parties : la première partie (A) donne un aperçu de la part de marché actuelle des produits de construction en bois, des obstacles et des possibilités d'accroître cette part, ainsi que des politiques et des mécanismes de marché en place dans les États membres pour favoriser l'utilisation des produits de construction à base de bois. La deuxième partie (B) fournit un examen critique des méthodologies et des normes existantes pour mesurer le carbone incorporé et le contenu en carbone biogénique des produits du bois. Enfin, la troisième partie (C) rassemble les résultats des parties précédentes, d'une part en testant la méthodologie proposée pour mesurer le carbone contenu dans les produits de construction à base de bois, et d'autre part en proposant un système de rémunération basé sur cette méthodologie pour récompenser l'utilisation du bois dans la construction.

La partie A fournit une vue d'ensemble de la part de marché actuelle des produits de construction à base de bois (PCB) utilisés en Europe, ainsi que les principaux obstacles et opportunités pour augmenter cette part de marché. Les produits de construction à base de bois étudiés comprennent le bois d'œuvre, mais aussi des produits en bois d'ingénierie capables de soutenir la structure des bâtiments, comme le bois lamellé-collé et le bois lamellé-croisé (CLT). Les principaux résultats indiquent qu'il existe un potentiel pour augmenter le flux de matière de la biomasse ligneuse vers la production de produits en bois. L'étude révèle que dans presque tous les États membres de l'UE, la consommation de bois provient principalement de la production locale, soit environ 85 % de la consommation totale de l'UE, mais il existe des différences substantielles entre les États membres, allant de 0 % à Malte à 99,5 % en Bulgarie.

Les PCB ont une part de marché moyenne de 2,4 % dans l'UE (ce qui représente une consommation totale de 26,2 Mm^3, soit 15,7 M de tonnes), tandis que les minéraux non métalliques (à la base du béton, des briques et du verre) constituent la majeure partie des matériaux utilisés dans le secteur de la construction (part de marché de 93 %). Le reste est constitué de minerais métalliques (notamment acier et aluminium). Cette part de marché des PCB dans les matériaux utilisés dans la construction varie considérablement d'un État membre à l'autre : les pionniers comme la Finlande ou la Suède atteignent une part de marché supérieure à 10%, tandis que la plupart des États membres affichent une part de marché inférieure à 2%. Sur la base d'un examen approfondi de la littérature au niveau de l'UE et des États membres, ainsi que de l'engagement et des consultations avec les parties prenantes, l'étude indique un potentiel relativement limité des forêts de l'UE pour augmenter l'offre (+10 à 15%, avec de grandes variations par EM). Nos résultats concordent avec les ordres de grandeur et les modèles trouvés dans d'autres études, mais des incertitudes demeurent quant à l'identification des zones disponibles pour l'approvisionnement en bois, aux niveaux actuels d'abattage et d'accroissement, et à l'influence des contraintes identifiées sur l'approvisionnement potentiel en bois.

Outre l'augmentation de la récolte dans l'UE pour répondre à la demande future de PCB, l'étude identifie d'autres moyens d'accroître l'apport de biomasse dans ce secteur. L'étude examine également le potentiel d'augmentation de la demande de PCB, les obstacles à la demande étant identifiés comme les principaux facteurs limitant actuellement la croissance de la part de marché des PCB.

En outre, la partie A fournit au chapitre 2 une analyse approfondie des politiques publiques mises en place ou décidées (mais pas encore mises en œuvre) pour soutenir l'adoption des produits de construction à base de bois dans deux études de cas dans l'Union européenne : la Finlande et la France. Ces deux États membres ont été choisis parce que, d'après l'analyse de leurs plans nationaux pour l'énergie et le climat (PNEC) et de leurs stratégies à long terme (SLT), ils ont accordé un niveau de priorité politique important à la promotion de la construction à base de bois.

Ces deux études de cas permettent de tirer les conclusions suivantes concernant la transposition dans l'Union européenne des politiques de soutien à l'adoption de produits de construction à base de bois. Pour qu'une politique soutenant la demande de produits de construction à base de bois, par exemple par le biais d'une réglementation, soit efficace, l'offre doit avoir la capacité technique et industrielle de répondre à cette demande. Cette capacité était bien avancée en Finlande, mais nécessitait néanmoins un fort soutien public (par exemple, dans la recherche et l'innovation, dans les démonstrateurs). Elle a mis beaucoup plus de temps à se développer en France (plus de 20 ans), mais semble maintenant avoir porté ses fruits. Comme décrit au chapitre 1 "Analyse du marché", ce renforcement des capacités est nécessaire sur l'ensemble de la chaîne de valeur : gestion forestière, scieries, fabrication de produits en bois d'ingénierie (par exemple, lamellé-collé, bois lamellé-croisé - CLT), architectes, ingénieurs civils, entreprises de construction.

En outre, compte tenu du faible ratio de nouvelles constructions par rapport au stock existant de l'environnement bâti, la réglementation pourrait être rendue plus efficace dans la lutte contre le changement climatique en étendant son champ d'application aux travaux de rénovation. Enfin, les deux domaines de la réglementation dans lesquels la politique publique semble avoir été, ou est censée être, la plus efficace sont (1) la sécurité incendie, en utilisant des règles simples pour autoriser les bâtiments à plusieurs étages avec une ossature en bois - sans aucun compromis sur le niveau de sécurité ; (2) le code de la construction, en attribuant des permis de construire uniquement aux bâtiments ayant un faible impact environnemental démontré sur leur cycle de vie.

Enfin, la partie A a identifié et analysé dans son chapitre 3 les systèmes fondés sur le marché qui encouragent l'utilisation de matériaux à faible teneur en carbone, et en particulier de matériaux en bois, en influençant la structure des incitations économiques des acteurs du marché. Le paysage des dispositifs fondés sur le marché visant à réduire les émissions de GES associées à la construction de bâtiments peut être résumé comme suit :

Un nombre important d'initiatives définissent et certifient la performance globale de durabilité d'un bâtiment au cours de son cycle de vie. Parmi celles-ci, Level(s) est la récente initiative holistique parrainée par l'UE, en concurrence avec le système mondial BREEAM, géré par le secteur privé, mis en place une décennie plus tôt. En plus de ces deux initiatives transnationales, plusieurs ont été développées au niveau national, telles que HQE Bâtiment Durable en France, BES 6001 au Royaume-Uni, Greencalc+ et GPR Gebouw aux Pays-Bas ;

Deux initiatives (Label Bas-Carbone et BenchValue) se concentrent sur l'évaluation quantitative et la certification des bénéfices en termes d'émissions de GES économisées d'un large éventail d'actions (Label Bas-Carbone) et plus spécifiquement de la substitution de matériaux de construction à base de minéraux par des alternatives à base de bois (BenchValue). Ces deux systèmes créent la base technique d'un marché de crédits carbone, mais ne développent pas un tel marché ;

Deux initiatives (Puro.Earth et Carbomark) sont passées au stade ultime de l'établissement d'un marché d'échange de crédits carbone, en créant une plateforme permettant de faire correspondre l'offre de crédits carbone par des entreprises qui suppriment des émissions de GES avec la demande d'entreprises désireuses de compenser les leurs.

La partie B de cette étude analyse et passe en revue les normes et méthodologies existantes pour mesurer le carbone incorporé tout au long du cycle de vie et pour examiner si et comment le contenu en carbone biogénique des produits en bois utilisés dans la construction est incorporé dans les méthodes et normes sélectionnées. Plus précisément, les objectifs sont les suivants :

fournir une vue d'ensemble des normes et méthodologies existantes pour mesurer le carbone incorporé et le contenu en carbone biogénique des produits en bois utilisés dans la construction ;

fournir et analyser un calcul complet pour un produit de construction en bois sélectionné, basé sur au moins deux méthodes et/ou normes différentes, en utilisant leur version la plus récente ;

faire des recommandations pour une méthodologie unique qui quantifie de manière transparente et crédible le stockage net de carbone dans les produits de construction en bois.

L'analyse révèle qu'aucune des méthodologies examinées n'est parfaite pour mesurer les GES intrinsèques des produits en bois utilisés dans la construction et que des méthodologies différentes peuvent donner des résultats très différents. Néanmoins, une bonne méthodologie peut être créée en prenant les bons éléments qui existent déjà et en utilisant la norme d'ACV EN 15804+A2, la norme d'ACV de facto utilisée dans le secteur de la construction comme point de départ, adaptable aux besoins spécifiques.

En tant que recommandation générale, la méthodologie devrait prendre en compte l'impact des flux de GES tant biogéniques que fossiles. Pour garantir la sauvegarde de l'effet de puits des forêts et leur durabilité, tout en maintenant la méthodologie relativement simple et applicable, une approche par niveaux est proposée. Cette approche prévoit l'utilisation d'un facteur de réduction exprimant le risque que le bois crédité soit récolté selon des pratiques qui ne tiennent pas compte des effets du carbone dans la forêt. Plus les garanties de sauvegarde du carbone de la forêt sont élevées, plus la réduction des crédits générés à recevoir est faible.

Pour prendre en compte les avantages du stockage temporaire (biogénique) du carbone dans les produits du bois et les créditer, il est suggéré d'utiliser une approche d’ACV dynamique simplifiée, qui ne suit pas l'hypothèse de la neutralité carbone. Cette méthode permet également de prendre en compte l'effet des pratiques de prolongation de la durée de vie.

Pour calculer les avantages en termes de GES de l'utilisation de la construction en bois et estimer les crédits de carbone relatifs générés, le bâtiment auquel la construction en bois est comparée doit être identifié. Il est suggéré d'identifier des bâtiments de référence représentatifs des (macro)régions et des typologies de bâtiments (résidentiels, commerciaux, industriels, etc.), pour lesquels l'impact du cycle de vie par mètre carré est précalculé.

La manière de traiter l'évaluation de l'impact de la fin de vie du bâtiment est un point qui doit prendre en compte plusieurs aspects, car il n'est pas facile d'évaluer aujourd'hui l'impact de ce qui se passera dans plusieurs décennies. L'évaluation de la phase de fin de vie sur la base de la situation actuelle a l'avantage d'être basée sur des chiffres précis, mais pourrait ne pas refléter correctement l'impact/les avantages de ce matériau de construction dans le futur. L'utilisation de projections s'accompagne de l'incertitude inhérente aux hypothèses/prévisions formulées. Les projections à long terme faites par les États membres peuvent être utilisées, bien qu'il s'agisse d'une approche qui n'est pas utilisée dans la norme ACV et généralement dans les pratiques comptables ACV qui sont basées sur l'évaluation des impacts de la situation existante.

La dernière partie C de cette étude vise à identifier les options de politique publique permettant d'encourager l'utilisation du bois dans la construction en se concentrant sur les avantages climatiques du matériau. Pour ce faire, elle compare différents systèmes pour le développement d'un système basé sur le marché et d'une méthodologie d'accompagnement qui quantifie et rémunère les volumes d'émissions de carbone économisés par l'utilisation de PCB. Le mécanisme développé ici se veut un tremplin pour passer progressivement à un marché plus vaste et pleinement développé pour les absorptions et les émissions de carbone, pour l'environnement bâti et au-delà, dans une situation de neutralité climatique globale (prévue pour 2050 et au-delà). Cela nécessite une approche qui tienne compte des complexités liées à la détermination des avantages climatiques nets des produits de construction à base de bois (PCB). Et surtout, des questions liées à la gestion durable des forêts et à la fin de vie des produits. Cette approche implique, tout d'abord, une méthodologie solide et réalisable pour le calcul des tonnes de carbone stockées pour des types de bâtiments spécifiques, la garantie de l'origine des forêts gérées durablement, et le développement d'un processus qui crée de la valeur pour la quantité de carbone économisée.

Tout d'abord, cette partie C fournit au chapitre 9 une application de la méthodologie proposée pour quantifier les volumes d'émissions de carbone économisés, afin d'accompagner le dispositif de marché pour la promotion des PCB dans la construction. Cette dernière est donc testée à la lumière de son utilisation prévue par les praticiens du secteur de la construction qui choisissent de l'appliquer pour la certification et la rémunération de leur effort de réduction des émissions de GES par l'utilisation des PCB. Plus précisément, une ACV utilisant la méthodologie proposée est réalisée afin d'évaluer les émissions de gaz à effet de serre de différentes versions structurelles d'un immeuble de bureaux à plusieurs étages (avec des techniques conventionnelles basées sur des matériaux minéraux, et avec des PCB), et d'évaluer la faisabilité et la précision de l'utilisation de cette méthode. Après ce test de la méthodologie proposée dans un cas concret, il est conclu que son application est directe et simple, tant que les conditions requises pour la collecte des données - à savoir l'accès à une base de données du cycle de vie et à un logiciel/outil qui calculerait l'inventaire du cycle de vie - sont garanties.

À la suite de cette évaluation, la partie C se penche, dans les chapitres 10 et 11, sur le développement et la conception d'un système qui applique la méthodologie proposée dans un cadre de politique publique. La rémunération directe du système, sous la forme d'un mécanisme de prix dépendant des quantités de CO_2 stockées dans le matériau en bois, a été considérée comme une option viable pour les objectifs de cette étude. Cependant, sur la base des évaluations réalisées lors de l'élaboration de la méthodologie de quantification et des tests de cette méthodologie, il a été constaté que l'ampleur des émissions économisées dans les bâtiments en bois est d'un niveau limité, et probablement pas suffisant pour donner un signal de prix assez fort pour le développeur de projet.

Néanmoins, comme décrit au chapitre 12, un système de rémunération fournissant d'autres formes d'incitations basées sur le carbone économisé grâce à l'utilisation de PCB est toujours une option de politique publique viable et réalisable dans ce contexte. En particulier, la méthodologie de quantification du volume de carbone supprimé fonctionnerait à deux niveaux : d'une part, la rémunération du producteur de poutre pour sa participation au système en certifiant son PCB, ce qui représente le point d'entrée du système ; d'autre part, le soutien au développeur de projet dans les revendications de réduction de carbone pour les labels, le marketing ou les autorités publiques.

Le système proposé comprend les éléments fondamentaux suivants :

Garantie de la durabilité de la gestion forestière : sur la base des considérations de la partie B de cette étude, le système comprendrait un système à quatre niveaux. Ce système comprend quatre niveaux pour l'évaluation qualitative de l'origine du bois. Chaque niveau est associé à un facteur de réduction qui reflète la qualité de l'information sur l'origine du bois ;

Rémunération du producteur de poutres : bien que la rémunération financière pour le carbone économisé soit limitée pour le développeur de projet par rapport à l'investissement global dans le bâtiment, il s'agit d'une contribution beaucoup plus substantielle pour un producteur de poutres, et pourrait donc déclencher un changement de comportement souhaité à ce niveau vers un approvisionnement à partir de sources durables fiables. Les estimations montrent qu'elle couvrira largement les coûts administratifs ainsi que la rémunération supplémentaire potentielle, en tant qu'incitation au changement de comportement. L'organisme de certification donnera ensuite au producteur de PCB le droit de vendre une certaine quantité de crédits carbone sur le marché volontaire, sur la base des volumes de carbone économiséset de l'origine du bois ;

Rémunération du développeur de projet : l'utilisation du système pour alimenter des avantages fiscaux et des incitations peut être envisagée en coordination avec les autorités nationales/locales qui souhaitent promouvoir les bâtiments verts et la réduction des émissions de GES des matériaux de construction. Cela prendrait la forme d'avantages fiscaux ou d'une réduction des taxes sur les permis lorsque l'élimination certifiée du carbone est prouvée ;

Un organisme de normalisation et d'accréditation : cet organisme devra accomplir plusieurs tâches clés pour permettre au système de fonctionner, comme décider de la méthodologie à utiliser pour calculer les émissions de carbone ; décider de ce qui est accepté comme source durable de bois ; concevoir les critères d'accréditation ; accréditer les organismes certificateurs ; promouvoir et communiquer sur les options de label ;

Des organismes de certification : un organisme de certification est nécessaire pour garantir la cohérence et l'intégrité du système. Cependant, cette fonction peut prendre différentes formes. Un organisme de certification peut être une entreprise ou une ONG qui répond aux critères fixés par l'organisme d'accréditation. Il n'est autorisé à certifier la conformité à la norme qu'après avoir été accrédité. Ce sont ces organismes qui, sur le terrain, doivent procéder à la certification et qui vérifient les calculs.

La proposition d'un système de crédits carbone, compte tenu des faibles volumes de crédits carbone disponibles, ne doit pas limiter la recherche d'autres cadres réglementaires. Cette étude constitue une première étape significative dans le développement et l'incorporation de méthodologies d'ACV rémunérant le stockage à long terme du carbone dans les cadres de politiques publiques du secteur du bâtiment. Bien que cette étude conçoive un système de rémunération ciblant les producteurs de poutres et les développeurs de projets, elle offre principalement une méthodologie qui peut être employée dans une variété d'instruments et de contextes politiques. L'intégration de cette méthodologie dans un système de permis de construire, exigeant donc la conformité au système, est considérée comme une option potentielle à explorer.

De plus, les parties précédentes de cette étude ont mis en évidence plusieurs barrières, en particulier en ce qui concerne les codes et les réglementations du bâtiment, ainsi que d'insuffisances de connaissances scientifiques et techniques et de compétences professionnelles, qui empêchent le développement de l'utilisation des PCB. Indépendamment du système basé sur le marché, ces barrières persisteront, à moins qu'elles ne soient levées par une intégration et une harmonisation plus poussées des règles et directives nationales, et par un soutien et un financement appropriés.

A. Scoping Study for the Promotion of Wood Products in the EU Construction Sector

The first task of this study aims at providing an overview of the current state of the market and regulatory environment of wood construction products in Europe. First, an overview of the characteristics and features of the sector of Wood-based Construction Products (WCP) is laid out, providing an insight into the state, challenges and opportunities of this market. In addition, two EU Member States are taken as case studies, to analyse the policy environment that aims at promoting the use of wood in construction. Finally, the task provides an overview of existing market-based schemes, not included in public policy, that promote wood as a construction material based on the climate benefits it offers.

1. Market Analysis of Wood-Based Construction Products

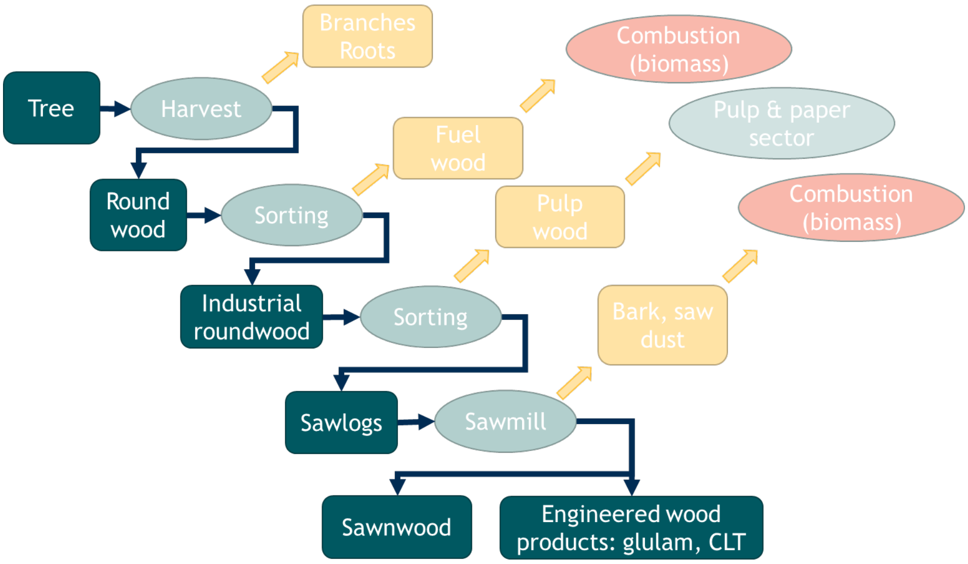
1.1. Overview of the sector of Wood-based Construction Products

This report aims to provide an overview of the current market-share of WCPs used in the EU construction sector – including an analysis of their production and sourcing and an outline of the main barriers and opportunities to increasing that market share. It also presents a comprehensive picture of the market players involved in the value chain and of the characteristics of the forestry and wood manufacturing sectors at EU and MS level. Statistics from several European and international sources, literature, and consultations with stakeholders along the whole WCPs value chain form the evidence base of this analysis. The market analysis provides an opportunity to present the sector, at both EU- and MS-level, and represents a foundation on which the rest of the study will stand.

1.1.1. Simplified value chain of Wood-based Construction Products

The succession of processes leading to the usage of Wood-based Construction Products can be summarised in the Figure 2-1 below. Figure 2-1 is a simplified representation of the one-way flow of biomass throughout the wood value chain, with a specific focus on WCPs. This figure is meant to clarify the terms used to describe the products and processing steps along that value chain. For further details on the yields from each step, please see Figure 3-1. For a visualization of the circular flows within the wood value chain, please see Figure 3-2.

Figure 2-1 Simplified value chain of Wood-based Construction Products



The first step in the production chain of timber towards WCPs is the harvest of wood. Roundwood is generated (i.e. felled trees without branches and trunks cut to a viable length for transportation from the forest to a sawmill). Roundwood is then further processed at the sawmill, where bark and surface defects are removed to obtain sawlogs (including hewn logs). Sawlogs can be used by the construction sector for structural purposes directly as sawnwood, or can be further processed into a variety of engineered wood products to be used in construction for structural purposes (mainly glulam and Cross-Laminated Timber – CLT).

The term Wood Construction Products (WCPs) encompasses both sawnwood and further-processed Engineered Wood products (EWPs). The main EWPs currently used by the construction sector, as subsequently illustrated in Figure 3-14 (section 3.5), are:

Glued lminated timber (or Glulam): a wood beam composed of wood laminations bonded together with adhesives, and with the grain of the laminations running parallel with the length of the member.[1]

Cross-Laminated Timber (CLT): panels made up of several layers of lumber boards stacked in alternating directions, which are bonded with structural adhesives and pressed to form a solid, straight, and rectangular panel.[2] For more information on the production and material properties of CLT, see Brander et al. (2016).

Medium-density fibre boards (MDF): dry-process fibreboards with a density of up to 0.8g/cm^3 (above this density, it may be referred to high-density fibreboard).[3]

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[1] APA Wood (n.d.) Glulam. Available here.

[2] APA Wood (n.d.) Cross-Laminated Timber (CLT). Available here.

[3] FAO (n.d.) Forest Products Definitions. Available here.

Particle boards: panels manufactured from small pieces of wood or other ligno-cellulosic materials (for instance chips, flakes, splinters, strands, shreds, shives), which are bonded together by an organic binder and by an agent such as heat, pressure, or humidity."[4]

Oriented strand boards (OSB): are a type of particle board "in which layers of narrow wafers are layered alternately at right angles [...] The wafers […] are coated with e.g. waterproof phenolic resin glue, interleaved together in mats and then bonded together under heat and pressure. The resulting product is a solid, uniform building panel having high strength and water resistance."[5]

Wood Fiber Insulation Boards (WFIB): porous or hard fibre board made of wood fibres connected to each other through the effect of heat and pressure. Glue and other additives can be used to improve the board's properties.[6]

A few datasets compile relevant information on WCPs at MS and/or EU level. The extent to which these datasets cover species, quality, types of products, and economic value is illustrated in Annex 1. This overview highlights that data on wood quality is very limited, and – to a lesser extent – so is data on species beyond the distinction between coniferous and non-coniferous species. An additional hurdle is that some datasets do not have recent data or have incomplete data for several MS.

1.1.2. Additional notes on terminology

Reports and studies use a variety of terms that can lead to confusion and misinterpretation of the results. It is not always clearly defined what exactly is meant by a certain term, and results are therefore to be interpreted with caution. We give an overview of terms that are commonly used, with their most appropriate interpretation and common confusions or ambiguities. These clarifications are especially useful to understand the discussions on the potential to increase harvest (section 4.2).

Stemwood volume refers to the volume of wood of a single stem or a population of stems. In a forest inventory this is usually estimated by measuring the diameter of a tree at breast height (dbh), often in combination with an assessment of the height of the tree. It includes the top of the tree and the stump (to ground level) and is generally defined by the main axis of the tree. After a tree has been felled (cut down), the volume can be estimated by measuring the diameter of the tree at the bottom of the tree and the length of the tree. For individual logs (i.e. separate pieces of the stem), volumes can be estimated by measuring the diameter in the middle of the log and the length of the log. These methods have differences in accuracy, and applying different methods to the same tree will result in different estimates. An important difference between volume estimation on standing and felled trees is that at least the stump is not included in felled tree, and usually the top has been removed (at for example 7 or 10 cm diameter). Some countries have different terms to indicate volume assessed on standing trees (Vorratfestmeter – standing stock m^3) and volume assessed on felled trees (Erntefestmeter – harvest m^3). Depending on the size of the trees, the volume of felled trees is roughly 10-20% lower than the volume of standing trees. Often only the term volume is used, without specifying if it is assessed as standing volume or felled volume. Sometimes the context gives an indication. Growing stock is always measured in standing trees, and increment and mortality are usually derived from the

[4] FAO (n.d.) Forest Products Definitions. Available here.

[5] FAO (n.d.) Forest Products Definitions. Available here.

[6] Wood Products FI (n.d.) Wood fibre board. Available here.

growing stock estimates. Harvest or felled volume is ambiguous, depending if it is assessed from an inventory perspective (volume disappearing from the stock), of assessed after felling the trees.

All volumes can be reported as including bark or excluding bark, referred to as respectively overbark (o.b.) and underbark (u.b.). At some point in the industrial processing chain, harvested trees/logs will be debarked to be able to process the wood itself. This may take place directly in the forest, but is usually only done in the factory. Logically the standing trees are measured (and usually reported) overbark. Felled or removed trees are usually measured overbark, but could be converted to underbark values for purposes of estimating wood availability for the processing sector. Many times it is not reported if values are overbark or underbark. The difference between overbark and underbark depends on the species and the size of the trees and is in the range of 5-20%.

If a forest inventory has permanent sample plots, exactly the same locations and trees are remeasured at regular intervals. During the re-measurement, trees that were present in the first measurement can be alive and have increased in size (diameter), can be harvested, or can have died. In addition, new trees can be present that were too small in the first inventory to be included. From these observations, several variables are deduced. Increment is the gain in tree volume over the measurement period. This consists of the growth of the existing (measured) trees and can be referred to as "ongrowth", and the volume of new trees appearing in the stand, referred to as "ingrowth". If no trees have died or are harvested, the increment is simply the difference in the total volume of the second measurement minus the volume at the first measurement. This will include the ingrowth. If trees have died or were harvested, their initial volume can be used to correct the estimate of the increment. In this way, only the increment of the trees that survived is taken into account, plus the ingrowth. Depending on the time of death or harvesting, this can cause a serious underestimation of the increment. Usually the increment (and thus also the amount of mortality and harvest) is corrected, assuming the trees have grown for half the measurement interval before they died or were harvested. If plots in an inventory are not permanent, increment can be estimated using increment functions, applied to all trees present during the measurement. This will not include ingrowth, but will include the expected growth of trees that will die or be harvested later. A correction for ingrowth can be added to the total increment to be comparable with the method of using permanent plots. Reported values for increment, mortality and harvest are thus subject to uncertainties, varying with the underlying methodologies and measurement intervals. As long as the methods do not change, countries will have a consistent time series that gives a good view on the development of these variables over time. A comparison among countries is difficult because the underlying methodological differences are not always known and systematic biases not quantified. An inclusion of ingrowth in the increment or not may for example lead to a difference in the felling/increment level of about 5 percentage points.

Mortality is the total volume of trees that die in a certain year or period. The felling volume is the total volume of trees that were cut down. If both quantities are expressed in in terms of m3 of standing stock, they can be compared to the increment to make a stock balance calculation. The sum of mortality and fellings is also sometimes referred to as total drain. Another variable that is often reported is the removals. This refers to the total stemwood volume that is really extracted from the forest (commercial volume). Compared to fellings as measured in m3 of standing stock, it is measured as volume on the ground, excluding tops, stumps, harvest losses (like the felling wedge), rotten stems and other pieces that are unusable or forgotten. Removals are commonly reported as underbark as well as overbark, depending on the tradition in the country, and therefore often without mentioning. The term harvest is also often used in national reports. It seems this term is usually used in the same way as fellings, but could also refer to removals. Another term used is production, which could refer to both, but is more likely similar to removals.

Gross increment is the total increase in wood volume occurring over a certain period. This is equal to the change in standing stock plus the volume of fellings and mortality. Net increment excludes mortality, and is thus equal to the stock change plus the fellings. Many countries and studies simply report increment, without explicitly mentioning if is it gross or net increment. Using gross or net increment has considerable consequences for the calculation of the felling/increment ratio, but usually the net increment is used.

1.1.3. Main socio-economic characteristics of the sector

Main market players in the European Union

Several types of market players exist along the WCP value chain from sourcing to production, and ultimately to final use. These players can be divided into the following categories:

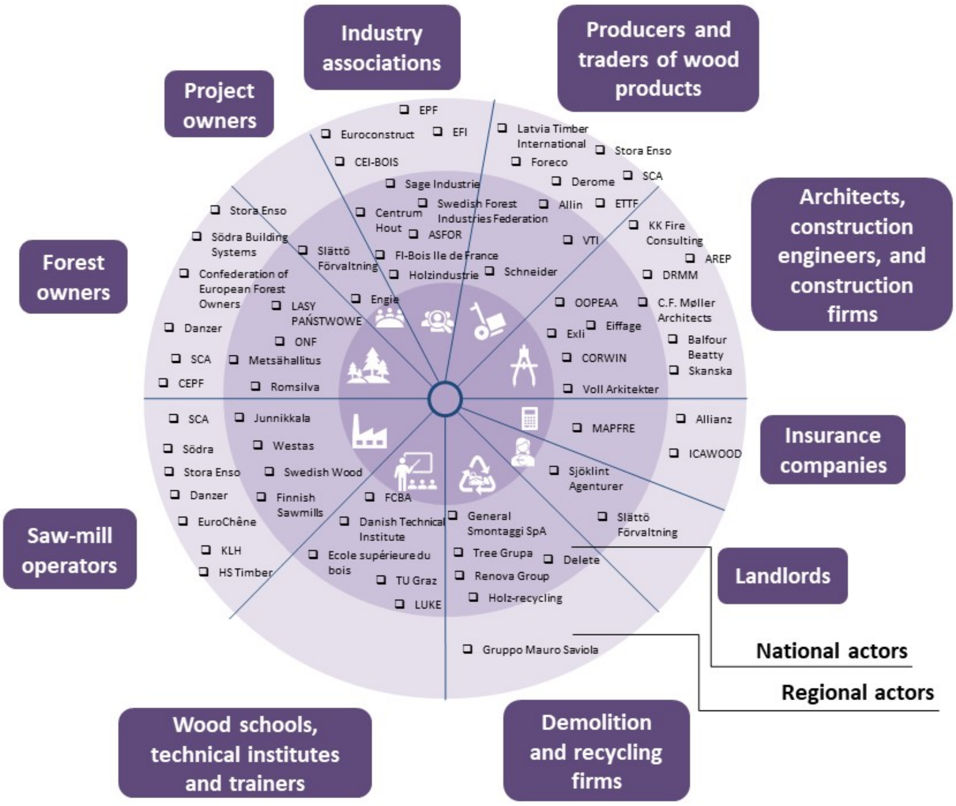
- Sourcing:
  - Forest owners/players in the forestry sector;
- Production of Wood-based Construction Products:
  - Saw-mill operators;
  - Producers and traders of WCPs;
- Construction of buildings:
  - Architects, construction engineers and construction firms (including those specialised in building renovation);
  - Project owners (in the construction phase);
- Usage of the building:
  - Long-term owners of the buildings (landlords);
- End of life:
  - Demolition and recycling firms.

Some players act along the whole value chain:

- Wood schools and wood trainers/technical institutes;
- Experts/industry associations;
- Insurance companies, banks and creditors.

Examples of EU-based players belonging to these categories are depicted in Figure 2-2 (for the full list with the country of operation of these actors, see Annex 2). This list is by no means comprehensive, especially as the wood production and construction sector is very diverse and fragmented, and as the map mostly depicts actors active in Northern- and Western-Europe. Nevertheless, the figure provides an overview of some of the major EU market players in the sector, at both national and supra-national levels. A wide array of these actors were interviewed as part of the consultation activities undertaken for the data collection of this analysis (see sections 4.2.6 and 4.3). The map reveals that some vertical integration exists along the value chain, whereby – for instance – one entity is a forest owner, a sawmill operator and a producer/trader of WCPs. As another example, project owners can also remain the long-term owners of the building.

Figure 2-2 Overview of the market players in the sourcing, production and final use of WCPs in the EU.



Forest ownership

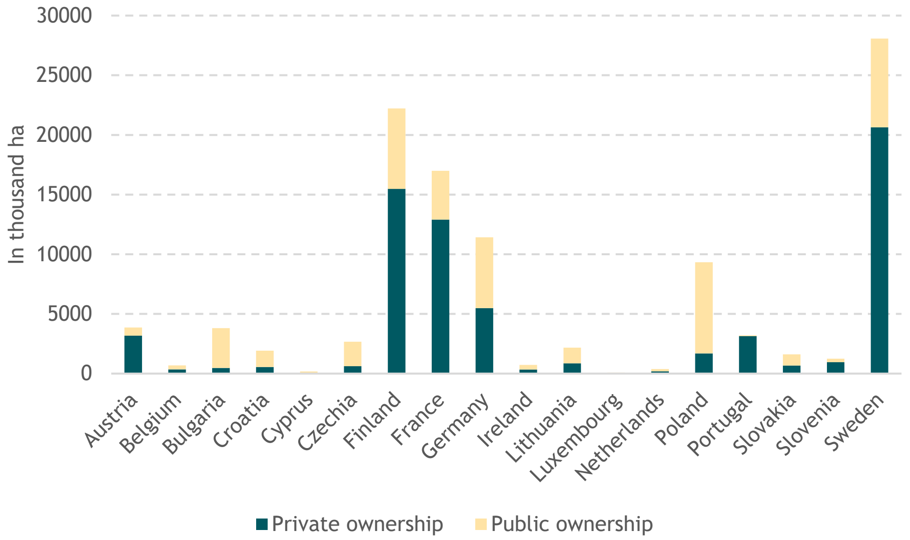
The total forested area as well as the ownership of these area varies across MS, as shown in Figure 2-3.[7] There is more publicly owned than privately owned forested area in Bulgaria, Croatia, Cyprus, Czechia, Germany, Ireland, Lithuania and Poland, and more privately owned than publicly owned in the other ten countries included in Figure 2-3.[8] Historical developments have strongly influenced these patterns of forest ownership, with a tendency for more privately-owned forests in Western Europe, and vice versa in Eastern Europe. Nevertheless, there is a trend towards privatisation and resitution, as observed for instance in Czechia, Slovenia and Germany.[9] Zooming in on private ownership, 13 MS provided data on forests owned by individuals and families in the UNECE database, with most of them reporting high level of individual ownership. Forest owned by individuals and families amounted to less than 75% of the total area of privately owned forests in only three of those countries (30.8% in Slovakia, 40.1% in the Netherlands, and 64.3% in Sweden). In five countries, this proportion reached at least 90% (with Croatia on top with 98%, followed by Poland with 94.1%) (for full data, see Annex 3).

[7] This figure only displays data for a limited number of MS due to data unavailability

[8] In Slovakia, which is not represented in Figure 2-3, about 40% of forest land is publicly owned, whereas 44.8% is privately owned (2015 data, available here).

[9] Pulla et al. (2013) Mapping the distribution of forest ownership in Europe. Available here.

Figure 2-3 Forest ownership in selected MS, in thousand ha (2015)[10]



Employment and economic contribution of the sector

Employment in the forestry and wood/wood products manufacturing sector (also including furniture) reached 1.46 million persons across the EU27 in 2019 (i.e. 0.76% of the total number of people employed across the EU),[11] with almost two-thirds being employed by the wood and wood products manufacturing sector (0.974 million), compared to one-third (0.493 million) in the forestry sector. As visible in Figure 2-4, the distribution of these jobs is uneven across EU MS, highlighting the relative size of the two sub-sectors. The same four countries employ the most people in the two sub-sectors - Poland, Italy, Romania and Germany – with Poland reaching the top position in both forestry and manufacturing. All the MS which have a total number of people employed in forestry lower than the EU27 average, also have a total number of people employed in wood manufacturing lower than the EU27 average, and vice versa, highlighting the link between production of raw material and manufacturing. Moreover, only Bulgaria and Finland employ more people in forestry than in manufacturing.

Unsurprisingly, the employment figures broadly mirror the relative sizes of the forest area available for wood supply in MS. However, the two MS with the largest area of forest available for wood supply (Sweden and Finland), have relatively little employment in the sector compared to countries such as Italy and Spain, which have less forest available for wood supply but are also more populated.[12]

At EU27 level, the overall number of people employed in the sector has remained approximately constant between 2015 and 2019 (+0.9%), with a slight decrease in numbers employed in forestry (-3.18%) and a slight increase in those in wood manufacturing (+3.16%). In that same period, 6 countries recorded an increase of over 10% in employment in forestry (Austria, Denmark, Ireland, Greece, Cyprus and Romania), while 8 recorded decreases of over 10% (Hungary, the Netherlands, Slovenia, Croatia, Poland, France, Lithuania and Czechia). Three countries which recorded important decreases in employment

[10] UNECE (2015) Area of forest and forest available for wood supply by ownership class, 1000 ha (Table 1a). Available here.

[11] Eurostat (2021) Employment and activity by sex and age - annual data. Available here.

[12] UNECE (2015) Forest area (Indicator 1.1a.) by Land Use Category, Country and Year. Available here.

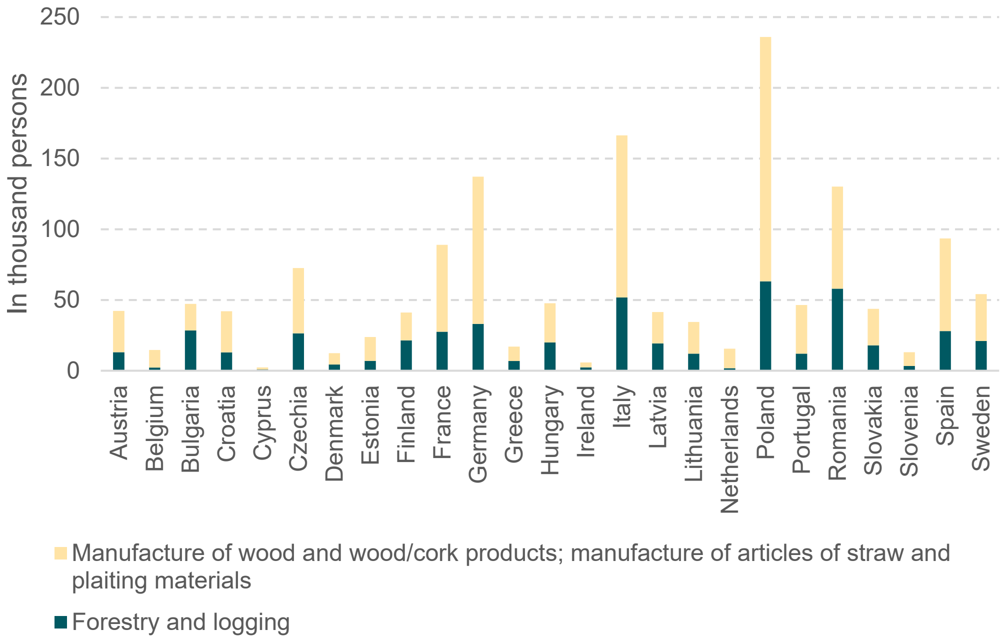
in the forestry sector have an above-EU average number of people employed in that sector (Poland, France and Czechia). In wood manufacturing, 7 countries reported an increase of over 10% in employment (Croatia, Slovenia, Hungary, Slovakia, Spain, Sweden and the Netherlands), whereas 6 reported a decrease of more than 10% (Cyprus, Belgium, Estonia, Ireland, Greece and France). France is the only country which recorded an important decrease in wood manufacturing employment while ranking above EU-average in the number of people employed by the sub-sector (see Annex 4 for the full data).

Data from 2010-11 shows that, then, the EU woodworking industry (i.e. production of sawnwood, wood-based panels, and WCPs) was employing people scattered across over 184 000 companies most of which were small or medium-sized enterprises (i.e.with an average of 5.9 employees per company),. The only exceptions are the wood-based panels and the sawmill sub-sectors, where a handful of larger companies exist.[13] It is noteworthy, however, that even in these sawmill sub-sectors, there are often a large number of small enterprises. For instance, in Poland, the sawmill sub-sector is composed of 9 800 enterprises, 92% of which employ less than 10 people, while only 11 companies employ more than 250 people.[14] Overall, these numbers show that the industry is also very fragmented further down the value chain than forestry.

[13] European Commission (n.d.) Woodworking. Available here.

[14] EOS (2018) Annual Report of the European Sawmill Industry 2017/2018. Available here.

Figure 2-4 Number of persons employed by the forestry sector and by the manufacture of wood and articles in wood sector, in thousand persons, 2019. Source: Eurostat (2021).[15]



Note: 2017 data used for Belgium, 2018 data used for Ireland. Data unavailable for Luxemburg and Malta.

Value added in forestry and wood products sector at factor cost (i.e. gross income from operating activities after adjusting for operating subsidies and indirect taxes), is shown in Figure 2-5.[16] The trend in value added by MS is broadly similar to patterns in employment, with MS recording relatively more people employed often recording relatively higher added value figures. There are, however, a few exceptions. For instance, Sweden ranks 3rd for the value added of its forestry sector, while employing less people than several of its European counterparts, and Poland employs the most people in manufacture, while ranking 6th in terms of value added of that sector. Moreover, as also observed in the State of Europe's Forests 2020 report,[17] the forestry sector is stronger in Northern and Central-Western Europe, while comparatively much weaker in the rest of the region, and especially in South-East Europe. At EU27 level, the forestry sector's value added at factor cost reached 26.2 billion EUR in 2018, with a slightly higher figure (30.8 billion EUR) in the wood product sector.[18]

The combined importance of the forestry and wood manufacturing sectors in terms of GDP varies across countries. The sectors are particularly important for the economies of Latvia, Estonia, Finland, Slovakia, Lithuania, and Sweden, where they accounted for 1.5 to 4.3% of GDP in 2015. JRC reports that the contribution of the sectors to GDP in Europe declined

[15] Eurostat (2021) Employment in forestry and forest-based industry. Available here.

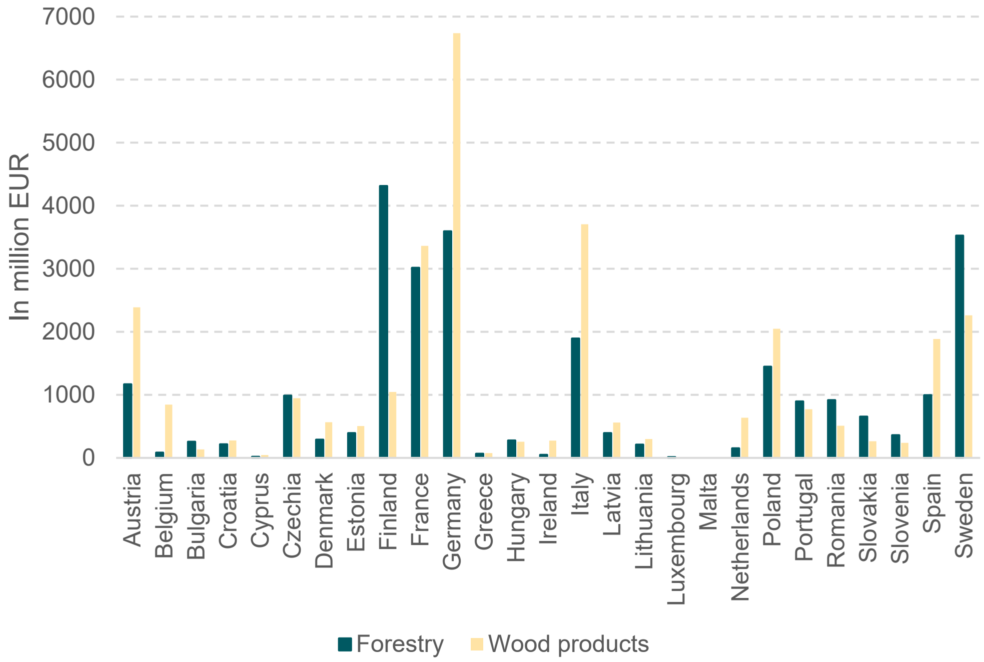
[16] Eurostat (2013) Glossary: value added at factor cost. Available here.

[17] Forest Europe (2020) State of Europe's Forests. Available here.

[18] JRC (2021) Bioeconomics. Available here.

from 1.14% in 2000 to 0.79% in 2015, mostly because the sectors did not keep pace with other rapidly growing sectors of the European economy.[19]

Figure 2-5 Value added at factor cost of the forestry and manufacture of wood products sectors, 2018, in million EUR. Source: JRC (2021)[20]



The market value of roundwood varies per region, with a minimum of 354 million euros of value in 2015 in South West Europe, and a maximum of 8 820 million euros in Central West Europe (based on data from 20 countries). These regions retain their respective lowest and highest positions in euros/hectares of FAWS (see Table 2-1). The highest value were reported by Germany (4 114 million euros), Sweden (2 826 million euros) and France (2 788 million euros). The 2020 State of Europe's Forests also report a steady increase in the value of marketed roundwood in almost all regions, with a resulting overall increase for Europe of 5 628 million euros (53.1%) between 1990 and 2015. The value per hectare of FAWS also increased steadily from 106 to 161.[21]

Table 2-1 *Market value of roundwood per region, 2015. Source: Forest Europe (2020)*

[19] Forest Europe (2020) State of Europe's Forests. Available here.

[20] JRC (2021) Bioeconomics. Available here.

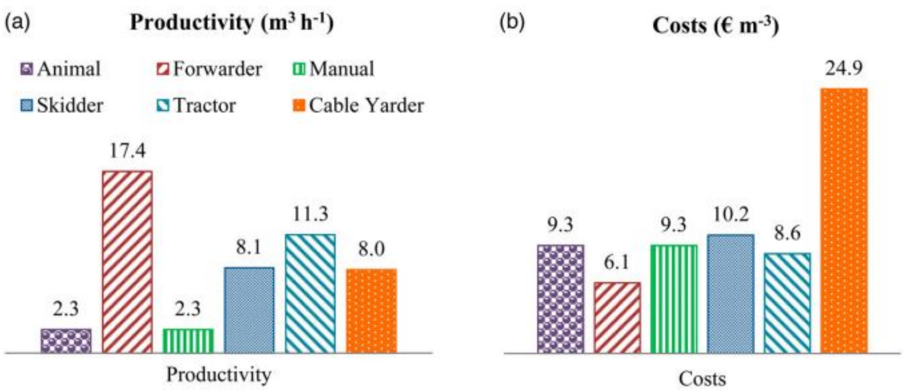
[21] Forest Europe (2020) State of Europe's Forests. Available here.

	In million EUR	EUR/ha of FAWS
North Europe	5 860	116.6
Central-West Europe	8 820	268.0
Central-East Europe	4 054	214.5
South-West Europe	354	43.1
South-East Europe	1 446	129.8
EU27+UK[22]	19 107	182.3

1.1.4. Harvesting costs and Wood-based Construction Products prices

At the sourcing stage of the value chain, the costs of logging depend on several factors: terrain topography, method of harvesting, degree of mechanisation, type of machinery and extraction distance. This is illustrated in Figure 2-6, which shows the cost of harvesting practices across over 600 logging operations in seven representative European case study areas. Labour costs also influence overall costs of logging.[23]

Figure 2-6 Efficiency of extraction methods. Source: Enache et al. (2016)



The prices of further processed wood products compared to industrial roundwood are displayed in Figure 2-7. The price of industrial roundwood is the lowest of all products displayed in the Figure, and has remained almost constant, hovering between USD 73 and 87 per m^3. This is due to the fact that roundwood is little processed compared to the other products. Nevertheless, the price of all products rose between 2000 and 2010, followed by a decline between 2010 and 2015 due to the prolonged downturn stemming from the economic crisis. The prices of panels, particle boards, fibreboards and MDF/HDF recovered between 2015 and 2019, while this has not been the case for industrial roundwood and sawnwood. In addition, fibreboard and MDF/HDF are the two most expensive WCPs;

[22] Based on data from 20 countries

[23] Enache, A., Kühmaier, M., Visser, R., & Stampfer, K. (2016). Forestry operations in the European mountains: a study of current practices and efficiency gaps. Scandinavian journal of forest research, 31(4), 412-427.

whereas fibreboard reached the highest value in 2010, by 2019 it was replaced by MDF/HDF.

Figure 2-7 Real price of selected WCPs, per m^3 exported from the EU27 (in USD). Adapted from: FAO (2021)[24]

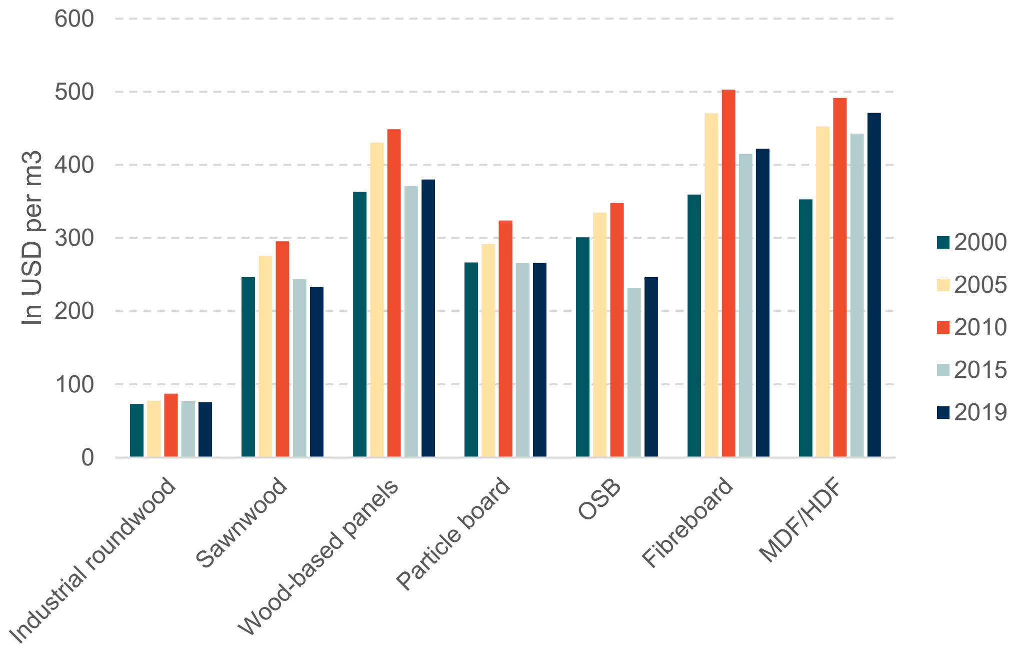


Table 2-2 computes the average value added over the years 2000 to 2019 at each stage of the value chain from the forest to wood-based panels. Wood-based panels are a common engineered wood product, on which statistical data is available. It shows that the stage in the value chain with the largest contribution to value added is the sawing, with an average value added 181 USD / m^3 (45% of the value added), whereas the harvesting only accounts for 78 USD / m^3 (20% of the value added) and the arrangement of sawn panels into wood-based panels contributes to 140 USD / m^3 (35% of the value added). This exposes, on a specific example, how the players along the value chain share the value of an engineered wood product. It is likely that the share of the final stage (assembly into the final product from sawnwood) will be higher for products with more demanding technical specifications, such as glulam and Cross-Laminated Timber (CLT) that are used for structural purposes. Quantitative data on these products is lacking.

[24] FAO (2021) Forestry Production and Trade Statistics. Available here.

Table 2-2 Average value added per stage in the value chain of Wood-based panels, EU27 (2000-2019)

Stage in the value chain	Output product of the stage	Average value added in USD / m^3	Share of value added
Growing and harvesting	Industrial roundwood	78	20%
Sawing	Sawnwood	181	45%
Assembly into wood-based panels	Wood-based panels	140	35%

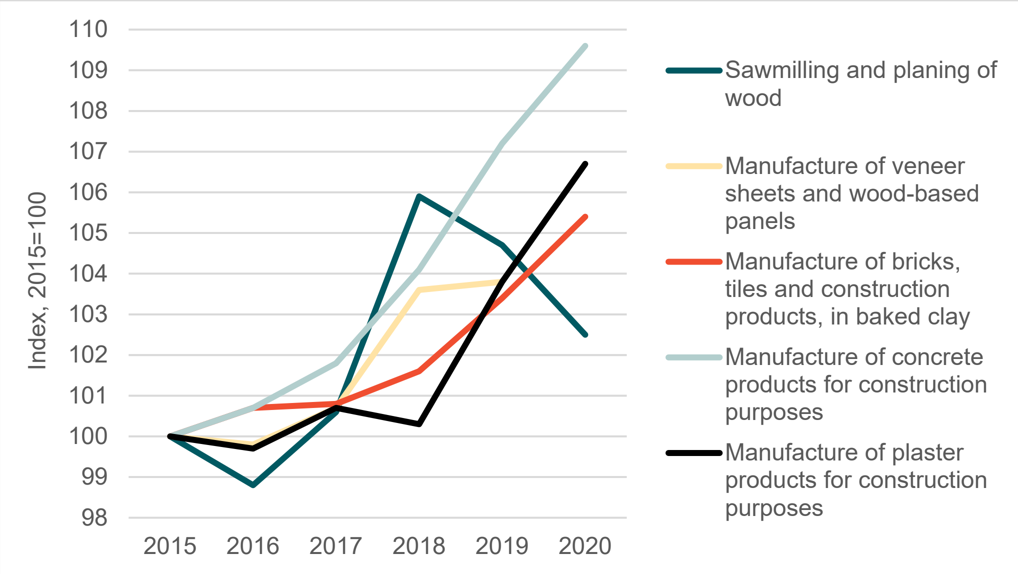
Figure 2-8 displays the output price of different construction materials, i.e. the average price development of all goods and related services resulting from that activity and sold on the domestic market.[25] As there is no index on wood-products for the construction sector specifically, the closest materials are included (sawmilling and planning of wood, and manufacture of veneer sheets and wood-based panels). The data shows an sharp increase of the output price index for non-wood construction products, while the veneer sheets and panels index has risen more slowly, and the index for sawmilling has declined between 2018 and 2020. This difference in trends may be explained by the fact that non-wood indexes are specific to the construction sector, while the wood indexes are not. It could also be partly explained by a combination of natural factors, namely drought, climate change, and the effects of bark beetles. As researched in the context of Czechia, bark beetle can be especially damaging, with the resulting increase in unplanned logging strongly correlated with the decrease in wood prices.[26] The problems of drought and bark beetle were also discussed during the stakeholder consultations in the case of Germany.[27] Some further explanations for the costs of WCPs and wood construction more broadly were discussed during the stakeholder consultations (section 4.3.3).

[25] Eurostat (2021) Short-term business statistics. Available here.

[26] Toth, D., Maitah, M., Maitah, K., & Jarolínová, V. (2020). The impacts of calamity logging on the development of spruce wood prices in czech forestry. *Forests*, *11*(3), 283.

[27] Industry association (1)

Figure 2-8 Output price for different types of construction materials, EU27, 2015-2020[28]



No previous analyses that break down the overall costs of construction and which focus on differences per construction materials in the EU were identified in the literature review undertaken in the scope of this study. The most relevant study identified dates from 2012 and calculated that – in the UK – the costs of construction are divided as follows: 43% of the costs are material costs, 46% are labour costs, and 11% are plant costs (i.e. machinery, equipment and apparatus).[29] As aforementioned, the price of WCPs are influenced by havesting costs and the type of wood product (primary vs. more processed products). During construction itself, speed of construction (due to be higher usage of pre-fabricated modules), reduced need for truck transportation, and the need for less massive foundation cranes (due to the lower density of wood) offer potential to reduce plant and labour costs when using wood, compared to more conventional materials. However, more research is needed to quantify these effects in terms of costs as well as other influencing factors such as insurance prices, uncertainty margins and costs of abiding to building regulations. These elements are analysed qualitatively in later parts of this analysis.

1.2. Market Analysis

1.2.1. Overview of material flows

Figure 3-1 illustrates the material flows along the wood biomass value chain in the EU in 2015, from harvest to production of wood-based products, and also including the use of wood as energy and material recovery. The sawmill industry processes roundwood into sawnwood and a large share of its biomass input is used for energy (at least 17.6%) or used by the panel and pulp industries as a by-product. This high share of by-products is caused

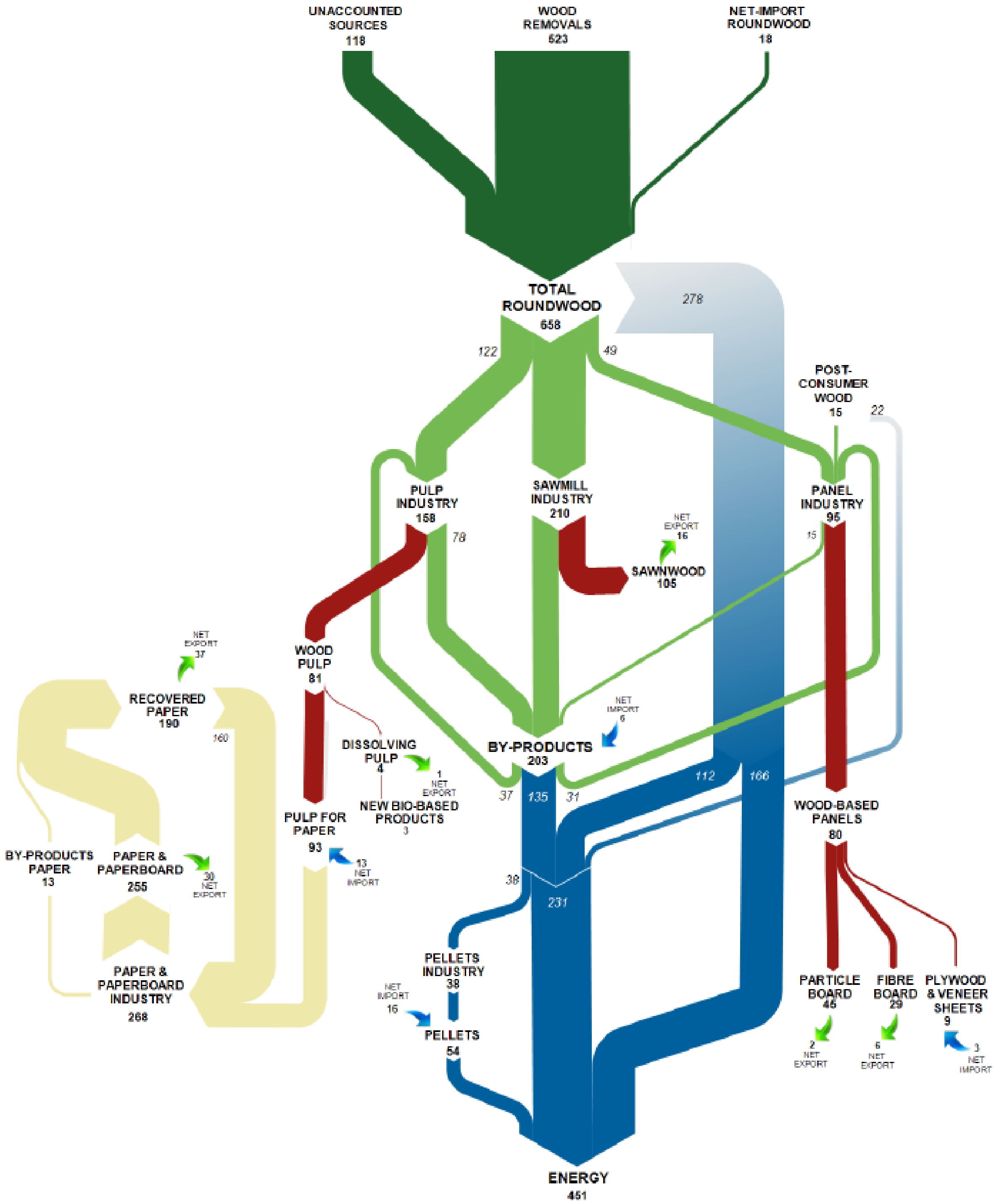
[28] Producer prices in industry, total - annual data [sts_inpp_a]

[29] Khuan Chan (2012) A Comparison of Construction Cost and Technology Choice. Available here.

by the high quality requirements for this application (sawnwood) of wood. The panel industry also relies on roundwood and post-consumer wood for its material input, and is much more efficient in its biomass use, because the quality requirements placed on the wood for this application are lower. Using data from the same year, Figure 3-2 more clearly illustrates the sources of woody biomass feeding into the value chain (i.e. its circularity). Of interest to the WCPs sector are the input flows used for the manufacture of solid wood products (i.e. WCPs but also furniture and other wood products). At the EU27+UK level, 68% of woody biomass use was reported to be primary woody biomass, 27% was from by-and co-products (including wood pellets), and 5% came from post-consumer wood.[30]

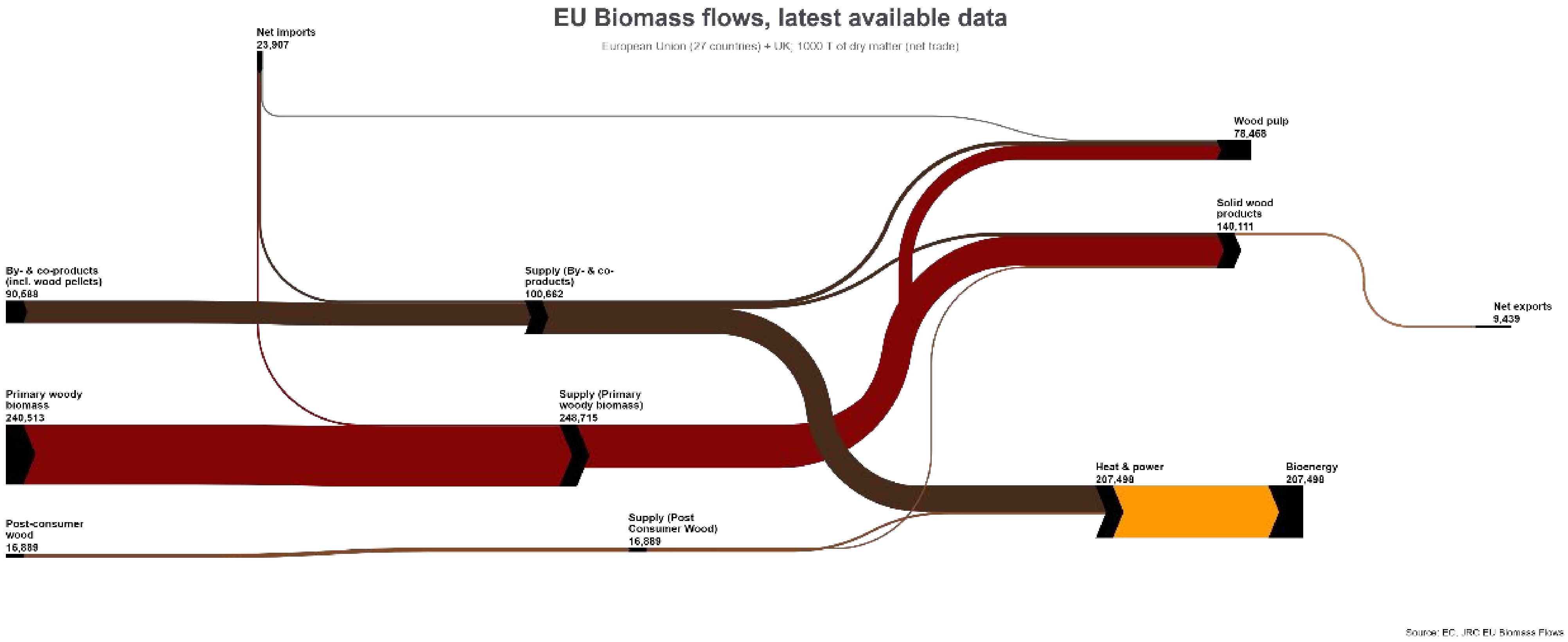
[30] JRC (2020) Biomass flows in the European Union. Available here.

Figure 3-9 Sankey diagram of woody biomass flows in the European Union, 2015 (in Mm^3 solid wood equivalent). Source: JRC (2019)[31]



[31] JRC (2019) Sankey diagrams of woody biomass flows in the EU-28. Available here.

Figure 3-10 EU forestry biomass flows, in thousand tonnes of dry matter, 2015. Source: JRC (n.d.)[32]



[32] JRC (n.d.) Biomass flows. Available here.

1.2.2. Harvesting and external trade of wood

This section presents data on timber (industrial roundwood) production and trade at MS-level and for all sectors, in an attempt to better understand the extent to which countries satisfy their own consumption via local sources of timber, or – conversely – whether they are more reliant on imports. It also contributes to understanding the capacity of a given country to sustain an increasing local consumption of its domestic timber production, for instance in the event of an uptake of WCPs in the construction sector.

1.2.3. Wood harvesting in the European Union

Forests fulfil many functions, such as wood production, biodiversity conservation, recreation, protection of water and soil, and protection of infrastructure and settlements against avalanches. Almost all countries in Europe have a history of (sometimes severe) overexploitation of their forests, leading to degraded forests and sometimes an almost complete loss of forest area (Morin et al. 1996). Worries about this overexploitation led to the introduction of concepts of sustainable forest management, national forest inventories and forest (supply) projection tools (Schelhaas and Lajos Mayr, 2017). The Forest Europe process (formerly known as Ministerial Conference on the Protection of Forests in Europe – MCPFE) defined sustainable forest management (SFM) as "using forests and forest land in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems", and introduced a system of criteria and indicators. They regularly produce reports to monitor the progress and state of SFM in Europe, the most recent one being the State of Europe's Forests 2020 (Forest Europe, 2020).

An indicator that is often used for a quick assessment of sustainability is the ratio between fellings and net annual increment. A value of 100% indicates that the amount of wood harvested annually is equal to the amount of wood that is growing. Values lower than 100% lead to an increase in the standing volume in the forest, while values higher than 100% lead to a decrease. While this indicator is simple to calculate and easy to interpret, it has some disadvantages as well. A ratio larger than 100% may temporarily be perfectly defendable to flatten out an uneven age class distribution, to bring the average stock down to a level where forests are less vulnerable, or due to the occurrence of natural disturbances that may increase (salvage) fellings and decrease the increment at the same time. It should therefore only be applied over large spatial scales and long time periods, but even better is to take into account the local circumstances and state and history of the forest. It should also be kept in mind that, in many regions, the reported felling may be well below the actual felling taking place, because a large fraction of the forest is owned by small-scale owners that exploit their forest for self-consumption of firewood, and do not report on it. As a result, the measured ration of fellings / net annual increment is likely to be under-estimated, sometimes significantly.

In the last report on the State of the Europe's Forests (Forest Europe, 2020), the ratio of fellings to increment in the EU27+UK was about 75% (Table 3-1), based on reports on 67% of the area available for wood supply. Table 3-2 presents for all EU27+UK countries the most recent value of NAI and fellings as presented in Forest Europe 2020 for the year 2015, or, if not available, for earlier years as presented in Forest Europe 2015 (for production, imports and exports data per MS, see Annex 8). Based on this more complete overview, the felling/NAI ratio for EU27 is 72%, with values for individual countries ranging from 20% (Cyprus) to 99% (Belgium). The difference between the total increment (743 million m3) and fellings (532 million m3) of 210 million m3 can be interpreted as an apparent potential to increase the harvesting level in Europe as a whole without becoming unsustainable. However, Jonsson et al. (2021) demonstrate that fellings of especially fuelwood are underestimated in official statistics, and estimate a felling/NAI ratio of 76%-85% for 2015.

Table 3-3 Net annual increment and fellings, by region (2015), as presented in Forest Europe 2020.

Region	NAI		Fellings		Utilisation rate
	million m³	m³/ha	million m³	m³/ha	%
North Europe	249.1	4.8	205.8	3.9	82.6
Central-West Europe	259.1	7.3	184.7	5.2	71.3
Central-East Europe	86.6	8.1	53.6	5.0	61.9
South-West Europe	-	-	-	-	-
South-East Europe	57.5	4.8	33.3	2.8	58.0
EU-28	576.4	6.3	432.2	4.7	75.0
Europe	652.3	5.9	477.5	4.3	73.2

Note: Data coverage as % of total regional FAWS area: NE 94%, C-WE 100%, C-EE 34%, S-WE 0%, S-EE 61%, EU-28 67%, Europe 65% (23 countries).

Table 3-4 Net annual increment and fellings (equal to wood production) per country and for the EU27+UK on Forest Available for Wood Supply. Values for 2015 based on Forest Europe 2020, for earlier years on Forest Europe 2015.

	Year	NAI (1000 m³ per year)	Fellings (1000 m³ per year)	Felling/increment
Austria	2015	27,024	23,534	87%
Belgium	2015	5,291	5,221	99%
Bulgaria	2010	14,361	6,972	49%
Croatia	2015	8,863	6,340	72%
Cyprus	2010	47	9	20%
Czech Republic	2015	21,696	18,247	84%
Denmark	2015	6,608	4,426	67%
Estonia	2015	12,326	10,221	83%
Finland	2015	96,200	77,348	80%
France	2015	81,375	48,805	60%
Germany	2015	104,160	79,663	76%
Greece	1990	3,813	1,486	39%
Hungary	2015	10,869	7,201	66%
Ireland	2015	7,291	4,702	64%
Italy	2010	32,543	12,755	39%
Latvia	2010	19,680	12,831	65%
Lithuania	2015	13,580	9,550	70%
Luxembourg	2010	760	NA	
Malta		NA	NA	
Netherlands	2015	2,156	1,026	48%
Poland	2010	62,300	46,600	75%
Portugal	2005	18,870	13,347	71%
Romania	2015	41,383	18,164	44%
Slovakia	2015	12,681	10,000	79%
Slovenia	2015	8,565	5,251	61%
Spain	2010	35,479	19,707	56%
Sweden	2015	94,843	89,025	94%
EU28		742,764	532,431	72%

Large-scale European wood supply studies often focus on the forest area available for wood supply (FAWS). FAWS is defined as: “Forests where there are no environmental, social or economic restrictions that could have a significant impact on the current or potential supply of wood. These restrictions could be based on legal acts, managerial owners' decisions or other reasons” (Alberdi et al. 2016). In such studies, management is usually defined in terms of age class ranges where thinnings and regeneration fellings can be applied. If there is sufficient demand, harvesting will take place, and the apparent potential can usually be reached or in some cases even be exceeded when the age class distribution is unbalanced. However, in practice there are many reasons why not all forests will be really harvested, even when they are labelled as FAWS, a topic explored in depth in section 4.2.

Primary wood sources certified

The climate benefits of using WCPs are largely dependent upon the sustainable management of the forest from which the raw material is harvested. Third-party certification is one way to estimate the minimum extent to which forestry resources are responsibly managed. While data on the exact amount of certified wood sourced from each country does not exist, it is possible to use the percentage of wood area available for wood supply under third party certification (i.e. results displayed in Figure 3-3) as a proxy to assume the share of wood products produced by each MS which is certified (for the full data, see Annex 7).

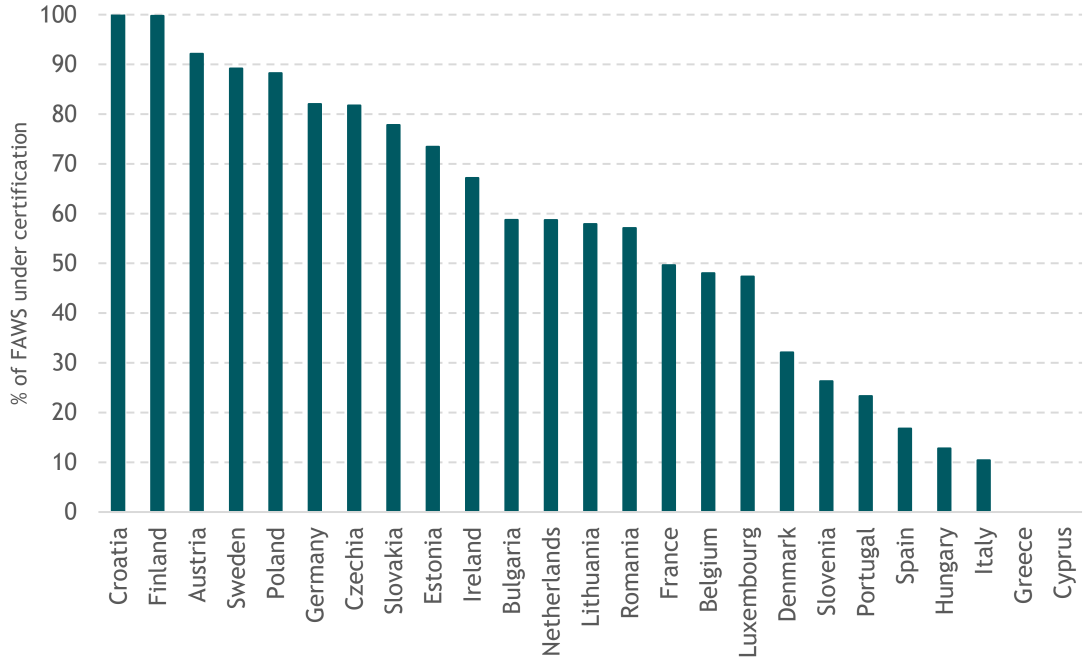
We estimated the percentage of wood area available for wood supply and certified per MS using the following steps:

Calculation of the total forest area under certification scheme per MS by using total forest area data from UNECE (2015) and data on proportion of forest under third party certification from Forest Europe (2020);

Calculation of how much FAWS is certified, using data on FAWS from UNECE (2015). This step is based on the assumption that 100% of the calculated total forest area under third-party certification scheme is FAWS.

Besides Croatia, all of the MS with a high share of their FAWS under third party certification have large forest cover. Data was incomplete for Latvia and Malta, hence these two countries are not included in the Figure. The total reached slighty over 100% for Croatia (101.6%), which could have been caused by some data irregularity.

Figure 3-11 Percentage of wood area available for wood supply under third party certification, per MS, 2015. Adapted from: UNECE (2015)[33] and Forest Europe (2020).[34]



[33] UNECE (2015). UNECE Statistical database - Forest area (Indicator 1.1a.). Available here.

[34] Forest Europe (2020) State of Europe's Forests. Available here.

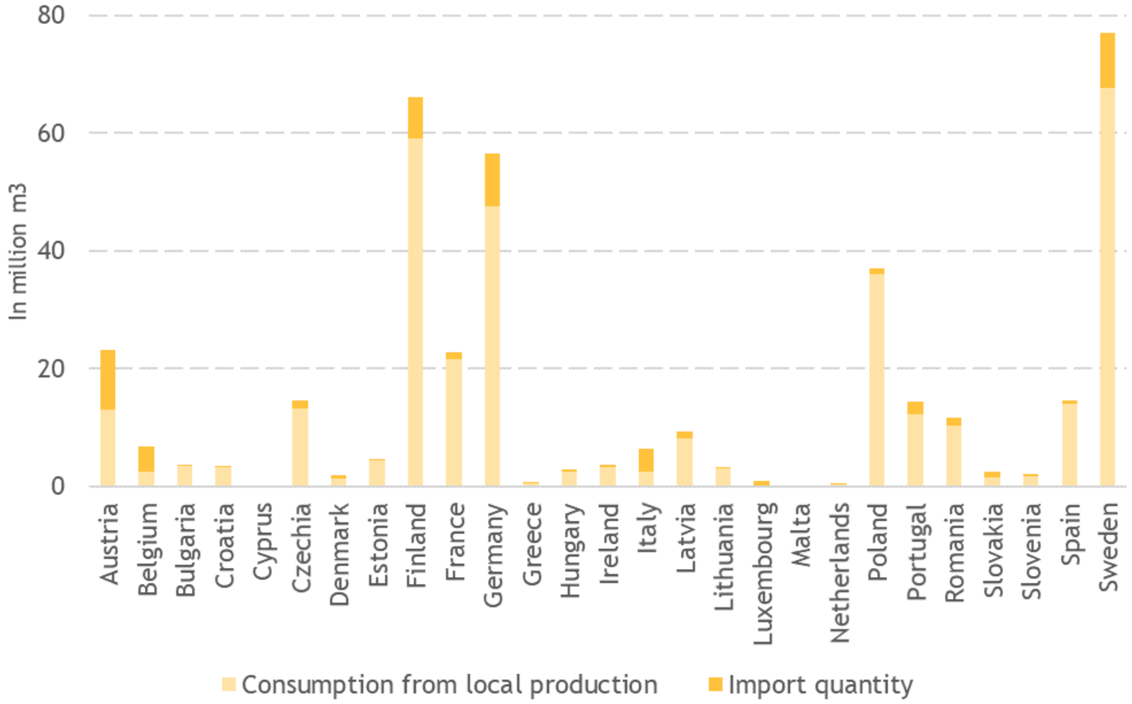
International trade of wood

Imports and local extraction within domestic consumption

Consumption from local production is calculated by substracting exports (both intra- and extra-EU) from local extraction. Adding imports (similarly, both intra- and extra-EU) to consumption from local production gives the total domestic material consumption of each MS. As is visible in Figure 3-4, results vary significantly per MS on the two indicators. Sweden, Finland and Germany reach much higher levels of industrial roundwood consumption (i.e. roundwood products such as saw logs, pulpwood, veneer logs, etc. intended to be processed into primary wood products at sawmills)[35] than the other MS, and also import larger quantities of timber (alongside Austria, which is the top importer amongst the EU27). However, in almost all MS, the consumption of wood comes primarily from local production, and to a smaller extent from imports.

EU-level data indicates that the EU imports more timber than it exports, but that imports represent around 15% of its total consumption, with the remainder being sourced domestically. This data, alongside production, imports and exports by MS, are presented in Annex 8.

Figure 3-12 Consumption from local production and imports of industrial roundwood, per MS, 2018 (in m^3). Adapted from: FAO Forestry Production and Trade database.[36]

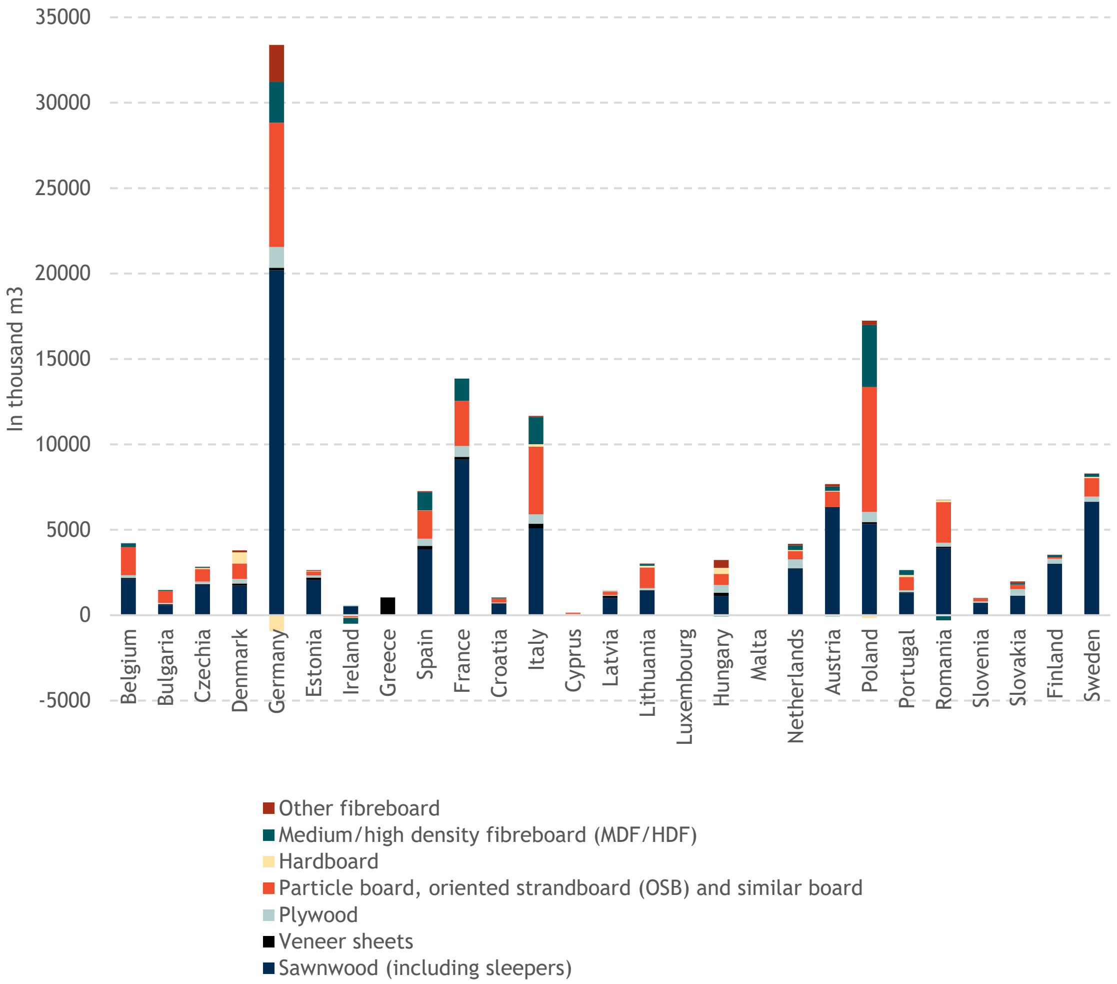


[35] USDA (2009). Definition of terms. Available here.

[36] FAOSTAT (2020). Forestry Production and Trade. Available here.

The total domestic material consumption of a selected number of further-processed WCPs was calculated using the same method (Figure 3-5). Although results vary per MS (with the highest aggregate consumption levels found in Germany, Poland, France and Italy), trends show a similar pattern in terms of the consumotion mix, with a tendency to consume sawmwood, particle boards/OSBs, and MDF/HDF to a greater extent (for the full data, see Annex 9). It is important to note, however, that those numbers encompass all uses of the materials.

Figure 3-13 Total domestic material consumption of selected WCPs, per MS, latest year available (from 2015 to 2019). Adapted from Eurostat (2021)[37]



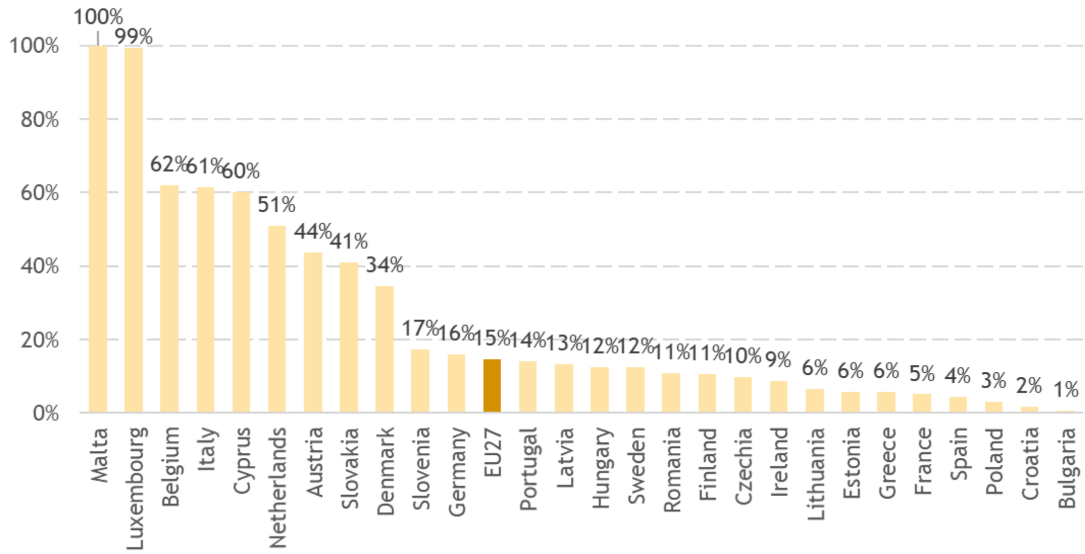
Fractions of imports and exports, and net trade balance

The figures below help to illustrate the trends observed in Figure 3-4 in more detail. Figure 3-6 highlights a wide variation across MS in the share of imports making up their Direct Material Consumption (DMC). Notably, Malta and Luxemburg, two very small Member States, reach extremely high level of imports relative to domestic consumption (100% and

[37] Eurostat (2021) Sawnwood and panels. Available here.

99% respectively), with the third highest share dropping to 62% for Belgium. The EU27 average stands at 15%, and the lowest proportion of 1% is obtained by Bulgaria.

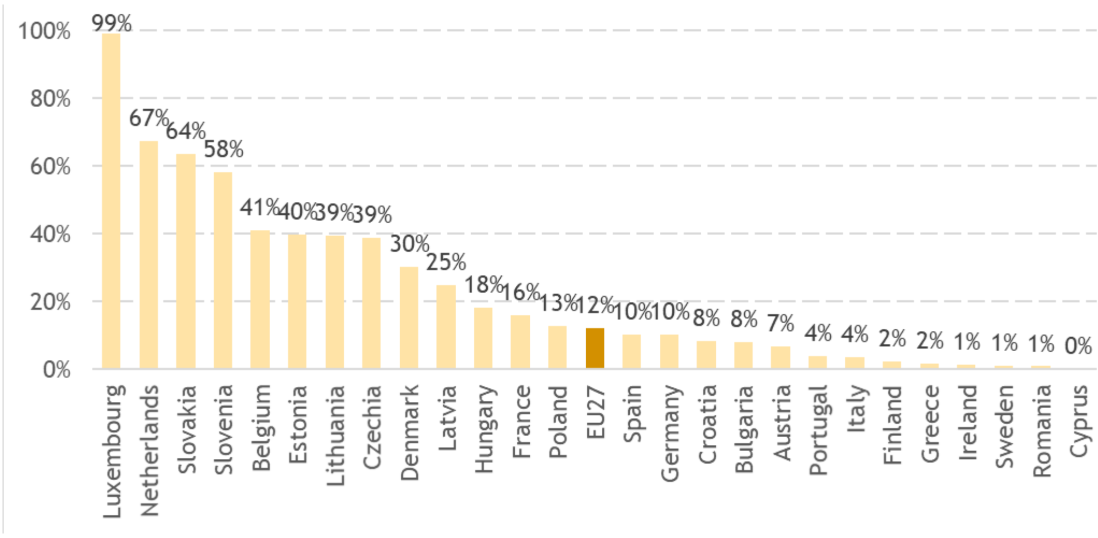
Figure 3-14 Imports as a percentage of total industrial roundwood consumption, per MS, 2018. Adapted from: FAO Forestry Production and Trade database.[38]



Again, Figure 3-7 displaying the ratio of exports (both to within and outside of EU) to domestic production illustrates wide diversity across MS. In addition to importing high quantities compared to domestic production, Luxembourg also exports almost as much as it produces (99%), suggesting that it is a transit country. The second highest percentage is obtained by the Netherlands (67%), which, for geographic reasons, is a known transit Member State for the international trade of goods. Cyprus did not report any exports (0%), and Malta is not included in the results as it did not report any domestic production. The EU average stands at 12%.

[38] FAOSTAT (2020). Forestry Production and Trade. Available here.

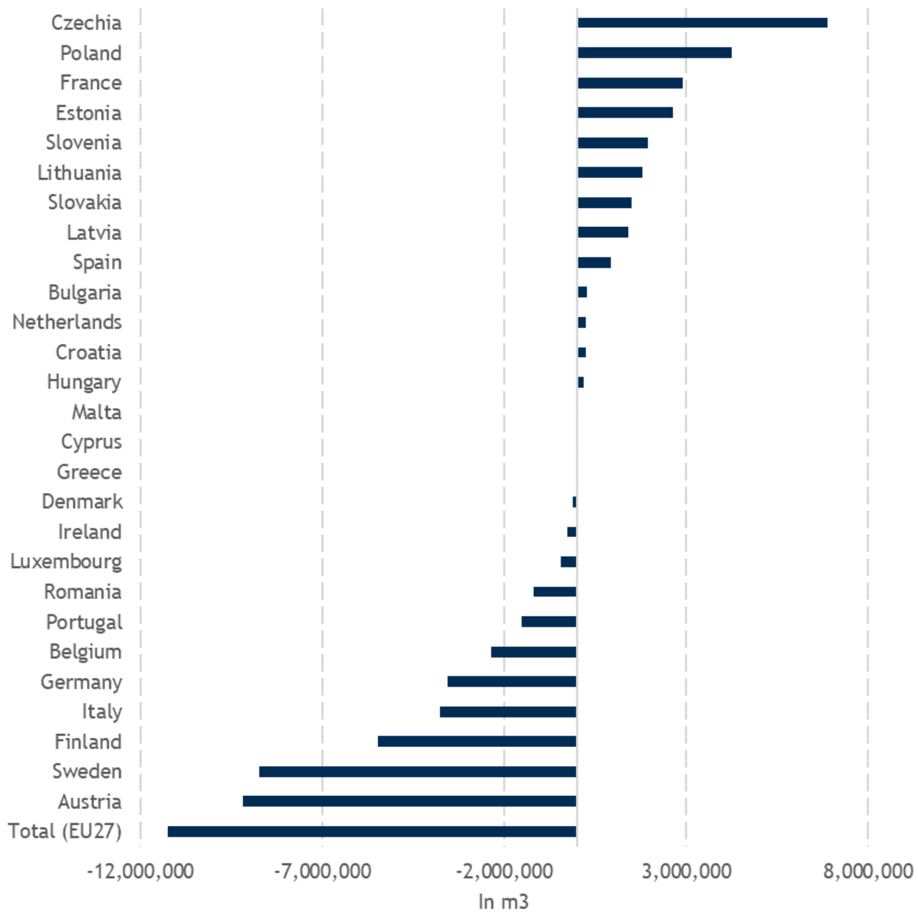
Figure 3-15 Exports as a percentage of domestic production of industrial roundwood, per MS, 2018. Adapted from: FAO Forestry Production and Trade database.[39]



The net trade balance of MS and of the EU27 as a whole is displayed in Figure 3-8. The balance of countries that both import and export significantly compared to domestic production (e.g. Luxembourg and the Netherlands) becomes relatively small. Results show that – except France – all the major net exporters are Central-Eastern European countries. On the other hand, some Northern and Western European countries with large forest cover and high consumption from local production (as visible in Figure 3-4) have relatively important negative trade balance (e.g. Germany, Finland, Sweden). This can partly be explained by the fact that some Eastern European countries tend to export primary products to a greater extent, while Northern and Western European countries import industrial roundwood for further processing, and therefore higher value products.

[39] FAOSTAT (2020). Forestry Production and Trade. Available here.

Figure 3-16 Net trade balance of industrial roundwood, per MS and for the EU27. Adapted from: FAO Forestry Production and Trade database.[40]



Some MS are exporting substantial amounts of industrial roundwood and further processed wood products to third countries, in terms of absolute quantities. According to 2019 European statistics,[41] out of the 11.94 million m3 of industrial roundwood exported by the EU27 to non-EU countries, Germany exported one third (3.96 million m^3), followed by Czechia (2.5 million m^3, or 20.9% of EU27 extra EU exports) and Poland (1.29 million m^3, or 10.8%). In 2019, these three countries therefore represented almost 65% of all exports of industrial roundwood to non-EU countries. Nevertheless, the EU27 exports to third countries are a small quantity compared to what is consumed within the EU (i.e. it represents only 3.1% of consumption).

For further processed wood products, the following data was retrieved from Eurostat:

Sawnwood: EU27 countries exported 23 979.33 thousand m^3 outside of the EU in 2019, with Sweden (6 301.62 thousand m^3) and Finland (5 701.39 thousand m^3) as the two main exporters.[42] Assuming that EU27 data is accurate, the EU27 exports of sawnwood to third countries amounts to almost a third of the quantity consumed within the EU (27%).

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[40] FAOSTAT (2020). Forestry Production and Trade. Available here.

[41] Eurostat (2020) Roundwood, fuelwood and other basic products. Available here.

[42] Eurostat (2021) Sawnwood and panels. Available here.

Veneer sheets: EU27 countries exported 267.67 thousand m^3 of veneer sheets to non-EU countries in 2019. Missing import data at EU level prevented from computing the share of apparent consumption that this amount represents.

Plywood: EU27 countries exported 870.44 thousand m^3 of plywood to non-EU countries in 2019. Missing import data at EU level prevented from computing the share of apparent consumption that this amount represents.

Particle board, oriented strandboard (OSB) and similar board: EU27 countries exported 3 147.74 thousand m^3 of particle board, OSB and similar board to non-EU countries in 2019. Missing import data at EU level prevented from computing the share of apparent consumption that this amount represents.

Hardboard: EU27 countries exported 1 148.02 thousand m^3 of hardboard to non-EU countries in 2019. Missing import data at EU level prevented from computing the share of apparent consumption that this amount represents.

Medium/high density fibreboard (MDF/HDF): EU27 countries exported 1 425.66 thousand m^3 of MDF/HDF to non-EU countries in 2019. Missing import data at EU level prevented from computing the share of apparent consumption that this amount represents.

Other fibreboard: EU27 countries exported 427.76 thousand m^3 of other fibreboard to non-EU countries in 2019. Missing import data at EU level prevented from computing the share of apparent consumption that this amount represents.

Wood chips, particles and residues: Germany also came first in 2019 for non-EU exports (264.05 out of 64 145 thousand m^3 exported by the EU27), followed by France (196.41 thousand m^3) and Sweden (142.63 thousand m^3).[43] Assuming that EU27 data is accurate, the EU27 exports to third countries represent a large quantity compared to what is consumed within the EU (i.e. 69.9%). There is therefore a larger potential to redirect exports of wood chips, particles and residues towards domestic consumption in the WCPs manufacturing sector.

The potential to re-direct some exports towards the internal EU market to supply a growing WCPs market could be fulfilled, provided that demand and prices align. This point will be elaborated upon in section 4, which presents an analysis of the Enablers and barriers to an increase in the usage of wood in the construction sector.

1.2.4. Material consumption by the construction sector

This section presents the use of timber (industrial roundwood) by the construction sector compared to other materials, both at EU-level and Member State (MS) level, as well as the methodology followed to produce the results. Additionally, it compares the use of timber by the construction sector across MS.

Material use in the construction sector

The European construction sector performs the following tasks: building new structures and renovations. It is split across three main types of structures: residential buildings, non-

[43] Eurostat (2020) Roundwood, fuelwood and other basic products. Available here.

residential buildings, and civil engineering. The following broad categories of primary raw materials of interest are used by the sector as a whole:

Timber (industrial roudwood), which comprises all roundwood except fuel wood (i.e. sawlogs and veneer log; pulpwood, round and split; and other industrial roundwood).[44] Industrial roundwood can be further processed into a variety of WCPs.

Non-metallic minerals, which include – among others – sand, gravel, limestone, clay, and fertiliser minerals.[45]

Metal ores (also called gross ores), which comprise all materials removed from mines for the purpose of extracting the desired metal(s).[46]

As the materials of interest to the purpose of this analysis are those that are part of the final, physical construction works, fossil energy materials/carriers (i.e. fossil energy used throughout the process and for plastics), biomass excluding wood (i.e. mainly crops) and wood fuel and other extraction (i.e. mainly wood burned to produce energy throughout the process) will be excluded from the calculations, even though these materials are also consumed by the sector.[47]

Material consumption at EU level

Material consumption in thousand tonnes (Eurostat data)

Material consumption at EU level and for the construction sector (NACE code F) is assessed with the Eurostat **raw material consumption (RMC) indicator**, for the latest year available (2017). RMC represents the amount of material in terms of raw material equivalents needed (i.e. the amount of extraction, domestic and abroad, required directly and indirectly) to produce the products consumed in the geographical reference area. It is calculated as raw material input minus exports in raw material equivalents.[48]

As depicted in Figure 3-9 (Graph A), timber (industrial roudwood) is used in the construction sector to a much smaller extent (1%) than metal ores (5%) and non-metallic minerals, with the latter dominating material use in the construction sector (87%). Non-metallic minerals include, among others, sand, gravel, clay and limestone.[49] In the first graph below, the materials that are used in buildings are underlined. Graph B zooms in on the latter materials, which will be the focus of the analysis that follows. As a share of total building materials by weight, non-metallic minerals make up 93% of building materials.

Figure 3-17 Raw material consumption in construction and consutruction works (NACE code F), 2017, EU28 (in thousand tonnes and percentages). All materials and

[44] UNECE/FAO/Eurostat/ITTO (2014) Joint Forest Sector Questionnaire – Definitions. Available here.

[45] EUROSTAT (2015) Glossary: Non-metallic minerals. Available here.

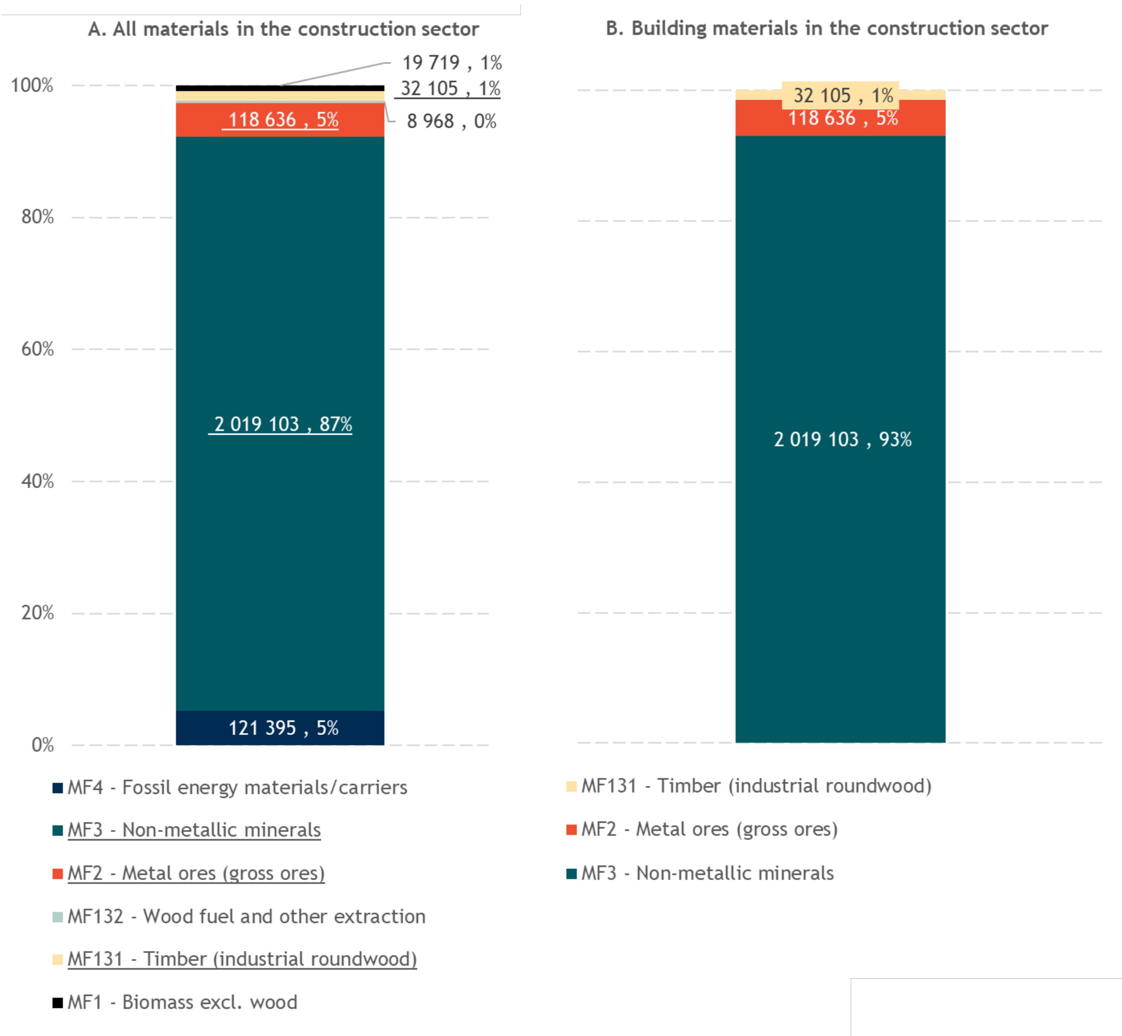
[46] EUROSTAT (2015) Glossary: Metal ores. Available here.

[47] EUROSTAT (2019) Material flow accounts in raw material equivalents - modelling estimates (env_ac_rme). Available here.

[48] EUROSTAT (2019) Material flow accounts in raw material equivalents - modelling estimates (env_ac_rme). Available here.

[49] EUROSTAT (2015) Glossary: Non-metallic minerals. Available here.

building materials only. Adapted from: Eurostat Material Flow Accounts (MFA) database.[50]



Estimations in cubic meters

Comparing materials using their weight skews results in favour of heavier materials; therefore, estimations in cubic meters (m^3) are believed to represent the relative proportion of materials used in the built environment more accurately. The main materials which are used by the construction industry and which end up being part of the physical buildings ('building materials') were converted from thousand tonnes to m^3 according to the material densities reported in Table 3-3.

Prior to the conversion of materials from thousand tonnes to m^3, the relative proportion of the materials used within each major category was assumed, based on their relative use, and as reported under the Eurostat RMC indicator. The assumptions made are outlined here:

Timber (MF131) was the only material of interest from the biomass category.

[50] EUROSTAT (2020) Material flow accounts in raw material equivalents by final uses of products - modelling estimates. Available here.

Non-metallic minerals were split between four categories: (1) concrete (i.e. sand and gravel, MF38) and (2) marble, granite and sandstone (MF31) are the main materials, approximately representing 72% and 11% of non-metallic mineral use by the sector, respectively. However, the materials listed as sub-categories of non-metallic minerals do not add up to 100% of the total of this category. Therefore, we assumed that that (3) clay (the raw material for bricks and cement) and (4) limestone (the main raw material for cement) represented the remainder of non-metallic mineral used by the construction sector, and ascribed them a 8.5% contribution each.

Metal ores were split between steel (i.e. iron, MF21) and non-ferrous metals (MF22), which account for the totality of this material category. However, the material use within the sub-categories of non-ferrous metals accounted for much less than 100% of MF22, which prevented us from calculating their relative contribution to the category. Therefore, we used the density of aluminium as a proxy for all non-ferrous metals, as it is extensively used in the construction sector.

We assessed the confidence of the assumptions as low/medium for three reasons. First, a single density was estimated for timber, while the density of different Wood-based Construction Products (WCPs) varies. Second, we assumed non-metallic minerals to be composed of four materials only, and their relative proportion within this category is uncertain. Finally, the density of non-ferrous metals is uncertain as it is based on an average of all materials within this category, which gave equal weight to all of them.

Table 3-5 Conversion table of relevant materials to the analysis. Sources: Engineering toolbox[51] and expert opinion.

Material category	Material	Estimated share of category	kg/m³
Biomass (only timber)	Timber	100%	600
Non-metallic minerals	Concrete (sand and gravel in the MFA-RME database)[52]	72%	1,425
	Marble, granite and sandstone	11%	2,475
	Clay	8.5%	2,350
	Limestone	8.5%	2,700
Metal ores	Steel (iron in the MFA-RME database)[53]	28%	7,820
	Non-ferrous metals (aluminium)	72%	2,700

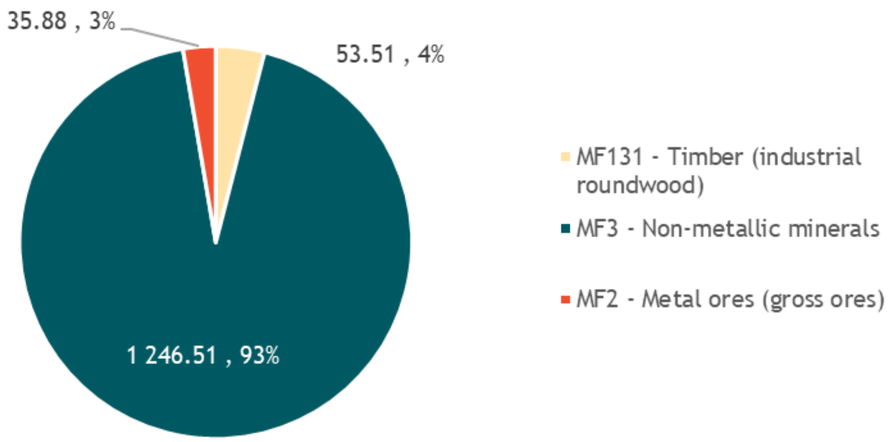
[51] Engineering toolbox (2009) Density of Selected Solids. Available here.

[52] EUROSTAT (2020) Material flow accounts in raw material equivalents by final uses of products - modelling estimates. Available here.

[8] EUROSTAT (2020) Material flow accounts in raw material equivalents by final uses of products - modelling estimates. Available here.

The results in m^3 are displayed in Figure 3-10. Non-metallic minerals remain the predominant material used in the construction sector (93%), but timber surpasses metal ores (4% and 3%, respectively). While the share of non-metallic minerals remains identical to the results in thousand tonnes (93%, see Figure 3-9, Graph B), timber gains in relative importance when comparing results in m^3, reaching a slightly higher percentage of use than metal ores (4% and 3%, respectively).

Figure 3-18 Raw material consumption in construction and construction works (NACE code F), 2017, EU28, in million cubic meters (Mm^3). Focus on building materials only. Adapted from: Eurostat Material Flow Accounts (MFA) database.[54]



Material consumption in the built environment at Member State level

RMC data for the materials used in the construction sector (metal ores, non-metallic minerals, fossil energy materials/carriers and timber) is available in the Eurostat database at the scale of the EU, but not per MS. On the other hand, **domestic material consumption (DMC)** for these materials is available in the Eurostat database per MS, but not per sector of use. DMC is a measure of the total amount of material consumed domestically. In a given country's national economy, DMC can be calculated as direct material input minus physical exports.[55] DMC is very close to RMC, with the only difference being that the latter includes the amount of extraction abroad (directly and indirectly) to produce the products consumed in the geographical reference area, while the former only accounts for the mass of the physical imports in its calculations.[56]

[54] EUROSTAT (2020) Material flow accounts in raw material equivalents by final uses of products - modelling estimates. Available here.

[55] EUROSTAT (2020) Material flow accounts (env_ac_mfa). Available here.

[56] EUROSTAT (2020) Material flow accounts (env_ac_mfa). Available here; EUROSTAT (2020) Material flow accounts in raw material equivalents - modelling estimates (env_ac_rme). Available here.

Therefore, we consider that the share of RMC for each material consumed by the construction sector can be used to calculate the share of DMC for each material by this sector. By doing so, we also make the simplifying assumption that the share of usage of that material in the construction sector compared to usage in the whole economy is the same for all MS (i.e. homogeneous across the EU). The equation and the consequences to be drawn are given in Equation 3-1 below, and the results for each material type is visible in

Table 3-4.

Equation 3-1 Calculation of DMC of material X by the construction sector in Member State A

$$\frac{DMC\ of\ material\ X\ by\ the\ construction\ sector\ in\ Member\ State\ A}{DMC\ of\ material\ X\ by\ all\ sectors\ in\ Member\ State\ A} = \frac{RMC\ of\ material\ X\ \ by\ the\ construction\ sector\ at\ the\ scale\ of\ the\ EU}{RMC\ of\ material\ X\ by\ all\ sectors\ at\ the\ scale\ of\ the\ EU}$$

Hence:

$$DMC\ of\ material\ X\ by\ the\ construction\ sector\ in\ Member\ State\ A = DMC\ of\ material\ X\ by\ all\ sectors\ in\ Member\ State\ A * \frac{RMC\ of\ material\ X\ \ by\ the\ construction\ sector\ at\ the\ scale\ of\ the\ EU}{RMC\ of\ material\ X\ by\ all\ sectors\ at\ the\ scale\ of\ the\ EU}$$

Table 3-6 Data used and results obtained on the proportion of use of each material by the construction sector. Adapted from: Eurostat Material flow Accounts (MFA) database.[57]

Material	RMC construction sector (in million tonnes, 2010-2017 average)	RMC all sectors (in million tonnes, 2010-2017 average)	Proportion of use by construction sector (%)
Timber	30.87	211.29	14.61%
Non-metallic minerals	1,946.56	3,096.97	62.85%
Metal ores	117.56	773.24	15.20%

Figure 3-11 displays the **DMC of the construction sector, per material and per MS**, as an annual average of the years 2010-2018. The DMC of each material was converted to m^3, as outlined in Table 3-3. For DMC, the 2010-2018 average was used, while the 2010-2017 average was used for RMC as 2017 was the latest year with data available. Latvia was excluded from the calculations because its 2010-2018 average was negative, which we assume to be caused by irregularities in reporting for that country. The Netherlands also had a negative value for 2018, but its eight-year average was positive. We expect that the use of the eight-year average, rather than the latest year available, reduces the risk of incorporating irregular data in the analysis. The results are presented in thousand tonnes in Annex 5. In addition, relative figures are presented below in the form of market shares (section 3.4).

Some significant **disparities across MS** can be observed in terms of the total material used by their respective construction sectors, with Germany (219 million m^3) clearly dominating consumption. France, Poland, Romania, Italy and Spain also reach high values ranging

[57] EUROSTAT (2020) Material flow accounts in raw material equivalents by final uses of products - modelling estimates. Available here; EUROSTAT (2020) Material flow accounts (env_ac_mfa). Available here.

between 100 and 160 million m³. Another striking point from Figure 3-11 is that despite some nuance in the relative importance of each material within each MS, **non-metallic minerals are dominant** across the construction sectors of all MS. While looking at the values presented in the figure, it is important to keep in mind that not all industrial roundwood ends up in the built environment. In addition to the significant losses along the value chain illustrated in Figure 3-1, part of the wood can end up in non-structural elements such as pellets, fencing at the construction site, and formwork for concrete.

Figure 3-19 Domestic material consumption by the construction sector, per MS, 2010-2018 average (in million m³). Adapted from: Eurostat Material Flow Accounts (MFA) database.[58]

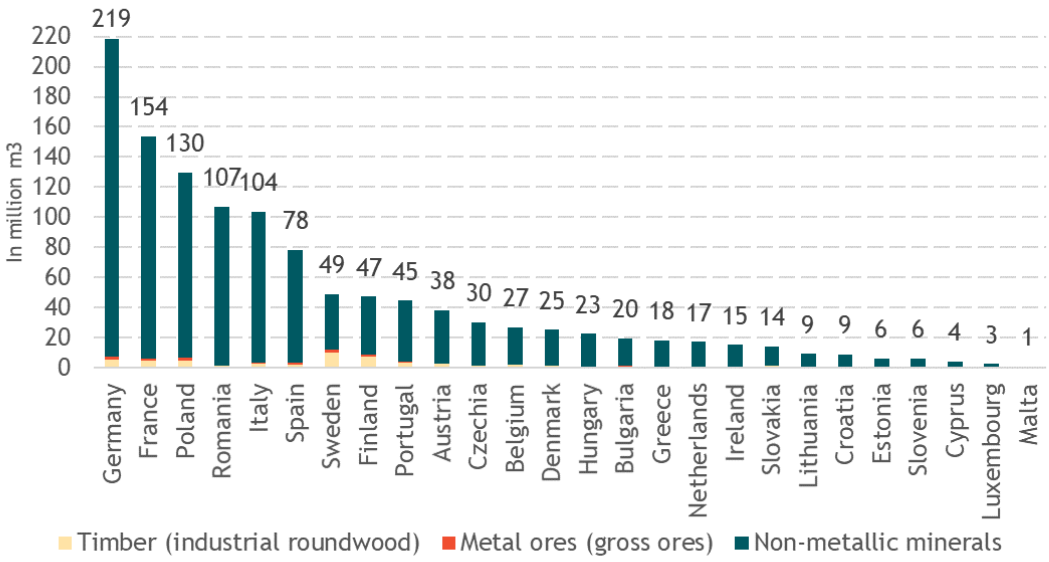
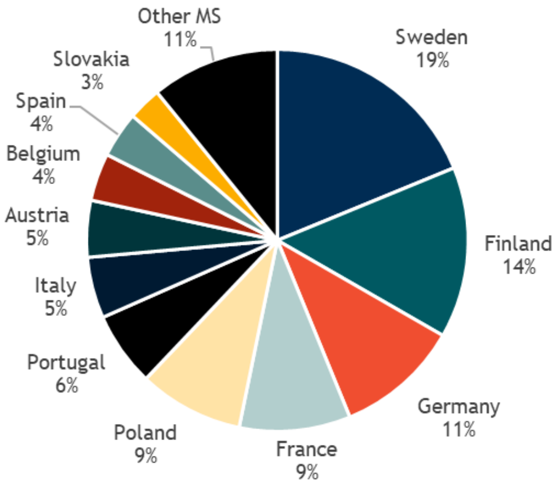


Figure 3-12 illustrates the **consumption of timber for the construction sector** across MS, and gives DMC values per MS, using the timber data for 2010-2018 also included in Figure 3-11. The two largest Nordic countries of the EU (Sweden and Finland) reach the top two positions, with 19% and 14% of the total EU consumption of timber by the construction sector occurring in these countries, respectively. The top five consumers (Sweden, Finland, Germany, France and Poland) make up almost two thirds (62%) of the total EU consumption in the sector. The results are presented in thousand tonnes in Annex 6.

Figure 3-20 Domestic material consumption of timber (industrial roundwood) in the construction sector, per MS, 2010-2018 average (in % of total timber use in the construction sector across EU26 and in million m³). Own calculations. Adapted from: Eurostat Material flow accounts database.[59]

[58] EUROSTAT (2020) Material flow accounts. Available here.

[59] EUROSTAT (2020) Material flow accounts (env_ac_mfa). Available here.



Note: The shares are calculated out of the total timber consumption in the construction sector in the EU, excluding Latvia.

1.2.5. Market share of wood-based construction products

This section elaborates on the methodology used to calculate the market share of wood-based construction products (WCPs) in the construction sector, and presents the results obtained per MS (when available).

To understand market share, we rely upon Eurostat's **domestic material consumption (DMC) indicator**, from the Material Flow Accounts (MFA) database.[60] The **market share** of timber (i.e. industrial roundwood) within the construction sector (referred to as 'constructions and construction works', corresponding to NACE code F) is calculated per MS as follows (also see Equation 3-2):

Use of DMC results for the construction sector converted in m^3 (see Figure 3-11)

Division of the total DMC of timber within the construction sector of each country by its total DMC of construction materials (following the methodology used to calculate DMC per MS for the construction sector outlined in Section 3.3.3).

Estimation of the losses of materials along the value chain, which will therefore not be part of the building. Based on Figure 3-1, we estimate that the losses of woody biomass for the processing of construction products reach 50%.[61, 62] For mineral-based products (metals ores and non-metallic minerals), we estimate that the losses are minimal, and therefore the original values are retained.

[60] EUROSTAT (2020) Material flow accounts (env_ac_mfa). Available here.

[61] Half of the sawmill industry output becomes by-products (i.e. mostly energy, but also other products which will not be used by the construction sector).

[62] This estimate corresponds to losses at the sawnwood processing stage. However, losses can be higher in the case of CLT manufacturing, and lower in the case of wood-based panels manufacturing (see FAO report available here).

Equation 3-2 Calculation of the market share of timber compared to other materials within the construction sector in Member State A

$$\frac{(DMC\ \ of\ timber\ by\ the\ construction\ sector\ in\ Member\ State\ A * 0.5)}{((DMC\ timber\ constr. * 0.5) +\ DMC\ metal\ ores\ constr. + DMC\ nonmetallic\ minerals\ constr.)\ in\ Member\ State\ A}$$

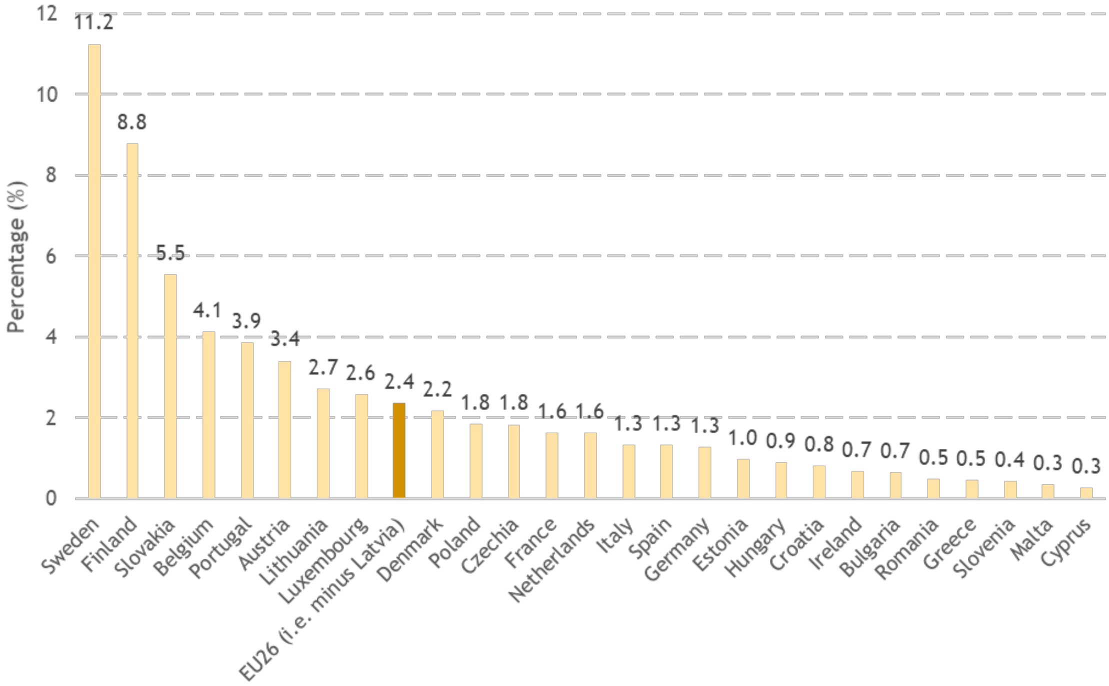
Figure 3-13 depicts the market share of timber as a percentage of total materials consumed in the construction sector ending up in the built environment, using data in m^3. It highlights marked differences across MS, with results ranging from 0.3% in Cyprus to a maximum of 11.2% in Sweden. The EU26 average (minus Latvia)[63] stands at 2.4%.

When calculating the market share in thousand tonnes and without accounting for the losses of timber along the value chain, the lowest market share stands at 0.2% in Cyprus and the maximum reaches 8.1% in Sweden, with an EU26 average of 1.7%. When calculating the market share using data in thousand tonnes and including fossil energy materials/carriers, the EU26 average (minus Latvia) stands at 1.65%. This result is very similar to findings from a 2017 study published by the European Forest Institute (EFI), which states that wood accounts for 1.6% of the EU construction sector material use.[64] Despite our reliance on assumptions to convert data from thousand tonnes to m^3 and to estimate the share of losses along the value chain, the latter estimates are likely to provide a more accurate representation of the current market share of timber used in the built environment. Sweden (11.2%) and Finland (8.8%) are the two outliers, being clearly more advanced in the incorporation of timber products in buildings than their EU counterparts.

[63] For explanations on why Latvia was excluded, see Section 2.3.

[64] Hurmekoski (2017) How can wood construction reduce environmental degradation? Available here.

Figure 3-21 Market share of timber (industrial roundwood), as a percentage of total relevant material use in the construction sector in cubic meters, per MS, 2010-2018 average. Own calculations.



The reader should bear in mind that these computations are based on a simplifying assumption which uses a static proportion at EU level to calculate material consumption by the construction industry at MS level (see above section 3.3.3), it reduces contrast across MS by underestimating the consumption in high-producing countries and, conversely, by overestimating it in low-producing countries. Although this impacts the exact percentage of the market share of the countries, we expect that the ranking of MS is likely to be accurate.

Some empirical evidence gathered in the literature and on national statistics websites helps to illustrate how the market share in Sweden and Finland may be slightly higher than our results. Hurmekoski[65] cites a report whereby the share of wood-based construction in single-family buildings "*varies regionally from above 80% in the Nordic countries to near zero in a number of southern European countries*". Comparing the market share results (Figure 3-13), the percentage for Nordic countries given by Hurmekoski, and data available on the national statistics websites of Finland and Sweden (Box 3-1 and 3-2), we observe that the market share calculated is lower, perhaps pointing to a slight underestimation. The following points can be made to explain the variations observed:

The figure given by Hurmekoski only concerns single-family buildings. As explained in the stakeholder consultations, such buildings are more likely to be built with wood than larger dwellings/buildings as they face less regulatory hurdles and less technical challenges (see section 4.3). This may (at least partly) explain why the figure given in this article is significantly higher that those in Figure 3-13, Box 3-1 and Box 3-2.

Conversely, the trends displayed for Sweden only represent new construction of multi-dwelling buildings with wooden frames, and are therefore likely to under-estimate the market

[65] Hurmekoski (2017) How can wood construction reduce environmental degradation? Available here.

share of wood in construction. One interesting point is that, although the proportion of wooden frames has increased over the past 10 years, it is equal to the 1995 figure (i.e. 20%).

The difference between multi-storeys and other buildings is especially visible in the Finnish case (Box 3-1), with a 3% market share for residential blocks of flats in 2019 compared to an average of 15% for all public buildings.

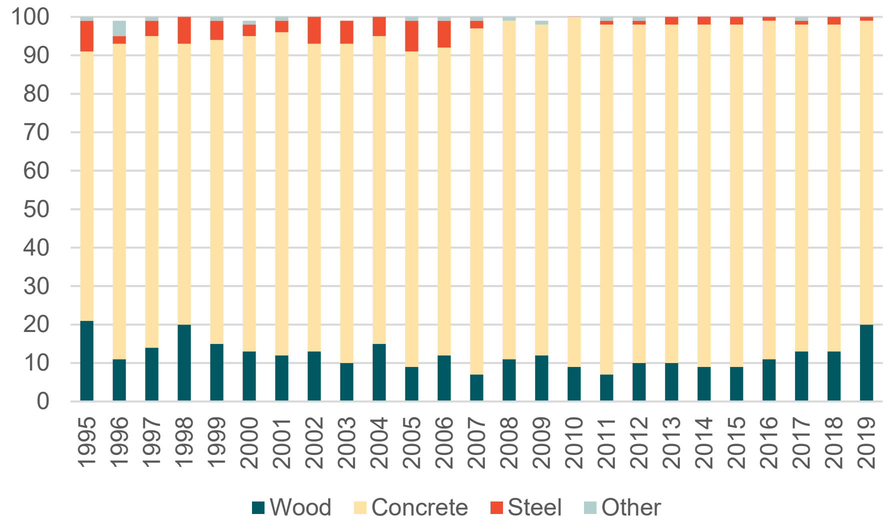
Box 3-1 Finnish national targets for wood construction in the public sector

Finland's **Wood Building Action Plan (2016-2022)** aims to increast the market share of wood construction in the public sector, and provides some national targets (of wood construction in relation to all new public construction). In addition to the targets, the current market share of wood construction in the public sector (as of 2019) is provided. The figures are as follows:

	2019	2022	2025
Educational buildings	31%	55%	65%
Buildings for institutional care	6%	20%	35%
Residential blocks of flats	3%	21%	46%
Assembly buildings	7%	20%	30%
All public buildings	**15%**	**31%**	**45%**

Source: Ministry of the Environment Finland (2020).[66]

Box 3-2 Dwellings in newly constructed conventional multi-dwelling buildings by materials in the frame of the houses in Sweden, 1995-2019, in percetages.



Source: Statistics Sweden (2020).[67]

[66] Ministry of the Environment Finland (2020) Construction and housing production. Available here.

[67] Statistics Sweden (2020) Dwellings in newly constructed conventional multi-dwelling buildings by materials in the frame of the houses. Year 1995 – 2019. Available here.

1.2.6. Consumption of further processed wood-based construction products

Recent trends in the consumption of WCPs

As explained in section 2.1, industrial roundwood is further processed into a variety of products before being used in the built environment by the construction sector, or for other uses. However, it is important to note that a significant share of the roundwood biomass that is processed by the sawmill industry ends-up as by-products (50%) and a large proportion of it is burned (i.e. energy flow), pointing to a high degree of losses at this stage of the processing process (Figure 3-1). Nonetheless, it is noteworthy that in certain sawmills, by-products are largely used for wood-based panels rather than for energy.

Sawnwood remains the most-used WCP in the construction sector, notably for structural purposes (Figure 3-14). Other products are also used to a significant degree:

Medium-density fibre boards (MDF) represents high but stagnating volumes used for non-structural purposes (notably flooring and door panels);

Oriented strand board (OSB), Wood Fiber Insulation Board (WFIB) and particle boards represent growing volumes used mainly for non-structural purposes. OSB is mainly used as sheathing in walls, in flooring, and in roof decking, while particle boards are used as flooring underlayment and WFIB for floor and wall insulation;

Glulam and Cross-Laminated Timber (CLT) are used for structural applications, in small but strongly growing volumes. Glulam is interesting for wooden construction due to its load bearing capacity and its price performance ratio; whereas CLT offers high potential for prefabrication as well as a good load bearing capacity.[68]

Out of the materials included in Figure 3-14, sawnwood has faced the most dramatic decline post-2007 (at least for the construction of residential house), as a result of the economic crisis which significantly drove down the number of building completion within Europe. Other WCPs faced relatively smaller declines, or no decline at all.[69] Between 2010 and 2014, the consumption of sawnwood for the construction of European residential houses stagnated. These trends can at least be partly explained by the advantages of newer WCPs compared to sawnwood (e.g. potential for prefabrication, potential to use trees of smaller diameters, etc.). For instance, the rising popularity of CLT in recent years has been attributed to its favourable natural and environmental properties (excellent energy efficiency, capacity for storing moisture and thermal energy, small weight, workability and flexibility in use), with this trend expected to continue in the future as even more research is undertaken.[70,71]

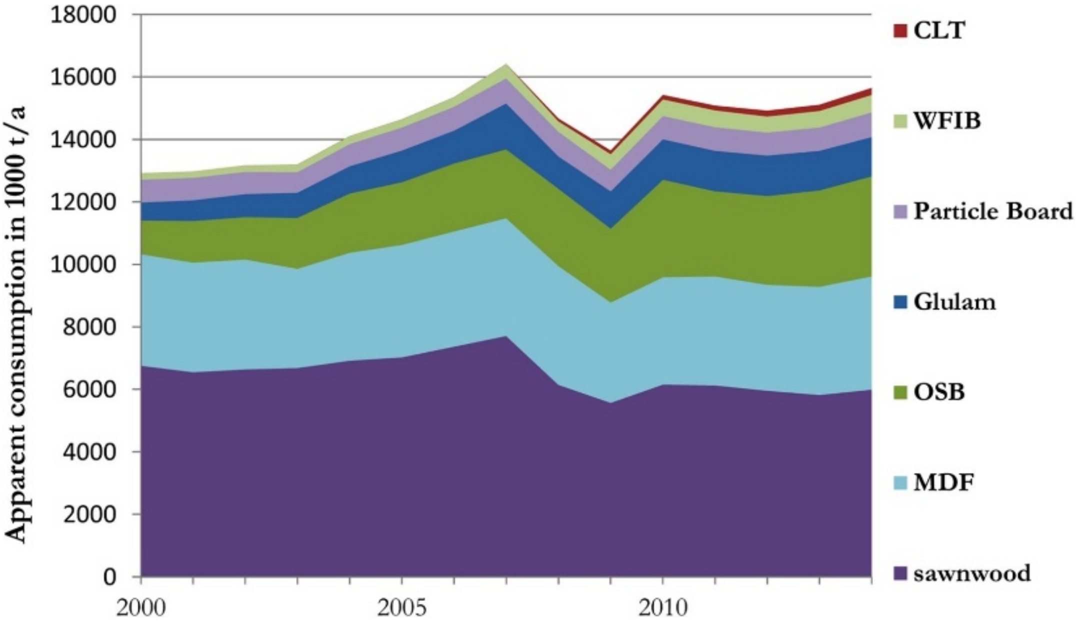
[68] Hildebrandt, Hagemann and Thrän (2017) The contribution of wood-based construction materials for leveraging a low carbon building sector in Europe. Available here.

[69] Hildebrandt, Hagemann and Thrän (2017) The contribution of wood-based construction materials for leveraging a low carbon building sector in Europe. Available here.

[70] Jeleč et al. (2018) Cross-laminated timber (CLT) – a state of the art report. Available here.

[71] Brandner, R., Flatscher, G., Ringhofer, A., Schickhofer, G., & Thiel, A. (2016). Cross laminated timber (CLT): overview and development. *European Journal of Wood and Wood Products*, *74*(3), 331-351.

Figure 3-22 Apparent consumption of wood-based products for the construction of residential houses in Europe. Source: Hildebrandt, Hagemann and Thrän (2017)[72]



As no EU-wide statistics exist on material use per type of building (e.g. single-house residential, multi-family dwellings, commercial, etc.), we cannot compare the trends observed in Figure 3-14 for residential buildings with other building types. Nevertheless, the properties of sawnwood as well as the two upcoming WCPs for structural use (CLT and glulam) give indications about the types of projects in which these two latter materials could be increasingly used in the future.

Sawnwood has traditionally remained confined single- or dual-family houses, and in apartment blocks in combination with bricks, stone or concrete. Sawnwood can be used as a building element (in the roof structure, joists and beams covering the basement and supporting the floors and ceiling, and various framework) or in joinery (flooring, doors, windows, stairs, cupboards, etc.).[73]

CLT is a versatile WCP which can be used as a stand-alone structural element, and is commonly used for long spans in walls, floors, and roofs.[74,75] This means that CLT is not necessarily in competition with the existing timber building sector, which focuses on linear timber elements, but is rather a direct competitor of mineral-based solid building materials.[76] CLT's potential is especially apparent in the construction of multi-storey buildings (residential or offices), but can also be used for public buildings (e.g. schools) and civil engineering

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[72] Hildebrandt, Hagemann and Thrän (2017) The contribution of wood-based construction materials for leveraging a low carbon building sector in Europe. Available here.

[73] FAO (1957) Utiliaztion of structural wood in housing. Available here.

[74] APA wood (n.d.) Cross-Laminated Timber (CLT). Available here.

[75] Brandner, R., Flatscher, G., Ringhofer, A., Schickhofer, G., & Thiel, A. (2016). Cross laminated timber (CLT): overview and development. *European Journal of Wood and Wood Products*, *74*(3), 331-351.

[76] Brandner, R., Flatscher, G., Ringhofer, A., Schickhofer, G., & Thiel, A. (2016). Cross laminated timber (CLT): overview and development. *European Journal of Wood and Wood Products*, *74*(3), 331-351.

projects such as bridges (either independently, or in combination with other wood- and/or steel-based materials).[77,78]

Glulam allow for very long and tall constructions. Indeed, custom glulam beams can span more than 30 meters, and in reticulated glulam framed dome structures, glulam arches can span more than 150 meters.[79] This makes this WCP suitable for many types of construction. In residential buildings, this material can be used for door headers, ridge beams, columns and floor beams.[80] Glulam can also be used to build large, flat roof systems or complex arches in public and commercial buildings (e.g. restaurants, churches) as well as bridges.[81]

Wood in building renovation

Some ambitious building energy renovation targets have been introduced in the European Green Deal, with the Renovation Wave aiming to renovate 35 million inefficient buildings by 2030. These recent developments in the policy context will lead to important investments in building renovations during this decade, and thus create significant opportunities for the further development of the WCP sector. There is currently no database providing information on the current use of wood in (energy) renovation. However, some studies and some projects have investigated the potential to use wood for renovating buildings. The following potential uses of wood have been identified:

The renovation of building envelopes (e.g. facades and roofs) with highly insulated wooden components.[82] Wood elements can be mounted on timber, concrete and brick structures, and can be of varying sizes, therefore easily adapting to the existing building structure. In addition, elements can be efficiently pre-fabricated with insulation.[83] For an example of the effects of building envelope renovation using wood panels, see Box 3-4.

The extension of existing buildings (i.e. horizontal building extensions, the closing of gaps between buildings, implants in existing buildings, and the vertical extension of buildings).[84]

The renovation of building envelopes and the extension of existing buildings offer opportunities to use both structural (e.g. sawnwood, CLT, glulam) and non-structural WCPs (especially panels made of OSB and insulating elements).

The following advantages of building renovation using wood were identified: [85]

Renovation of building envelopes with highly-insulated wooden components can significantly reduce transmission heat losses and related heating energy demand;

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[77] Brandner, R., Flatscher, G., Ringhofer, A., Schickhofer, G., & Thiel, A. (2016). Cross laminated timber (CLT): overview and development. *European Journal of Wood and Wood Products*, *74*(3), 331-351.

[78] Jeleč et al. (2018) Cross-laminated timber (CLT) – a state of the art report. Available here.

[79] APA wood (n.d.) Commercial Building Design. Available here.

[80] APA wood (n.d.) Residential Construction. Available here.

[81] APA wood (n.d.) Commercial Building Design. Available here.

[82] Schuetze, T. (2018). Wood Constructions for Sustainable Building Renovation. In Advanced Materials Research (Vol. 1150, pp. 67-72). Trans Tech Publications Ltd.

[83] Sandberg, K., Orskaug, T., & Andersson, A. (2016). Prefabricated wood elements for sustainable renovation of residential building façades. Energy Procedia, 96, 756-767.

[84] Schuetze, T. (2018). Wood Constructions for Sustainable Building Renovation. In Advanced Materials Research (Vol. 1150, pp. 67-72). Trans Tech Publications Ltd.

[85] Schuetze, T. (2018). Wood Constructions for Sustainable Building Renovation. In Advanced Materials Research (Vol. 1150, pp. 67-72). Trans Tech Publications Ltd.

Wood is lighter, which is particularly important for vertical extension as there is less often a need to reinforce the foundations of buildings;[86]

Wood facilitates project execution by enabling a higher degree of prefabrication, leading to high precision and quality and seasonal independence of the construction process;

Some logistics-related advantages have been identified, notably fast and silent construction, no long-term building site installations are required,[87] and prefabrication reduces risks of moisture and weather effects as elements are built indoors;[88]

Potential to deconstruct and reuse components.[89]

Box 3-3 Using wood panels for energy renovation: the BERTIM project

The EU-funded BERTIM project used prefabricated wood panels to accelerate building renovation in Sweden and France. The panels were installed in 15 hours and achieved a 62% energy reduction. In addition, the pre-fabrication process reduces construction waste by 15%, and the buildings' global warming potential was reduced by two thirds.[90] Prefabricated wood panels therefore present an opportunity for a fast and efficient renovation of buildings across the EU. However, the BERTIM project also identified fire safety codes as a potential limiting factor, as many countries are still reluctant about visible wood and structural wood in buildings higher than 3 storeys.[91]

1.2.7. Discussion of results

The following major observations are derived from the analysis:

The market share results point to some potential in some MS that have a significant forest cover, but a limited market share so far (e.g. Romania, Germany, France, Spain, Italy).

With the exception of Portugal, all southern European countries score below the EU average in terms of market share, even though some have a large area of their territory available for wood supply (e.g. Spain, and to a lesser extent Italy and Greece).

Surprisingly, Belgium has a high market share despite a somewhat small forest cover. The share of its timber imports amounts to 62% of its domestic consumption (all sectors) and the country's net trade balance is negative (i.e. it imports more than it exports). Its exports are also somewhat high compared to domestic extraction (41%), highlighting its role as a trade hub, especially the port of Antwerp. Part of the explanation also lies in its manufacturing capacity; as visible in Figure 2-5, the added value of the wood manufacturing sector is somewhat high considering the very small added value of the forestry sector.

Sweden and Finland, which rank in the top positions in terms of the market share of WCPs, do not export much of their domestic production of timber (all sectors) (i.e. 1% and 2%

[86] Industry association (1)

[87] Schuetze, T. (2018). Wood Constructions for Sustainable Building Renovation. In Advanced Materials Research (Vol. 1150, pp. 67-72). Trans Tech Publications Ltd.

[88] Sandberg, K., Orskaug, T., & Andersson, A. (2016). Prefabricated wood elements for sustainable renovation of residential building façades. Energy Procedia, 96, 756-767.

[89] Schuetze, T. (2018). Wood Constructions for Sustainable Building Renovation. In Advanced Materials Research (Vol. 1150, pp. 67-72). Trans Tech Publications Ltd.

[90] European Commission (2020) Using prefabrication to accelerate building renovation. Available here.

[91] BERTIM (2017) Legislative and regulatory requirements for the building renovation project. Deliverable 2.2. Available here.

respectively). This is not the case of other high-ranking countries such as Germany (still exports 10%), France (16%), and Poland (13%).

The use of sawnwood is decreasing both in relative and in absolute terms in use for residential construction in Europe, which is the construction sector where it has been used the most traditionally. Conversely, for structural elements, we observe an increase in the use of CLT and glulam, which offer more possibilities for usage than sawnwood, notably in high-storey buildings.

The use of OSB has grown significantly since 2000, and – to a smaller extent – so has the use of WFIB.

WCPs offer opportunities for building renovation, both for the renovation of building envelopes and for building extensions. Wood offers several benefits, notably due to its lightweight and high potential for prefabrication.

1.3. Enablers and barriers to an increase in the usage of wood in the construction sector

1.3.1. Methodology

Following the assessment of the current market share of WCPs, and in the view of understanding whether this share could grow in the future while using sustainably harvested wood, two elements are analysed in this chapter:

The potential of EU forests to increase the supply of sustainably-harvested wood for construction purposes. The analysis rests on data on EU forests gathered by an extensive literature review and on information collected via 30 interviews with market players (including 10 written answers), among which 15 were especially relevant to this part of the analysis (i.e. with forest owners, sawmills, and forest industry associations). The stakeholder consultations helped to identify some barriers to increasing supply as well as alternative solutions to increase the amount of EU-sourced wood available to the construction sector.

The potential to increase the demand of Wood-based Construction Products in the EU. We identified barriers and opportunities along the value chain through 30 interviews with EU market players (including 10 written answers). For the full list of interviewed organisations, see Annex 10.

1.3.2. Potential of EU forests to increase supply of wood for construction purposes and alternatives to increasing harvest

EU-level discussion

Table 4-1 presents an overview of the results found, grouped by regions following the Forest Europe (2020) classification (for the detailed assessment per MS, see Annex 10), regarding the potential of EU forests to increase harvesting.

Northern Europe already has relatively high felling levels, but presents the ambition to harvest more in the future, up to nearly the full increment in many countries. Barriers for increased mobilisation are only mentioned in the Baltic states and relate to the public opinion and strict management guidelines. About 20 million m^3 could be harvested extra annually in this region, about 34% of the additional potential found.

Central-West Europe is a rather heterogeneous group with a corresponding larger variation in felling/increment ratios. In total 26 million m^3 extra harvest potential (45% of the total) is reported for this region, with large quantities in Germany and France. The additional harvest is often reported to consist of mainly broadleaves and specifically beech. Mobilisation issues often relate to ownership (fragmentation, small owners, not active), lack of infrastructure, and difficult terrain conditions.

In Central-West Europe, Poland, Czech Republic and Slovakia have a current ratio of 75-85%. We have assumed a possible increase only in Poland . Both Czech Republic and Slovakia report problems due to the recent bark beetle outbreaks, which may cause an oversupply at the short term, and a reduction of supply of especially spruce in the mid to long term. Hungary, Bulgaria and Romania report ratios of 44-66%, potentially increasing to 53-75%. A lack of infrastructure, old fashioned equipment and low wood quality are main barriers, while other functions of the forest (nature conservation, protection forest) would prevent a further increase. The potential in this group is estimated at 11 million m3, 18% of the total.

Most countries in South-West and South-East Europe show low ratios of 20-50%. Some regions show higher ratios, connected to more favourable growing conditions. This includes Portugal, Galicia (Spain), Slovenia and Croatia. Not many studies are available for these regions, and a potential increase in harvest could be identified only for Slovenia. The low productivity and thus the low economic return and a lack of a strong forest industry and related demand is an important bottleneck in the whole Mediterranean Basin. Further problems relate to ownership, lack of infrastructure and difficult terrain conditions in the often mountainous areas.

Harvesting is currently concentrated in the regions and species where it is economically most viable. These include productive species like spruce and Eucalypt, in productive regions, with sufficient area and supply to sustain larger industries, and where harvesting can be done in a cost-effective way (in a mechanised way, gentle terrain, large owners). The majority of the reported extra potential is located in these regions (Northern Europe and Central-West Europe), with mobilisation barriers mainly relating to ownership issues, legal restrictions and the public opinion. Increased mobilisation in these regions may lead to a larger share of harvested broadleaves, as these are generally underused. An increase in supply from other parts of Europe will come at an increased cost, requiring investment in infrastructure and equipment especially in Central-East Europe, and general investment in the forest sector in Southern Europe. In all of Europe an increase in supply will be hampered by (increased) demand of the forest to fulfil other functions, such as recreation, protection of infrastructure and biodiversity conservation. Central-East Europe for example harbors a sizable share of areas hardly impacted by harvesting due its remoteness, and concerns exist of the effective protection of these forests against increased utilisation. In addition, it should be kept in mind (as mentioned above in § 3.2) that a fraction of current fellings is under-reported, due to self-consumption of firewood by small-scale forest owners (typically in France, South-West and South-East Europe), so that the reported fellings / net annual increment may under-estimate reality – and conversely that the potential for increased harvesting in these regions may be over-estimated.

It is thus unrealistic to assume that the felling/increment ratio can be raised to 100%. Based on the overview of the countries presented here, a ratio of 80-85% at maximum seems more likely, but strongly depending on the country. This would mean an increase in fellings of about 50-80 million m^3 overbark, an increase of 9-15% compared to the current felling level. After accounting for felling and transport losses, this would mean 45-72 million m^3 wood overbark available for the industry. Most countries don't give insights in the dimensions of the extra harvest. However, it seems likely that it will not deviate from the existing harvest, and may even contain larger diameters because many countries report imbalances in the current age-class structure with a bias towards mid-aged and mature forests.

Higher prices would be beneficial to overcome some of the barriers identified here. However, apart from stimulating domestic supply, this may well lead to increased imports from price-competitive regions outside the EU. Jonsson et al. (2021) studied a scenario with increased use of wood for construction, and found that an increase in consumption of coniferous sawnwood of 36 million m^3 by 2030 was satisfied only for 50% by increased domestic supply. The remaining 50% was imported, turning the EU from a net exporter to a net importer. This is similar to the work of Eriksson et al. (2012) where 60% of additional demand in a more extreme sawnwood demand scenario was imported from outside the EU. Studies focussing on the effect of increased demand for bioenergy found more possibilities to increase domestic supply, sourcing mainly more by-products from the industry and increasing the extraction of harvest residues (UNECE-FAO 2011; Forsell et al. 2016). If increased demand for sawnwood would need to be covered by domestic supply, additional measures are needed such as investments in infrastructure and equipment, and stimulating forest owners to engage actively in forest management.

Our results agree with orders of magnitude and patterns found in other studies. Verkerk et al. (2011) project a felling/NAI ratio in the range of 83-93% in 2030 in the EU, Switzerland and Norway, for three mobilisation scenarios (low, medium, high), based on a single projection model for all countries and constraints for stemwood extraction related to area under protection and lower supply from small forest owners. They identify the supply behaviour of small private owners as an influential factor in a sensitivity analysis, but also note that there is hardly any empirical data at the EU-level to support analyses on this topic. They also found the protected area to be influential in the sensitivity analysis. Verkerk et al. (2014), using the EFISCEN model, found that the supply potential decreased by 73 million m^3 of wood annually due to harvest restrictions in protected areas, a reduction of 10% compared to the maximum theoretical potential. We found a reduction of 21%, taking the net annual increment as the maximum potential, and taking into account all nationally identified constraints. Vauhkonen et al. (2019), using the EFDM model, found a reduction of 3.7% as compared to the baseline scenario when including restrictions on the felling as identified in NFIs for 7 EU countries. Since they do not estimate a theoretical potential and do not report increment, it is difficult to compare to our results. Kerr et al. (2017) found in the 11 case studies included about 30% of the apparent potential to be possibly mobilised with low or medium effort, which is very comparable to the 27% we found. Alberdi et al. (2020) found economic viability to be the main reason to classify forests as being not available for wood supply, followed by slope, accessibility and protected areas. Although this refers to the distinction between forest being available for wood supply or not, while we focussed on the are available for wood supply only, the conclusions on the main barriers to increased supply are very similar.

Current and future policies may restrict the supply even further. Dieter et al. (2020) investigated the effect of the implementation of the EU BioDiv strategy on the production of roundwood in Germany. When extrapolated to the EU level, they found a supply reduction of 32% in 2050 as compared to the business-as-usual scenario. Decreased domestic supply was largely compensated by increased imports from outside the EU. An increase in supply can also be hampered by considerations on the carbon sink function of the forests. The EU-LULUCF regulation (Regulation 2018/841) introduces a no net debit target for EU countries for the LULUCF sector. This is calculated as comparison between actual (future) carbon sequestration minus the sequestration under a Forest Reference Level (FRL), assuming “continuation of current maangement practices”. Nabuurs et al. (2018) studied the effect of different interpretations of the FRL on wood supply in Europe. They found that the wood removals could increase by 140 million m3 per year by 2050, driven by a progressing age class distribution and assuming current management practice per age class. The introduction of an additional constraint to limit the felling/NAI ratio for individual countries to about 90% reduced the increase in removals to 73 million m3 per year, comparable to our findings.

The numbers as presented in this report should not be interpreted as absolute estimates but are meant to give an impression about the orders of magnitude. Uncertainties are caused by differences in underlying methods of data collection in the countries, lack of harmonisation of terminology, differences in the definition of forest area available for wood supply, differences in projection methods and scenario assumptions per country, and rough assumptions for quite a few countries based on the area reported as being available for mainly wood production and area where other functions prevail. All reviewed modelling studies at the EU scale mention uncertainties on actual felling levels, increment, and area available for wood supply under different assumptions. Moreover, increment is not a static number. It varies from year to year depending on the weather conditions, shows long-term variability depending on (changes in) the age or size class distribution and the species distribution, and is influenced by the harvesting level as well.

The establishment of new forests (plantations) can contribute to the supply in the longer term, but is generally ignored in shorter term projections (Jonsson et al. 2018) as they will generally start to produce wood only after 20-30 years. Nevertheless, this supply solution is considered at EU level. The 2014-2020 EU Rural Development programs planned for the planting of 510 thousand hectares,[92] and although afforestation and reforestation were not explicitly included in the 2014-2020 EU Forest Strategy,[93] the forthcoming new strategy will include afforestation, forest preservation and restoration in the EU as key objectives.[94]

Trees outside forest do provide a certain amount of wood, but this is mostly used for fuel and lower quality applications, as dimensions and quality are generally poor. Moreover, the logistics to collect this wood are challenging, The EUwood study estimates this amount at 58.5 million m^3 in 2010, increasing to 73.5 million m3 in 2030 (Mantau et al. 2010).

[92] Climate-ADAPT (2019) Afforestation and reforestation as adaptation opportunity. Available here.

[93] EC (2013) A new EU Forest Strategy: for forests and the forest-based sector. Available here.

[94] European Parliament (2021) Legislative train schedule. Available here.

Table 4-7 Overview of bottom-up estimated mobilisation potential in EU27, including main species mobilised and main barriers if available.

Region	Country	year	NAI (1000 m^3 per year)	fellings (1000 m^3 per year)	current felling/NAI ratio	estimated realistic potential (1000 m^3 per year)	increased felling/NAI ratio	species	ownership	forest protection	infrastructure	equipment	wood quality	terrain conditions	wood demand	public opinion	management rules	workforce	forest productivity
North Europe	Sweden	2015	94843	89025	94%	0	94%												
	Finland	2015	96200	77348	80%	15000	96%												
	Denmark	2015	6608	4426	67%														
	Estonia	2015	12326	10221	83%	1579	96%												
	Latvia	2010	19680	12831	65%	1929	75%									x			
	Lithuania	2015	13580	9550	70%	1314	80%										x		
Central-West Europe	Ireland	2015	7291	4702	64%	2589	100%	mainly Sitka spruce	x		x								
	Germany	2015	104160	79663	76%	13500	89%	pine, oak, beech											
	Netherlands	2015	2156	1026	48%	0	48%		x	x									
	Belgium	2015	5291	5221	99%	0	99%												
	Luxembourg	2010	760	NA															
	France	2015	81375	48805	60%	8158	70%	mainly broadleaves	x		x			x					
	Austria	2015	27024	23534	87%	1745	94%	spruce, beech	x										
Central-East Europe	Poland	2010	62300	46600	75%	6230	85%												
	Czech Republic	2015	21696	18247	84%	-2747	71%	spruce											

Region	Country	year	NAI (1000 m^3 per year)	fellings (1000 m^3 per year)	current felling/NAI ratio	estimated realistic potential (1000 m^3 per year)	increased felling/NAI ratio	species	ownership	forest protection	infrastructure	equipment	wood quality	terrain conditions	wood demand	public opinion	management rules	workforce	forest productivity
	Slovakia	2015	12681	10000	79%	0	79%												
	Hungary	2015	10869	7201	66%	951	75%			x									
	Bulgaria	2010	14361	6972	49%	2363	65%	broadleaves		x	x	x	x						
	Romania	2015	41383	18164	44%	3724	53%				x	x	x						
South-West Europe	Spain	2010	35479	19707	56%	0	56%												x
	Portugal	2005	18870	13347	71%	0	71%		x									x	
	Italy	2010	32543	12755	39%				x		x			x	x				
South-East Europe	Croatia	2015	8863	6340	72%			broadleaves	x										
	Cyprus	2010	47	9	20%														
	Greece	1990	3813	1486	39%														
	Malta		NA	NA															
	Slovenia	2015	8565	5251	61%	1299	76%		x										
	EU27		**742764**	**532431**	**72%**	**57633**	**79%**												

* Current harvest levels in Czech Republic are higher than the planned felling levels due to high amounts of sanitation fellings

Note: Shown are the most recent figures for net annual increment (NAI) and fellings from Forest Europe, and their corresponding ratio. A realistic potential to increase the felling level based on a bottom-up review is presented, as well as the new fellings/NAI ratio when this new level would be realised. If available, an indication is provided on the species that will be mobilised, and the main barriers for increased mobilization in that country.

Conclusions from desk research

This study is based on a mixture of supply projections published by the countries, regional cases using a harmonised approach, and assumed availability based on the area under different types of protection or dedication to other forest functions. We found that the ratio felling/NAI could probably increase from the current (2015) level of 71% to 80-85% in the coming decade, which would mean removals of 45-72 million m^3 wood overbark available for the industry, and a relative increase of 9 to 15% compared to current levels. These would for a large part be sourced in regions where wood supply is already high, facilitated by existing infrastructure and presence of industry. Expected dimensions are similar to the existing supply, but containing a higher share of broadleaves (especially beech and oak). Countries in South-West Europe have a rather large forest area, but face a multitude of mobilisation barriers, including a low productivity, a weak forest sector, difficult terrain conditions and problems related to ownership size and attitude. National supply projections for these countries are lacking. Countries in the Balkans (South-East Europe and part of Central-East Europe) have more favourable growing conditions and thus higher supply potentials, but face problems related to infrastructure, outdated logging equipment and wood quality. Additionally, there are concerns in some countries about illegal logging and effective protection of near-natural forests. Increased biodiversity protection, for example following the EU BioDiversity strategy, may limit an increase in supply, and even cause a reduction. Also climate policies may influence willingness of countries to increase the supply, steered by considerations about consequences for the carbon sequestration potential of the forest, and pressure by NGOs and the general public. In the longer term however, reforestation and afforestation policies, including agroforestry practices and the greening of urban areas, performed for the sake of climate change mitigation (direct absorption of carbon dioxide by photosynthesis) and of climate change adaptation (local cooling effect of evapotranspiration) can increase the woody biomass available for harvesting. This is however a very long-term prospect (beyond 50 years).

Potential for increased harvest by species

The species permitted for use of structural timber (see Table 4-2) are discussed with regards to their distribution range and (potential) share in the harvest in future. This overview is largely based on the European Atlas of Forest Tree Species (San-Miguel-Ayanz et al., 2016).

Table 4-8 Summary of European softwoods and hardwoods permitted for stuctural timber (EN 1912:2020).

Softwood			Hardwood		
ID Num	Commercial Name	Botanical Name	ID Num	Commercial Name	Botanical Name
1	*Fir*	*Abies alba*	*75*	*Maple*	*Acer pseudoplatanus*
15	*Larch*	*Larix decidua*	79	Sweet Chestnut	*Castanea sativa*
16	*Larch*	*Larix eurolepis*	92	Eucalyptus	*Eucalyptus globulus*
17	*Larch*	*Larix kaempferi*	119	Beech	*Fagus sylvatica*
22	*Spruce (whitewood)*	*Picea abies*	*122*	*Oak*	*Quercus petraea*
28	*Spruce*	*Picea sitchensis*	*123*	*Oak*	*Quercus robur*
39	*British Pine*	*Pinus nigra*	*131*	*Ash*	*Fraxinus excelsior*
44	*Maritime Pine*	*Pinus pinaster*			
47	*Pine (redwood)*	*Pinus sylvestris*			
49	*Radiata Pine*	*Pinus radiata*			
50	*Poplar*	*Populus a*			
51	*Poplar*	*Populus nigra*			
54	*Douglas Fir*	*Pseudotsuga menziesii*			

Abies alba mainly grows at higher altitudes in Central Europe and the Balkans. It usually occurs in admixture with other species, and thus constitutes only a small fraction of the standing stock and the harvest. It is considered a valuable species for both the industry as well as for biodiversity. No increase in the relative share of this species in the harvest total is to be expected.

Larix leptolesis is a synonym for Larix kaempferi. For application purposes in the industry no differences exist between different Larix species. Larix is a pioneer species found at high altitudes in Central Europe, but it is also planted in Northwestern Europe and Scandinavia because of its fast growth and durable wood. However, it proves to be susceptible to a shortage of water, which may be a limiting factor for cultivation under future climate conditions. It is in high demand for the industry, and is currently already harvested intensively. No increase in the relative share of this species in the harvest total is to be expected.

Picea abies is a very common coniferous species, originally growing in the mountain ranges of Central and Eastern Europe and throughout Scandinavia, but planted far outside its natural range mainly in Northwestern Europe. It is highly productive and in great demand with the industry. It is sensitive to the European spruce bark beetle (Ips typographus) that can kill mature trees under certain conditions. In the past, such outbreaks tended to be local, connected to the availability of downed and weakened trees after storm events. Nowadays outbreaks occur at much larger scale, driven by unfavourable summer conditions. This will form a severe threat to the future of this species, first of all in the areas where it was planted outside its natural range. Salvage fellings in Czech Republic for example are estimated to be twice as high in recent years compared to the usual annual harvest quantity. In the short term this may lead to an increased supply in some countries, but in the longer term its share in the total harvest may be reduced.

Picea sitchensis is an introduced species and is mainly grown as plantations in Ireland and the United Kingdom, where it dominates the wood production. It is highly productive and produces high quality timber. A large share of the recent afforestation in Ireland was done with this species, and as these plantations mature, a higher supply can be expected.

Pinus nigra is a pioneer species growing mainly in the Mediterranean Basin, but is planted widely elsewhere in Western and Central Europe. Its wood is valued by the industry. Only if increased mobilisation efforts in Southern Europe are successful, could its share in the harvest be increased. Outside this area, it will form a marginal part of the harvest.

Pinus pinaster mainly grows in Portugal, Spain, South-western France and Italy. In these areas it is an important commercial species, especially in Les Landes (France) where it supports a major timber industry. Increased mobilisation efforts mainly in Portugal and Spain could increase the future share of this species in the harvest.

Pinus sylvestris is the most common tree species found in Europe and grows nearly everywhere. The wood is valued by the industry for a variety of purposes, including construction. However, the intensity of management seems to vary across Europe, with in some regions (like Western Europe) a tendency to being under-utilized. This is partly connected to the importance of other forest functions in these areas, but also by a lack of (perceived) quality compared to the high-quality timber produced in Northern Europe. Increased mobilisation efforts could well lead to a higher share of this species in the future.

Pinus radiata, also known as Monterey pine, is a native species to North America. It was introduced in Europe in the 19th century. Since then it’s mainly cultivated in Spain, where it is an important species in the total harvest of conifers, and small areas in Italy. It is mainly used for sawlogs, and grown in mixed plantations and agroforestry.

Pseudotsuga menziesii was introduced from the West Coast of North America to (Western) Europe in the 19th century. It proved to be a very productive species producing high-quality timber. In some countries it is seen as a possible substitute for the cultivation of Norway spruce, although regulations may sometimes limit the use of this species for tree planting. It may well increase its share in the future harvest.

Populus alba mainly grows in Central and Southern Europe. It is not considered an important commercial species.

Populus nigra has a wide distribution range in Europe (except Scandinavia), but is only found sparsely. It is considered as a threatened species, and will hardly contribute to the future harvest.

Acer pseudoplatanus grows in the temperate and mountainous zones of Europe, from Ireland to Poland and the Balkans. Although having a high productivity and nice timber, it covers only a small fraction of the current growing stock in Europe.

Castanea sativa originally grows in the Mediterranean Basin, but is cultivated in Western Europe for millennia. The main forests of this species are located in Italy, France and the Iberian peninsula. Its wood is very durable and used for outdoor purposes. Its share in the total harvest is very modest, and not expected to increase much in future.

Eucalyptus globulus is an introduced species which is mainly grown in plantations in Portugal and Galicia. It is mostly used for pulp production, using a coppice system with a rotation length of 8-12 years. It is therefore unlikely to show a higher share in the future harvest.

Fagus sylvatica is a widely distributed species in Europe, growing in temperate and mountainous conditions and being absent in Mediterranean and boreal conditions. It is a shade-tolerant species, able to invade existing stands and dominate the forest in the longer term. In Central Europe it is admixed in Norway spruce stands to increase the diversity and resilience of these stands. Also in other regions it increases its share, either by natural processes or as actively to increase tree species diversity. It has a very diverse range of usages in the industry, but is also a preferred species for fuelwood. In many regions it is an underutilised species, which a clear potential for an increase in harvest level. In some areas the wood quality may be a limiting factor for usage.

Usually no distinction is being made between Quercus robur and petraea, although they have slightly different ecological requirements. It has been of great value in Europe, in terms of timber production, fruit production for cattle, firewood, and also culturally. They are widely distributed but do not grow in boreal and Mediterranean climate. In general their potential is underutilised, but an increase in harvesting is hampered by wood quality issues, especially in those areas formerly managed as coppice.

Fraxinus excelsior grows all over temperate Europe, but its' share in the area and growing stock usually does not exceed 5%. It suffers heavily from a recently occurring disease (Chalaria fraxinea) and is expected to be decimated in the near future.

We estimate that 80-90% of the additional harvest will be of species suitable for construction, and thus that the increase in potential remains at 13%. The major thing to note is that the additional part will contain relatively more broadleaves (especially beech and oak) and less conifers (pine and spruce) than the current harvest.

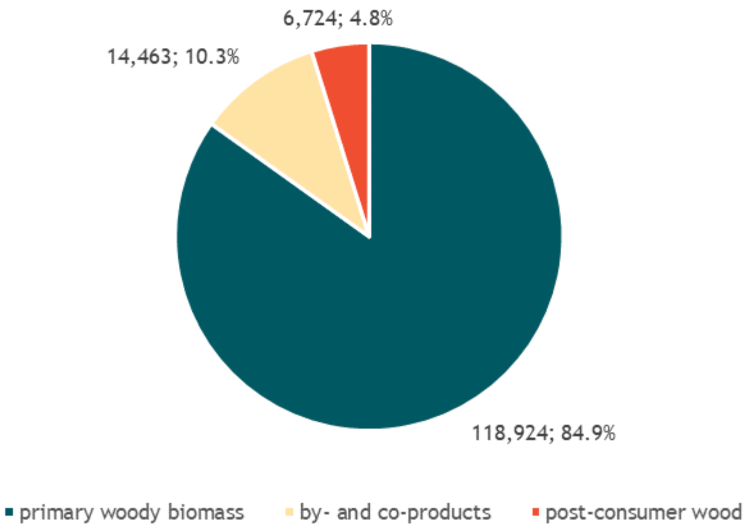
The other 10-20% of the harvest consists mostly of broadleaved species. In the northern part of Europe this is birch (Betula spp.) and to a lesser extent alder (Alnus spp.) and willow (Salix spp.). Good quality birch is used for plywood and furniture, with the remainder being used as pulpwood and firewood. Alder can be used for joinery and veneer, but is most often used for firewood. It is not strong enough for use in heavy construction. The fast growing Salix spp. can be grown in short rotation coppices for biomass (bio-energy) production, but also occurs as admixture in the forest and as a pioneer invading disturbed sites. Its wood is not suitable for construction purposes. Eastern and Southern Europe harbor a variety of other oak species, such as Quercus ilex, Q. suber, Q. pyrenaica, Q. cerris, Q. pubescens and Q. frainetto. The wood of most these species have traits that make them less suitable for construction purposes, but many are used as firewood. At least Q. frainetto is reported to be used in construction in the past. Additionally, these regions host more Pinus species, such as Pinus brutia, P. halepensis and P. pinea. These are used for pulpwood and firewood, but could likely be suitable for construction purposes as well. Their share in the total harvest is however small. In mountainous regions additional pine species are found such as P. mugo and Pinus cembra. These are only used for firewood, due to their small dimensions and because they grow in high elevations where harvest is more difficult and costly. Carpinus betulus is a broadleaved species of the temperate zone, usually mixed in stands with other broadleaves. The wood is tough and dense, which makes it difficult to work, but it is valued as firewood. Robinia pseudoacacia is a species introduced from North America and distributed quite widely in Europe. In several parts of Europe it is considered an invasive species. Its wood is used for furniture, veneer, fences etc. but can also be used for pulpwood. It may be suitable for construction purposes as well. These less common species often occur only under specific conditions and/or as an admixture in the forest. As such, they are generally important for biodiversity. In the view of adaptation to climate change, these species could be important to increase the number of tree species per stand to increase the resilience. Increased use of these species in the forest may lead to a somewhat higher supply in future, but this will take many decades. Most of these species are not or less suitable for construction purposes, but used instead for local applications and often as firewood.

Potential for recycling and consumption of recycled wood

The circularity of biomass flows manifests itself as **post-consumer wood** (i.e. wood and wood products made available for re-use or recycling), but also the supply of **by- and co-products** along the value chain (i.e. bark as by-product from industry processes, sawmill by-products, black liquor, wood pellets and other industrial residues). Latest EU data shows that the supply of post-consumer wood into biomass flows amounts to 16,889 thousand tonnes of dry matter, among which 6,724 thousand tonnes (i.e. 39.8%) is used in solid wood products manufacturing, and 10,165 thousand tonnes (i.e. 60.2%) is used for heat and power generation. By-and co-products are for the vast majority used for heat and power generation (102,252 thousand tonnes of dry matter, or 76.5%), 14,463 thousand tonnes (i.e. 10.8%) used for solid wood products manufacturing, and 16,871 (i.e. 12.5%) used by the pulp industry (see Figure 3-2). The contribution of the two flows, as well as of primary woody biomass, to the manufacture of solid wood products (i.e. WCPs but also furniture and other wood products) is depicted in Figure 4-1. It shows that a large proportion of the biomass derives from primary sources.

Zooming in on post-consumer wood from construction and demolition (C&D), BTG estimated that about 1,200 to 2,400 thousand tonnes of wood waste from construction (i.e. offcuts, broken pieces, casings or support structures) was recycled in 2010 in the EU27+UK, and 16,000 thousand tonnes of wood waste from demolition. Instead of being recovered separately, demolition waste is often collected, managed and disposed in a mix with other C&D waste.[95]

Figure 4-23 Source of biomass used for the manufacturing of solid wood products, EU27+UK, 2015. Adapted from: JRC[96]



The panel industry is already heavily reliant on co- and by-products, a point which was confirmed in the stakeholder consultations.[97] Recycled wood can be used for WCPs manufacturing in the following ways:

Wood from formwork from construction can be recycled to produce cement-bounded particleboards of high strength, light weight, and thermal/noise insulation for reuse in building and construction applications.[98]

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[95] Vis M., U. Mantau, B. Allen (Eds.) (2016) Study on the optimised cascading use of wood. No 394/PP/ENT/RCH/14/7689. Final report. Brussels 2016. 337 pages.

[96] European Commission (n.d.) Biomass flows. Available here.

[97] Industry association (1)

[98] Wang, L., Chen, S. S., Tsang, D. C., Poon, C. S., & Shih, K. (2016). Value-added recycling of construction waste wood into noise and thermal insulating cement-bonded particleboards. *Construction and Building materials*, *125*, 316-325.

Non-impregnated wood can be used to produce particleboard.[99] For instance, MDF, MDP, plywood and timber recovered from C&D can be used to produce the inner layer of MDP (medium-density particle board) products.[100]

Houses with prefabricated wooden components are mainly built with untreated wood, and thus can be reused as product or material in different ways.[101] For instance, OSB could be made with this type of recovered wood, although as the size and species from recycled wood will likely vary, so will the cleanliness of the material used.[102]

In a literature review of 41 peer-reviewed publications, Jarre et al. (2020) identified several main factors influencing the circularity of woody biomass, which are thus relevant to increasing the stock of post-consumer wood used to produce WCPs:

Policy barriers:

Policies on wood regulation can restrict wood recycling due to the potential presence of chemical compounds and pollutants (e.g. surface contamination with lead-based paint, nails, stones, plastic, gypsum, and concrete; or impregnation with preservative or fire-retardant chemicals).[103] In addition, identifying these contaminants is complex. Some countries such as Germany and Finland have classifications based on wood treatment, chemical additives and components that determine a suitable end of life for the product (material use, energy use, non-hazardous disposal). Often, wood suitable for reuse is sent to incineration because legislation leaves this option open.

Policies on energy production may limit the potential for reuse or recycling as WCP, while incentives for the reuse of wood as a WCP are insufficient or lacking.

Economic barriers:

In addition, reusing post-consumer wood into new products presents more market risks as the additional processes required compared to reuse for energy generation are more complex (wood recycling or reuse requires additional sorting, cleaning, chemical or mechanical treatment, and additional administrative work). These additional step add up to the final costs, and contribute to make recycling into WCPs less economically competitive.

Technical barriers:

The problem of product design is particularly relevant in the building demolition sector, as building elements are usually tailored to the specific building's needs and not constructed for reuse. This makes the disassembly and reuse of building components difficult when wood is incorporated into construction elements. A deep level of knowledge is needed at the design, construction and deconstruction phases to address this problem.

Physical characteristics of the wood waste product, and notably the presence of chemicals, the wood quality, and the particle size, limit the reuse possibilities. As mentioned previously, wood can only be reused if it is not contaminated with harmful substances, which is problematic as wood is often treated with poisonous chemicals to reduce risk of mould or

[99] BTG biomass technology group (2014) Cascading in the wood sector. Available here.

[100] Azambuja, R. D. R., Castro, V. G. D., Trianoski, R., & Iwakiri, S. (2018). Recycling wood waste from construction and demolition to produce particleboards. *Maderas. Ciencia y tecnología*, *20*(4), 681-690.

[101] BTG biomass technology group (2014) Cascading in the wood sector. Available here.

[102] Falk (1993) Building Products From Recycled Wood Waste. Available here.

[103] Falk (1993) Building Products From Recycled Wood Waste. Available here.

impregnation against insects.[104] Contamination due to adding spray foam in corners, added glue between panels or (chemically) treated materials can also make wood frame constructions difficult to disassemble.[105]

Adequate infrastructure needs to be in place (waste wood collection, sorting facilities and technologies). In some places, infrastructure is much better developed for incineration. Other factors are detrimental to the reuse of wood for WCPs compared to incineration: high costs are involved in the chemical analyses, high losses occur during sorting and recycling operations, and there exists logistical difficulties to the collection of waste wood and its transportation from a collection site to a recycling facility and then, to a distribution network. These logistics-related difficulties significantly influence the overall costs.

Determining the environmental impacts of different uses thoughout their life cycle is challenging, including due to a lack of data on potential benefits.

Stakeholder barriers:

It is difficult to make producers responsible for managing the disposal of their products when they have a long lifespan, which is especially relevant for demolition waste. One way forward could be to create policies on product design or on the sharing of information related to the quality parameters of specific products.

In the case of co- and by- products (i.e. mainly from the sawmill stage of the value chain), less barriers faced by recycling would not apply (e.g. no need for treatment and less contamination). Nevertheless, some of the technical constraints could remain relevant, for instance the presence of infrastructure for processing close into EWPs close to the sawmills and determining the environmental impacts of different uses.

Potential to re-direct woody biomass from other industries

Woody biomass is used by several EU industries: the construction industry (in the form of various WCPs), the pulp and paper industry (including packaging), the furniture industry, and the bioenergy industry (also see Figure 3-1). Whereas the carbon embedded into wood furniture can be stored in a scale of decades, the use of woody biomass for energy generation or for the pulp and paper industry has a much shorter lifespan, which makes a compelling case for diverting some of of the use from these two sectors to the production of WCPs. It is noteworthy to stress, nevertheless, that carbon emissions and storage benefits depend on a variety of factors, among which transport, what woody biomass is replaced with in the pulp and bioenergy sectors (and whether the sectors turn to imports from countries with weaker sustainable forest management practices), waste separation and treatment (especially in the case of post-consumer wood), the length of storage in the products, and what happens to the products after being used (landfilling, recycling, etc.).[106] Finally, in the case of the furniture, re-directing EU woody biomass may contribute to the decline of a sector also important for the bioeconomy, as it already faces enormous competition from countries with lower production costs.[107] This makes the bioenergy industry and the pulp and paper industry more interesting candidates to divert woody biomass use.

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[104] Hafner, A., Ott, S., & Winter, S. (2014). Recycling and end-of-life scenarios for timber structures. In *Materials and joints in timber structures* (pp. 89-98). Springer, Dordrecht.

[105] Lindeløv and Lange (2019) The selection of 3 renovation packages: The decision making process for selecting the renovation packages. Available here.

[106] Research organisation (1)

[107] European Commission (n.d.) Furniture industry. Available here.

In 2015, at least 37% (166Mm^3) of the woody biomass used by the bioenergy industry came from primary wood, with 4% of industrial roundwood in the sector's total consumption, and 24% of fuelwood (i.e. main stems normally of lower quality than roundwood used for industrial purposes, branches, and tree parts). At least 49% (223Mm^3) of its woody biomass consumption came from secondary wood. Also of relevance to competing use with the WCPs sector, 5% (22Mm^3) of total use derives from post-consumer wood, and 21% (94Mm^3) from domestic solid by-products.[108] Adding up the sector's use of primary wood, post-consumer wood and by-products, there is an approximate total of 282Mm^3 of biomass used annually by the sector, which could – in theory - be used to produce WCPs instead. As visible in Figure 3-2, the pulp industry mainly consumes primary woody biomass (55,965 thousand tonnes of dry matter in 2015, or 71.3% of its total woody biomass use), for 16,871 thousand tonnes of by- and co-products (21.5%). There is therefore also competition for by-products with the pulp industry.[109]

It is however unrealistic to expect that the total amounts of biomass that could be re-directed from these two sectors to WCPs production will be. The obvious primary reason is that these sectors produce goods currently needed, so that some demand will remain. In addition, not all the biomass from the aforementioned flows could be used to make structural WCPs. For example, fine wood chips used to make particleboards and fibreboard (and sawdust as well for fibreboard) could not be used to manufacture CLT or glulam. Finally, as elaborated upon in section 4.3.3 with the case of bioenergy, the potential for the WCP manufacturing sector to compete for by- and co- products and post-consumer wood depends on a variety of factors.

Considering that the effects of re-directing large amounts of woody biomass from the bioenergy and pulp industries are highly uncertain, and considering that such a scenario is also dependent upon demand for various products and the capacity of the WCPs value chain to process a larger variety of primary materials, it is difficult to quantitatively estimate a desirable and feasible amount to be redirected from bioenergy and pulp. Here, the case for a reliable quantification of carbon sequestration can be stressed (see also section 4.4.4), and so is the need for some modelling to obtain proper estimates, based on several policy options focusing on the three sectors.

Insights from the stakeholder consultations

Most interviewees with whom we discussed supply options for an expanding WCPs market believed that EU forests could increase their wood supply to match growing demand. The argument given by several forest owners, sawmill operators, wood industry associations and technical institutes was that at an aggregate level, European forests are under-exploited, and therefore harvesting levels could increase in a sustainable way in some areas, including where wood has been difficult to reach. Some interviewees also argued that there was a possibility to increase harvest in their country of operation. Sweden was discussed as one such example by three interviewees.[110] For instance, a large forest owner and WCP manufacturer explained that while the company cannot produce more sawn timber from its own forests, it could buy wood from other regions in Sweden if it needed to scale up production.[111] This opinion stands in contrast with results from our own analysis, which show no potential for increased harvest in the country (Annex 9). Industry associations from

[108] JRC (2021) The use of woody biomass for energy production in the EU. Available here.

[109] JRC (2021) The use of woody biomass for energy production in the EU. Available here.

[110] Industry association (1); forest owner/forestry (1); producer/trader of WCPs (1)

[111] Producer/trader of WCPs (1)

Germany, the Netherlands and France also expressed confidence that sustainable harvest could be increased in their respective countries to match a growing demand for WCPs. While we found that an increase in harvesting is possible in Germany and France, such prospects are dimmer for the Netherlands (Annex 9).

Conversely, a more limited number of market players believed there was little or no potential to increase harvest. One industry association argued that this potential is limited because Finnish policies aim to freeze the cutting levels and set aside big forested areas. Conversely, our analysis suggests a potential for increased harvesting in Finland (Annex 9). Similarly, in Romania, an industry association explained that stricter environmental regulations have led to a downward trend in harvest levels, which is not expected to be reversed, while we found a potential for increased harvest, albeit a small one (Annex 9). While one interviewee from an international sawmill operator and forest owner saw some potential to increase harvest in Europe, another from the same company disagreed when providing us with written feedback, examplifying the diversity in viewpoints expressed during the consultations in this respect.

Several barriers to the increase in supply from EU forests were discussed during the consultations:

Some regulations, especially the **conflicting EU policy objectives of nature conservation and wood production**, were viewed as impediments by some market players.[112] This problem is also identified in academic literature (section 4.2.1). An interviewee from a resource institute argued that environmental targets such as the target from the EU Biodiversity Strategy to 2030 to protect 30% of land and sea area will lead to an increased reliance on imports from countries where sustainability is insufficiently regulated (e.g. Russia, South America), and simultaneously negatively impact EU economies heavily reliant on their (sustainable) forestry sector such as Finland.

Difficulties linked to **fragmented forest ownership** were discussed in the contexts of France and Germany.[113] The portion of small forest owners is significant in both countries, and most of these small owners manage their forest as a heritage, rather than as a resource. This was deemed to be an important untapped reservoir, although these small owners may be difficult to incentivise. This point corroborates findings on Central West Europe from existing literature, and desk research also pointed to the existence of this problem in South-West Europe (section 4.2.1).

Geographic constraints mean that some forest resources are hard to reach (e.g. mountainous areas).[114] According to one interviewee from an international sawmill operator and forest owner, a proportion of this resource could be accessed with more infrastructure and better competences. Desk research also pointed to geographic constraints, more specifically in Central-West South-West Europe, as well as to the lack of appropriate infrastructure in parts of Central-West and South-East Europe (section 4.2.1).

Climate change was discussed by some stakeholders, who pointed to several changes. Centrum Hout expects that the construction sector will need to adapt in the next decades due to changes in species composition. One forest owner confederation stated that emergency harvests are sometimes needed due to droughts and bark beetles, which lead to high spikes of wood amounts coming suddenly onto the market without the industry being prepared. If the logs are harvested quickly, large amounts can be stored under wet conditions, preventing the wood from deterioration. Stored volumes can be sold over the

[112] Industry association (1); school/technical institute (1); forest owner/forestry (1)

[113] School/technical institute (1); industry association (1)

[114] School/technical institute (1); forest owner/forestry (1)

subsequent years, allowing a more even flow of timber on the market, reducing price effects, and making sure the wood is used in an optimal way. However, such storage comes at a price as well, and large-scale facilities and equipment need to be made available at short term.[115] This problem was also identified in some parts of Central Europe during desk research (section 4.2.1). Holzindustrie explained that the quality of wood harvested in Germany has decreased in the past three years, due to climate change leading to more diseases. Hence, it has become increasingly difficult for the industry to produce high-quality timber. On the other hand, the change from softwood to mix forests to increase climate resiliency represents an opportunity to harvest this additional softwood in the next two decades.

Competition from agriculture was mentioned as a barrier by a confederation of forest owners, which can curtail the effectiveness of re-planting initiatives as they find it difficult to find space.

All the barriers identified during the stakeholder consultations were also discussed – to some extent – in academic literature reviewed in section 4.2.1, with the exception of competition for land-use from agriculture. A few additional points made in existing studies were not discussed: opposition from the general public, low productivity and a weak forest sector in South-West Europe, and low wood quality in Central Europe and the Balkans. The lack of mention of the two latter points can be explained by the fact that most stakeholders who agreed to participate in the consultations were located in Northern and Western Europe.

In addition, several solutions to increase the share of wood available for the construction sector without increasing EU harvest nor imports were brought up during the stakeholder consultations:

Reliance on **wood from other varieties** could be scaled up, as well as **the use of different parts of the tree, trees with smaller diameters, damaged trees, and trees of overall lower quality**. Several market players highlighted that research is either underway or desirable to study the possibilities to use hardwood species more extensively (e.g. birch, beech).[116] At present, hardwood (harvested in Europe or elsewhere) is also harvested for use by the furniture industry and for energy generation,[117] and findings from section 4.3.4 pointed to the possibility to re-direct some of this share to the WCPs industry. Any additional harvest compared to current levels would need to follow sustainable forest management practices that ensure that soil and biodiversity are not adversedly impacted. As the choice of species is highly dependent on location, hardwood is not expected to be processed in parts of Europe where it does not grow.[118] It is technically possible to use either wood damaged (by bark beetle or blue stain fungi) or softwood of inferior quality in CLT for the internal layer, although the residential market sometimes demands premium quality only (e.g. in Sweden).[119] One Swedish industry association reported that the country's sawmills have drastically increased their production of CLT and see financial benefits from producing more engineered wood products more broadly speaking, as it enables them to redirect some lower quality wood that usually goes in low-value products such as paper.

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[115] European Forest Institute (2013) Living with Storm Damage to Forests. Available here.

[116] School/technical institute (1) ; industry association (4)

[117] Sawmill (1); industry association (1)

[118] Industry association (1)

[119] Industry association (1)

To facilitate this last point, **capacity and resource efficiency in sawmills could be increased**.[120] As visible in Figure 3-1, a large share of the wood being processed in sawmills ends up being burned. One industry association had a rather positive view on sawmills' technical capacity to use that resource more efficiently, although the interviewee highlighted the high investment costs needed, which may prevent smaller sawmills from doing so. Efficiency gains can also be made by setting up new infrastructure for engineered wood products at the same location as traditional sawmills.[121] Conversely, in France, a technical centre noted that despite recent progress and significant investments in sawmills, the country still imports a lot of sawn timber while it exports logs because of a mismatch between the average quality of wood produced by French sawmills and what is required by the construction sector.

Increasing the speed at which trees grow was discussed as a way where research and investments into sustainable forest management practices could help forests to become more productive.[122]

The use of recycled wood - which is already used to make panels quite extensively[123] - could be increased, although the practice remains sporadic and not very efficient at scale in construction.[124] Recycling wood from construction and demolition waste presents technical and logistical issues, notably on-site sorting, getting the material to the right sawmills, and treatment.[125] In light of these difficulties, a Swedish demolition and recycling firm argued that incentives to increase the value of recycled materials should be established, including in order to stimulate their use in construction so as to boost demand.[126] One forest owner and WCP manufacturer explained that circularity could also be enhanced by design support (info, tools etc.), including in order to facilitate end-of-life reuse (i.e. design for deconstruction).

Redirecting exports initially aimed for outside the EU was mentioned as a solution to increase local supply,[127] and was seen as beneficial because of the low risk associated with intra-EU trade.[128]

Increasing the share of wood going to construction by diverting some wood currently going to other industries such as pulp, furniture, pellets, energy and biofuels was discussed.[129] There would be climate benefits associated as wood would have a longer lifespan in buildings. One industry association pointed that current subsidies supporting biofuels are detrimental to WCPs.

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[120] Industry association (1); sawmill (1)

[121] Industry association (1)

[122] Industry association (1); forest owner/forestry (1)

[123] Industry association (1)

[124] Forest owner/forestry (1); demolition/recycling (1)

[125] Forest owner/forestry (1); demolition/recycling (1)

[126] Demolition/recycling (1)

[127] Industry association (3)

[128] Industry association (1)

[129] Industry association (2); sawmill (1); producer/trader of WCPs (1)

1.3.3. Potential to increase the demand for Wood-based Construction Products in the EU

This section begins by introducing recent research on the future outlook for WCP demand. This is followed by an overview of the major barriers to increased demand, which highlights how uncertain this future demand is, as well as policy recommendations on how these could be overcome. In addition to addressing the identified barriers, the study explores major benefits and selling points of WCPs, including the economic valuation of climate benefits, and how policy could capitalise on those to boost demand.

Future outlook for primary and secondary wood products demand

A recent study conducted by Jonsson et al (2021) modelled developments in consumption and trade of wood products in the EU under an ambitious scenario for the growth of the wood construction sector. Its results are not used here as a prediction of the future situation by a certain time, as market developments are highly uncertain and would be influenced by future policies. Rather, it helps to understand how much more timber products would be consumed under a certain increase in use by the sector.

The study finds that, if the wood construction quota (related to total area of residential floor space) increases by 9.1% between between 2015 and 2030, such a hike in demand would translate into a significant increase in the consumption of coniferous sawnwood (all sectors), compared to business as usual (BAU) (see Table 4-3).

In their conclusions, Jonsson et al (2021) find that the EU would become a net importer of coniferous sawnwood, which does not happen under the BAU scenario. Based on our analysis, we find that – in theory – this amount could be provided by EU forests (as the predicted increase in consumption is below the 45-72 million m^3 estimate), although only if the industry transitions to a more heavy reliance on hardwood species. However, considering current trade (both exports and imports), it is not realistic to expect all wood for WCP manufacturing in the EU to be supplied by EU forests.

Table 4-9 Consumption of selected wood-based products by 2030, based on a BAU and a high increase in wood construction scenario (in Mm^3 under bark). Source: Jonsson et al (2021)

	Consumption 2030 BAU	Consumption 2030 with increased WCPs use	Difference with BAU
Coniferous sawnwood	92.5	128.8	+36.2
Non-coniferous sawnwood	11.5	11.7	+0.2
Plywood	7.8	7.7	-0.1
Particle board and osb	36.8	41.4	+4.6
Fibreboard	16.4	16.8	+0.4

Main benefits and selling points of Wood-based Construction Products

The following benefits and selling points were identified during the stakeholder consultations:

Sustainability was the most-often cited aspect, notably the renewable nature of wood, its low carbon footprint and CO_2 storage capacity, and the reduction of waste and number of trucks needed during the construction process compared to conventional materials.[130] This sustainability benefit however varies, in some circumstances very significantly, per nature of CLT, as can be seen in below, which shows that the benefit compared to concrete may be not as high as what would be intuitively expected.

Table 10 Greenhouse Gases Emissions of some Wood-based Construction Products, compared to mineral-based materials[131]

Nature of the material	Embedded GHG emissions
Beam, hardwood, raw, air drying to u=20%, Europe without Switzerland	51.2kgCO_{2eq}/m^3
Beam, hardwood, raw, kiln drying to u=10%, Europe without Switzerland	72.8kgCO_{2eq}/m^3
Beam, softwood, raw, air drying to u=20%, Europe without Switzerland	41.3kgCO_{2eq}/m^3
Beam, softwood, raw, kiln drying to u=10%, Europe without Switzerland	56.9 kgCO_{2eq}/m^3
Glued laminated timber production, average glue mix, Europe without Switzerland	140.4 kgCO_{2eq}/m^3
Cross-laminated timber production, RER	147.4 kgCO_{2eq}/m^3
Concrete production, for building construction, with cement CEM II/A, CH	203.11 kgCO_{2eq}/m^3
Steel production, electric, low-alloyed, Europe without Switzerland and Austria	0.56 kgCO_{2eq}/kg
Clay brick production, RER	0.24 kgCO_{2eq}/kg

Some market players noted that they mostly use certified wood (PEFC and FSC) for WCPs/projects because when customers opt for a wood building, they want guarantees of the sustainability of the material.[132] Stora Enso also explained that the environmental product declarations they have developed are very appreciated by their customers, further highlighting end-users' appreciation for transparency when companies promote the sustainability of their products. One project and building owner argued that buyers more commonly require wood compared to people who seek to rent a dwelling, whose decisions are more cost-driven.[133] A couple of interviewees however believed that sustainability is less important than costs, with the influence of sustainability expected to increase thanks to a generational change in home buyers and architects.[134]

Several benefits at the construction phase were identified, in comparison to conventional construction methods:

The **speed of construction** increases when using WCPs, with some interviewees specifically refererring to the potential offered by prefabrication in this respect.[135]

Interesting properties of WCPs were discussed, including their light weight, strength, and the possibility to have thinner foundations. The properties of WCPs **lead to benefits for**

[130] Industry association (3); school/technical institute (1); forest owner/forestry (2); producer/trader of WCPs (1)

[131] Source: Eco-Invent Database ##

[132] Sawmill (1); producer/trader of WCPs (1); industry association (1)

[133] Project owner (1)

[134] School/technical institute (2); industry association (1)

[135] Producer/trader of WCPs (1); technical institute/school (2); industry association (1); forest owner/forestry (1); architect/construction engineer (1); government body (1)

those living around the construction site, including the need for smaller cranes, less truck traffic, and less noise.[136] The Finnish Ministry of Environment also mentioned that when working with wood, construction workers tend to enjoy the process more, and tend to be more satisfied with the end-result.

Improved health and safety due to the use of WCPs compared to other materials are experienced because WCPs are lighter, produce less dust, and make construction sites less noisy.[137]

Health and safety benefits derived from living in the building linked to better indoor air quality and well-being were also mentioned.[138]

Wood buildings can be **seen as trendy and chosen for architectural and aesthetic aspects**.[139]

Wood buildings can present some **interesting properties in terms of thermal resistance/insulation**[140] **and soft acoustics**.[141]

The benefits identified may be best utilised at different levels in the value chain. Sustainability is especially important to emphasise to the designers (architects, engineers) and buyers (project owners, end-owners). Designers' interest of – and knowledge in – sustainable building practices with wood may influence an undecisive project owner to choose wood as a building material.[142] But ultimately, the interest in sustainability of the project owner and the (perceived) interest of the end-users are fundamental to the decision. The relative weight ascribed to sustainability concerns compared to costs will impact that decision. Benefits during the construction phase are not so relevant when considering how to drive-up demand from end-users, but could be used as selling points to workers in the construction sector, especially in light of the construction industry's conservative attitude to the adoption of new materials (see section 4.4.3). All other benefits mentioned (health and safety in the building, aesthetic aspects, insulation and acoustics) may be good selling points to end-users, depending on the location and end-use of the building. For instance, indoor air quality may be an especially good selling argument for school buildings.

Main barriers to the use of Wood-based Construction Products

Several barriers were identified during the consultation process. Interestingly, some of those were seen as only misperceived barriers by some players along the value chain, who argued that insufficient knowledge contributed to the persistence of negative assumptions about WCPs among potential buyers (both project owners and end-buyers).[143]

The following arguments against WCPs were discussed by interviewees:

Fire safety (also see Box 4-2) was widely seen as a misperceived risk (particularly because of technological developments in wood-based construction products and their assembly), yet

[136] Producer/trader of WCPs (1); technical institute/school (1); forest owner/forestry (1); architect/construction engineer (1)

[137] Forest owner/forestry (1); architect/construction engineer (1); government body (1); technical institute/school (1)

[138] Industry association (1); forest owner/forestry (1); government body (1)

[139] Industry association (1); forest owner/forestry (1); architect/construction engineer (1)

[140] Forest owner/forestry (1); architect/construction engineer (1)

[141] Industry association (1)

[142] Technical institute/school (1); industry association (1)

[143] Producer/trader of WCPs (1); technical institute/school (1); industry association (3)

very prevalent amongst potential buyers of WCPs.[144] As explained below, this can lead to higher costs and barriers to the development of skills and know-how in the sector (particularly for high-rise buildings).

Acoustic insulation/performance was seen as the major technical challenge associated with WCPs by one technical centre, while an industry association stressed that acoustic insulation issues can be designed out, provided that engineers and architects have the right skills and that the decision to build with wood is made early in the project, in order to find the right people to work on the project. Acoustics was therefore discussed as a perceived barrier, a technical challenge, and a benefit by different interviewees.

Moisture was also mentioned, although less so than fire safety and acoustics, and including once explicitly as a misperceived risk.[145] Due to the rain, wood buildings need to be covered with tents during the construction phase and they cannot be built all-year long in certain parts of Europe, which creates difficulties.[146]

Issues related to **durability** were viewed as a misperception by some stakeholders.[147] However, one large building owner in Sweden mentioned some extra requirements related to maintenance in wood-based buildings (e.g. related to moisture if sprinklers go off).[148]

The lack of standardized materials was mentioned by one technical institute, using the example of CLT. As manufacturers cannot agree on a standard lay-up, products are not geometrically in the same category, making it confusing to customers and negatively affecting the CLT manufacturing industry as a whole.

In contrast with the trendiness and aesthetic benefits of wood buildings mentioned above, this material can be **seen as low-quality** compared to more ‘robust’ ones such as concrete. This was mentioned in the case in Germany, where wood was allegedly viewed as a material fit for social-housing,[149] as well as in the case of Eastern Europe.[150]

Lobbying from the concrete and cement industry was seen as a real hurdle by some actors. This lobbying was deemed quite effective because the concrete industry is centralized, while the whole wood industry/market is very fragmented, making it harder for the latter to organize and follow a unified political strategy.[151]

The conservative and risk-averse nature of the construction sector was mentioned by several actors. Many players lamented the lack of knowledge about WCPs and the unwillingness to learn about new ways of building with wood. This problem was deemed more prevalent in countries with a building tradition heavily oriented towards mineral-based materials, but was also mentioned by actors in Finland, where wood-based buildings are more common.[152]

A **lack of formal training programs and skilled workers** along the value chain. Educational and training opportunities on WCPs and wooden buildings for manufacturers,

[144] Industry association (5); School/technical institute (1); architects/construction engineers (1); producers/traders of WCPs (1); forest owners/forestry (1)

[145] Forest owner/forestry (1); producers/traders of WCPs (1); industry association (2)

[146] Project owner (1)

[147] Industry association (3)

[148] Project owner (1)

[149] Government body (1)

[150] Technical institute/School (1)

[151] Industry association (4); technical institute/school (2); producers/traders of WCPs (1)

[152] Industry association (3); technical institute/school (1); architects/construction engineers (1)

designers/architects, engineers and construction workers were deemed insufficient by stakeholders, which gave some recommendations on ways forward to address the problem (see below).

Unadapted regulations, policies and standards – and especially building codes and fire safety regulations – are not harmonized nor necessarily aligned with latest technical knowledge, which can disadvantage building with WCPs compared to other construction materials (see below).

Cost-related issues were linked to several drivers: economies of scale, the price of other materials (including the need for internalization of environmental externalities), legal requirements, the risk profiles of projects, and the type of WCPs used (including their origin) (see below).

Some interviewees recommended education of the broader public in order to address some of the misconceptions identified, especially in relation to fire risks, moisture and insulation.[153] Meanwhile, some benefits surrounding climate impacts, health impacts, comfort and trendiness can be emphasized.[154] To a lesser extent, the broader public may also be receptive to the argument that construction sites will be less noisy, less dusty and last less time, thus reducing disturbance for those living close-by.

Box 4-4 Recent research and regulatory developments in fire safety

In recent years, some progress has been been made on fire safety related to the use of wood in buildings via regulations updates, guidelines publication and and research; however, advances are slow and uneven across MS. Many countries have material restrictions in their building regulations (especially for taller and larger buildings) due to the combustibility of timber, therefore limiting its use as a building material. The renewed increase in wood as a building material due to its climate and environmental benefits has been accompanied by more research on the fire behaviour of timber structures, and to the design of novel fire design conceps and models. This improved knowledge coupled with technical solutions – especially sprinkler systems and well-equiped fire services – now allow the safe use of timber in a wide range of applications (Östman et al. 2017). This has translated to some updates of fire regulations in certain instances. For instance, Finnish regulations have been updated several times, with the latest amendement in 2017 introducing a performance-based approach for timber building over eight storeys tall (see Task 1.2). For an overview of fire regulations in several MS, see the database compiled by the Build in Wood project.[155]

Some European technical guidelines for fire safety in timber buildings were published in 2010,[156] which outline how to fulfill requirements from the European system for fire safety in buildings, including with regards to:

Fire safety objectives

Wood products as linings, flooring and facades

Fire stops

Service installations

Active fire protection

The guidelines also provide advanced calculation methods for both separating timber structures and load-bearing timber structures with and without layers of gypsum board protection (Östman et al. 2017).

Some more recent research has specifically focused on fire safety in tall buildings, including on the implementation of fire safety design concepts (see, for example, the Structural Engineering Document on the Use of Timber in Multi-Storey Buildings published by the International Association for Bridge and Structural Engineering in 2014[157] or the analysis of Östman et al. (2017)).

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[153] Sawmill (1); industry association (2); technical institute/school (1)

[154] Industry association (1); technical institute/school (1)

[155] Build in Wood (2020) Build-in-Wood Regulation Analysis – Fire Safety. Available here.

[156] SP Technical Research Institute of Sweden (2010) Fire safety in timber buildings: Technical guideline for Europe. Available here.

[157] International Association for Bridge and Structural Engineering (2014) Use of Timber in Multi-Storey Buildings. Available here.

Lack of formal training programs and skilled workers along the value chain

It can prove difficult to find workers with the specific set of skills required to handle WCPs along a large swathe of the value chain. Manufacturers, designers/architects, engineers, and contractors/construction companies were specifically mentioned during the consultations.[158] Interviewees active in the field of education noted that students and professionals tend to be increasingly interested in wood construction, either for environmental concerns[159] or because they have identified it as a growing societal trend with market opportunities.[160] There appears to be a widespread belief within the sector that the lack of knowledge and skills experienced does not primarily come from a lack of interest, but rather from the insufficient number of courses and programmes offered at educational institutions or for practitionners.[161] The development of skills is also linked to national legislations, which may limit the type of constructions that students focus on.[162] Addressing this issue is likely to play a role in decreasing the construction industry's wariness of wood as a new material, in addition to filling skilled labour shortages. The issue was seen by some as partly due to difficulties faced by established educational institutions having to get space for such courses.[163]

Recommendations to address this problem focused on increasing education and training opportunities at three levels:

Production and dissemination of more material for self-study or direct use by companies and organisations.[164]

Setting-up organised and supervised training for practitionners along the value chain. One interviewee estimated that a company should spend – on average – 1 day per year to train its engineers in wood construction, and 1-2 days for workers, although this depends on the staff's expertise.[165]

Creation of more courses on topics related to wood construction in the curricula of conventional educational institutions.[166] The need for more training about WCPs in architecture and engineering – including notions of environmental awareness - appears especially important for two reasons: the design phase of wood buildings is where most technical issues arise (especially for multi-storey buildings),[167] and as graduates will be the ones designing buildings, they will influence the choice of materials.[168] Some support may be needed for instutitons which struggle to get space for new courses.

[158] Architect/construction engineer (2); industry association (2); forest owner/forestry (1); producer/trader of WCPs (1); government body (1)

[159] Technical institute/School (1)

[160] Sawmill (1)

[161] Industry association (2); sawmill (1); government body (1)

[162] Technical institute/School (1)

[163] Industry association (1); sawmill (1)

[164] Sawmill (1)

[165] Sawmill (1)

[166] Sawmill (1)

[167] Government body (1)

[168] VIA University College

Collaboration for the production and/or dissemination of educational material would benefit these three points. One interviewee argued that most material on technical aspects, durability, sustainability, and aesthetics is of general character, and could therefore be shared across EU countries after being gathered and structured.[169] Another interviewee pointed that cross-national knowledge exchanges would be especially useful as there are different pockets of specialized knowledge across countries.[170]

Unadapted regulations, policies and standards

Some market players noticed some positive developments in the political/regulatory environment of their respective countries.[171] For instance, some city planning policies actively promote the use of wood by setting targets for wood buildings, including in public procurement.[172] However, several remaining difficulties linked to construction regulations were identified, either at a general level,[173] or specifically with regards to the following:

Building codes can include strict requirements to build with wood. For instance, in Denmark, projects for wood buildings higher than 4 storeys must hire specialists – who are scarce - to make specific calculations to ensure the safety of the building.[174]

As noted in Box 4-2, fire regulations have evolved in some countries, making it easier to build with wood.[175] Nevertheless, several interviewees stated that they remain very heterogeneous across the EU.[176] This is further discussed in Sub-task 1.2.

In addition to updating these regulations in light of technical knowledge and to ensure that some materials are not unfairly discriminated against others, some market players discussed a need for the harmonisation of fire regulations, building codes and environmental standards across the EU. Their rationale is that harmonisation would facilitate the work of product manufacturers, architects and engineers, and would enable countries with less knowledge to learn from others.[177] The selection of appropriate standards will be extensively discussed in Task 2.

Cost-related issues

The question of cost was discussed by many actors.[178] For some, it is a perceived barrier,[179] with wood sometimes automatically assumed to be too expensive.[180] Others noted that pre-fabrication and high-storey buildings offer some opportunities for WCPs to become cost-

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[169] Sawmill (1)

[170] Government body (1)

[171] Architect/construction engineer (2); technical institute/school (1); producer/trader of WCPs (1)

[172] Industry association (2)

[173] Forest owner/forestry (2)

[174] Technical institute/school (1)

[175] Architect/construction engineer (1); producer/trader of WCPs (1)

[176] Architect/construction engineer (1); technical institute/school (1); industry association (1)

[177] Technical institute/school (1); industry association (2); architect/construction engineer (2)

[178] Architect/construction engineer (1); industry association (5); technical institute/school (2); forest owner/forestry (2); project owner (1)

[179] Industry association (1)

[180] Architect/construction engineer (1)

competitive.[181] For most interviewees, however, costs remain an important barrier. This leads some companies to import wood from other countries, which may follow less stringent environmental standards and practices.[182] Several causes were identified:

Economies of scale currently mean that wood is more expensive than other building materials, but the more the WCP market develops, the cheaper the material will become, with wood expected to lead to economic gains in the future.[183]

Concrete can be very cheap in some areas, making it even more difficult for wood to compete.[184]

Some market players explained that the additional legal requirements that projects with wood must comply with are more expensive than for projects using mineral-based materials (e.g. related to upstream studies, fire and moisture requirements).[185]

One industry association noted that the climate costs of mineral-based materials are insufficiently internalized in the price of construction products.

The cost of a construction project can be driven up if it has been ascribed a high risk profile. Policies spreading information about wood construction would contribute to de-risking investments, and thus lower the price of wood construction projects.[186]

The overall price of a wood construction project also depends on the type of wood, its quality and where it is sourced. Wood from Poland, for example, is imported for construction projects in Sweden despite being of a lower quality than local wood. This ends up being cheaper despite transport costs as the price of Swedish wood is driven up by labour costs and taxes.[187] In addition, the high costs associated with using hardwood in construction were singled out by market players with a French, a Swedish, and an European perspective.

Comparing these insights from the stakeholder consultations with information on costs presented in section 2.4, there is an apparent contradiction between the prices displayed in Figure 2-8 – where WCPs appear cheaper than conventional building materials – and feedback received from stakeholders along the value chain. Again, this may be explained by the lack of data of wood used specifically in construction. Moreover, the high cost of using wood may derive from other factors than the price of the building itself, notably: the more stringent requirements to comply with building regulations (e.g. more analyses needed to prove fire safety) and the prices of risk preniums.

Economic valuation of climate benefits

Several interviewees agreed on the importance of economically valuing the climate benefits of WCPs, but also saw the calculation of the climate benefit itself as a way to influence actors' decision-making on the demand-side, independently from the set-up of related economic incentives.[188] Some market players shared comments and concerns on the

[181] Technical institute/school (1); industry association (1); producer/trader of WCPs (1)

[182] Technical institute/school (2); project owner (1)

[183] Technical institute/school (1); industry association (1)

[184] Forest owner/forestry (1)

[185] Technical institute/school (1); producer/trader of WCPs (1); project owner (1)

[186] Forest owner/forestry (1)

[187] Project owner (1)

[188] Industry association (3); forest owner/forestry (1); architect/construction engineer (1); producer/trader of WCPs (1)

calculation methods. While Stora Enso were of the opinion that the calculation of climate benefits is a rather mature topic, others pointed that such an endeavour remains complex, especially as numerous approaches exist.[189] A shared concern was that the method should be carefully designed in order to be science-based, reliable, transparent and standardised.[190] Conversely, one large manufacturer of WCPs spoke against the economic valuation of carbon storage in WCPs, arguing that the value of carbon sinks is difficult to monetise, and that this approach creates complexities if the carbon is released sooner into the environment (e.g. due to a fire). They instead advocated for incentives for producing WCPs, rather than for storing CO_2.[191]

Aside from discussing the economic valuation of climate benefits as a solution to boost demand for WCPs, a variety of other potential policy actions were brought up by the market players interviewed. These stemmed from reflections on how to better tap into identified opportunities and address some of the existing barriers, as discussed above. The main emerging take-aways are laid out in the next section.

1.3.4. Discussion on the potential to increase the usage of Wood-based Construction Products in the EU

Stemming from the analysis of EU forest data, there is a potential to increase harvest to meet a potential increase in use by the construction sector, but it appears somewhat limited, in the range of 10 to 15% relative increase compared to the current harvest. The majority of market players appeared more confident in EU's capacity to increase harvest levels. Conversely, while market players in Finland and Romania identified no potential for increased harvest, our analysis contradicted this opinion. These differences may be explained by the fact that market players' knowledge mainly stems from their respective position in the value chain, thus making it difficult to understand all the factors affecting the potential to increase sustainable harvest.

Nevertheless, this limited potential does not necessarily preclude a growth of the WCPs market share using EU-sourced wood. The main solutions identified include:

Redirecting the lower-quality segments of the existing wood production (e.g. wood parts, trees with small diameters, and damaged wood) to be transformed into WCPs (specifically into CLT), so as to meet the demand of the construction sector. At present, wood of lower quality is used to produce lower-added value products (e.g. packaging and paper) or burned for energy (see flows from Figure 3-1 and section 4.3.3)

Using wood from under-exploited varieties (such as hardwood) to produce WCPs more extensively (with investments in R&D to continue developing these solutions). Some hardwood could also be re-directed from the furniture industry or from energy generation, which would increase climate benefits as the final product would sequester carbon longer (see section 4.3.4);

Increasing efficiency and circularity along the value chain, so as to re-direct wood beams from demolition sites towards direct re-use or to be transformed into WCPs;

Re-directing EU exports towards its internal market. Trade figures presented in section 3.2.3 show that many MS consume a large share of their domestic production of industrial

[189] Technical institute/school (1); industry association (1)

[190] Industry association (2); architect/construction engineer (2); technical institute/school (1);

[191] Producer/trader of WCPs (1)

roundwood, with an average of 12% being exported by countries. Nevertheless, several Central-Eastern European countries have a high net trade balance of industrial roundwood, which indicates that some exports could be re-directed to further processing into WCPs domestically, provided that manufacturing infrastructure is in place or developed. In absolute terms, Germany and Sweden also export significant amounts of industrial roundwood to third countries. In addition, Germany, Sweden, France and Austria export high amounts of further processed wood products to third countries. The potential to re-direct third countries exports to the EU market was also confirmed in the stakeholder consultations. To be able to use these resources domestically, prices and demand need to be aligned.

1.3.5. Policy recommendations

Future policy could focus on several stages of the value chain:

Several actions at the forest management stage were identified:

In line with the EU carbon farming policy, training for forest owners and managers could contribute to:

Improving forest management methods for harvesting wood without impacting on forest carbon stocks (especially soils);

Converting production forests to the production of long-lived materials (e.g. the conversion of coppice into high forest or "balivage");

Sustainable afforestation and reforestation.

Promoting clustering into forest associations or networks could encourage small forest owners to use their property as a resource. Local and regional cooperation helps (small-scale) forest owners to obtain information related to mobilising their forest resource and making it available on the market, which translates into higher wood utilisation in countries with developed organisational structures.[192]

Investments in infrastructure, especially to increase logging in areas with geographic constraints. Research points to the need to extend the forest road network (e.g. in France, Austria, Sweden and Slovakia) and investments in harvesting systems adapted to the local context. In terrain with moderate slopes, cut-to-lenght methods (felling, delimbing and bucking before extraction) should be fostered instead of tree-lenght methods (felling and delimbing before extraction), as well as the use of forwarders instead of skidders or tractors. For steep terrain, cable yarders are more appropriate, in combination with any of the whole tree (only felling before extraction), tree length or cut-to-lenght harvesting methods (but the road network should be very well developed). Inappropriate harvesting systems are sometimes used (i.e. animals, skidders and forwarders) in steep terrain, leading to negative economic, environmental and social impact.[193] An alternative method still under development for places where road networks cannot be built is airship logging.[194]

In light of some stakeholders' wariness of the trade-offs between biodiversity conservation (notably the target to protect 30% of land and sea area from the EU Biodiversity Strategy to 2030) and wood production, how both objectives will be reached should be better explained

[192] Hirsch, F., & Schmithüsen, F. J. (2010). *Private forest ownership in Europe* (Vol. 26). ETH Zurich.

[193] Enache, A., Kühmaier, M., Visser, R., & Stampfer, K. (2016). Forestry operations in the European mountains: a study of current practices and efficiency gaps. *Scandinavian journal of forest research*, *31*(4), 412-427.

[194] Example of an innovative method developed by a French start-up and supported by the Nouvelle Aquitaine region available here.

and communicated. For instance, sustainable forestry management and afforestation can present win-win opportunities. The upcoming Forest Strategy 2021, which will build on the biodiversity strategy and will aim to support the circular bioeconomy, presents an opportunity to reconcile these objectives and provide clarity to stakeholders in the WCPs value chain.

Action in the following main policy areas could benefit sawmills:

Sawmills would benefit from training, investment, and more research in order to process additional wood species (e.g. hardwood, recycled wood), to improve the quality of products produced for construction and a greater variety of tree parts, as well as to reduce losses. By doing so, sawmills could increase the value of their production by switching from low-value products (e.g. paper) to more engineered wood products (especially CLT).

At EU level, the European Economic and Social Committee has called for R&D funds to be harnessed to support new and innovative applications of hardwood species.[195] In the context of France specifically, a recent study commissioned by the Ministry of Agriculture and Food found that although French sawmills' production equipment is relatively recent, the processes are still not very automated and digital integration remains very partial. Diversifying species (notably hardwood) and qualities of wood requires a great deal of adaptability of transformation tools and flexibility of organizations, which they found to be insufficiently present across the territory. Delving into a model of sawmills adapted to the future (in which they identify wood construction with hardwood species as an opportunity), the research pointed to a large number of actions, including support for modernization and innovation. Such investments may not be necessary across all MS, as the study pointed to Romania as a country where the sawmills are better able to process trees of smaller lengths and smaller diameters, including hardwood species.[196]

As a important step for the further development of CLT, there is a need for harmonisation of test, evaluation and design approaches in order to provide adequate, reliable and reproductible verification of characteristic properties.[197] The first European standard for CLT (EN16351) was introduced in 2015 but does not contain uniform design procedures.[198]

For sawmills to be able to use a greater variety of tree parts, tree types, and wood waste produced along the value chain (notably during the manufacturing stage at which they themselves operate) to produce WCPs, policy should also consider the re-directing of wood used by other industries, notably the pulp and paper industry and the energy industry.

Companies manufacturing engineered wood products such as glulam and CLT could be supported in their Research & Innovation work related to reducing the GHG emissions intensity of their products. This could be further enhanced in the scenario of increased decarbonization of the chemicals used in the production process, e.g. by modifying the glues used;

Companies manufacturing wood-based construction modules could be encouraged to develop size and shape standards, for them to be more easily re-used at end of life of the building. This point feeds into the widely supported need for harmonization across the EU in terms of the standardization of the design and production of WCP. In this regard, the development of standardized building modeuls could be an option to further explore;

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[195] EOS (2019) Annual report of the European Sawmill Industry. Available here.

[196] Ministère de l'Agriculture et de l'Alimentation (2019) Les scieries du futur : quel modèle industriel ? Analyse n.143. Available here.

[197] Brandner, R., Flatscher, G., Ringhofer, A., Schickhofer, G., & Thiel, A. (2016). Cross laminated timber (CLT): overview and development. *European Journal of Wood and Wood Products*, *74*(3), 331-351.

[198] Jeleč et al. (2018) Cross-laminated timber (CLT) – a state of the art report. Available here.

Architects and engineering bureaux need more employees with the knowledge and skills required to design wood buildings, and to use the standard sizes and shapes of wood-based modules, which could be achieved via more training and more courses offered in educational institutions.

At the stage of architects and project owners, two important areas of interventions could stimulate demand for WCPs:

The quantification of the climate benefits of using WCPs via a universal, transparent and standardised approach. The display of this climate benefit is seen as beneficial and susceptible to modify decisions on the choice of a construction material, independently from an economic incentive. Indeed, such a robust quantification method would contribute to obtaining higher quality and comparable information about the sustainability of WCPs vis-à-vis other construction materials, and could ultimately be used to strategically market and promote WCPs to potential users likely to be swayed by the sustainability argument linked to using wood (either municipalities or private project owners).

On top of this computation of climate benefits of using WCPs, there could be a benefit for an economic incentive, based on a carbon credit. The relevance of the carbon credit depends upon the comparison between:

The cost of the construction;

The amount of the carbon credits to be expected, i.e:

$$\begin{aligned}&\textit{the quantity of GHG emissions saved}\\&\qquad\qquad * \textit{ the price that buyers are ready to pay per tonne of } CO2eq \textit{ saved}\end{aligned}$$

Measures to address cost-related issues. Two crucial elements here relate to:

Updating fire safety regulations in light of most recent empirical evidence with regards to the safety of wood buildings, and ideally adopt a unified EU level approach. If fire safety in buildings is part of “civil protection”, as defined in Art. 196 of the TFEU, then the EU has little capacity to act beyond supporting MS (Art. 6 of the TFEU). Conversely, if it is part of “consumer protection” and “internal market” policies which are a shared competence with Member States, the EU would be able to legislate.

Reducing the notion of uncertainty about WCPs and wood buildings more generally speaking, as the uncertainty margin in projects increase their overall budget. This could be addressed via training and communication. The findings from the COST network, and their contribution to the update of Eurocode 5, constitute an important stepping stone in this direction.[199]

Construction companies should also be trained, notably on the use of pre-fabricated modules and on the higher level of precision in the assembly process that this requires.

At the demolition stage, incentives for using recycled products could enlarge the market for such products, and therefore lead to more material recovery from construction and demolition sites. The climate impact is delayed by only a few decades if the wood from a demolition site is burned, while a potential economic incentive for storing the CO_2 is wasted. If an economic incentive for CO_2 storage is set up, or if a market is established for re-using wood from demolition sites towards another cycle of usage in construction (e.g. to be transformed into WCPs), it should then also incentivise the reuse of wood after the building is demolished.

The need for training spans the entire value chain, and there are some benefits derived from cross-border collaboration. The EC could facilitate these processes by:

[199] European Cooperation in Science and Technology (2019) Building up standards on timber design. Available here.

Proposing an Alliance for wood-based construction as an additional sector of the Blueprint alliances for sectoral corporations on skills. An existing construction blueprint focuses on the construction industry and re-groups 3 EU umbrella sectorial organizations, 9 national sectorial representatives and 12 Vocational and Education Training providers from 12 MS. This blueprint aims to set up a sectoral alliance to reduce the skill gap between industry requirements and sectorial training provision, as well as to boost growth, innovation and competitiveness. However, it addresses the potential of WCPs in a limited manner only.. A similar blueprint specifically focused on WCPs could fill this gap.

Funding demonstration projects across the EU to help provide information and material for training as well as regulatory change;[200]

Fund R&D projects on wood-based construction products help to share knowledge between EU MS.

1.4. Conclusions

Some major high-level concluding remarks are outlined below (for more detailed conclusions, see the boxes at the start of each section):

The current market share of WCPs is very low at EU level (2.4%), with a large variation between a few front-runners (notably Sweden and Finland) and many MS with an almost inexistant use of WCPs in the construction industry

Harvest in the EU could only be increased by +10-15% to meet the potential future needs of a growing demand for WCPs, therefore presenting limited opportunities. Some alternative solutions to meet an increased demand are put forward, but their potential has not been quantified.

One exception is the potential to re-direct wood from other industries, with the Sankey diagram (Figure 3-1) giving a rough indication.

Other potential avenues for policy include: using a greater array of wood varieties; increasing efficiency and circularity along the value chain (for instance by incentivising the use of recycled wood); increasing tree growth speed; using more recycled wood; and redirecting exports towards EU consumption).

Several policies could foster and support an increase in demand for WCPs:

- Increasing educational and training opportunities for occupations along the whole value chain
- Quantifying the climate benefits of WCPs with an universal, transparent and standardised approach
- Updating fire safety regulations
- Reducing the notion of uncertainty about WCPs and wood buildings more generally speaking
- Further research is necessary to acuurately establish the climate impact of CLT specifically
- Increasing opportunities for collaboration and knowledge exchange at EU level

[200] Build in Wood is one example of such projects (https://www.build-in-wood.eu/)

2. Case studies of incentive programmes

2.1. Introduction of the subtask

Public policies such as fiscal reforms, subsidy schemes, industrial strategies, improved fire safety regulations, building code reforms, and knowledge transfer and training programmes can trigger the transformation towards a resource-efficient and green construction sector and support the uptake of wood-based construction products (WCPs). The policies relevant to this study aim to **promote the use of wood as a building material**, at national, regional, or local levels. They have also been referred to as **wood encouragement policies (WEPs)** by the FAO Advisory Committee on Sustainable Forest-based Industries (ACSFI)[201]. According to the latter, such policies commonly recognise the importance of supporting local forest industries, sustainable economic development, and climate change mitigation objectives[202]. In 2016, a report by the FAO-UNECE underlined the importance of the forest and the use of wood in achieving sustainability and meeting the UN's Sustainable Development Goals (SDGs)[203]. The latter report focused on public policies promoting sustainable building materials in Europe and North America, in view of overcoming the lack of knowledge and misunderstanding of wood construction and providing a starting point for countries interested in addressing the environmental impacts of construction materials. The FAO Department of Forestry notes that it is critical to "increase the visibility of the benefits of sustainable wood production and consumption, shifting mindsets to encourage a more positive and responsive attitude to develop and strengthen sustainable wood value chains"[204]. With the help of the Sustainable Wood for a Sustainable World (SW4SW), the FAO hopes that the benefits from sustainable wood value chains are recognised worldwide, forest management capacity is improved, markets and finance for sustainable wood value chains and associated products are broadened, and that the contributions of such value chains to the bioeconomy and circularity approach are strengthened in all countries. Furthermore, the joint UNECE/FAO Forestry and Timber Section encourages the transition to a forest sector that is fully engaged in the green economy[205]. This entails opportunities for providing forest-based services and products, growing business and revenue in the sector, and job creation.

A literature review by Milestone and Kremer (2019) describes WEPs as a set of guidelines fostering the stimulation of wood use in construction[206]. They highlight that such policies do not specifically mandate for timber to be used as a primary material in construction, but they acknowledge that wood is a renewable construction product with significant advantages. As explained in in Subtask 1.1 of this project, "Market study", **WCPs have certain benefits that justify the prescription of policies promoting their uptake**. These include their natural properties, efficiency in construction, impact on health and wellbeing, thermal resistance and

[201] Advisory Committee on Sustainable Forest-based Industries (ACSFI) (2020), Status of public policies encouraging wood use in construction – an overview. FAO.

[202] Advisory Committee on Sustainable Forest-based Industries (ACSFI) (2020), Status of public policies encouraging wood use in construction – an overview. FAO.

[203] Goodland, H. (2016), Promoting sustainable building materials and the implications on the use of wood in buildings. United Nations Publication.

[204] FAO (2021), Sustainable Wood for a Sustainable World. FAO.

[205] UNECE, FAO, and Forest Europe (2020), Guidelines on the Promotion of Green Jobs in Forestry. United Nations Publication.

[206] Milestone, S. N., and Kremer, P. (2019), Encouraging councils and governments around the world to adopt timber-first policies: A systematic literature review. *Mass Timber Construction Journal*, 2(1), 8-14.

insulation, soft acoustics, aesthetic qualities, and contribution to sustainable development.). Milestone and Kremer (2019) also include policies aimed to encourage the sourcing of responsible timber under the WEP umbrella[207]. This is supported by the State of Europe's Forests 2020 report, which considers the forest policy framework crucial to aiding forest management and contributing to the renewability of a resource for future generations[208]. Such policies help maintain and enhance forest resources, and motivate forest owners to make more effective use of their forests, ensuring timber supply for the bioeconomy.

With the aim of decarbonising their economies, EU Member States have the opportunity to think about and describe their approach to WEPs in their National Energy and Climate Plans (NECPs)[209], Long-Term Strategies (LTSs)[210], land use, land use change and forestry (LULUCF) policies, and bioeconomy policies. According to the European Commission's Communication on the final NECPs, LULUCF is the only sector which represents a net carbon sink, i.e., which can sequester carbon from the atmosphere and store it in soils, biomass, and harvested wood products (including WCPs)[211]. Several Member States indicate that their carbon sinks are decreasing due to ageing of forests, harvesting and increasing natural disturbances. The NECPs reveal that around a third of the 2005 EU carbon sink could be lost by 2030, while the LULUCF sector may even become a net emitter after 2030. Some Member

States plan measures to increase the LULUCF sink (e.g., by providing subsidies for converting arable land to protected natural areas, or for afforestation in agricultural land) with the Common Agricultural Policy (CAP) as the main tool for supporting measures to enhance sustainable forest management, as well as afforestation and forest resilience. Ensuring consistency with the NECPs, the LTSs will, inter alia, cover emission reductions and enhancements of removals in individual sectors (including the buildings sector, agriculture, and LULUCF)[212]. Specifically relating to the LULUCF sector, an overview of public policies and measures reported by Member States under Article 10 of the LULUCF Decision between shows a large number of interventions relating to forest management[213]. Member States are also involved in developing their bioeconomy strategies[214],[215], as well as research and innovation in support of sustainable food and farming systems, forestry, and biobased products[216].

Nevertheless, the uptake of innovative wood-based construction products depends on a variety of factors; many of which go beyond market incentives. These factors include competences and skills, mental models, restrictions within building codes, the conservative and risk-averse nature of the construction sector, and misconceptions surrounding the use of

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[207] Milestone, S. N., and Kremer, P. (2019), Encouraging councils and governments around the world to adopt timber-first policies: A systematic literature review. *Mass Timber Construction Journal*, *2*(1), 8-14.

[208] Forest Europe (2020), State of Europe's Forests 2020. Ministerial Conference on the Protection of Forests in Europe.

[209] European Commission (2021), National energy and climate plans (NECPs). European Commission.

[210] European Commission (2021), National long-term strategies. European Commission.

[211] European Commission (2020), An EU-wide assessment of National Energy and Climate Plans COM(2020) 564 final. European Commission.

[212] European Commission (2021), National long-term strategies. European Commission.

[213] Paquel, K., Bowyer, C., Allen, B., Nesbit, M., Martineau, H., Lesschen, J. P., and Arets, E. (2017), Analysis of LULUCF actions in EU Member States as reported under Art. 10 of the LULUCF Decision. European Union.

[214] European Commission (n.d.), Bioeconomy strategy. European Commission.

[215] Motola, V., De Bari, I., Pierro, N., and Alessandro Giocoli, A. (2018), Bioeconomy and biorefining strategies in the EU Member States and beyond. IEA Bioenergy.

[216] See research by the Standing Committee on Agricultural Research (SCAR), in particular the work of the SCAR Strategic Working Group on Forests and Forestry Research and Innovation.

WCPs from various stakeholders along the value chain (as was explored in Subtask 1.1). Public policies can help overcome these barriers and level the playing field for different building materials.

The purpose of this subtask is to **identify and document effective policies encouraging the use of wood in the construction sector in two Member States**. The two case studies provide examples of enabling mechanisms and successful strategies that might be applicable at EU level. The analysis focuses on concrete policies (e.g., subsidy schemes, industrial strategies, permissive building codes) and assesses their impact on the use of wood in the construction sector. The analysis also identifies important barriers and success or enabling factors. These have been taken into consideration when discussing the transferability of the measures in other Member States.

2.2. Methodological notes

The analysis of policy measures has been conducted according to the following steps:

- Selection of case studies;
- First selection of five candidate countries (out of 27 Member States) through a mapping of political priorities in relevant national strategies and plans;
- Second selection of two countries, based on a brief overview of policies in the five candidate countries;
- Overview and in-depth analysis of policies in the two selected Member States.

The **selection of case studies (Step 1)** began with a review of the national LTSs[217] and NECPs[218] of the EU Member States (in their availability status of December 2020), as a way to evaluate whether the use of wood in construction represents a political priority for each Member State. The LTSs and NECPs were scanned using key terms such as “wood”, “timber”, “construction”, and “building”. Based on this quick scan, the use of wood in construction was deemed as “low priority”, “medium priority”, or “high priority” at national level. The results of this analysis are presented in Appendix A, alongside the definitions of each priority level. The scan of the national strategies and plans was combined with the results of Subtask 1.1 and a preliminary search for publicly available information on incentive policies or programmes in a series of Member States. The 27 Member States were then narrowed down to five candidate countries (Step 1a) that were considered most interesting to explore further (see Appendix B). The short analysis of the five Member States pointed in the direction of **France and Finland** being optimal candidates for the two case studies, on the basis of their policies, geographical positioning, and different experiences with wood-based construction products (Step 1b). France is an example of a country that has a low market share of wood-based construction products (but high potential in terms of its forest coverage), while Finland is more familiar with the use of such products in the construction sector and has implemented one of the most advanced policy mixes supporting their uptake. The European Commission’s individual assessment of the French NECP, and particularly that of the LULUCF sector, shows the country’s focus on substituting fossil-based materials with bio-based ones, promoting the use of harvested wood products, and sequestering carbon in forest ecosystems[219]. The LULUCF sector is also an important sector in Finland,

[217] European Commission (2021), National long-term strategies. European Commission.

[218] European Commission (2021), National energy and climate plans (NECPs). European Commission.

[219] European Commission (2020), Assessment of the final national energy and climate plan of France. European Commission.

with measures focusing on the increase of carbon storage, afforestation of organic soils, and active forest management, amongst others[220].

In a **second step (Step 2), relevant policies** were identified and investigated in the two selected Member States, namely Finland and France. The focus was on concrete policy measures and their impact on the uptake of wood-based construction products. The case studies have been structured according to the following headings:

- Introduction and political context;
- Overview of selected measures;
- Assessment of measures.

In addition, a discussion on the transferability of measures follows the two case studies.

Both qualitative and quantitative data have been used in the case studies, and information has been collected through desk research and interviews (including 11 interviewees from eight organisations). The organisations that were interviewed are presented in Table 2-1 below.

Table 2-11 List of interviewees

Organisation	Date of interview	Comments
Finnish Ministry of Environment	21/12/2020	
Office for Peripheral Architecture (OOPEAA), Finland	16/12/2020	Also interviewed as part of Subtask 1.1
Institut Technologique Forêt Cellulose Bois-construction Ameublement (FCBA), France	21/12/2020	Also interviewed as part of Subtask 1.1
KK-Fireconsult, Finland	22/12/2020	
Natural Resources Institute Finland (Luke)	13/01/2021	
Stora Enso	15/01/2021	Also interviewed as part of Subtask 1.1
FIBois Île-de-France	20/01/2021	
Ministry for the Ecological Transition, France	09/02/2021 and 16/02/2021	

2.3. Case studies

2.3.1. Finland

Introduction and political context

In Subtask 1.1, it was estimated that Finland's market share of WCPs among all materials used in construction amounted to 8.8% (i.e., industrial roundwood, as a share of total relevant material use in the construction sector, expressed in m^3). Finland's market share was the second-highest in Europe. This reflects the country's familiarity with WCPs, which stems from its long tradition of building with wood. Finland is **one of the most heavily-forested countries in Europe**, with more than 16 times more forest per capita than the

[220] European Commission (2020), Assessment of the final national energy and climate plan of Finland. European Commission.

European country average[221]. Forests cover 24 million hectares or roughly 71% of the land area of Finland[222]. Given their scale, forests are considered to be the country's most valuable natural resource. Forest land helps sequester a significant share of greenhouse gas emissions, while the built environment also holder a very large stock of carbon[223]. Finland's National GHG Investory Report states that carbon removals from forest land amounted to 20 million tonnes CO_2 equivalent in 2018. The harvested wood products (HWP) sink represented over 4.4 million tonnes CO_2 equivalent in 2018[224]. The forestry sector (including timber, plywood, paper and pulp production) accounts for more than 20% of Finland's export revenue and employs, directly and indirectly, around 160,000 people[225] (i.e., just under 7% of the workforce[226]).

Finnish forest policy and legislation is primarily administered by the Ministry of Agriculture and Forestry and the Ministry of Environment, as well as the Ministry of Trade and Industry, the Ministry of Foreign Affairs, the Forest and Park Service, the Forestry Development Centre (Tapio), the Finnish Environment Institute, and various forest management associations, such as the Finnish Forest Association. Finland has a history of aiming to support its forest industry through public policies. Between 1995 and 2000, it was reported that sawnwood consumption per capita approximately doubled, in part due to public wood promotion campaigns and technology platforms, and removal of institutional obstacles (e.g., through the revision of fire safety regulation)[227,228].

Finland's **National Forest Strategy**, adopted in 2015 and updated in 2019, lays out the main objectives for forest-based industries and activities until 2025[229,230]. The strategy was founded on the Government Report on Forest Policy, defining sustainable forest management as a **source of growing welfare**[231]. The strategy's objectives are three-fold: (1) Finland is a competitive operating environment for forest-based business; (2) forest-based business and activities and their structures are renewed and diversified; and (3) forests are in active, economically, ecologically, socially and culturally sustainable, and diverse use. The strategy is implemented through 10 strategic projects relating to climate sustainable forestry, international forest policy, EU policy, and new wood products; as well as through Regional Forest Programmes, accounting for special regional characteristics[232]. Other important background documents that link to the strategy are:

The **Finnish Bioeconomy Strategy** envisions a sustainable bioeconomy, which can support Finnish wellbeing and competitiveness. Its overarching objective is to generate new

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[221] UPM Pulp (n.d.), Want to make forestry sustainable? Look to the Nordics. UPM Pulp.

[222] Eurostat (2018), Over 40% of the EU covered with forests. Eurostat.

[223] Eurostat (2018), Over 40% of the EU covered with forests. Eurostat.

[224] UNFCCC (2020), Finland. 2020 National Inventory Report (NIR). UNFCCC.

[225] UPM Pulp (n.d.), Want to make forestry sustainable? Look to the Nordics. UPM Pulp.

[226] Assuming a total workforce of about 2.4 million, according to the latest available data on Eurostat (2021), Employment and activity by sex and age - annual data. Eurostat.

[227] Hurmekoski, E. (2016), Long-term outlook for wood construction in Europe (academic dissertation). University of Eastern Finland.

[228] Ministry of Agriculture and Forestry of Finland (n.d.), Wood construction is being promoted in Finland. Ministry of Agriculture and Forestry of Finland.

[229] Ministry of Agriculture and Forestry of Finland (n.d.), National Forest Strategy 2025. Ministry of Agriculture and Forestry of Finland.

[230] Ministry of Agriculture and Forestry (2019), National Forest Strategy of Finland. Ministry of Agriculture and Forestry.

[231] Ministry of Agriculture and Forestry (2014), Government Report on Forest Policy 2050. Ministry of Agriculture and Forestry.

[232] Ministry of Agriculture and Forestry of Finland (n.d.), National Forest Strategy 2025. Ministry of Agriculture and Forestry of Finland.

economic growth (pushing bioeconomy output up to EUR 100 billion by 2025) and new jobs (+100,000) from an increase in the bioeconomy business and from high added value products and services, while securing the operating conditions for the nature's ecosystems[233];

The **National Biodiversity Strategy and its associated Action Plan** draw out a vision and actions (105) to mainstream the conservation and sustainable use of biodiversity across government and society, reduce pressures on biodiversity, safeguard ecosystems (including forest ecosystems) and their services, as well as species and genetic diversity[234,235]. The strategy also talks about the nature management methods used in commercially utilised forests, which are deemed important given the proportion of forests used for commercial forestry (90%); and,

The **National Energy and Climate Strategy for 2030**. The Government report on the strategy, published in 2017, makes direct references to the promotion of wood construction for long-term carbon storage. It also talks about lowering the carbon footprint and material efficiency of the construction sector[236].

Overview of selected measures

As indicated above, forestry is an important sector for the Finnish economy, and plays a pivotal role in the country's first Bioeconomy Strategy. To promote the use of wood in construction, while improving the competitiveness of the sector, several key policy instruments can be highlighted. The list of measures in Table 3-1 is directly linked to the promotion of WCPs in Finland. Please note that impacts in terms of encouraging the use of WCPs have been assessed based on available information (found through desk research and interviews), and may have limitations. Impacts (i.e., on the use of WCPs) are colour-coded to reflect positive or negative or no[237] impacts. Neutral, mixed results, or limited information are indicated in yellow.

[233] Bioeconomy (n.d.), Finnish Bioeconomy Strategy. Ministry of Agriculture and Forestry, Ministry of Economic Affairs and Employment of Finland, Ministry of the Environment.

[234] Biodiversity (n.d.), Finland's Biodiversity Action Plan. Convention on Biological Diversity, Ministry of the Environment, SYKE.

[235] Biodiversity (n.d.), Strategy. Convention on Biological Diversity, Ministry of the Environment, SYKE.

[236] Ministry of Economic Affairs and Employment (2017), Government report on the National Energy and Climate Strategy for 2030. Ministry of Economic Affairs and Employment

[237] Negative or no impacts represents situations where the outcome of the policy measure is expected to have reduced the use of WCPs or have had limited to no impact on their uptake.

Table 3-12 List of policy measures incentivising the use of wood in construction in Finland

Measure	Type	Short description	Geographic level	Impacts/results
Strategic Programme for the Finnish Forest Sector (2011-2015) and the National Wood Constuction Programme (2011-2015)	High-level strategy or programme	The Strategic Programme for the Finnish Forest Sector represented one of the key projects of the 2011-2015 government term[238]. It established a target of increasing the market share of wood multi-storey constructions from nearly 0% to 10% by 2015. The Ministry of Employment and Economy also headed a National Wood Construction Programme under the Strategic Programme for the Forest Sector, aiming to diminish the carbon footprint of construction by increasing the use of domestic wood in construction[239]. The programme also aimed to make Finnish wood construction an international brand. A new version of the programme was implemented after 2015, the Wood Building Programme, described in the following row.	National	The programme promoted the competitiveness and renewal of the Finnish forest sector[240]. It was reported that the programme contributed to the growth of the annual use of domestic industrial and energy wood (reaching 65 million m^3) and to the increase of the market share of wooden multi-storey buildings (reaching the 10% target). The value of forest industry exports also rose, but not to the desired levels (€11.2 billion vs €13 billion). New wood-based products saw a lot of growth, but did not reach the target of €1 billion in turnover.
Wood Building Programme (2016-2022)	High-level strategy or programme	Building on the progress of the National Wood Construction Programme (described above), the Wood Building Programme is a joint government undertaking, which aims to increase the amount of wood used in construction[241]. The programme aims to promote the growth of internationally competitive industrial wood construction knowledge and material manufacturing. It also focuses on diversifying and expanding the different applications for wood, so as to add more value to the wood value-chain. Furthermore, the programme works to	National	This programme is considered as an important and efficient public support tool in developing timber construction. According to interview data, the programme funds a lot of research, which has helped enhance the knowledge base (around 20-30 projects have been funded in the research and industry fields). Furthermore, the public sector targets are considered to be ambitious but realistic.

[238] Bio-based News (2015), Finland: Strategic Programme for the Forest Sector reached its targets. Bio-based News.

[239] Ministry of Employment and the Economy (n.d.), Status and possibilities of wood construction in Finland. Ministry of Employment and the Economy.

[240] Bio-based News (2015), Finland: Strategic Programme for the Forest Sector reached its targets. Bio-based News.

[241] Ministry of the Environment (n.d.), Wood Building Programme. Ministry of the Environment.

Measure	Type	Short description	Geographic level	Impacts/results
		strengthen the skills base in the industry, updating legislation and building regulations relating to wood construction to embed wood products in the Finnish construction industry. In the context of this programme, national targets for public sector buildings have been defined. The latter have been set at 31% by 2022 and 45% by 2025 of wood construction in relation to all new public construction[242].		
Aid Scheme for Growth and Development from Wood	Financial aid	Linked to the Wood Building Programme, the scheme promotes the use of wood in construction by providing support for various R&D project. The scheme focuses on specific themes, and aims to activate stakeholders and encourage new actors. Its purpose is to accelerate the growth of the sector. In 2021 (fifth call), support will target all existing themes of the aid scheme, namely, digitalisation and technology of wood construction, low-carbon construction, user-driven solutions, circular economy, and industrial networks[243]. A maximum of €1.5 million will be awarded during the fifth round of funding. Support for pilot projects may not exceed 40% of eligible costs or maximum €150,000 per project.	National	Examples of projects funded by the scheme can be found on a dedicated projects portal: https://www.hankeportaali.fi/. No further evidence could be found on the effectiveness of the aid scheme. However, several interviewees noted the importance of R&D in encouraging the use of WCPs. It is, therefore, expected that the scheme has some positive influence on the uptake of WCPs (at least in the long term).
The Housing Finance and Development	Financial aid	The agency provides loans to public/private building projects, which can be supported and partly compensated by the government if the projects use	National	Interview data suggests that the agency financially supports timber constructions, thus incentivising the use of WCPs. However, no further evidence could be found

[242] Ministry of the Environment (2020), Julkisen puurakentamisen kansalliset tavoitteet. Ministry of the Environment.

[243] Ministry of the Environment (n.d.), Kasvua ja kehitystä puusta -tukiohjelma. Ministry of the Environment.

Measure	Type	Short description	Geographic level	Impacts/results
Centre of Finland (ARA)[244]		wood.[245]		on how effective ARA's support is.
Revision of fire regulations (multiple), e.g., Ministry of the Environment Decree on the fire safety of buildings (848/2017)	Building code	Finnish fire safety regulations were changed in 1997 to allow the use of wood in building frames and façades for buildings of up to four storeys[246]. In 2011, the Government revised the fire regulations again, allowing wood multi-storey constructions of up to eight storeys[247]. Later in 2017, the Ministry of the Environment Decree on the fire safety of buildings (848/2017) introduced a performance-based approach for timber buildings of over eight storeys (i.e., 28 m). This means that timber buildings of up to eight storeys can be built based on a set of defined table values (making it easy for engineers), while a performance- (risk-) based assessment is made for timber buildings exceeding eight storeys. The assessment consists of functional fire-safety calculations and comparisons with buildings having the same use and non-combustible load-bearing structures. The aim is to reach the same overall fire safety level.[248]	National	Given that fire safety concerns have been cited numerous times as an important barrier to the uptake of WCPs, the revision of fire safety regulations is considered an important step in ensuring that construction materials are treated in a more equal manner. Interviewees agreed that fire safety regulations have an impact on the uptake of WCPs, and that the restrictions imposed by such regulations influence the development of the WCP industry. Taller wood-based constructions improve the competivenes of WCPs and improve the knowledge base for future multi-storey constructions. According to one interviewee, the revision of fire safety regulations in 2011 helped create a new market. In the City of Helsinki, for example, the relaxation of regulations contributed to an increase in timber multi-storey projects.[249] The more recent revisions are expected to generate similar impacts.
Low Carbon Construction	Roadmap	In 2017, the Ministry of Environment commissioned a study on a roadmap to reduce the carbon footpring of the	National	This roadmap paved the way for ambitious regulations, including the Revised Land Use and Building Act and the

[244] The Housing Finance and Development Centre of Finland: https://www.ara.fi/en-US.

[245] Information collected during interviews.

[246] Ministry of Agriculture and Forestry of Finland (n.d.), Wood construction is being promoted in Finland. Ministry of Agriculture and Forestry of Finland.

[247] Ministry of Employment and the Economy (n.d.), Status and possibilities of wood construction in Finland. Ministry of Employment and the Economy.

[248] Information collected during interviews.

[249] The B1M (2020), Why Finland is Building a Wood City. The B1M.

Measure	Type	Short description	Geographic level	Impacts/results
Roadmap		construction sector (and especially of building materials) and to promote wider climate goals[250]. The roadmap was prepared in support of Finland's national goal of carbon neutrality by 2035 and carbon negativity shortly thereafter. The roadmap calls for the incorporation of the whole life carbon assessment of buildings into the building regulations by the mid-2020s[251]. It covers the life cycle of buildings from land use and zoning to operation, maintenance, and demolition, and sets demanding milestones for emission reductions.		normative carbon limits for different building types (as described below), and offered legislators a new perspective for policymaking.[252]
Revision of the Land Use and Building Act (forthcoming)	Building code	The reform of the Land Use and Building Act (replacing the Land Use and Construction Act) is being prepared by the Ministry of Environment[253]. It aims to contribute to a carbon-neutral society, strengthen biodiversity, improve the quality of construction, and promote digitalisation. The revised act will introduce strict requirements for buildings, stating that the carbon footprint of the building should be evaluated before the building process. It will become mandatory to have carbon footprint information as one of the criteria in decision-making to choose the materials of the building.[254]	National	The new act is expected by 2023[255]. According to one interviewee, it is expected to have a strong influence on the competitiveness of wood as a contruction material. This measure does not directly favour WCPs, but rather takes a material-neural approach, prioritising environmental performance overall.
Normative carbon limits for different building types	Building	To support the country's carbon neutrality target (by 2035), Finland is developing legislation for low-carbon construction, including normative carbon limits for	National	The carbon limits for buildings (expected by 2025) will introduce the construction sector to life-cycle approach and assessment[260]. Meanwhile, the scope of optimisation

[250] Bionova Oy (2017), Tiekartta rakennuksen elinkaaren hiilijalanjäljen huomioimiseksi rakentamisen ohjauksessa. Bionova Oy.

[251] European Commission (2020) Thematic Group 3 "Sustainable use of natural resources" meeting. Working Group – 9th December 2020 – 9:15-12:45 [Annotated agenda]

[252] European Commission (2020) Thematic Group 3 "Sustainable use of natural resources" meeting. Working Group – 9th December 2020 – 9:15-12:45 [Annotated agenda]

[253] Ministry of the Environment (n.d.), The Land Use and Construction Act is Being Reformed. Ministry of the Environment.

[254] Information collected during interviews.

[255] Presentation by Petri Heino for the CLC Forest Group Meeting on January 26, 2021, "Policy maker's perspective on substitution opportunity".

Measure	Type	Short description	Geographic level	Impacts/results
(forthcoming)	code	different building types. Finland's Ministry of Environment has developed an assessment method and will develop a generic emission database. The assessment method and future reporting will look at both the carbon 'footprint' (i.e., the global warming potential associated with a building's life-cycle) and 'handprint' (i.e., the absolute climate benefits that would not be achieved without the building project)[256]. The EN 15978 is used to assess the whole-life carbon assessment of buildings (i.e., embodied plus operational use), which represents the basis for the proposed methodology in Task 2. The carbon sequestration and long-term storage in wooden products is seen as a way to improve the carbon handprint of buildings[257]. A definition and methods for the latter have recently been developed in a report by the Finnish Ministry of Environment[258]. The database will cover all main types of products and materials, sources of energy, modes of transportation as well as other main processes such as site operations and waste management.[259]		will widen from operational emissions to buildings' full life-cycle. This change is expected to impact building design and the demand for products with a superior environmental profile, as the carbon footprint limit becomes an additional performance requirement for building permits. According to a study by Bionova, commissioned by the Ministry of Environment, the following carbon-footprint reduction targets would be achievable: 25% for residential and school buildings, 30% for service buildings and 20% for office and commercial buildings[261]. Having commond definitions and clear rules for the handprint approach should also motivate building professionals, owners, and investors to voluntarily search for and implement new ambitious solutions[262].
Finland's Recovery and	High-level	Finland's preliminary Recovery and Resilience Plan (RRP) was presented by the Ministry of Finance on March 15th, 2021[263,264]. The plan is part of a larger Green	National	The RRP is yet to be implemented, and the specific measures and projects are yet to be submitted to the European Commission, which is expected to occur on

[260] Kuittinen, M., and Häkkinen, T. (2020), Reduced carbon footprints of buildings: new Finnish standards and assessments. Buildings & Cities.

[256] Kuittinen, M., and Häkkinen, T. (2020), Reduced carbon footprints of buildings: new Finnish standards and assessments. Buildings & Cities.

[257] Presentation by Petri Heino for the CLC Forest Group Meeting on January 26, 2021, "Policy maker's perspective on substitution opportunity".

[258] Häkkinen, T., Nibel, S., and Birgisdottir, H. (2021), Definition and methods for the carbon handprint of buildings. Danish Housing and Planning Authority and Ministry of the Environment Finland.

[259] Kuittinen, M., and Häkkinen, T. (2020), Reduced carbon footprints of buildings: new Finnish standards and assessments. Buildings & Cities.

[261] Ministry of Environment (2021), Carbon Footprint Limits for Common Building Types. Ministry of Environment.

[262] Häkkinen, T., Nibel, S., and Birgisdottir, H. (2021), Definition and methods for the carbon handprint of buildings. Danish Housing and Planning Authority and Ministry of the Environment Finland.

[263] Ministry of Finance (2021), Finland's Recovery and Resilience Plan. Ministry of Finance.

[264] Ministry of Finance (2021), Finland to use EU funding to boost investment and accelerate emissions reduction. Ministry of Finance.

Measure	Type	Short description	Geographic level	Impacts/results
Resilience Plan	strategy	Growth Programme in the context of Finland's 2035 carbon neutrality target, that also includes measures additional to the RRP. The preliminary recovery plan mentions as one of the main objectives within the green transition, the acceleration of the uptake of environmental solutions and the switch from oil heating in the real estate and construction sector[265]. Industrial circular economy solutions are also mentioned. However, there is no specific mention of the uptake of bio-based material in the construction sector.		May 15th, 2021. No direct mentions of WCPs could be found, but the RRP aims to support the country's overall carbon neutrality target (by 2035) to which the normative carbon limits mentioned above are linked.

[265] Ministry of Finance (2021), Green transition – Preliminary Recovery and Resilience Plan. Ministry of Finance.

Assessment of measures

The Finnish public policies described above are all national level policies. These were considered the most important policies to tackle in this case study because they represent the government's **clear ambition and strategy to increase the uptake of WCPs**.[266,267] Several interviewees acknowledged the Ministry of Environment's active promotion of timber construction over the past years. This ambition aligns with the country's climate and energy targets and green recovery objectives, which clearly identify the need to lower the carbon footprint of the construction sector while promoting wood products of higher added value. Interviewees agreed that there is potential, both technically and economically to **further increase the use of wood in construction** in Finland. In Subtask 1.1, it was estimated that an additional 15 million m^3 of wood could be harvested in Finland (i.e., going from a felling ratio of 80% to a ratio of 96%). This estimate represents a total potential increase in supply of timber, irrespective of use. However, construction remains a priority at national level.[268] It is seen as the only potential sector in which to increase the use of wood in Finland[269]. Furthermore, the development of exports is crucial to the industry, since the domestic market is limited[270].

Finland's forestry sector is an important pillar of the national economy, and, by supporting the uptake of WCPs, the Finnish government aims to increase the sector's competitiveness. By building up capacity and know-how, Finland can diversify its exports, boost revenues, and support its local economy. As reported by one interviewee, the Finnish construction sector imports a lot of cement and steel, and exports a lot of unprocessed wood as raw material. The economy would thus benefit from using more locally-sourced materials and exporting engineered wood products of higher added value.

As illustrated in Table 3-1, Finland has several high-level strategies, programmes, and targets in place to encourage the use of WCPs. These policy initiatives have been successful in **boosting the demand for wooden buildings and bringing new products to market**.[271] Regulatory actions, such as the revision of fire codes, have had an even more direct impact on the uptake of WCPs, particularly in multi-storey constructions. Upcoming revisions of the Finnish building code (including the Land Use and Building Act and new standards and norms for low-carbon buildings) will favour the environmental performance of buildings, taking a material-neutral and life-cycle approach. This measure can be expected to have a strong impact, since a building permit would be refused if the environmental performance of the building over its life-cycle is too low. In this context, WCPs are expected to have a competitive advantage.

Although it appears that the demand for WCPs has generally gone up, the picture may vary depending on the statistics considered. The volume of wood used in construction increased gradually over the past decades, but has recently gone down. In the 1990s, the annual per capita use of wood for construction exceeded 1 m^3, while now it is around 0.4-0.5 m^3.[272] This

[266] Woodproducts.fi (2016), Advocate of Wood Construction in the Ministry of the Environment. Woodproducts.fi.

[267] Finland Promotion Board (n.d.), The Moment for Industrial Wood Building in Finland is Right Now. Finland Promotion Board.

[268] Presentation by Petri Heino for the CLC Forest Group Meeting on January 26, 2021, "Policy maker's perspective on substitution opportunity".

[269] Ministry of Employment and the Economy (2018), Toimialaraportit – Puutuoteteollisuus. Ministry of Employment and the Economy.

[270] Ministry of Employment and the Economy (2018), Toimialaraportit – Puutuoteteollisuus. Ministry of Employment and the Economy.

[271] Information collected through interviews.

[272] Information collected through interviews.

can be explained by the **lower number of single-family houses being built**[273], in a situation where the demand for WCPs in single-family houses remains higher than in multi-storey buildings (for reasons of fire safety and of technical difficulty, as described in Task 1.1 – Market study). According to interview data, around 90% of single-family houses in Finland are made with wooden frames, as opposed to 5% of multi-storey buildings. The actors involved in multi-storey constructions have more difficulties using wood compared to those building smaller buildings. This is where the government wishes to step in.[274]

It is important to note that the national policies and goals set out by the Ministry of Environment have been taken on board by municipalities (e.g., City of Pudasjärvi[275]). In fact, interview data suggests that 60% of municipal strategies have adopted some form of ambition to increase the use of wood in buildings. **Local support** can thus be seen as a success factor in the implementation of national policies.

Several other factors can be cited as **enabling** the support or implementation of policies aimed at encouraging the use of wood in construction, namely:

Finland has a **long tradition of building with wood**, dating back to the 16th century.[276] This was largely limited to housing, which can be seen by the number of wood-dominated neighbourhoods in various Finnish cities (e.g., Helsinki, Oulu, Porvoo);[277]

Given the long tradition of building with wood, the pervasiveness of wooden houses, as well as the importance of the forestry sector, the general **attitude towards wood construction** is positive (i.e., wood has a good reputation as a building material).[278] Wood can be seen as an image and brand factor for cities, while Finns acknowledge the various benefits of wooden buildings (e.g., aesthetics, good acoustics, improved air humidity).[279,280] In 2012, a survey on wooden multi-storey buildings indicated that over 100,000 Finns were considering moving into a wooden apartment building;[281]

As reported in interviews, recent issues surrounding indoor air quality in concrete buildings have triggered **health concerns** (especially when it comes to schools and kindergardens). Interviewees reported that some schools in Finland were closed due to air quality concerns, which resulted in more demand for wooden buildings in the educational sector (e.g., it is reported that the school complex made out of log timber in Pudasjärvi was built to solve indoor air problems[282])[283];

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[273] Information collected through interviews.

[274] Information collected through interviews.

[275] Woodproducts.fi (2016), City of Pudasjärvi in Finland favours wood for public sector construction. Woodproducts.fi.

[276] The B1M (2020), Why Finland is Building a Wood City. The B1M.

[277] Fourtané, S. (2020), Wood City: A Sustainable Smart City Development That Follows Finland's Tradition Using Wood As a Building Material. Interesting Enfineering.

[278] This was mentioned by several interviewees.

[279] Woodproducts.fi (2016), City of Pudasjärvi in Finland favours wood for public sector construction.

[280] Bioeconomy (2014), Building with Wood. Ministry of Agriculture and Forestry, Ministry of Economic Affairs and Employment of Finland, Ministry of the Environment.

[281] Bioeconomy (2014), Building with Wood. Ministry of Agriculture and Forestry, Ministry of Economic Affairs and Employment of Finland, Ministry of the Environment.

[282] Yle (2015), World's largest timber building draws international attention in Pudasjärvi. Yle.

[283] See also Savelieva, K., Elovainio, M., Lampi, J., Ung-Langi, S., Pekkanen, J. (2020), Psychosocial factors and indoor environmental quality in respiratory symptom reports of pupils: a crosssectional study in Finnish schools. BMJ Open. The study mentions one of the drivers of indoor environmental quality to be “extensive coating damage and emission due to moisture damage in concrete floor structures (most commonly refers to situations where adhesive or plasticiser of a polyvinyl chloride or similar floor reacts with an alkaline moisture of the concrete slab causing volatile organic compounds emissions)”.

Attitudes towards wood construction are also increasingly positive as a result of a growing **interest in ecological issues and climate-friendly products**.[284] This is particularly the case for younger generations.[285] According to one interviewee, current demand for timber construction is primarily driven by normative guidance and cost-competitiveness, but it will be further boosted by consumers in the future (especially if other construction materials are not able to develop as environmentally sound solutions as wood is).

In contrast to the abovementioned enabling factors, a number of barriers were brought up in interviews (many of which are common to the general barriers described in Subtask 1.1):

The **cement, bricks, and steel industries** dispute policies that aim to promote WCPs. Furthermore, discussions between the wood sector and the cement and steel industries are not fruitful. As mentioned by some interviewees, the best policies are those that promote sustianble materials, more generally. The recent shift to normative carbon limits for buildings (as seen in Table 3-1) could help reduce some of these aforementioned antagonisms, by promoting low-carbon constructions, without favouring any specific building material;

Although **fire safety regulations** have become more lenient, they remain a barrier to the uptake of WCPs, and to public policies trying to promote the use of wood in construction. Various interviewees noted that Finland still has an old trauma with fire safety due to past experiences (e.g., the Great Fire of Turku[286]);

The **relevant ministries in Finland need to improve their working relationship** (Ministry of Agriculture and Forestry, Ministry of Environment, and Ministry of Economic Affairs and Employment) so that regulations for wood construction become fairer[287].

2.3.2. France

Introduction and political context

Forests cover more than **30% of France's metropolitan territory** and continue to grow by about 85,000 ha per year, on average.[288] The outermost territories (Départements d'Outre-mer) include a forest cover of 8.7 million hectares, with La Guyane featuring a total of 7.5 million ha, meaning 85% of the territory. Forest cover reaches 38% in Guadeloupe (64,400 ha), 42% in Martinique (46,500 ha) and 40% in La Réunion (100,000 ha ca.).[289] The industry association, France Bois Forêt, considers that France has enough resources to boost the use of wood-based products in construction, which would contribute to the country's low-carbon aspirations.[290,291] Subtask 1.1 estimated that wood makes up around **3% of material use in the construction sector** in France, with a small share originating from imports (5% out of 3%). In comparison to Finland, wood is not associated with French building traditions.

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284 Bioeconomy (2014), Building with Wood. Ministry of Agriculture and Forestry, Ministry of Economic Affairs and Employment of Finland, Ministry of the Environment.

285 This was mentioned by several interviewees.

286 Fourtané, S. (2020), Wood City: A Sustainable Smart City Development That Follows Finland's Tradition Using Wood As a Building Material. Interesting Enfineering.

287 As reported by one interviewee.

288 The World Bank (2018), Forest area (% of land area). The World Bank.

289 ONF (n.d.), Les forêts de nos territoires. ONF.

290 France's Low Carbon Strategy plans to reduce GHG emissions by 75% by 2050.

291 France Bois Forêt (n.d.), Le Bois dans la construction. France Bois Forêt.

However, wood is considered a renewable, bio-based material that has significant climate mitigation potential.[292] This is particularly relevant in one of the country's highest-emitting sectors.[293] Buildings alone are estimated to account for 30% of CO_2 emissions.[294] According to France's National GHG Inventory Report, French forests[295] absorbed 49 million tonnes CO_2 equivalent in 2018, while HWPs absorbed 0.9 million tonnes CO_2 equivalent in 2018[296].

The first attempt at combining the discussions on climate and wood-based construction products was through the national charter, **"Bois-Construction-Environnement"** (i.e., Wood-Construction-Environment), signed by the French government and major professional organisations in 1996.[297] The charter aimed to fight greenhouse gas emissions by furthering the use of wood in construction (e.g., by encouraging cooperation between different actors in the construction sector and increasing education and research within the field of timber construction).[298] The charter had the merit of encompassing a wide range of stakeholders and their respective areas of action, such as regulation, communication, marketing and research. On the other hand, assessing the impacts of this measure remains tentative being a declarative, not enforceable norm.

In 2010, a national decree was approved, making it mandatory to include a minimum percentage of wood in construction projects.[299] However, in many cases the obligation was circumvented by simply applying wooden skirting boards to the walls of the buildings, hence, avoiding the use of wood in more structural elements.[300] Moreover, the same decree was judged unconstitutional, on the grounds of inhibiting the freedom of enterprise. For these reasons, the decree was withdrawn in 2012.

Since 2012, buildings in France can receive a label certifying that they have used bio-based materials in their construction. While this label does not target wood products specifically, it promotes the use of bio-based materials, which can include WCPs. This represents one of the first concrete measures going beyond declarative strategies, and which contributes to the increased share of wood in buildings.

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[292] France Bois Forêt (n.d.), Le Bois dans la construction. France Bois Forêt.

[293] Institute for Climate Economics (2020), Key figures on climate. Ministry of Ecological Transition.

[294] Ministry of Ecological Transition (2020), RE2020 : Une nouvelle étape vers une future règlementation environnementale des bâtiments neufs plus ambitieuse contre le changement climatique. Ministry of Ecological Transition.

[295] Referring to the French territory according to the Kyoto Protocol parameters.

[296] UNFCCC (2020), France. 2020 National Inventory Report (NIR). UNFCCC.

[297] Ministry of Equipment, Transport and Housing (2001), Accord cadre bois - construction – environnement. Ministry of Equipment, Transport and Housing.

[298] Jonsson, R. (2009), Prospects for timber frame in multi-storey house building in England, France, Germany, Ireland, the Netherlands and Sweden. Växjö University.

[299] French Government (2015), Décret n° 2010-273 du 15 mars 2010 relatif à l'utilisation du bois dans certaines constructions. French Government.

The following requirements were established for buildings approved after 2011:

- 35 cubic decimeters per square meter of floor area for a residential building with no more than two dwellings intended for the same owner; however, buildings whose roof structure is made mostly from materials other than wood, or which do not have a roof structure;

- 5 cubic decimeters per square meter of floor area for an industrial, storage or transport service building;

- 10 cubic decimeters per square meter of floor area for any other building.

[300] As reported by one interviewee.

More recently, the **National Forest Plan (2016-2026)**[301] and the **National Low Carbon Strategy to 2050**[302] have highlighted the use of bio-based materials in construction and renovation work, demonstrating that the use of bio-based materials such as wood in new and existing constructions is a political priority. The forestry sector is also an important pillar of France's industrial strategy, having its own dedicated sub-strategy called "Contrat stratégique de Filière Bois 2018/2022"[303]. According to the strategy, the use of wood in construction accounts for 36% of added value and 37% of direct employment within the forest-wood sector. The strategy sets overarching objectives for the sector, including reinforcing collaboration in innovation, and the improvement of competences across enterprises. Among practical targets, it includes a chapter on the realisation of the works and sites for the Olympic Games, which will be hosted in Paris in 2024.

Moving beyond strategies and incentive-based schemes (such as labelling schemes), one of the most relevant policy measures that is expected to impact the uptake of WCPs, is the regulation on the climate and energy performance of new buildings, **RE2020** (expected in 2021).[304] More information on this is provided below. Other important background documents that link to the strategy are:

The **French Bioeconomy Strategy** defines a framework for the sustainable development of the bioeconomy, and includes an action plan (2018-2020) that operationalises the strategy[305]. The strategy focuses on the transition from fossil-based to bio-based products, and the transformation of the economic systems that supply these materials. The agricultural and forestry sectors thus play an important role in supplying the bioeconomy. The strategy is also consistent with other national strategies linked to the production of bio-based resources, their use, and environmental issues, such as the National Low Carbon Strategy;

The **French NECP** highlights the revitalisation of forestry management to support the use of bio-based products, energy recovery from bio-based products or from their waste, and carbon sequestration in the forestry ecosystem[306]. The NECP notes several policies aimed at leveraging these ambitions, and foresees growth in carbon sequestration through the HWP sink. The plan also mentions the intended review of environmental legislation which would apply to new buildings, introducing a criterion for GHG emissions over the building's entire lifetime.

Overview of selected measures

As indicated above, the timber industry is increasingly acknowledged as a strategic sector for the French economy. To promote the use of wood in construction, while improving the competitiveness of the sector, several key policy instruments can be highlighted. The list of measures in Table 3-2 is directly linked to the promotion of WCPs in France. Please note that impacts in terms of encouraging the use of WCPs have been assessed based on available information (found through desk research and interviews), and may have

[301] Ministry of Agriculture (2021), Le programme national de la forêt et du bois 2016 – 2026. Ministry of Agriculture.

[302] Ministry of Ecological Transition (2020), Stratégie Nationale Bas-Carbone. Ministry of Ecological Transition.

[303] French Government (2018), Contrat stratégique de Filière Bois. French Government.

[304] Ministry of Ecological Transition (2020), RE2020 : Une nouvelle étape vers une future règlementation environnementale des bâtiments neufs plus ambitieuse contre le changement climatique. Ministry of Ecological Transition.

[305] Ministry of Agriculture (2018), Une stratégie bioéconomie pour la France - Plan d'action. Ministry of Agriculture.

[306] Government of France (2020), Integrated National Energy and Climate Plan for France. Government of France.

limitations. Impacts (i.e., on the use of WCPs) are colour-coded to reflect positive or negative or no[307] impacts. Neutral, mixed results, or limited information are indicated in yellow.

[307] Negative or no impacts represents situations where the outcome of the policy measure is expected to have reduced the use of WCPs or have had limited to no impact on their uptake.

Table 3-13 List of policy measures incentivising the use of wood in construction in France

Measure	Type(s)	Short description	Geographic level	Impacts/results
Plan "Immeubles de Grande Hauteur en bois" (High-rise Timber Building Plan), implemented by ADIVbois	High-level strategy or programme; Public-private partnership	This plan aims to demonstrate the feasibility of high-rise timber buildings, in a very concrete way. It also aims to showcase the most appropriate technical solutions. The plan was implemented by the ADIVbois Association (Association for the Development of Wooden Buildings), a dedicated organisation created in 2016 in the context of the governmental initiative, "New Industrial France".[308,309] The association's work made it possible to support demonstration projects through technical support, better structuring of the sector, the promotion of innovations for their normative and regulatory appropriation,	National	The plan enabled the deployment of high-rise timber demonstration projects, the validation of adapted technical solutions and the support of stakeholders. From a list of potential sites, a national competition selected 13 sites for the demonstration projects.[310] The projects must comply with ecological, climate, and economic goals (e.g., biodiversity, soil protection, carbon sequestration, employment in zero-fossil carbon sectors).[311] The projects (36, according to interview data) are all in progress at different stages. The first construction sites have started at the beginning of 2020. The first completed project will be Wood'Art in Toulouse, completed by 2021.[312]

[308] ADIVbois: https://www.adivbois.org/.

[309] FAO Advisory Committee on Sustainable Forest-based Industries (2020), Status of public policies encouraging wood use in construction – an overview. FAO.

[310] ADIVbois (2017), Vade-Mecum des Immeubles à Vivre Bois. ADIVbois.

[311] FAO Advisory Committee on Sustainable Forest-based Industries (2020), Status of public policies encouraging wood use in construction – an overview. FAO.

[312] ADIVbois (n.d.), Étapes du projet. ADIVbois.

Measure	Type(s)	Short description	Geographic level	Impacts/results
		and their industrialisation. ADIVbois is still continuing its work through the regrouping of major construction players in terms of high-rise timber construction and the production of guidelines, the financing of technical tests for the industrialisation of suitable construction systems, among other initiatives.		
Charte Bois – Construction - Environnement[313]	High-level strategy or programme	The national charter, Bois – Construction - Environnement, initiated in 1996 with the participation of the French government and major professional organisations, is an effort to fight GHG emissions by furthering the use of wood in construction. For example, the programme encourages cooperation between different actors in the construction sector and promotes education and research within the field of timber construction.	National	Each signatory has taken up one of the strategic areas of action, including communication, marketing, competition, research, and regulation. Specific measures allowing the practical realisation of this charter (e.g., decrees aimed at increasing the share of wood in buildings, the creation of the Label Biosourcé) followed much later, according to one interviewee. The share of wooden construction in one family housing amounted to 12% in 2012 according to the research carried by the Cellule économique de Bretagne (2013). Within multi-unit housing, this same figure amouted to 4.9% in 2013. These numbers point at a market progress compared to the previous years, and this effect, according to on interviewee, was tracebale to the input of the Charter.[314]
"Plans bois" (Wood Plans)	High-level strategy or	The three plans aim to accelerate the	National	According to one interviewee, the first plan prompted regulatory changes. Furthermore, the

[313] Ministry of Equipment, Transport and Housing (2001), Accord cadre bois - construction – environnement. Ministry of Equipment, Transport and Housing.

[314] CDC Climat (2014), L'attenuation du changement climatique par les produits bois au sein des politiques françaises : priorité au bois énergie. CDC Climat.

Measure	Type(s)	Short description	Geographic level	Impacts/results
I, II and III (2009 – 2020)	programme	use of wood in construction. The first plan targeted normative and regulatory barriers with the financing of technical education. The second plan has been structured around three principles: training of professionals, rehabilitation of buildings, and the valorisation of hardwood in construction. Finally, the third plan was expected to assist market actors in the development of the use of wood in construction. This took the form of a specific tool ("Ambition bois")[315] to assist project managers in choosing wood as a material, and an extensive tool aimed at construction engineers ("Catalogue bois construction"[316]).[317]		tools developed in this plan have proved useful, but there is still work to be done in terms of communication, to reach a larger audience. These works have contributed to the update of the Eurocodes related to fire regulation (Eurocode 5), the adaptation of future environmental regulation specific to wood, and the development of constructive solutions to regulatory needs.
Campaign "Le bois – c'est essentiel" ("Wood is essential")	Public campaign	The campaign started in 2004 and aimed to promote the use of wood in construction. The campaign was a partnership between the Swedish Forest Industries Federation and the French National Committee for the Development	National	No evidence could be found on the effectiveness or the results of the campaign.

[315] Objectif Réhabilitation (n.d.), Qui sommes-nous ? Objectif Réhabilitation.

[316] Catalogue Bois Construction: https://catalogue-bois-construction.fr/.

[317] The description of the three plans was obtained from interview data.

Measure	Type(s)	Short description	Geographic level	Impacts/results
		of Wood (Comité National pour le Développement du Bois - CNDB).[318]		
"Bâtiment Biosourcé" label	Labelling/ certification	Buildings in France can receive a label certifying that they have used bio-based materials in their construction. It represents one of the first concrete measures going beyond high-level strategies and which aims at increasing the share of wood in buildings. In place since 2012 (since Decree 2012-518), this label does not target wood products specifically, but rather bio-based materials more generally (including WCPs). Several levels have been defined for this label, based on the quantity of bio-based materials used and the building type. For instance, for single-family housing, the label levels 1, 2 and 3 correspond to 42, 63 and 84 kg of bio-based material per squared meter.[319]	National	While this is not a mandatory requirement, it represents a communicative measure promoting the use of wood in construction. This measure was mentioned several times by the interviewees as a widely used certifications by the professionals of the sector.
Contrat stratégique de Filière Bois 2018/2022 (Wood sector industrial sub-strategy)	High-level strategy or programme	The timber sector is an important pillar of France's industrial strategy and has its own dedicated sub-strategy called "Contrat stratégique de Filière Bois 2018/2022".[320] The first strategy was signed in 2014, with the objective to gather all actors across the wood value	National	The strategy helps put forward the interests of the sector at the national level and is the access point of the Ministry of Ecology for communicating with the sector during common projects. The project called "Cadre de vie : demain le bois !" is an example of projects falling under the

[318] Jonsson, R. (2009), Prospects for timber frame in multi-storey house building in England, France, Germany, Ireland, the Netherlands and Sweden. Växjö University.

[319] French Government (2012), Décret n° 2012-518 du 19 avril 2012 relatif au label « bâtiment biosourcé ». French Government.

[320] Conseil National de l'Industrie (2018), Contrat Stratégique de la Filière Bois. French Government.

Measure	Type(s)	Short description	Geographic level	Impacts/results
		chain, to coordinate measures that contribute to the development of the sector, and to promote the use of wood in construction.[321] The second version of the strategy was signed in 2018 for a period of four years by the professionals of the sector and the government. It also aims to promote the use of wood in construction and increase the competitiveness of the sector by boosting its added value[322]. The strategy also promotes sustainable production and the limitation of waste, by valuing the recycling of wood materials. According to the strategy, the sector's ambition is to increase the market share of wood in new multi-family residential housing (from 3% to 6%), and in single-family housing (from 10% to 15%), as well as increase the use of WCPs in renovation projects[323].		framework of strategy.[324] It reinforces collaboration and promotes innovation in new uses of wood. A document, in the form of a handbook,[325] has already been published. This document presents four large emerging venues for the sector: "Wood-Health" on the health benefits of wood; "Wood-City" on urban and community markets for wood; "Wood-Luxury" on luxury markets for wood; "Wood on demand" on wood products tailored to specific demands. Another output of the strategy is the "Veille Economique Mutualisée (VEM)", an online platform providing economic data on the forestry and wood processing sector[326]. This data helps stakeholders measure the weight of the sector in the national economy and assess the distribution of added value at different stages of the value chain[327]. Overall, demand of WCPs is expected to increase by 2035, and with it the need to upscale sawmill capacity (e.g., to an additional 0.5 to 3 million m^3 in softwood production by sawmills between 2015

[321] Conseil National de l'Industrie (n.d.), La filière bois. French Government.

[322] French Government (2018), Contrat stratégique de Filière Bois. French Government.

[323] Conseil National de l'Industrie (2018), Contrat Stratégique de la Filière Bois. French Government.

[324] CODIFAB (2019), Cadre de vie, demain le bois ! CODIFAB.

[325] France Bois Industries Entreprises (2018), Cadre de vie : demain le bois. France Bois Industries Entreprises

[326] CODIFAB (2020), Ouverture de la plateform de veille économique mutualisée de la filière forêt-bois. CODIFAB.

[327] France Bois Forêt (n.d.), Veille Économique Mutualisée. France Bois Forêt

Measure	Type(s)	Short description	Geographic level	Impacts/results
				and 2035, depending on the scenario[328]).
Decree n. 2010-273	Legislative decree	The measure made it mandatory to include a minimum percentage of wood in construction projects.	National	The measure was withdrawn shortly after based on the argument of unconstitutionality, as inhibiting the freedom of enterprise. Therefore, this measure was not successful.
RE2020 (forthcoming)	Legislation	RE2020 is a national building regulation (i.e., Decree on the energy and environmental performance requirements for residential, office or primary or secondary education buildings in metropolitan France)[329,330]. The decree defines the indicators for the regulatory requirements in terms of energy and environmental performance that apply to new buildings for residential, office, or primary or secondary educational use. The aim is to reduce the impact on the climate of new buildings by taking into account all of the	National	While the RE2020 is expected to have a fundamental impact, its implementation will begin in the summer of 2021. Through the new RE2020, France is moving from thermal regulations to environmental regulations, which is more ambitious and demanding for the construction industry. Its objective is to continue improving the energy performance and comfort of buildings, while reducing their carbon impact. The decree’s main requirements relate to limiting energy needs for heating, cooling and artificial lighting, limiting energy consumption and associated climate impacts, limiting the impact of building components on climate change, and

328 BIPE and FCBA (2019), Étude perspective : Évolution de la demande finale du bois dans la construction, la rénovation et l’aménagement des bâtiments. Conseil National de l’Industrie.

329 European Commission (2020), Decree on the energy and environmental performance requirements for residential, office or primary or secondary education buildings in metropolitan France. European Commission.

330 European Commission (2020), Order on the energy and environmental performance requirements for residential, office or primary or secondary education buildings in metropolitan France. European Commission.

Measure	Type(s)	Short description	Geographic level	Impacts/results
		building's emissions over its life cycle, from construction[331]. This will be the first regulatory measure (as opposed to an incentive-based measure) promoting more climate-friendly buildings. The priorities of the future regulation are: • Reduce the climate impact of new buildings by taking into account all of the building's emissions over its life cycle; • Continue to improve the energy performance of buildings; • Guarantee residents that their housing will be adapted to future climatic conditions, able to better withstand future heatwaves.		limiting summer discomfort in buildings[332]. Accounting for the carbon impact of new buildings will therefore make it possible to promote the use of bio-based materials and encourage construction methods that emit fewer GHGs or that store carbon. The European Commission supports the decree and shares its goals[333]. RE2020 aligns with several European initiatives promoting environmental sustainability of building solutions and materials, including the uptake of bio-based materials in buildings and long-term carbon storage in wood[334]. The notified drafts of the French decree also pertain to the policies and measured mentioned in the French NECP. However, the Commission makes some recommendation with regard to ensuring

[331] Ministry of Ecological Transition (2020), RE2020 : Une nouvelle étape vers une future règlementation environnementale des bâtiments neufs plus ambitieuse contre le changement climatique. Ministry of Ecological Transition.

[332] European Commission (2020), Notification on the Decree on the energy and environmental performance requirements for residential, office or primary or secondary education buildings in metropolitan France. European Commission.

[333] European Commission recommendations on Notifications 2020/790/F, 2020/791/F and 2020/792/F.

[334] See Circular Economy Action Plan (COM/2020/98 final), Stepping up EU's 2030 climate ambition (COM(2020) 562 final), Renovation Wave for Europe (COM(2020) 662 final), European Climate Pact (COM(2020) 788), A sustainable Bioeconomy for Europe (COM(2018) 673 final).

Measure	Type(s)	Short description	Geographic level	Impacts/results
				compliance with the Construction Products Regulation[335] and the Product Environmental Footprint methodology[336], amongst others.
Pacte Bois Bisourcés (launched recently)	Voluntary pact	The pact includes 28 project owners and developers who voluntarily commit to using more wood and bio-based materials in construction (between 10% and 40% of the surface area of new buildings).[337] There are also qualitative objectives - for example, 30% of the wood used must be French and the wood must be certified (PEFC or FSC).	Local	This pact can promote a construction of 1,200 million m^2 in wood in France in 2021. Timber construction varies by region. Nationally, about 6-7% of housing is made of wood. In Alsace, this is 10%, while Île-de-France is below the national average (4-5%). FIBois Île-de-France wants to increase this market share with incentive actions. Actions remain voluntary but it is a way to get ahead of the upcoming RE2020.
Fonds Bois & Plan de relance de la compétitivité des scieries	Financial aid; High-level strategy or programme	This plan, adopted in 2007, aimed to contribute to the competitiveness of the sawmill industry[338].	National	This plan received funding of €10 million between 2007 and 2009, before being replaced by the plan Fonds Bois. Created in 2007, Fonds Bois represents investment support for public and private measures. The investors are the Office National des Forets (ONF), Crédit Agricole, Eiffage, and Fonds stretégique d'investissement. In 2014, the the fund, currently managed by the Banque publique d'investissement (BPI), comprised of €20 million, aimed at investing directly in SMEs

[335] See Regulation (EU) No 305/2011 laying down harmonised conditions for the marketing of construction products.

[336] See Commission Recommendation 2013/179/EU of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations.

[337] FIBois Île-de-France (2020), Le Pacte Bois Biosourcés. FIBois Île-de-France.

[338] CSFPFTB (2007). Plan de modernisation des scieries. CSFPFTB.

Measure	Type(s)	Short description	Geographic level	Impacts/results
				operating in the transformation and treatment of wood.[339] As of 2013, total investment by the Fonds Bois amounted to €14.4 million going to eight SMEs (+€13.4 million in co-financing)[340]. SMEs operating in the transformation of wood saw their numbers declining dramatically in the last decades. Numbering 15,000 in 1964, French sawmills had their number divided by 10 in almost sixty years, to 1,464 in 2016[341]. While it would be tentative to assess the impacts of this measure on the state of sawmills since its implementation, the figures show a sector in France that has been undergoing a profound crisis, and needs structural funding for its renewal.
France Bois 2024	High-level strategy or programme	This policy's objective is to elaborate an offer of services from the wood sector to project managers, with the specific aim of developing the works and sites of the Olympic Games, hosted in Paris in 2024[342].	National	On 18 March 2019, a meet-up was organised in Paris to facilitate the setting up of the teams managing and coordinating different wood-based solutions.[343] Beyond, this there is limited evidence on the impact of the measure on the uptake of WCPs.
Plan de relance 2020-2022 (Recovery Plan 2020-	High-level strategy or	In order to recover from the COVID-19	National	Sustainability and the green transition are at the core of the plan, and within this, the forestry and

[339] UNECE (2016), Le marché du bois en France. UNECE.

[340] BPI France (2013). Le fonds bois réalise son 8 ème investissement et son premier dans une scierie de feuillus. BPI France.

[341] Caillouel, D. (2020), Il faut sauver les scieries françaises ! Les Echos.

[342] Interview data.

[343] Interview data.

Measure	Type(s)	Short description	Geographic level	Impacts/results
2022) – "France Relance" (forthcoming)	programme	crisis, an exceptional recovery plan of €100 billion has been deployed by the Government, focusing on three areas of development: ecology, competitiveness, and cohesion. Two aspects particularly concern bio-based construction. First, the energy renovation component: this promotes the use of bio-sourced materials in renovation. Second, the agricultural, food and forest transition component: this provides for aid for investments to protect against climatic hazards and a plan for reforestation of French forests and support for the timber industry[344]. One important area of the recovery plan is the climate adaptation of the forestry sector and capacity building of the wood processing industry to support the development and uptake of wood-based		wood sector have been given a focal role. The plan aims to promote and accelerate innovations for wooden construction systems allowing compliance with regulatory requirements, promoting national initiatives, and improving the competitiveness of wood products. €200 million in recovery funds are earmarked for the timber sector[346]. The funds aim to support forest resources towards greater resilience and adaptation to the challenge of climate change (including 45,000 ha of forest area to be improved, adapted, regenerated, or reconstituted), promote wood as a renewable and ecological resource, strengthen the link between upstream (forests) and downstream (wood processing), and invest in education surrounding sustainable forest management[347]. The recovery plan includes examples of projects related to WCPs and specifies that supporting investments in the wood-processing industry are important[348]. It is expected that such investments can boost the uptake of WCPs.

[344] Description obtained from interview.

Measure	Type(s)	Short description	Geographic level	Impacts/results
		products, particularly for the construction sector[345].		
Label bas carbone	Labelling/ certification	The Label Bas Carbone was created in 2019 by the Ministry for the Ecological and Inclusive Transition to reward private initiatives that wish to voluntarily reduce their climate impacts.[349] The Low-Carbon Label establishes financial schemes to fund local projects that contribute to GHG emissions reductions. As increasingly numerous and various sources of funding remunerate projects that benefit the climate, there is the need for certificates that guarantee these positive actions. The Label Bas Carbone provides this guarantee, by signalling to investors and funders those projects that	National	There are currently 79 projects benefiting from the low-carbon label. The registry of projects notes potential CO_2 reductions and other co-benefits that are expected from each project[351]. For example, the afforestation project in the Haute Doller forest is expected to have a (potential) impact of -6,139 tCO_2. The project covers an area of over 10 ha. Although only launched in 2019, the label was brought up by several interviewees as having the potential to support the uptake of WCPs.

[346] Ministry of Agriculture (2020), Plan France Relance : une feuille de route au service de la filière forêt bois face au défi du changement climatique. Ministry of Agriculture.

[347] https://www.economie.gouv.fr/files/files/directions_services/plan-de-relance/annexe-fiche-mesures.pdf

[348] French Government (2020), France Relance. French Government.

[345] French Government (2020), France Relance. French Government.

[349] Ministry of Agriculture (2020), Qu'est-ce que le Label bas-carbone ? Ministry of Agriculture.

Measure	Type(s)	Short description	Geographic level	Impacts/results
		bring a positive impact to the environment and the climate[350].		
Filière foret bois – plan recherche innovation 2025	High-level strategy	The plan is specifically developed to enhance the competitiveness of the French wood and forestry sector, by targeting the social, economic and environmental performance. The plan focuses on the strengthening of research, development and innovation practices in the sector. In particular, the plan intnds to adopt a system-wide approach, tackling three major objectives: increasing overall sector performance through system approaches; developing the use of wood from a bioeconomy perspective; enhancing sustainable forest management practices.[352]	National	The plan involves 13 projects that fall within the three high-level objectives as identified in the plan:[353] 1. Enhancing performance of the sector through mobilization of economc, social and human resources; 2. Providing France with the system innovation practices in the forestry sector; 3. Characetrising and improving the performance of the forestry sector; 4. Favouring digital innovation;\= 5. Reform of the education system in the forestry sector; 6. Modernisation and adaptation of the industry; 7. Enhancing national resources; 8. Strengthening wood in construction; 9. Market and product development;

[351] Ministry of Ecological Transition (2021), Label bas-carbone : récompenser les acteurs de la lutte contre le changement climatique. Ministry of Ecological Transition.

[350] Ministry of Ecological Transition (2021), Label bas-carbone : récompenser les acteurs de la lutte contre le changement climatique. Ministry of Ecological Transition.

[352] Ministry of Agriculture (2016), Filière forêt-bois : le plan recherche-innovation 2025. Ministry of Agriculture.

[353] Ministry of Agriculture (2016), Filière forêt-bois : le plan recherche-innovation 2025. Ministry of Agriculture.

Measure	Type(s)	Short description	Geographic level	Impacts/results
				10. Enhance resilience of the sector to climate change; 11. Improve sustainable forest management; 12. Improve forests monitoring; 13. Ecosystem services evaluation and biodiversity conservation.
Bâtiment à énergie positive et réduction carbone	Labelling/certification	The E + C- label was created to support the development and improvement of low-carbon buildings. This label is issued by accredited certifiers (COFRAC or European counterparts) in participation with the national authorities. In particular, the label certifies buildings based on energetic performance, environmental performance and economic evaluation. The label is part of a national experiment began in autumn 2016 to test the level of ambition with the existing capacities and skills in the construction sector. This experiment has been implemented ahead of the strategic plan comprised in the RE2020.[354]	National	The experiment has resulted in a total of 1182 buildings being certified in France, up to 2019. Of these, 705 are individual houses, 323 are collective housing, and 154 tertiary buildings.[355]

[354] Ministry for the Ecological Transition (2018), Bâtiment à énergie positive et réduction carbone. Ministry for the Ecological Transition.

[355] Bâtiment à Énergie Positive & Réduction Carbone (n.d.), L'expérimentation en chiffres. Ministry for the Ecological Transition, Ministry for Territorial Cohesion, Environment and Energy Agency.

Assessment of measures

The policies highlighted above bring together the regulatory development of the promotion of wood as a construction material in France. In the last decade, this development has been marked by a shift from declarative, communicative initiatives, towards increasingly concrete and enforceable measures. In 1996, the Charte Bois-Construction-Environnement established the link between climate ambition and the use of wood in construction. Today, the RE2020, while yet to be put into force, is set to have a fundamental impact on the building sector. Nonetheless, until this regulation is fully implemented, the regulatory environment remains based on an incentive logic.

The most relevant measure highlighted in the interviews has been the Label "Bâtiments Biosourcés". This national certification has proven to be widely used among project managers, and was therefore identified as an effective measure. In addition, another set of voluntary measures, the Plans Bois I, II and III, was mentioned. Providing useful tools for different sets of actors, from policy-makers, to project managers and engineers, these measures would, according to one interviewee, benefit from a more extensive communication campaign, in order to reach a wider audience.

Moreover, what emerges from the interviews and the recent regulatory developments in France, is the strategic interest associated with the wood industry. This is exemplified in the *Contrat Stratégique de Filière Bois* (Strategic Contract for the Wood-based value chain - CSF Bois), comprising two four-year plans signed in 2014 and 2018. The first measure aimed at bringing together the pool of actors operating across the wood value chain, with a particular attention to the construction sector. In 2018, the CSF was extended to further target the competitiveness of the sector. The measure has been mentioned as an effective attempt to foster the interests of the sector at the natonal level, guaranteeing a mutual exchange with the public authorities on shared projects. As another interviewee points out, the development of the wood value chain has been on the political agenda in France for a decade. This gives the sector a strategic importance, particularly in respect to the increased implementation of the circular economy.

According to one interviewee, the material and technological potential to meet this strategic ambition is already there: while acknowledging that wood will hardly ever become the majority of construction materials, the current conditions could, according to this interviewee, allow a market share of 30% to 40%[356]. In this regard, lowering the VAT for biobased materials (from 20% to 5%) has been identified as one of the possible steps forward. At least 50% of this potential demand can be covered by French timber and the rest at European level. The RE 2020 will be a major test for this potential. It will be the first non-incentive measure that promotes the use of wood in construction, by building a regulatory basis. What appears from the interviews is that the industry will not be starting from scratch: following a process of improvement abnd modernisation, the industry has reached a level of maturity that enables to meet a drastic increase in demand.

Several **enabling factors** have been pointed at, which could further accompany the positive trend in the timber industry (if implemented):

The climate benefits of wood compared to conventional construction materials should be shared by all those involved in construction. As underlined in Sub-task 1.1, there is a need

[356] Although the potential increase in market demand was not calculated in Subtask 1.1, the latter estimated a potential felling-increment ratio of 70% (compared to the current 50% ratio). The majority of this potential is assumed to come from broadleaves.

for a **commonly agreed methodology that quantitatively assesses this attribute of wood**. It can be argued that the RE2020 project has made progress in this regard;

Similarly, knowledge and data on the actual additional costs wood construction, in order to overcome preconceptions about this material. Therefore, there is the need for **accountable economic data, specific for different building types**;

Training engineers, architects and building owners in techniques and tools for building with wood;

Local authorities can play an important role, by **developing tools and frameworks for territories to directly enhance their forest resources** in municipal buildings.

In addition to enabling factors, the interviews have pointed at several **barriers** inhibiting the development of the use of wood in construction:

There is **internal resistance** from manufacturers and builders around the idea that wood is expensive. But we must start a virtuous circle to reduce the cost that begins with an increase in demand for wood. The idea is not to go from all concrete to all wood, but to go towards a mix of materials.

The French timber industry has a very **fragmented representation**: many upstream / downstream structures which represent the interests of each type of profession (forest managers, primary wood processing companies, wood construction products companies, upstream / downstream inter-professions, professional committees, etc.). This translates into difficulties in conveying a common message or in developing a single set of tools for the entire sector.

Acceptance by the general public/civil society. For example, if a homeowner believes that a wood construction will **cost too much**, he/she will be less likely to opt for WCPs. It is, therefore, important to play on the arguments in favor of wood (e.g., the impact on health, comfort, aesthetics). Furthermore, some consumers in France are **reluctant to cut down trees.** More work is needed to educate the public on sustainable forest management practices.

There is a lot of talk about the use of bio-based materials in new constructions, but it should also be the case for **renovation works**. Aid can be created for this purpose as well (which does not exist in France at the moment). There are grants for the insulation of homes, but the **grants are not allocated according to eco-criteria/materials used**. The biobased aspect is rarely part of the eco-criteria used to prioritize the allocation of public funds.

Another issue brought up throughout the interviews is related to **forest ownership and sustainable management of forests**. This issue, which is not limited to France, sees forest owners treating their properties as mere inheritance, lacking awareness or interest in harvesting and sustainably maintaining their forests[357]. Furthermore, forest ownership remains fragmented in France[358,359]. These aspects of forest owneship have been identified as a barrier to achieve forests' full harvesting potential, as well as a barrier to a coordinated policy towards forests. However, initiatives such as creating a status for entities managing

[357] More information on the motivations of forest owners, split into five types of forest owners, varying in degrees of knowledge about other forest owners or risks of climate change, willingness to gain revenues from their forests, or willingness to be actively involved in the management of their forests can be found here: Polomé, P., Bouvet, A., and Bigot de Morogues, F. (2016), Enquête Adhésions Propriétaires Forestiers Privés PNR Ballons des Vosges. The research shows that forest owners with strong knowledge of their forests and willingness to engage in sustainable forest management practices with the aim to earn revenue off of their properties (i.e. Group 1) represent a small share of forest owners (3.8%).

[358] ONF (n.d.), #Toutsavoirsurlesforêts : les forêts appartiennent-elles à tout le monde ? ONF.

[359] French Government (2018), Contrat stratégique de Filière Bois. French Government.

forests collectively, under the name of the *Groupements d'intérêt économiques, environmentaux et forestiers (GIEEF)*, promoted by the French Ministry of Agriculture, have the potential to reduce this barrier[360].

2.4. Discussion on transferability of measures

A number of different public policies in Finland and in France were described and investigated in the previous chapter. It is interesting to reflect on the transferability of these policies across the EU. What the two case studies above showed is that countries in Europe have different experiences using WCPs, which implicitly means that the WCP industry is at different stages of development. This was also illustrated by the large variation in the market share of wood as a building material (ranging from 0.3% to 11.2%), depicted in Subtask 1.1. Forestry sectors also vary across Europe.

Policies incentivising the use of wood in construction, therefore, need to tackle the specific barriers and challenges that are unique to each country. For example, in some parts of Europe, there is a strong culture of using concrete. The latter is considered of better quality, while wood is considered a cheap alternative. The reputation that wood has as a building material varies greatly around Europe. Furthermore, in some parts of Europe (particularly Southern Europe), forests face technical problems such as termites and biological degradation. In that respect, countries that have a strong forest-based industry and that depend on their forests tend to invest more in sustainable forest management practices. Forest fires are also more prevalent in some countries compared to others, putting their forest resources in greater danger. These varying challenges across Member States have also been underlined in Subtask 1.1 in more detail. Some additional challenges that have been described in the previous subtask include lack of infrastructure to harvest or process timber, poor transport infrastructure, lack of interest in forest management, and illegal logging. These differences also mean that European countries have diverse knowledge that can be exchanged through more collaboration.

Interviewees generally agreed that common policies are needed in the EU, but that it is important to consider local conditions and barriers. As concluded in Subtask 1.1, one area that can benefit from more homogeneity is fire safety. This can be achieved by sharing lessons learned and exchanging knowledge. Fire codes are slow to change and are a politically sensitive topic. In countries that have experienced recent catastrophic events related to fire safety (e.g., the Grenfell Tower incident in the United Kingdom), fire safety will be even more politically sensitive. If the general public is not educated about the benefits of WCPs and the technological advancements that have improved their safety, old fire traumas will remain a challenge.

Mentalities can be changed through legislation, economic incentives, and persuasive knowledge-sharing programmes (focused on knowledge gaps specific to different countries or regions). At EU level, an example of such a programme is the New European Bauhaus[361], and, in particular, the associated wood-sector alliance, wood4bauhaus[362]. The right set of policies, adapted to the needs of each region or country in Europe, can help promote a level playing field, founded on a stronger knowledge base. As reflected in Subtask 1.1, this can be achieved through more educational and training opportunities for occupations along the whole value chain.

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[360] Ministry of Agriculture (2015), GIEEF : Ensemble, la passion de la forêt. Ministry of Agriculture.

[361] European Union (n.d.), Our conversations will share our tomorrow. European Union.

[362] Wood Sector Alliance for the New European Bauhaus (wood4bauhaus): https://wood4bauhaus.eu/about-us/.

2.5. Conclusions

In this section, the regulatory practices around the use of wood in construction were analysed by means of two case studies, looking at the current policy frameworks in Finland and France. The two countries, while both presenting political attempts in promoting WCPs, feature rather different approaches and results. Grounded in the specific aspects defining each national context, the findings also point at insightful differences in regulatory approaches.

Finland has a long tradition of building with wood, coupled with a strong domestic forestry sector. Findings from the interviews with stakeholders operating in Finland pointed at a **very positive attitude towards wood constructions and the various benefits of this material**. Nonetheless, widespread acceptance of wood in construction, particularly for high-rise buildings, is still inhibited by concerns over fire risks, a policy barrier highlighted by several interviewees. The need for training and skills to build higher-rise buildings and create WCPs of higher added value was also mentioned by interviewees. It has been emphasised that Finland can benefit from **making the forestry sector more competitive, while also meeting its climate objectives**. Overall, Finland's regulatory framework has been judged as **coherent and comprehensive**, benefitting from a national context and conditions favourable to the wood sector.

France, on the other hand, shows a clear development trend in its regulation of WCPs, **from voluntary-based initiatives, towards more enforceable measures**. This shift in regulatory approach signals the increasing acknowledgement of the wood industry as a strategic sector for France. This strategic interest is strongly emerging from the latest broad regulations approved in the country as part of the climate strategy, which positions wood as a privileged material due to its environmental benefits. In particular, the presence of measures targeting wood specifically within the Recovery Plan in the aftermath of the COVID-19 pandemic, draws a strong **link between the use of wood in construction with a broader strategy of resilience**. While policies promoting the use of wood have been put in place in France since the late 1990s, until now the regulatory environment comprises a variety of voluntary instruments, which appear at times sporadic and fragmented. In the latest regulations, particularly the RE2020 and the Recovery Plan, there is an ambitious shift from voluntary incentives, towards enfporced standards and regulations. These strategies are yet to be implemented, and their impacts will become possible to assess only in the next years. Nonetheless, as it was raised by one of the interviewees, the French wood industry has reached in the past years an improved level of economic and technical maturity, enabling to meet and commit to foreseen increase in demand for wood products in the next phase.

These two case studies lead to the following conclusions regarding the transposition across the European Union of policies supporting the uptake of Wood-based Construction Products:

In order for a policy supporting the demand of WCPs, e.g., via regulation, to be effective, the supply side must have the technical and industrial capacity to meet this demand. This capacity was well advanced in Finland, but nevertheless needed strong public support (e.g., in Research & Innovation, in demonstrators). It has taken much longer time to develop in France (more than 20 years), but seems now to have reached fruition. As described in Subtask 1.1 "Market Study", this build-up of capacity is necessary across the whole value chain, from the forest management to the construction company;

Considering the low ratio of new construction compared to the exiting stock of built environment, regulation applying to new construction could be made more effective in addressing climate change by extending its scope to renovation works;

The two areas of regulation where public policy appears to have been, or is foreseen by our interviewees to be, most effective are (1) fire safety, using simple rules to allow multi-storey buildings with a wooden frame – with no compromise made on the safety level; (2) the construction code, by attributing building permits only to the buildings with a demonstrated low environmental impact over their life-cycle. This enhances the relevance, identified in Subtask 1.1 “Market study”, of a reliable, accurate, standardised measurement of the carbon content of wood-based construction.

3. Assessment of Market-Based Schemes Encouraging the Use of Wood-Based Products

3.1. Introduction

The aim of this subtask is to identify and assess **market-based schemes (MBS)**, which reward market players along the supply chain for the production or use of wood-based construction materials. MBS are understood as instruments using markets, pricing, and other economic variables to incentivise market players to adopt a certain course of action – in this case, the adoption and use of wood-based construction materials. Ultimately, market-based schemes influence the behaviour of market players by changing their economic incentive structure. Market-based instruments (MBIs) can be grouped in several broad categories, namely, price-based (or cost-based), quantity-based (or quality-based), and market friction instruments (see Figure 2-4 for the typology and examples of instruments). Furthermore, they can be positive or negative – i.e., encouraging or discouraging a given behaviour, respectively. In this sub-task, we will identify positive schemes rewarding producers and/or consumers of WCPs. influence the behaviour of market players by changing their economic incentive structure. This subtask aims to inform the following tasks 2 and 3, namely the study of existing methodologies for the calculation of embodied carbon in Wood-based Construction Products (WCP) and, subsequently, the design of a mechanism that quantifies and remunerates carbon credits for these products. In particular, th subtask contributes towards these objectives by studying existing initiatives that incentivise the use of WCP based on their measured climate benefits.

As described in previous subtasks,WCPs provided that they have a certified sustainable sourcing and end-of-life, offer a series of climate benefits. Amongst these benefits, one of the key selling points relates to sustainability. WCPs are considered sustainable due to their renewable nature, their low carbon footprint, and their carbon storage capacity. From a **life cycle assessment (LCA)** perspective, the use of WCPs (in comparison to non-renewable construction materials) thus reduces carbon emissions occurring in the value-chain and along the lifecycle.

The inherent difficulty that comes from conducting LCAs relates to the issues of data and scope, meaning what stages of the value chain are included and what metrics are used to quantify emission savings. To facilitate this task, several tools, such as certification schemes and metrics, have been developed in the past decades, attempting to harmonise existing practices and ultimately aiming at developing a level playing field sector-wide. The tools and certifications operating across the supply chain of WCPs that attempt to measure, or at least provide means to compare, the climate benefits of biosourced materials fall within the scope of this analysis.

At EU level, a set of standards exist that defines how companies, particularly in the construction sector should go about creating their Environmental Product Declarations (EPDs), a standardized document informing about a product's environmental and human health impact, based on LCA calculations.[363] Among these standards, a few look specifically at the environment and climate impacts of buildings, focusing, based on recent revisions,[364] on the biogenic carbon content thereof (e.g. EN15804-A2). A few such standardisation schemes focus specifically on WCP, and their climate assessment based on their carbon

[363] https://ecochain.com/knowledge/environmental-product-declaration-epd-overview/

[364]

content. Among these, the most relevant are the product category EN16485, defining rules for wood and wood-based products for use in construction, specifically round and sawn timber. Furthermore, the product standard EN16449, in place since 2014, provides LCA standards to assess the amount of atmospheric carbon dioxide based on the biogenic carbon content of wood.

Next to building standards and guidelines, international schemes are already in place which certify emission reduction projects and provide a platform for the issuance and trade of carbon offset credits. These are divided into **compliance markets**, meaning schemes that are grounded in regulation (these include the EU ETS, the Clean Development Mechanism and the Joint Implementation mechanism established by the Kyoto Protocol) and voluntary markets (including the Gold Standard, VCS/Verra). While considered for this analysis, these schemes have not been included in the in-depth assessment of measures. Whereas they include assessments of forestry projects, such as afforestation and reforestation, they do not feature, in the methodologies they propose or the projects they endorse, the evaluation of climate benefits of WCP.

The various schemes and tools identified and reported here show significant variation, both in terms of scheme-type and the methodology they follow to reward or assess a certain activity. The schemes identified have been grouped under three headings:

certification or labelling schemes (instruments reducing market frictions), which certify activities and operations based on a set of criteria, and typically an established assessment mechanism;

schemes allowing for the trade of certificates, comprising certification systems that also provide a trading platform for the commercial exchange of the certificates; and

sustainability performance tools, which provide a methodology or a metric to quantify or at least provide a standardized approach to compare across several options.

Furthermore, the schemes vary according to the **methodology** employed. While some of the schemes identified provide an established methodology for the thorough calculation of the climate benefits of woods (in terms of the stored and produced emissions, directly and indirectly, across the supply chain), others offer assessment methods that more broadly target the sustainability of buildings and related activities. They then usually follow a set of criteria that go beyond the calculation of the emissions, and rather adopt a holistic approach. This type of methodologies have been included in the analysis as they tend to be more established internationally, and can provide interesting insights into the operation and implementation of the schemes.

In this report, **Chapter 2** provides factsheets on several MBS that have been identified as relevant. These are analysed according to a common matrix which includes a series of relevant aspects and attributes. The schemes are then compared amongst each other in **Chapter 3**, reflecting on a range of criteria. These comparisons especially focus on the differences in methodologies adopted, and – when available – on the lessons learned and implications that can be derived from the implementation of the schemes. Finally, **Chapter 4** provides some brief conclusions for the findings and their position within the broader context of this study, and in particular in relation to subsequent tasks in the study.

3.2. Relevant market-based schemes

3.2.1. Methodology for the selection and description of Market-Based Schemes

This section provides an overview of how market-based schemes were selected for review. The identified schemes constitute both private and public initiatives which, in different ways, incentivise the use of WCPs on the basis of their climate benefits. Criteria used to select appropriate schemes for review were:

Targeted beneficiaries: this study focuses on market-based schemes that specifically target the construction sector across its value chain (from material sourcing, to the management of the supply-chain);

Voluntary structure: the search for the schemes has targeted those that influence the behaviour of market players by changing their economic incentive structure. Therefore, this criterion includes schemes (such as labels, certification systems, voluntary marketplaces) that incentivise the use of WCP, without recurring to regulation-based approaches. The latter constitute public policies that pertain to the scope of subtask 1.2;

Explicit methodology: the schemes identified all provide an explicit methodology that defines the measuring, quantification and accreditation of climate benefits, independently of the type of rewarding system (be it a label, a tradable certificate, or carbon credits).

Following the identification of the schemes, they were analysed based on a matrix intended to capture their core characteristics, through a list of key descriptors. This analysis aims not only to highlight the most significant aspects, but also to allow for comparison across the schemes in an effective way. The schemes are presented by means of factsheets that include these descriptors:

Name of the scheme

Link;

Date of foundation;

Type of scheme;

Description;

Public vs private;

Geographic scope;

Target beneficiaries;

Carbon storage: Whether or not the scheme has a carbon storage component (yes/no) and volume of GHG emissions reduced or sequestered (if available);

Carbon price: Whether or not the scheme provides a carbon price and price range and volume of carbon credits/units (if available);

Type of rewarding system: implicit vs explicit and type of credit/unit (ex-ante and/or ex-post);

Eligible activities;

Methodology: how the carbon storage of WCPs is quantified (including the management of risk of non-permanence, the additionality, the safeguards and the cobenefits for other sustainability goals, if appropriate);

Description of the rewarding system: including the certification process (validation, verification, ex-post control, validation and verification body);

Connection with national climate policies: including measures to stimulate demand and supply if any;

Lessons learned and replicability at EU level.

3.2.2. Factsheets of the reviewed Market-Based Schemes

The Market-Based Schemes that we reviewed are the following:

Price-based mechanisms

Puro.earth;

CARBOMARK.

Labelling and certification schemes

Label Bas Carbone;

BenchValue.

Tools

HQE Batiment Durable;

Level(s);

BES 6001;

BREEAM;

Greencalc+;

GPR Gebouw.

Puro.earth

Table 2-14 Puro.earth factsheet

Name	***Puro.earth***
Link	https://puro.earth/
Dates of scheme	May 2019 - present
Type of scheme	Price-based
Public/private	Private
Geographic scope	Global
Target beneficiaries	Suppliers of carbon net-negative technologies and climate conscious companies.
Carbon storage component	Yes; Total carbon emissions sequestered or reduced by this scheme not available.

Name	*Puro.earth*
Carbon price	The prices proposed by the 10 suppliers on the transaction platform[365] range from 20 to 150 EUR / tonne removed CO_{2eq}. No information is available regarding the price at which actual transactions have taken place.
Description	The aspiration of the system is to create a functioning market for Long-Term CO_2 Removal, which is reliable, efficient and location independent. CO_2 Removal Marketplace is a platform for the issuing, trading and cancelling of CO_2 Removal Certificates (CORCs), each corresponding to 1 tonne of removed CO_{2eq}. In the system, production facilities capable of removing CO_2 are registered and audited. CORCs are issued for the volume of Long-Term net CO_2 Removal realized over a time period in these production facilities. These CORCs are then transferable to other account holders. The value of the CORC is realized by Cancellation, thereby removing it from circulation and making the Beneficiary of the Cancellation the sole owner of the CO_2 Removal Attributes. The market applies to a limited number of carbon removal methods, namely: • Non-fuel usage of charcoal (biochar); • Carbonated building elements; • Wooden building elements.
Methodology	The producer (CO_2 Removal Supplier) provides data and documentation on the production volume (in kg) of the CO_2 removal output in the production process of the eligible production facility. Carbon content is proved by sampling process (e.g. according the European Biochar Certificate, EBC[366]). Carbon content is described as kg CO_2 / kg of product. The Net CO_2 Removal is determined by subtracting the CO_2 emissions generated directly or indirectly due to the production process (including the production process itself, the extraction of the raw materials, and transport) from the CO_2 absorbed and stored. One CORC corresponds to 1 tonne of CO_2 stored. The eligibility of the production facility is determined in the Production Facility Audit.
Risk of non permanence:	• The end use of biochar is included to the extent that the use is proven to be non-energetic, in which case the CO_2 storage in biochar is considered permanent.[367] • The verification ensures that the corresponding CO_2 removal has taken place and that the CO_2 removal is considered permanent as defined in the methodology. • The carbonated element will be used for construction purposes

[365] As observed on the transaction platforms at URL https://puro.earth/services/ on 29 March 2021.

[366] The EBC was developed to limit the risks of biochar usages to the best of our scientific knowledge and to help the users and producers of biochar to prevent or at least to reduce any hazard for the health and for the environment while producing and using biochar.

https://www.european-biochar.org/en

[367] Biochar is used as a soil amendment. Biochar has several properties, depending on the feedstock and the conditions of production. Biochar represents a viable option to mitigate both land degradation and climate change. Nevertheless, the climate benefits of biochar could be substantially reduced through reduction in albedo if biochar is surface-applied at high rates to light-coloured soils or if black carbon dust is released (IPCC Special Report on Climate Change and Land).

https://www.ipcc.ch/srccl/chapter/chapter-4/

Name	*Puro.earth*
	only and the storage of CO_2 is a priori permanent regardless of the use of the carbonated building elements. • The risk of non permanence for wooden building elements is addressed indirectly, based on the expected lifetime of buildings. Because buildings in the EU designed to last over 50 years, the CO_2 storage in a wooden building is considered long-term.
Additionality	Not considered
Safeguards	End of life emissions from demolition or other transformations at end of life are not considered. At end of life the carbonated element retains the stored CO_2 – hence the removal is a priori permanent. The demolition of a house or other constructions made from the carbonate building element does not impact the CO_2 storage capability. The amount of decomposing or re-emitting of CO_2 in the normal use of the product needs to be estimated. If there is no re-emitting or decomposition, proof needs to be presented that the product does not leak CO_2 and the storage is permanent in normal conditions (e.g. theoretical calculations, chemical formulas or test results).
Co-benefits with other sustainability goals	Not specified
Rewarding system	Ex ante 1. A supplier makes a claim on the net-negativity of their products by presenting evidence: Lifecycle Assessment (LCA) or Environmental Product Declaration (EPD) which attests that the product has absorbed more CO_2 that it has emitted. 2. Based on this evidence, compliance to Puro methodology requirements is audited by Puro's independent assessor, DNV GL, who visits the production facility, validates the accuracy of data and issues an audit statement. The costs of the verification are covered by Puro.earth. 3. The verified volume of extra carbon absorbed in the products is then issued CO_2 Removal Certificates (CORCs) for every metric ton of CO_2 removed and stored. 4. CORCs are sold in the Puro.earth marketplace to companies who want to neutralize their emissions by removals and become climate positive.
Eligible activities	Eligible output: - Biochar: charcoal that is produced by pyrolysis of biomass, yet in the absence of oxygen, and is used as a soil ameliorant for both carbon sequestration and soil health benefits. - Carbonated building elements: Carbonation is a chemical reaction between CO_2 and metal hydroxides or oxides (CaOH, MgOH, CaO, MgO) to form a strongly-bonded, stable carbonate mineral ($CACO_3$, $MgCO_3$) - Wooden building elements: mass timber elements, glued laminated timber, cross-laminated timber, laminated veneer lumber or cellulose fiber insulation (CFI), sourced from sustainably managed forests and plantations

Name	*Puro.earth*
	in Europe, and used for the construction of buildings.
Connection with national climate policies	In case of forest biomass raw material, the scheme follows internationally established certification systems - Programme for the Endorsement of Forest Certification (PEFC) Sustainable Forest Management Standard: National standard under the PEFC, such as PEFC Finland Standard (PEFC FI 1002:2014); or - Forest Stewardship Council (FSC) Forest Management Certification, e.g. FSC Standard for Finland (FSC-STD-FIN-(Ver1-1)-2006)
Lessons learned	The scheme represents a successful example of voluntary market for carbon removal. The focus on three carbon removal methodologies provides a standardized and unified approach to carbon storage and the issuing of certificates.
Replicability at EU level	High replicability: the scheme operates internationally and abides to relevant EU legislation, concerning built constructions and raw material sourcing and quality (including wood sourcing and biochar).

Carbomark

Table 2-15 Carbomark Factsheet

Name	*CARBOMARK*
Link	https://pdc.minambiente.it/it/area/temi/clima/progetto-carbomark
Date of foundation (and end of initiative, if applicable)	2009-2011
Type of scheme	Emission credits trading platform (voluntary carbon market)
Public/private	Public
Geographic scope	Italy (regional: Veneto, Friuli Venezia Giulia)
Target beneficiaries	Agricultural and forestry activities, local administrations, SMEs, forest owners.
Carbon storage component	Yes; At the end of the project, 21 private companies and 27 public forest owners had joined the CARBOMARK market and three buying contracts had been signed. According to these contracts, 350 tonnes of carbon have been stocked.
Carbon price	N/A
Description	The project explored the possibility of establishing a voluntary carbon market at the local level, i.e. involving a geographical proximity between buyers and sellers of carbon. It is believed that the physical proximity of the market participants significantly contributes to the increase of visibility and credibility of the exchange mechanism. Carbomark is a voluntary market characterized by the "local" territorial dimension and responds to

Name	*CARBOMARK*
	two main challenges: - developing mitigation projects that offer lasting and reliable carbon credits; - contributing to reducing emissions at the local level. It recognizes the contribution that forestry activities offer to the reduction of concentration of carbon dioxide, promoting the realization of projects related to forest management, urban greenery and wood products. By virtue of the geographical proximity of the carbon "sinks" and their visibility, the Carbomark market not only guarantees effective mitigation of emissions but it also promotes investor confidence in the initiative. The Carbomark market was developed in two neighbouring regions: Veneto and Friuli Venezia Giulia. The project created an online trading exchange for carbon credits between entities that can store carbon (sellers) and entities wishing to offset their emissions (purchasers).
Methodology	Credit relative to wood products is sellable ex-post, meaning after the definitive project for the building and infrastructure has been approved, and after the creation of the building and its certification by the competent Authorities. Only the fraction of certified wood used may generate credits. The documentation that must be presented in order to generate credits is: - project execution from which the share of wood for structural use utilised is deduced; - the percentage of certified wood (FSC, PEFC or similar); - the certificates of the building test issued by the competent Authorities (only for already created buildings). The methodology includes a coefficient which guarantees that the use of wood products does not cause a negative impact on the woods of origin and on emissions, particularly as a result of deforestation elsewhere (leakage effect). However, no further details on this coefficient have been found
Risk of non permanence:	Permanence: the permanence of carbon in wood products is usually considered to be at least 30 years (it is a conservative value, considering that 50 years represents the average life cycle of these products). For the credits holder is required to report any problems to the Kyoto Observatory throughout the duration of the credit which involve a reduction in the sink, so that the necessary actions can be taken. The Kyoto Observatory (two per region) have been established to manage the meeting between supply and demand. They provide information on the commitments each party enters into as well as the different phases dividing the trade of certificates. They also play a number of market development support activities, dedicated to both sellers and buyers, including the updating of a public registry which comprises all the activities involved in CARBOMARK. Information on the Kyoto Observatories, however, is rather scarce, and it is unclear whether these have continued in their operation, and in what manner.

Name	*CARBOMARK*
Additionality	Additionality: for the purpose of credit generation, only buildings or infrastructures, completed or under construction, which result in a higher use of timber than the average use at local or national level (calculated according to the methodology developed by Carbomark) can be considered,
Safeguards	None identified
Co-benefits with other sustainability goals	The scheme claims to be the first case of large-scale dissemination of knowledge to SMEs and regional forest owners about the importance of the investments in GHG emissions mitigation and the possibility to exchange carbon credits. It enhances the awareness of the forest owners on the importance of forests in fighting climate change and on the chance to reward their mitigation effect through a mechanism that allows to diversify economic strategies in forest management. The project has also promoted a mechanism of CO_2 "sequestration" as an approach to mitigate emissions through projects able to determine a positive environmental effect.
Rewarding system	Ex-ante The Carbomark logo represents a marketing operation that certifies a positive environmental and territorial impact by an activity.The duration of the use of the logo is different for those who sell and those who buy carbon credits. - For the seller, the release of the logo will have a duration of 30 years, corresponding to the timeframe of the commitment to absorb CO_2 from the atmosphere. The period will start from the date of accession to the market. - For the buyer, the release of the logo will have a duration of 5 years, a period of time during which the additional policies to reduce emissions foreseen by the commitments will have to be activated. The logo is issued by the Kyoto Observatory of reference and is associated with a code attributed by this entity. The identification code is attributed upon joining the market, while the use of the logo combined with the owner's code follows the stipulation of the contract. The meeting between supply and demand is managed by the Kyoto Observatory (one per region) which provides information on the commitments to be entered into by each party and on the different phases in which the purchasing and selling of credits is divided. They also play a number of market development support activities, dedicated to both sellers and buyers, including the updating of a specific public "register". The Kyoto Observatory therefore play the role of management and organization of the functioning of the Carbomark market.

Name	*CARBOMARK*
Eligible activities	Agricultural and forestry activities, local administrations, SMEs, forest owners.
Connection with national climate policies	The results of the project (given its replicability) can be improved by creating new local carbon markets in other Italian regions which have already expressed interest for that during the CARBOMARK information activities (among them in particular Lazio and Piemonte). Moreover, in 2014 the municipalities of Lusiana (VI) and Mel (BL) set up two carbon credit auctions.
Lessons learned	The available project information claims that, although the CARBOMARK project has come to an end, the two Kyoto Observatories continue to operate after the end of the initiative, through their consultancy activities for businesses involved in the trade of carbon certificates. However, it is unclear whether these Observatories are currently operating.
Replicability at EU level	High replicability at EU level as this project operated under the EU programme LIFE, while acknowledging the important local dimension of the scheme.

HQE Bâtiment Durable

Table 2-16 Factsheet HQE Bâtiment Durable

Name	
Link	https://hqe-batimentdurable.certivea.fr/certification
Date of foundation (and end of initiative, if applicable)	December 2016
Type of scheme	Certification system
Public/private	Private
Geographic scope	France
Target beneficiaries	Private and public actors in territorial and construction planning
Carbon storage component	Not applicable.
Carbon price	N/A
Description	The HQE (high environmental quality) approach is a quality approach that makes it possible to integrate environmental requirements into construction, rehabilitation and area development projects. It was created in 2002 by the HQE association, which continuously evolves to adapt to technical progress and the habits of professionals. This was the case in 2015, when a new “reference framework” was put in place. It is managed by the umbrella organisation Certivéa, which manages a number of labels and certifications across different sectors.

Name	
Methodology	The HQE approach applies the so-called “reference framework” (*cadre de référence*). The methodology guides professionals towards environmental performance: the owner remains free to prioritize certain elements within a given framework, unlike a label where the requirements are predefined, therefore the system is characterised by a high flexibility. The framework is constructed around the following elements: - Quality of life, defined by: accessibility, adaptability, acoustic comfort, hygrothermal comfort, visual comfort, water quality, indoor air quality, electromagnetic waves, services, transport; - Economic performance, defined by: benefits and costs, contribution to territorial dynamics; - Sustainable management, defined by: improvement, commitment, evaluation, planning, resources and means, site phase specifications; - Respect for the environment, defined by: biodiversity, carbon, climate change, water, circular economy, energy, waste, environmental impacts on the life cycle. It constitutes a common base of principles and objectives, tailored to specific construction, rehabilitation or territorial planning projects.
Risk of non permanence:	Not described
Additionality	Not described
Safeguards	Not described
Co-benefits with other sustainability goals	The website reports a roadmap that shows the connection of the HQE initiative with 12 of the 17 UN SDGs. These are namely: good health and well-being; quality education; clean water and sanitation; affordable and clean energy; decent work and economic growth; industry, innovation and infrastructure; sustainable cities and communities; responsible consumption and production; climate action; life below water; life on land; partnership for the goals.
Rewarding system	Ex ante The accreditation method follows a series of steps: 1. Acceptance of the Certivéa contract based on the project's credentials; 2. Initiation of the HQE Sustainable Building standard, choice of the desired performance level and actions to be carried, implementation and preparation of supporting documents; 3. Verification by an independent panel;

Name	
	4. Highlighting the overall level of performance achieved.
Eligible activities	HQE Sustainable Building is suitable for all tertiary buildings under construction, renovation, or private or public operation in France and internationally: offices, schools, cultural, logistics, hotels, shops, etc. Certification can be obtained in the program, design, construction or operation phase with the same reference system.
Connection with national climate policies	Information not available.
Lessons learned	The scheme offers a flexible assessment framework, hence giving flexibility to applicants in designing their own sustainability priorities.
Replicability at EU level	Although so far all the projects certified by the scheme are located in France, eligible projects are not confined to this national territory. Therefore, there is a high level of replicability outside France and across the EU.

Label Bas Carbone

Table 2-17 Factsheet Label Bas Carbone

Name	*Label Bas-Carbone*
Link	https://www.ecologie.gouv.fr/label-bas-carbone
Date of foundation (and end of initiative, if applicable)	November 2018
Type of scheme	Label
Public/private	Public
Geographic scope	France
Target beneficiaries	Construction, agriculture, forestry, transport, etc. Different types of methods are approved by the Ministry of the ecologic transition, but they are proposed by the individual stakeholders.
Carbon storage component	Yes. The total volume of carbon emissions sequestered or reduced by this scheme is not available.
Carbon price	Yes: The possibility is given to employ the certified reduced emissions within the framework of a voluntary carbon compensation mechanism. The latter, however, remains outside the scope of the European emission trading (ETS).

Name	*Label Bas-Carbone*
	No carbon price given.
Description	The Low-Carbon Label sets up an innovative and transparent framework offering funding prospects for local projects to reduce greenhouse gas emissions. It thus makes it possible to support the ecological transition at the territorial level, by rewarding behaviour that goes beyond usual practices. The certificates issued for avoiding or removing GHG emissions are neither transferable nor exchangeable. Communities, companies, and even citizens, are ready to remunerate actions beneficial for the climate on a voluntary basis, for example to offset their residual emissions. To get involved, these potential funders want the quality and environmental integrity of projects to be guaranteed. The low-carbon label offers them these guarantees and thus makes it possible to direct funding towards virtuous projects for the climate and the environment.
Methodology	While it is up to the applicant to determine and propose a sequestration method to the public authority, the latter certifies the project, by comparing the baseline scenario (absence of project) with the emissions reduction brought by the project, taking into account both direct emissions (produced within the scope of the project) and indirect ones (transport, energy use, production inputs and outputs, etc.)
Risk of non permanence:	The application of a minimum discount of 10% on the emission reductions generated: the method fixes this discount according to the estimated risk level of non-permanence of the project: the more risky the project is, the higher the discount will be and may therefore exceed 10%. This option is valid for all types of emission reductions. In the case of anticipated emission reductions only, the method may propose to model the occurrence of future hazards and their impact on carbon sequestration. So the applicant can propose the calculation of the variation of the average carbon stock over the long term due to the sequestration in biomass or soils, in a scenario taking into account the possibility of occurrence of accidental events that may decrease this sequestration. This variation is then reduced by the variation of the average carbon stock over the long term in the baseline scenario. For example, a forestry method might choose to take into account in the calculation of future carbon sequestration the probability of occurrence of storms or fires within the perimeter of the project. This option is reserved for the calculation of anticipated emission reductions.
Additionality	The low-carbon label targets projects that reduce greenhouse gas emissions compared to the baseline scenario. These projects must be additional, that is to say, go beyond regulation and current practice. They can cover changes in practices, the introduction of new technologies, changes in systems, in behaviour or any other action to accelerate the low-carbon transition. Dispositions are given regarding the interaction between the Label Bas carbone and the support measures available under the EU Recovery Plan, addressing the crisis of the COVID-19 pandemic. These are considered mutually exclusive and cannot be cumulated, due to the additionality rules defined in the forestry methods of Low-Carbon Label. Project managers will therefore have to choose to activate either of the two mechanisms.

Name	*Label Bas-Carbone*
Safeguards	Not described
Co-benefits with other sustainability goals	Not described
Rewarding system	Ex ante Rewarding application based on 5 steps: 1. Notification to the Ministry of the ecologic transition; 2. Request of validation by the project manager, bringing a description of the project and the carbon reduction methodology, which is to be validated by the Ministry; 3. Instructions and validation, guaranteeing that the project implements the proposed methodology thereby reaching the desired results; 4. Verification of the emission reduction by an external independent panel of experts; 5. Certification of the emission reduction, which is recorded by the Ministry, and officially certifies the quantity of emissions reduced or sequestrated by the project.
Eligible activities	The label involves enterprises, associations, collectives, as well as particular initiatives which intend to support projects that have a certified positive impact on the climate. Two types of actions are envisaged: - Avoiding GHG emissions into the atmosphere by changing specific sectorial practices (construction, transport, waste management, etc.); - improving carbon sequestration (soil, forests).
Connection with national climate policies	Labelled emission reduction projects contribute to the low-carbon economy and are fully compatible with the emission reduction trajectory that France has set itself in the framework of the National Low-Carbon Strategy (SNBC), as well as with the climate objectives set at European level and within the framework of the Paris Agreement.
Lessons learned	The scheme comprises a well-established verification methodology while giving full initiative to the applicants in determining the methodology used to estimate carbon removal.
Replicability at EU level	The Label Bas-Carbone is an initiative of the French Ministry for the Ecological Transition, and therefore follows procedures and requirements specific to the French context.

Benchvalue

Table 2-18 Factsheet Benchvalue

Name	*BenchValue*
Link	http://benchvalue.efi.int/partners.html
Date of foundation (and end of initiative, if applicable)	2013-2018
Type of scheme	Tool
Public/private	Private
Geographic scope	EU
Target beneficiaries	No beneficiaries, rather users: policy makers and market players can employ the tool to measure the sustainability and climate benefits of wood compared to non-renewable materials in the construction sector.
Carbon storage component	Yes; Total carbon emissions sequestered or reduced by this scheme not available.
Carbon price	N/A
Description	The aim of the project was to develop a versatile benchmarking method to compare between renewable wood-based and non-renewable value chains and to quantify the sustainability impacts and climate change mitigation potential of substituting non-renewable with wood-based materials to support market and policy actors. BenchValue proposes a common method for comparing impact values for different materials for informed decision making. The construction sector was chosen as the demonstration case to test the BenchValue method, as timber can be a viable and long-term alternative for storing green carbon in buildings and substituting GHG emissions from more energy intensive materials.
Methodology	BenchValue uses the tool ToSIA (Tool for Sustainability Impact Assessment), an established decision support tool for the forestry sector. ToSIA analyses environmental, economic, and social impacts of changes in forestry-wood production chains, using a consistent and harmonised framework from the forest to the end-of-life of final products. It allows users to analyse different kinds of sustainability effects in a balanced way. ToSIA is a flexible tool, based on three concepts: 1. Alternative process chains (baseline and scenarios); 2. Material flow along the chain (e.g. wood, timber products, reindeer meat - all converted to tons of Carbon); 3. Indicators per process and indicators multiplied with the material flow ToSIA assesses the sustainability impacts of alternative supply chains.

Name	*BenchValue*
Risk of non permanence:	No information provided
Additionality	No information provided
Safeguards	No information provided
Co-benefits with other sustainability goals	No information provided
Rewarding system	N/A
Eligible activities	BenchValue involves the whole value chain, comparing wood with non-renewable materials in the construction sector.
Connection with national climate policies	At the moment of creation, no such label, standard or method existed, but its need had been stressed in relation to the EU “Energy Performance of Buildings Directive” which entered into force in 2020.
Lessons learned	The scheme represented one of the first attempts of its kind in measuring climate benefits of wood as a means to compare across different materials. The lastest available activity of the project date to 2019, where a further monitoring of the case studies was conducted, including the organisation of a public event.
Replicability at EU level	High replicability, as this tool has been employed in different case studies, by looking at four Member States (Austria, France, Ireland, Lithuania).

Level(s)

Table 2-19 Factsheet Level(s)

Name	*Level(s)*
Link	https://ec.europa.eu/environment/topics/circular-economy/levels_en
Date of foundation (and end of initiative, if applicable)	2020
Type of scheme	Certification system
Public/private	Public

Name	***Level(s)***
Geographic scope	EU
Target beneficiaries	Different actors operating in the building sector, spatial planning, designing, financing and execution.
Carbon storage component	No carbon storage component.
Carbon price	N/A
Description	Level(s) is an assessment and reporting framework that provides a common language for sustainability performance of buildings. Level(s) promotes lifecycle thinking for buildings and provides a robust approach to measure and support improvement from design to end of life, for both residential buildings and offices. Level(s) uses core sustainability indicators, tested with and by the building sector, to measure carbon, materials, water, health, comfort and climate change impacts. It takes into account lifecycle costs and value assessments. Level(s) is open source and freely available to all. For all those in the sector, the challenges of cost control and environmental gain are met both by the reduction in energy, materials, and water use, and by future-proofing buildings. For those commissioning, designing, or occupying buildings, Level(s) helps them ensuring that their high quality, fit-for-purpose buildings meet their cost and environmental objectives.
Methodology	Level(s) is divided into three areas, each with its own subject matter and desired outcomes: 1. Resource use and environmental performance during a building's lifecycle - Use stage energy performance (kWh/m^2/yr) - Life cycle Global Warming Potential (CO_2 eq./m^2/yr) - Life cycle Global Warming Potential (CO_2 eq./m^2/yr) - Construction and demolition waste - Design for adaptability and renovation - Design for deconstruction - Use stage water consumption (m^3/occupant/yr) 2. Health and comfort - Indoor air quality - Time out of thermal comfort range - Lighting - Acoustics 3. Cost, value, and risk - Life cycle tools: scenarios for projected future climatic conditions

Name	*Level(s)*
	- Increased risk of extreme weather - Increased risk of flooding - Life cycle costs (€/m²/yr) - Value creation and risk factors Each of the three areas has its own set of indicators dealing with a building's environmental, social, and economic long-term sustainability.
Risk of non permanence:	No information provided
Additionality	No information provided
Safeguards	No information provided
Co-benefits with other sustainability goals	No information provided
Rewarding system	Benefits (rather than reward system). Level(s) enables building professionals and their clients to use fewer resources, and therefore improve the environmental performance of their buildings. Level(s) can be used as an entry-level tool and at each stage of building projects, to give a complete picture throughout the full lifecycle. It offers a framework to measure performance in key areas at each stage – namely: i) concept for the building project; ii) detailed design and construction; iii) reality after completion and including the handover to the client. The Level(s) framework: i) encourages users to think about the whole lifecycle of a building, providing a basis for quantifying, analysing and understanding the lifecycle; ii) addresses a number of aspects of circularity, providing indicators that can help understand how to extend the utility of the building (useful in terms of a building's service life and value, and future potential for recovery, reuse and recycling of its materials); iii) enables comparative performance measurement through cumulative reporting, including across property portfolios; iv) provides a framework of measurement which can be incorporated to assessment and certification schemes and policy initiatives supporting the development of the circular economy at European, national, and local levels.
Eligible activities	Level(s) enables building professionals and their clients to use fewer resources, and therefore improve the environmental performance of their buildings. Level(s) can be used as an entry-level tool and at each stage of building projects, to give a complete picture throughout the full lifecycle.
Connection with national climate policies	Policy initiatives that can help mainstream lifecycle and circularity in the built environment include the Green Deal and new PPPs under Horizon Europe, as well as adoption and implementation of the Sustainable Finance Delegated Act on tackling climate change
Lessons learned	Users believe that common assessment methods and reporting systems such as Level(s) can support (1) green public procurement, (2) assessments of the life cycle performance of products used in buildings, (3) the benchmarking of building stocks, (4) the definition of processes, products, equipment and systems in existing buildings; (5) providing full sustainability performance of a project across its while lifecycle

Name	*Level(s)*
Replicability at EU level	The programme is already operating at EU level.

BREEAM

Table 2-20 Factsheet BREEAM

Name	*BREEAM*
Link	https://www.breeam.com/
Date of foundation (and end of initiative, if applicable)	2009
Type of scheme	Certification method
Public/private	Private
Geographic scope	Global
Target beneficiaries	Project developers and corporations.
Carbon storage component	No carbon storage component.
Carbon price	N/A
Description	BREEAM stands for Building Research Establishment Environmental Assessment Method and is the certification method for a sustainable built environment. It claims to be the most broadly used real estate certification. BREEAM assesses buildings on nine different sustainability categories, in order to provide a complete insight into a project in the field of sustainability. With this method, projects can be assessed on integral sustainability. The method was developed by the Building Research Establishment (BRE) and is now used in more than 80 countries worldwide. In total, nearly 600,000 projects already have a BREEAM certificate.
Methodology	The assessment of a building (plus plot) is based on a so-called credit list. The points to be allocated may vary by type of building (retail, school, office). The applicant must indicate in his registration for each part of the building which building type is applicable. A BREEAM standard covers issues in the following sustainability categories: management; health and well being; energy; transportation; water; materials; waste; land use and ecology; pollution. Most credits have a certain freedom of choice, which means that development and construction teams can choose themselves which credits they wish to obtain and thus build up a total score. For a number of items a minimum standard is applicable, that must be achieved in order to obtain a total score. These are mandatory credits. If all subjects within a category are assessed, then a score category can be determined, to which an environmental weighting is applied. The weighted category scores are summed up, and lead to an overall score,

Name	*BREEAM*
	which may have additional scores if innovation credits have been awarded. This total score eventually leads to a BREEAM rating. The assessments of buildings result in a final report and a BREEAM certificate, in which the environmental performance of the building is listed against the issues from the standards framework.
Risk of non permanence:	No information provided.
Additionality	No information provided.
Safeguards	None in the context of carbon storage as this is not specifically assessed. More generally, the Assessor assesses the BREEAM project on the basis of the burden of proof provided. When the project is completed, the Assessor will also visit for an inspection. The national authority then carries out a random check. This is called the Quality Assurance (QA). From a quality point of view, this QA is periodically tested by the parent organization at international level BRE. Additional evidence of the sustainability of the project may need to be provided. After all checks, the final BREEAM certificate is issued by the Assessor.
Co-benefits with other sustainability goals	BREEAM standards offer certifications for water and energy usage and health and well-being – for the latter attention is paid to for example the indoor climate, ventilation, light and volatile organic compounds. According to BREEAM, the standard covers a wide range of sustainability topics beyond climate – having an impact on the built environment, transport, energy, water, waste, pollution, health, materials, land-use and ecology
Rewarding system	Ex ante Assessment and certification can take place at a number of stages in the built environment life cycle, from design and construction through to operation and refurbishment. For the following stages in the development and construction process of buildings, a BREEAM assessment of building (plus plot) can be made: - Design stage: leads to a preliminary BREEAM certificate - Post-construction stage: leads to a final BREEAM certificate The assessments of buildings result in a final report and a BREEAM certificate, in which the environmental performance of the building are listed against the issues from the standards framework. The user will obtain a score on a five- or seven point rating scale depending on whether the project involves new construction and renovation or if it refers to existing buildings where the objective is to reduce operating costs and improve environmental performance.
Eligible activities	Construction projects
Connection with national climate policies	Depends upon national implementation of the scheme.

Name	*BREEAM*
Lessons learned	It works to raise awareness amongst owners, occupiers and designers of the benefits of taking a sustainable building approach. In the Netherlands there are subsidy opportunities linked to the adoption of BREEAM-NL.
Replicability at EU level	This scheme is already operating internationally. The method is used in 80 countries worldwide. The Dutch Green Building Council has made the method suitable for the Netherlands, under the reference BREEAM-NL.

BES 6001

Table 2-21 Factsheet BES 6001

Name	*BES 6001*
Link	https://www.bsigroup.com/en-GB/bes-6001-responsible-sourcing-of-construction-products/
Date of foundation (and end of initiative, if applicable)	October 2009
Type of scheme	Certification system
Public/private	Private
Geographic scope	UK
Target beneficiaries	BES 6001 is relevant to any organization that manufactures construction products from foundation products such as cement and steel to concrete pipes and blocks, windows, flooring, roof tiles, plastics, wood products.
Carbon storage component	No carbon storage component.
Carbon price	N/A
Description	The BES 6001 certification scheme is based on the BS 8902:2009 standard “Responsible sourcing sector certification schemes for construction products. Specification”. This certification scheme has been set up to enable construction product manufacturers to ensure and then prove that their products have been made with constituent materials that have been responsibly sourced. The standard describes a framework for the organisational governance, supply chain management and environmental and social aspects that must be addressed in order to ensure the responsible sourcing of construction products. BES 6001 is recognized by the BREEAM family of certification schemes and the Code for Sustainable Homes where credits can be awarded for construction products independently certified through BES 6001 Framework Standard.
Methodology	The requirements of the Standard consist of actions to be taken to demonstrate adoption of the principles of responsible sourcing. The requirements and associated actions have been structured into three components: - Organisational Management Requirements;

Name	*BES 6001*
	- Supply Chain Management Requirements; - Requirements related to the management of sustainable development. Certain requirements, or elements of the requirements, are considered compulsory for organisations applying for certification against this Standard. This is indicated in the description of the requirement. Furthermore, additional Performance Ratings and supplementary credits are allocated to the voluntary elements of the requirements.
Risk of non permanence:	No information provided.
Additionality	No information provided.
Safeguards	No information provided.
Co-benefits with other sustainability goals	Indicators of the BES 6001 certificate include GHG, ecotoxicity, energy use, transport impacts, resource use, employment and skills, waste prevention and management, impact on local communities, water abstraction, business ethics, life cycle assessment.
Rewarding system	The assessment process delivers a total score based on the number of points scored above the Compulsory level. The number of points determines whether a certificate of 'Pass', 'Good', 'Very Good' or 'Excellent' level is issued. Each certificate is valid for three years with Annual Verifications ensuring the continued robustness of the information provided. Each certificate for assessments will include a bar chart indicating how well the assessed product(s) scored in each clause – this ensures the transparency and usability of the certification. Benefits include: i) demonstrating to stakeholders that the company sources products responsibly; ii) becoming more competitive to increase opportunities and prospects; iii) making more informed decisions when selecting suppliers; iv) improving overall social and environmental performance; v) gaining access to schemes such as BREEAM and Code for Sustainable Homes.
Eligible activities	Whilst it is more relevant to the business-to-business market, BES 6001 is also relevant to retail organizations that sell construction products such as the large DIY stores.
Connection with national climate policies	No information provided.
Lessons learned	The scheme is more relevant for the B2B market, and provides standards related to product sourcing.
Replicability at EU level	This scheme operates in the UK, but given its flexible components, it offers possibilities for replicability at EU level.

Greencalc+

Table 2-22 Factsheet Greencalc+

Name	*Greencalc+*
Link	https://www.duurzaaminstaal.nl/p/426/greencalc.html
Date of foundation (and end of initiative, if applicable)	1997
Type of scheme	Certification system
Public/private	Private
Geographic scope	Netherlands
Target beneficiaries	Governments (including the Government Buildings Agency), project developers, corporations, architects, consultants and educational institutions.
Carbon storage component	No carbon storage component.
Carbon price	N/A
Description	GreenCalc was developed by the Sureac Foundation (with DGMR, NIBE and NUON) on behalf of the Government Buildings Agency, initially for the assessment of non-residential buildings. GreenCalc +, the successor, is suitable for offices, schools and homes. GreenCalc+ is a calculation program that can be used to calculate the environmental costs of the material, energy and water consumption of a building, as well as the mobility of the building users. Because environmental costs are used, all outcomes (in euros) can be added together for the final result. If a reference building or “environmental budget” has been entered by the user, GreenCalc + converts the results into an “environmental index” that indicates how the building scores in relation to the reference. The Government Buildings Agency has had the environmental index determined for many buildings.
Methodology	Greencalc+ assesses sustainability on four elements: 1. The materials module within Greencalc + is based on the materials database of the National Environmental Databaseand are based on LCAs . 2. The energy module within Greencalc + is based on NEN 2916: 2004 and NEN 5128: 2004 . This allows the normative building-related energy consumption to be calculated. This is supplemented with a calculation of the non-building-related energy consumption. In addition, Greencalc + offers the possibility to provide insight into the influence of alternative (bio) fuels. 3. The water module within Greencalc + is based on the WPN (Water Performance Standard) NEN 6922 . From this calculation comes a ratio of the water consumption and the standard use of a home. This is called the Water Performance Coefficient (WPC). Non-residential buildings are calculated using the Water Performance Standard (WPN). 4. The mobility module within Greencalc + is based on the software program VPL-KISS, which stands for ‘Traffic Performance on Location’ developed by Novem (now AgentschapNL) and the Ministry of Economic Affairs (now EL&I).

Name	*Greencalc+*
	Greencalc + values the degree of sustainability of a project in an environmental index score, based on a reference building from the year 1990. Greencalc + makes a distinction between the environmental quality of a building (Milieu-Index-Building MIG), the environmental index of an organization in relation to the building (Milieu-Index-Operations MIB) and environmental index of a real estate portfolio (Milieu-Index-Portefeuille MIP) and its own index (if no reference building from 1990 for a usage function is available). The score is placed in a label class format.
Risk of non permanence:	No information provided.
Additionality	The environmental benefits are computed by comparison with a reference building of 1990.
Safeguards	No information provided.
Co-benefits with other sustainability goals	The environmental performance also considers the impacts of the building on mobility.
Rewarding system	Ex post
Eligible activities	Construction projects
Connection with national climate policies	In June 2011, a cooperation agreement was signed between Stichting Sureac (administrator Greencalc +) and the Dutch Green Building Council (administrator Breeam-NL), with the aim of integrating both methods. With this, the intention to arrive at a single common language for assessing sustainable buildings and areas in the Netherlands has come a significant step closer. Greencalc can be used within the Breeam method to calculate the environmental impact of material use.
Lessons learned	The scheme offers an effective tool to calculate the sustainability of buildings based on different indicators.
Replicability at EU level	While operating in the Netherlands, this scheme is closely linked to BREEAM, which offers the expectation to expand the scheme internationally, following the structure of BREEAM.

GPR Gebouw

Table 2-23 Factsheet GPR Gebouw

Name	*GPR Gebouw*
Link	https://www.gprsoftware.nl/gpr-gebouw/
Date of foundation (and end of initiative, if applicable)	1995

Name	***GPR Gebouw***
Type of scheme	Certification method and software tool
Public/private	Private
Geographic scope	Netherlands
Target beneficiaries	GPR Gebouw has been developed for municipalities and regions, corporations, real estate owners, architects, consultants and project developers and health institutions who want to choose sustainable construction.
Carbon storage component	No carbon storage component.
Carbon price	No carbon price available.
Description	GPR Gebouw is a digital instrument to measure the sustainability of buildings. The measuring instrument is suitable for both residential and commercial construction. The abbreviation GPR stands for Municipal Practice Guideline. The method was developed in 1995, and since then, different versions have appeared and the software has been expanded and improved with the help of various parties.
Methodology	Assessment by GPR is based on five broad themes: 1. Energy: combating climate change and keeping energy affordable. 2. Environment: GPR Gebouw calculates the environmental impact of buildings. This allows to assess performance and make design choices. 3. Health: limiting noise pollution, sufficient fresh air, comfortable ventilation and sufficient daylight. 4. Quality of use: GPR Gebouw shows how a building or design meets the wishes of target groups. 5. Future value: a building can be adapted to changing user requirements or legislation and regulations without high costs or much waste of material. This means taking into account the change of function and amenity value of the environment during construction or renovation. For each theme, a building is rated on a scale from 1 to 10. The total GPR score is then translated into a quality label. With the help of this label, the building receives one to five stars. The Building Decree level equals one star. The assessments are quality assured by an internal assessor and an expert, who evaluate whether to assign the GPR Certificate.
Risk of non permanence:	Information not available.
Additionality	Information not available.
Safeguards	Information not available.

Name	*GPR Gebouw*
Co-benefits with other sustainability goals	Good health and well-being: limiting noise pollution, sufficient fresh air, comfortable ventilation and sufficient daylight. Improved energy performance.
Rewarding system	Ex ante and ex post Users can earn points for their certificates which are valued by the Global Real Estate Sustainability Benchmark (GRESB), which annually measures the sustainability policy and its implementation in real estate funds and portfolios.
Eligible activities	The GPR Building measuring instrument is suitable for corporations , governments (especially municipalities), project developers, architects, consultants and educational institutions
Connection with national climate policies	Carbon content of the materials and of the usage phase of the building are considered.
Lessons learned	The GPR software has been effectively used across the Netherlands to guarantee sustainability in construction projects in different phases, including policy, design, realization and renovation.
Replicability at EU level	While operating in the Netherlands, the certification tool could be adapted to a broader EU context given the wide range of indicators it is based on.

3.2.3. Additional schemes considered

In addition to the above-mentioned schemes, several other schemes were considered. These schemes will be briefly described below, but they have not been included in the detailed analysis. In some cases, the schemes do not differ significantly from other schemes included in the analysis in terms of features, or they do not offer significantly valuable examples of rewarding systems or methodological insights that can be of relevance to this study (and particularly Task 3, which draws insights from this sub-task). Nonetheless, the schemes are interesting to consider in the wider discussion on stimulating the use of bio-based materials (including WBPs) in construction and reducing the environmental or carbon footprints of buildings:

Labels:

Nordic Swan Ecolabel for the product category “construction and façade panels”, which comprises panels for both indoor and outdoor use[368]. Wood-based panels, solid wood for assembly into a panel, panels based on renewable raw materials other than wood, plasterboards, mineral wool panels, high-pressure laminate panels, and cement-based panels are included in the category. The ecolabel imposes certain requirements for different panel types (depending on the material used). Panels made out of wood, veneer, bamboo,

[368] https://www.nordic-ecolabel.org/product-groups/group/?productGroupCode=010

or cork must meet traceability requirements and a significant share of the material must be certified[369];

The German environmental label, **"Blue Angel"**, for the product category "composite wood panels". The category includes products such as chipboards, fibreboards, MDF, solid wood panels, and OSB panels. The label ensures that products are low-emission (ensuring VOC limits), made from sustainable forestry resources, and are safe for human health[370];

EU Ecolabel for the product category "wood- cork- and bamboo-based floor coverings"[371]. Products have to meet strict limitations on chemical use and emissions, and comply with circular-economy principles. The EU Ecolabel also sets a maximum threshold for electricity and fuel consumption during the product manufacturing[372].

Certifications:

LEED (Leadership in Energy & Environmental Design) is a green building project and performance management system[373]. "LEED v4.1" defines LEED's building standards and addresses energy efficiency, water conservation, site selection, material selection, day lighting, and waste reduction. One of LEED's priorities is the use of sustainable building materials[374];

The **DNGB (German Sustainable Building Council)** certification system considers the entire life cycle of a project and a variety of sustainability factors[375]. Sustainable building is defined as "using and introducing available resources consciously, minimisign energy consumption and preserving the environment". DNGB goes beyond the conventional pillars of sustainability (i.e. a model focusing on economic, environmental and sociocultural aspects) to include the functional aspects of planning and factors that are important during the construction of a building: technology, processes, and location[376]. The DNGB compiled a definition of carbon neutrality and the corresponding explanations of procedures and strategies, to educate all actors involved in the planning, construction, operation and management of real estate with respect to means of reducing greenhouse gas emissions[377]. The DNGB is a relevant and interesting example of a Market-Based Scheme that promotes climate-friendly buildings, and should be considered in future research. However, it was difficult to access information regarding how the organisation manages the carbon content of construction materials due to limited information (publicly) available.

3.3. Assessment of market-based schemes

[369] Other criteria are specified here: https://www.nordic-ecolabel.org/product-groups/group/?productGroupCode=010

[370] More detailed requirements are described here: https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ 076-201602-en-Criteria-V9.pdf

[371] http://ec.europa.eu/ecat/category/en/33/wood---cork--and-bamboo-b

[372] All relevant requirements and criteria can be found here: https://ec.europa.eu/environment/ecolabel/documents/Wood_Floor_Coverings_Factsheet.pdf

[373] https://www.usgbc.org/leed

[374] More information on this standard is available here: https://www.usgbc.org/leed/v41#bdc

[375] https://www.dgnb.de/en/

[376] https://www.dgnb.de/en/topics/sustainable-building/

[377] More information on DNGB's framework for carbon neutral buildings and sites is available here: https://www.dgnb.de/en/topics/climate-action/framework/

This section provides an overview of the schemes identified, by going beyond the previous factsheets specific to each program. Based on the findings at scheme-level, this section looks at the bigger picture drawn by these programmes, and attempts to provide the state of the art of existing initiatives. This overview offers a critical assessment of the schemes by focusing on their differences and similarities, reflecting on their gaps and identifiable patterns. This analysis is particularly relevant for the conclusions to be drawn from this task, as they inform on the current designs and methodologies of MBS incentivising the use of wood in construction. Therefore, following a general assessment of the schemes based on their core characteristics, this section delves into the lessons learned from these schemes, and the implications that can be drawn from them, as well as their degree of transferability and replicability at EU level.

3.3.1. General assessment

As shown below in Table 3-1, the majority of schemes included in the analysis of Subtask 1.3 are private schemes (60%), as opposed to public schemes. This relative concentration of privately managed schemes is due to a number of factors, among which it is acknowledged the scarcity of public policies that generally promote the use of wood in construction (as found in task 1.2 of the study). Moreover, it shows the relevance of voluntary carbon markets and certification systems, compared to regulation-driven approaches. Nonetheless, public schemes are still well represented in this pool, and a few of them help make the case for public involvement in the design of voluntary carbon markets, as for example in the cases of CARBOMARK and Label Bas-Carbone.

As explained above, large carbon credit schemes were considered for this study, but not brought forward in the analysis. These include compliance markets, such as the Clean Development Mechanism and the Joint Implementation mechanism, but also voluntary markets, like the Gold Standard and the VCS/Verra. Despite being significantly large market-based schemes for the valuation of carbon emissions, these schemes have not been include in the analysis because they lack a recognized methodology for the calculation of carbon embodied in construction materials. Another scheme, identified within the discussion of the previous subtask is Batiment biosourcé label. Buildings in France can receive a label certifying that they have used bio-based materials in their construction. It represents one of the first concrete measures going beyond high-level strategies and which aims at increasing the share of wood in buildings. In place since 2012 (since Decree 2012-518), this label does not target wood products specifically, but rather bio-based materials more generally (including WCPs). While acknowledging and rewarding the use of biobased materials in construction, it does not involve the quantification of carbon stored in the building, and was therefore excluded from this analysis.

The MBS identified as relevant are predominantly European or are implemented in certain European MS (e.g. Netherlands, France), with the exception of two international schemes (Puro.earth and BREEAM). In general, the schemes cover a mixture of approaches, from emission credit markets or marketplaces to certification systems, to tools and methods quantifying the sustainability impacts of various construction materials. They attempt to influence market behaviour in three different ways, namely:

By rewarding players along the value chain for carbon removals through quantity- or price-based credits that can be exchanged in a match-making market (e.g. Puro.earth, CARBOMARK);

By quantifying and certifying the GHG emissions removals that result from more sustainable construction choices (e.g. Label Bas Carbone); and

By facilitating more sustainable building standards through tools and methodologies that assess the sustainability performance of buildings, which include the consideration of the benefits of using less carbon-intensive building materials (e.g. Level(s), BREEAM).

Beneficiaries include both public and private stakeholders along the value chain. Some schemes target public procurement actors, by providing a tool to compare across different projects. Other specifically target supply-chain actors and the business-to-business market.

Only four of the ten schemes evaluated include quantitative assessment of carbon sequestration and storage (Puro.earth, CARBOMARK, BenchValue, Label Bas-Carbone), This may reflect difficulties in defining a valid methodology to measure the amount of GHG emissions that are stored in the materials. Moreover, guaranteeing the storing of carbon necessitates the fulfilment of a number of conditions, including the assurance of emissions permanence in the materials and the principle of additionality of reduced emissions.

Table 3-24 General review of market-based schemes

Scheme	Type of scheme	Public/ private	Target beneficiaries	Carbon storage	Type of rewarding system	Replicability at EU level	Lessons learned
Puro.earth	Emission credits trading platform (voluntary carbon market)	Private	Suppliers of carbon net-negative technologies and climate conscious companies.	Included in the methodology	Tradable certificates	High replicability: the scheme operates internationally and abides to relevant EU legislation.	The scheme represents a successful example of voluntary market for carbon removal. The focus on three carbon removal methodologies provides a standardized and unified approach to carbon storage and the issuing of certificates.
CARBOMARK	Emission credits trading platform (voluntary carbon market)	Public	Agricultural and forestry activities, local administrations, SMEs, forest owners.	Included in the methodology	Tradable certificates	Hight replicability at EU level as this project operated under the EU programme LIFE.	This scheme provides a valuable example of a carbon market at the local level, which however has not lasted long beyond the end of its LIFE funding.
Label Bas Carbone	Certification system of GHG emissions removals	Public	Construction, agriculture, forestry, transport, etc.	Included in the methodology	Certificates of GHG emissions removals	The scheme necessitates adaptations to be replicated at EU level, as it is managed by the French Ministry for the Ecological Transition.	The scheme comprises a well-established verification methodology while giving full initiative to the applicants in determining the carbon removal methodology.
BenchValue	Tool to evaluate GHG emissions removals	Private	Policy makers and market players can employ the tool to compare the climate benefits of wood to non-renewable materials in the construction sector.	Included in the methodology	N/A	High level of replicability, as this tool has been employed in different case studies, by looking at four Member States (Austria, France, Ireland, Lithuania).	The scheme represented one of the first attempts of its kind in measuring climate benefits of wood as a means to compare across different materials. However, since its inception in 2013, new methodologies and tools have been developed.

Scheme	Type of scheme	Public/ private	Target beneficiaries	Carbon storage	Type of rewarding system	Replicability at EU level	Lessons learned
HQE Bâtiment Durable	Certification system of sustainability benefits of buildings	Private	Private and public actors in territorial and construction planning	Not included in the methodology	Certificates	While mainly operating in France, the certification is open to international projects as well. Therefore, there is a high level of replicability outside France and across the EU.	The scheme offers a flexible assessment framework, hence giving flexibility to applicants in designing their own sustainability priorities.
Level(s)	Certification system of sustainability benefits of buildings	Public	Different actors operating in the building sector, from planning, designing, financing to execution.	Not included in the methodology	Certificates of sustainability of buildings	This is a scheme developed at the EU level.	The scheme has been given positive feedback by users as it can support green public procurement and provides an assessment for life cycle performance of construction products.
BREEAM	Certification system of sustainability benefits of buildings	Private	Project developers and corporations.	Not included in the methodology	Certificates of sustainability of buildings	This scheme is already operating internationally. The method is used in 80 countries worldwide. The Dutch Green Building Council has made the method suitable for the Netherlands, hence BREEAM-NL.	It works to raise awareness amongst owners, occupiers and designers of the benefits of taking a sustainable building approach. In the Netherlands there are subsidy opportunities linked to the adoption of BREEAM-NL.
HQE Bâtiment Durable	Certification system of sustainability benefits of buildings	Private	Private and public actors in territorial and construction planning	Not included in the methodology	Certificates of sustainability of buildings	While mainly operating in France, the certification is open to international projects as well. Therefore, there is a high level of replicability outside France and across the EU.	The scheme offers a flexible assessment framework, hence giving flexibility to applicants in designing their own sustainability priorities.

Scheme	Type of scheme	Public/ private	Target beneficiaries	Carbon storage	Type of rewarding system	Replicability at EU level	Lessons learned
BES 6001	Certification system of sustainability benefits of buildings	Private	Organizations that manufacture construction products at large.	Not included in methodology	Certificates of sustainability of buildings	This scheme operates in the UK, but given its flexible components, it offers possibilities for replicability at EU level.	The scheme is more relevant for the B2B market, and provides standards related to product sourcing.
Greencalc+	Certification system of sustainability benefits of buildings	Private	Governments (including the Government Buildings Agency), project developers, corporations, architects, consultants and educational institutions.	Not included in the methodology	Certificates of sustainability of buildings	While operating in the Netherlands, this scheme is closely linked to BREEAM, which offers the expectation to expand the scheme internationally, following the structure of BREEAM.	The scheme offers an effective tool to calculate the sustainability of buildings based on different indicators.
GPR Gebouw	Certification system of sustainability benefits of buildings	Private	Municipalities and regions, corporations, real estate owners, architects, consultants and project developers.	Not included in the methodology	Certificates of sustainability of buildings	While operating in the Netherlands, the certification tool could be adapted to a broader EU context given the wide range of indicators it is based on	The GPR software has been effectively used across the Netherlands to guarantee sustainability in construction projects in different phases, including policy, design, realization and renovation.

3.3.2. Comparison of methodologies to assess GHG content in existing schemes with the methodology developed for this project

Among the market-based schemes investigated in this study, only four aim at computing the GHG emissions content of buildings or of construction products with a level accuracy compatible with the requirements of our own project:

Puro.Earth;

CarboMark;

Label Bas Carbone;

BenchValue.

Following the Terms of Reference of this study, we have compared the methods described in these schemes to assess the GHG emissions content with the one developed for our study in Task 2:

Puro.Earth: the methodology is described in their General Rules[378], Annex C, pp. 33-39. This methodology applies to wooden elements for construction, not to complete buildings. It thus only covers the life cycle stages from cradle to gate (stage A), not the full life cycle as the methodology of Task 2 does. It relies on standards that were considered by the Task 2. It only looks at biogenic carbon, but not at the other sources of GHG emissions taking place in the manufacturing process, such as those generated by the glues used in Engineered Wood Products;

CarboMark: the methodology is described in their Management Manual for local carbon markets – General Part[379], §4.3, pp.43-46. The methodology applies to complete buildings. However, it is based on the principles of Land Use, Land Use Change and Forestry – LULUCF accounting of the UNCCC, and only takes into account biogenic carbon in a simplified way. As such, it addresses the forest that sources the wood more than the construction product or the building;

Label Bas Carbone: the legislation describes a procedure to follow to obtain credits, for a very broad range of actions and of products. The methodology is thus defined on an ad-hoc basis by the claimant, to be approved by the administration. It is thus not possible to assign a specific methodology to that label;

BenchValue: The method defined at the end of the project is not available on the project's website[380].

As a conclusion, the methods used in the existing market-based schemes aiming at fostering the usage of wood in the construction sector do not provide any added value compared to the method developed in the current project under Task 2.

[378] Puro.earth CO2 Removal Marketplace General Rules, accessible at: https://static.puro.earth/live/uploads/tinymce/Puro_Documents/Puro-Rules-CO2-removal-marketplace_v2.0_final.pdf
[379] Accessible at: https://pdc.minambiente.it/sites/default/files/progetti/carbomarkmanualecbk16_06_11pgrev1_5_ingversion.pdf
[380] http://benchvalue.efi.int/work-packages/method.html

3.3.3. Lessons learned and replicability of schemes

This study identified three types of relevant MBS that incentivise the use of wood in construction based on the climate benefits of the life-cycle: (1) voluntary emission trading platform or carbon markets; (2) certification systems of GHG emissions removals; and (3) generic certification of the sustainability benefits of buildings.

Findings from the available emission trading platforms provided important insights on what can be the desirable characteristics for such systems. First, a clear methodology for assessing the GHG emissions content of materials appears as fundamental, particularly one that targets specific activities or materials. Puro.earth, in this regard, provides a credible, transparent methodology for the calculation of carbon storage based on three types of materials, namely wood for construction, biochar for non-fuel purposes and carbonated materials.

The size and inclusivity of the market emerges also as a highly relevant aspect. Current initiatives span global schemes (e.g. Puro.earth) to local and territorial markets (CARBOMARK). The two “extremes” both have their advatanges: while broader and more inclusive markets provide more availability of choice in terms of emission carbon storage credits, local-scale markets provide the proximity that better enhances the image and mutual synergies between trading activities. This was exemplified by the case of CARBOMARK. The early termination of the scheme may be an indication however that it lacked sufficient market depth to reach a self-sustaining volume of transactions.

Certification and labelling systems value flexibility as one of the successful characteristics of such a system. This concerns the methodology but also the broader frameworks defining the evaluation criteria, which is highlighted as an attractive factor for participants. It was found also that many of these schemes operate at the public procurement level, hence targeting policy makers and project managers. Some schemes rather target the business-to-business market, acting as an intermediary scheme between commercial activities. This is the case for BES6001 and, to a certain extent, Puro.earth and CARBOMARK, as the latter two provide a trading platform for businesses that wish to offset their carbon emissions. Finally, a few schemes provide a link with public policies, and in particular with subsidy programmes (e.g. BREEAM-NL), which appears to be a successful strategy for enhancing participation in these voluntary programmes. It further points at the necessity for dialogue and coordination between voluntary private schemes and public incentive measures.

There is a variety of tools and metrics that attempt to quantify the climate benefits of construction materials. Some tools are limited to the elaboration of a qualitative framework to assess the sustainability of a building or construction, composed of various analytical elements. A few provide tools for thequantification of emissions reductions, while others provide thorough calculation and attempt to integrate carbon sequestration over the materials’ life-cycle (e.g. Label Bas Carbone and BenchValue).

A few of the schemes take the form of computer softwares, as an alternative to more conventional methodologies. These appear to be valuable options, particularly softwares that are tailored for specific users, be it policy makers, manufacturers, customers, and other actors across the value chain (this is the case of GreenCalc+ and GPR Gebouw).

In terms of replicability at the European level, the schemes offer quite some degree of variation. Some of the schemes, spanning across the different types identified, are already operating at EU level, such as Level(s), BenchValue, and to a certain extent CARBOMARK, being a EU funded program despite its sub-national characteristics. Other schemes are already established internationally, which provide a solid basis as cross-border programmes, and therefore represent viable options for EU adoption (e.g. Puro.earth, BREEAM). Nevertheless, almost half of the schemes are explicitly engrained in national policy guidelines. These schemes, despite their usefulness in the discussion and elaboration of the present study, necessitate particular attention as to what links bind them to their national contexts. This is the case for the schemes such as Label Bas-Carbone, which might present procedures and structures proper to their nation administrative contexts. However, it is safe to assume that harmonisation and integration efforts could prove effective in extending or connecting these schemes across Member States.

3.4. Conclusions

The landscape of Market-Based Schemes to reduce the GHG emissions associated with the construction of buildings can be summarised as follows:

A significant number of initiatives define and certify the overall sustainability performance of a building over its lifecycle. Among these, Level(s) is the recent EU-based and EU-sponsored holistic initiative, competing with the global, privately-managed BREEAM scheme set up a decade earlier. In addition to these two trans-national initiatives, several have been developed at national level, such as HQE Bâtiment Durable in France, BES 6001 in the United Kingdom, Greencalc+ and GPR Gebouw in the Netherlands;

Two initiatives (Label Bas-Carbone and BenchValue) focus on the quantitative evaluation and certification of the benefits in terms of saved GHG emissions of a broad range of actions (Label Bas-Carbone) and more specifically of the substitution of mineral-based construction materials with wood-based alternatives (BenchValue). These two schemes create the technical base for a market in carbon credits, but do not develop such a market;

Two initiatives (Puro.Earth and Carbomark) have moved to the ultimate stage of establishing an exchange market for carbon credits, whereby they create a platform to match the supply of carbon credits by companies that remove GHG emissions with the demand by companies eager to compensate theirs.

The purpose of the first category of schemes is to provide an overall qualitative mark to the various dimensions of the sustainability of a building, as a **reputational incentive**. Among the criteria contributing to the assessment of this overall sustainability, the GHG emissions associated with the embodied materials is only one part that is not measured with particular attention. As such, these reputational schemes are not directly useable to build a scheme that would be targeted at incentivising specifically the uptake of Wood-based Construction Products.

Despite initial public support provided by the EU LIFE programme, the Carbomark scheme seems to have ceased its operations. The termination of this project has not been followed up, based on what could be found on the issue, by further monitoring of the system, nor on the question of permanence of the carbon credits. Puro.Earth is more recent and still operational. Although its ambition is to set up a fully-fledged market with large numbers of suppliers and acquirers converging towards an equilibrium price, its current state is that of a match-making platform with limited supply opportunities and large differences in the prices being proposed by suppliers (from 20 to 150 EUR/ tonne CO_{2eq}). In the absence of information on the prices at which actual transactions have taken place, it is difficult to assess whether the scheme enables attractive prices for GHG emissions removals. In both cases, the creation of a market with a number of players on both sides (suppliers and acquirers) that is sufficient to set an equilibrium price seems to prove difficult and has not been demonstrated. These precedents should lead to caution regarding the level of ambition of a EU-funded Market-Based Scheme supporting the uptake of Wood-based Construction Products. It is likely that the difficulties encountered by these two frontrunners remain relevant, and that **a fully-fledged market** for the carbon credits created by substituting mineral-based materials with Wood-based Construction Products remains a **difficult target** to reach.

The approach taken of quantifying and certifying the GHG removals or avoided emissions, officially at Member State level in the Label Bas-Carbone and, as a research project, in the BenchValue scheme take a middle ground that may trace a way forward to design a Market-Based Scheme to support the uptake of Wood-based Construction Products. These schemes concentrate on the essential operation consisting in providing a reliable, quantified assessment of climate benefits. Based on this quantitative assessment, market players can make environmental claims (as a reputational tool), obtain public funding (as illustrated in the Dutch adaptation of BREEEAM) or seek third parties interested in compensating their own GHG emissions, in peer-to-peer or intermediated transactions. This approach appears promising, and will be used as an input considered in **Task 3** of the present study on the design of a Market-Based Scheme.

The findings of this sub-task are also relevant to consider in the context of recent or upcoming EU policy initiatives supporting a better environmental footprint of the built environment. For instance, the initiative on green claims will require companies to substantiate claims they make about the environmental footprint of their products or services by using standard methods for quantifying them[381]. This will be facilitated by the Products Environment Footprint (PEF) methodology, developed by the European Commission[382]. The latter initiatives call for a harmonised and substantiated approach to marketing environmental footprint performance, to avoid 'greenwashing'. The Market-Based Schemes, in particular the certification schemes, described in this report are also interesting to consider in the context of the EU's Renovation Wave[383] and the The New European Bauhaus initiative[384]. The Renovation Wave urges EU Member States to adopt certain key principles when improving and refurbishing their building stocks, amongst which life-cycle thinking, circularity, and the use of biotic building materials that can store carbon are some of the key principles mentioned[385]. These principles can be explored through the New European Bauhaus initiative, which aims to connect the European Green Deal to European living spaces. The initiative will mobilise a variety of stakeholders to reimagine sustainable living and will support innovative ideas and products. The existing Market-Based Schemes that we reviewed in this report and that reward market players along the supply chain for the production or use of wood-based construction materials can support the transition to more sustainable living spaces aimed at by these initiatives. Task 3 presents an example of a recommended scheme that can further promote the uptake of WCPs.

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[381] https://ec.europa.eu/environment/eussd/smgp/initiative_on_green_claims.htm

[382] https://ec.europa.eu/environment/eussd/smgp/pdf/product-environmental-footprint-PEF-methode_en.pdf

[383] https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

[384] https://europa.eu/new-european-bauhaus/about/about-initiative_en

[385] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662

B. Review and Comparison of Existing Methodologies and Standards for Measuring Embodied Carbon and Biogenic Carbon Content of Wood Products Used in Construction

4. Introduction

The creation of a carbon market for storing carbon in wood-based construction materials requires the development of a reliable method for the assessment of the net GHG content of wood-based construction materials. This method should include all carbon embodied in the material, all additional GHG emissions that may be necessary in order to achieve full functional equivalence with traditional materials (e.g. adhesives incorporated in the engineered wood products, all additions and subtractions of materials) and take into account the fate of the construction material at the end-of-life.

This work has the overall goal to analyse and review existing standards and methodologies for measuring embodied carbon through the entire life cycle, and to examine whether and how biogenic carbon content of wood products used in construction is incorporated into the selected methods and standards. The three specific objectives of the deliverable are:

- To provide an overview of existing standards and methodologies for measuring embodied carbon and biogenic carbon content of wood products used in construction
- To provide and analyse a complete calculation for a selected wood construction product, based on at least two different methods and/or standards, using their most up to date version
- To make recommendations for a single methodology that transparently and credibly quantifies the net carbon storage in wood construction products

This is accomplished in the three following subtasks in this report:

- Review of standards and methodologies for measuring embodied carbon and biogenic carbon content of wood products used in construction (Section 2).
- Calculation for a selected wood construction product (Section 3).
- Recommendations for single methodology (Section 4).

5. Review of standards and methodologies for measuring the embodied biogenic carbon content of wood products used in construction

The objective of this section is to analyse and review existing standards and methodologies for measuring embodied carbon through the entire life cycle of wood products. Alongside this it is examined whether and how the biogenic carbon content of wood products used in construction is incorporated into the selected methods and standards.

Embodied carbon represents the carbon footprint of materials, products etc. Related to buildings and their components, it represents the carbon emissions associated with production, transport, construction, maintenance, replacements and end-of-life of materials used in the buildings (Figure 1). Embodied carbon calculations exclude the carbon impact of the energy and water consumed during the use phase of the building. Energy-related emissions for heating, cooling or lighting the building are thus not considered.

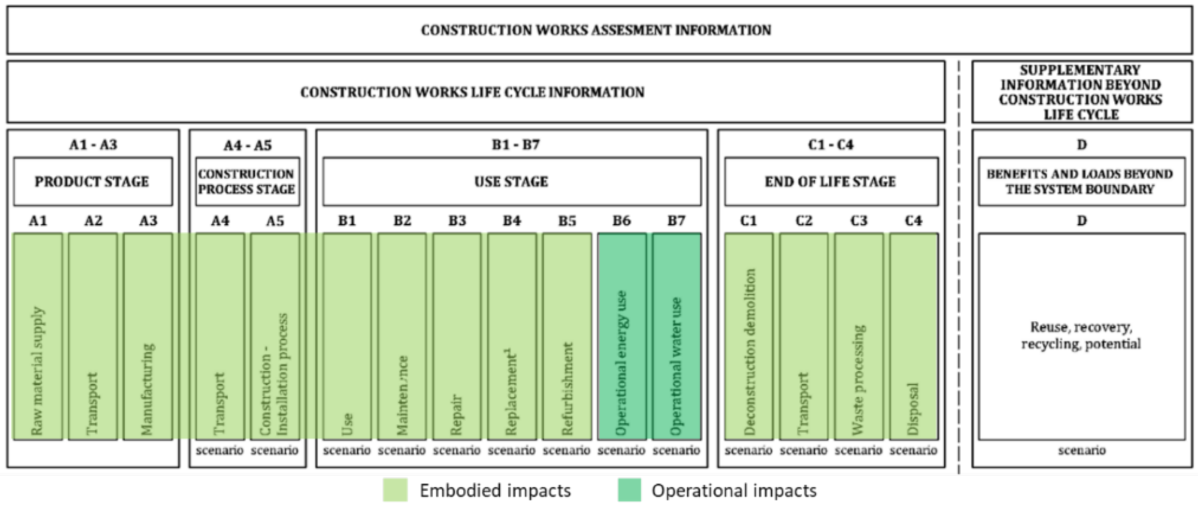


Figure 24 Life-cycle modules used for the description of the life cycle of a construction product, building or project as defined in the standard EN 15804+A2 (ISO, 2019).

A detailed review analysis of methods for measuring embodied carbon in building has been performed with the goal of answering the following 3 research questions:

How is biogenic carbon and carbon storage accounted for?

Is biomass sustainability and the forest carbon sink effect considered? If so how?

Are the benefits of wood re-use as a raw material or as an energy source included? If so how?

The review includes technical standards, guidelines as well as research papers that are relevant for LCA, carbon footprinting of wood construction products, as well as forest carbon accounting as the carbon accounting scheme of the United Nations Framework Convention on Climate Change (UNFCCC). The final goal is to give an overview of methodologies that are most commonly used for assessing embodied carbon over the whole life cycle of construction materials.

5.1. Methodology

The literature sample to be evaluated was gathered by performing a literature review on the topic following the so-called ‘snowball approach’ (Wohlin 2014). In the first step, studies known to be important to experts’ opinion to answer the research questions were included in the sample. In a second step, a literature review on the topic scarcely addressed in the initial pool of studies was performed. A total of 48 sources were initially reviewed (Figure 2).

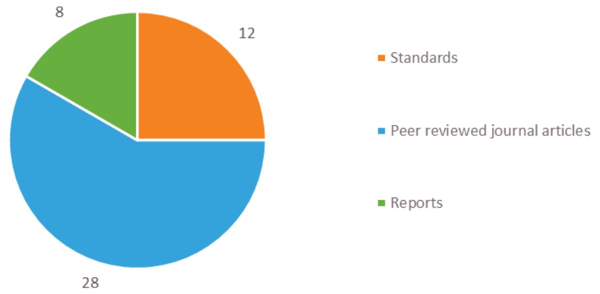


Figure 25: Number and types of sources reviewed

From these initial 48 sources only those addressing at least one of the research questions were kept.

For example, work such as the reviews of D'Amato et al. (2020) and of Klein et al. (2015) were excluded since, although dealing with the application of LCA in forest-based bioeconomy activities, the former focuses on the assessment of ecosystems services and the latter on forestry operations, both out of the scope of this work.

The results of this analysis are summarized in Table 1 , where they are grouped into the three following main macrofamilies:

LCA standards: including the standards used for life cycle assessment of construction products[386].

LULUCF accounting: including methods and approaches used for reporting the carbon fluxes of LULUCF related activities

Innovative methods: methods used by the scientific community relevant to address one or more of the three research questions.

Each of the aspects identified in the Table are discussed in more detail in the following sections.

Box 5 Life Cycle Assessment methodology

To understand the report some background knowledge on Life Cycle Assessment (LCA) methodology are required. For those LCA-specific methodological concepts the reader might not know or understand he is advised to consult the following two textbooks:
Hendrickson, C. T., Matthews, H. S., & Matthews, D. (2016). Life cycle assessment: Quantitative approaches for decisions that matter. (freely downloadable at https://www.lcatextbook.com/)
A beginner guide to LCA that carefully explains all terms and concept introduced.
European Commission - JRC-IES: International Reference Life Cycle Data System (ILCD) Handbook – General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. Luxembourg. Publications Office of the European Union; 2010
A document targeting readers with some prior knowledges on LCA providing detailed technical guidance for consistent and quality assured LCA analysis.

[386] Only standards at the product level were considered. Standards at the building level, such as the EN 15978, are not included in the literature review as they do not add any specification related to embodied carbon accounting compared to the standards at product level (EN 15804+A2 in this example). They are, in fact, built on top of the products standards and have the exact same requirements for what concerns embodied carbon and just give further indication on specific aspects related to building (i.e. they specify how to model stages B6 and B7 which is outside the scope of embodied carbon estimation as shown in Figure 1).

Table 25 Overview of the reviewed methods for what concerns the assessment of biogenic carbon

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services	LCA standard	-1/+1	• Yes, CF of -1 CO_2 eq for CO_2 - only when the wood originates from sustainably managed forests	• Yes, emissions from land use change are included for not sustainably managed forest - assessed in accordance with internationally recognized methods such as the IPCC guidelines • Reported separately as GWP (land use change) in additional information	• Not specified	• Not included (C neutrality)	• No, delayed emissions may be reported as additional information	• Yes, CF of +1 CO_2 eq for CO_2.	• Benefits and loads may be reported in Module D (outside the system boundary) • No specification on the substitution approach
14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification	LCA standard	-1/+1	• Yes, CF of -1 CO_2 eq for CO_2. • Reported separately	• Yes, emissions from land use change - assessed in accordance with internationally recognized methods such as the IPCC guidelines. • Land use changes which occur within a period of at least	• No, should be included once an internationally agreed procedure exists	• Yes, emissions and removals from land use that is not the result of changes to management of land should be assessed in accordance with internationally recognized methods such as the IPCC guidelines. • Land use which occur within a period of at least a full rotation period.	• No, impact of carbon storage may be documented separately	• Yes, CF of +1 CO_2 eq for CO_2. • Reported separately	• Two types of allocation method: • - Closed-loop allocation: benefits and loads are fully allocated to the product system (to be applied when no changes occur in the

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
				a full rotation period. • Reported separately		• Reported separately			inherent properties of the recycled material) • - Open-loop allocation: benefits and loads are shared between the first and second life cycle • No specification on the substitution approach
EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products	LCA standard	-1/+1	• Yes, CF of -1 CO_2 eq for CO_2 except for biomass from native forests • Reported separately as GWP-biogenic	• Yes, emissions from land use change - assessed based on latest version of PEF Guidance document • For native forests, all CO_2 emissions are included in this category (CO_2 uptake is set to zero) • Reported separately as	• Not specified	• Not included (C neutrality) • Net increase in carbon stock, including soil carbon uptake, is set to zero (soil carbon storage may be included as additional information)	• No temporary or • permanent carbon storage	• Yes, CF of +1 CO_2 eq for CO_2, except for biomass from native forests • Reported separately as GWP-biogenic	• Benefits and loads shall be reported in Module D (outside the system boundary) • Substitution based on current average technology or practice

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	**Module A***	**Module A***	**Module A***	**Module B***	**Module C***	**Module D***
				GWP-luluc					
EN 16485 Round and sawn timber - Environmental Product Declarations - Product category rules for wood and wood-based products for use in construction	LCA standard	-1/+1	• Yes, CF of -1 CO_2 eq for CO_2 in case of sustainable forest management (0 CO_2 eq in case of unsustainable forest management). • Reported separately from the fossil carbon fluxes	• Yes, emissions from land use change - assessed in accordance with internationally recognized methods such as the IPCC guidelines. • Reported separately	• Not specified	• Not included (C neutrality)	• No, effect of delayed emissions may be calculated based on PAS 2050 or IPCC and reported as additional information	• Yes, CF of +1 CO_2 eq for CO_2. • Reported separately from the fossil carbon fluxes	• Benefits and loads reported in Module D (outside the system boundary) • Benefits calculated based on: • - recycling: avoided impact of primary material from forest or sawmills for the production of wood-based boards • - energy recovery: avoided impact of electricity production and thermal energy (substitution of heat from

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
									fossil fuels, e.g. natural gas)
Product Environmental Footprint (PEF) guide (2013)	LCA standard	-1/+1	• Yes, CF of -1 CO_2 eq for CO_2. • Reported separately in the Resource use and Emissions Profile	• Yes, emissions and removals from land use change - assessed based on Commission Decision C(2010)3751 , IPCC guidelines and PAS 2050. • Land use changes which occurred within a period of 20 years or a single harvest period	• No, unless PEFCR require to do so	• Not included (C neutrality)	• No, credit for temporary carbon storage may be included as additional information.	• Yes, CF of +1 CO_2 eq for CO_2 and 25 for CH4 • Reported separately in the Resource use and Emissions Profile	• Benefits and loads allocated based on the circular footprint formula (share between first and second life cycle based on allocation factor) • No specification on the substitution approach (generic data should be used by default)

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
PEFCR Guidance - Product Environmental Footprint Category Rules Guidance version 6.3 (2017)	LCA standard	0/0	• No, CF of 0 CO_2 eq for CO_2.	• Yes, emissions from land use change - assessed based on default land use change values from PAS 2050 or IPCC guidelines. • Land use changes which occurred within a period of 20 years or a single harvest period • Included under the sub-category "Climate change - land use and land transformation"	• No, methods and data requirements under development	• Not included (C neutrality)	• No temporary carbon storage (within 100 years). • Credit (-1) for permanent carbon storage (more than 100 years)	• Partially, CF of 0 CO_2 eq for CO_2 and CO, 34 CO_2 eq for CH4. • Included under the sub-category "Climate change - biogenic"	• Benefits and loads allocated based on the circular footprint formula (share between first and second life cycle based on allocation factor) • No specification on the substitution approach
PAS 2050: 2011 - Specification for the assessment of the life cycle greenhouse gas emissions of goods and services	LCA standard	-1/+1	• Yes, CF of -1 CO_2 eq for CO_2	• Yes, emissions and removals from land use change - based on default values for selected countries. • Land use changes which occurred within a period of 20 years or at least a full rotation period.	• No, methods and data requirements under development	• Not included (C neutrality)	• No, weighting factor for delayed emissions (within 100 years) may be calculated based on linear discounting (2 equations for the storage from 0 to 25 years and from 25 to 100 years). -->	• Yes, CF of +1 CO_2 eq for CO_2 and 25 for CH4.	• Two types of allocation method: • - Recycled content or cut-off method (100-0): to be applied if the recycled material does not maintain the same inherent

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
							applied to bio-based and fossil-based products (polymer) • Carbon storage of more than 100 years considered as permanent carbon storage (permanent negative credit)		properties as the virgin material --> recycling at the end-of-life is outside the system boundary • - Closed-loop approximation method (0-100): to be applied if the recycled material maintains the same inherent properties as the virgin material --> recycling at the end-of-life is within the system boundary • No specification on the substitution approach

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
International Reference Life Cycle Data System (ILCD) Handbook -- General guide for Life Cycle Assessment -- Detailed guidance (2010)	LCA standard	-1/+1	• Yes, CF of -1 CO_2 eq for CO_2.	• Not specified	• No, no widely accepted provisions for indirect land use	• Not specified	• No, credit for delayed emissions (within 100 years) may be calculated based on linear discounting --> applied to bio-based and fossil-based products (polymer) • Delayed emissions beyond 100 years included in "Carbon dioxide, biogenic (long-term)"	• Yes, CF of +1 CO_2 eq for CO_2	• Benefits and loads to be allocated to the first and second life cycle (in case of attributional modelling) • No specification on the substitution approach
GHG protocol - Product Life Cycle Accounting and Reporting Standard (2011)	LCA standard	-1/+1	• Yes, CF of -1 CO_2 eq for CO_2. • Reported separately	• Yes, emissions from land use and land use change - assessed based on the IPCC guidelines. • Land use changes which occurred within a period of 20 years or at least a full rotation period. • Reported	• Not required, but if impacts can be calculated and are significant it should be reported separately	• Yes, Included in the assessment of direct land use IF direct result of extraction or production of biogenic material to create the product under study and occurred within a period of 20 years or at least a full rotation period. • Reported separately	• No, weighting factors for delayed emission should not be applied	• Yes, CF of +1 CO_2 eq for CO_2 • Reported separately	• Choice between two allocation methods: • - recycled content method: benefits and loads are allocated to the life cycle that uses the recycled

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	**Module A***	**Module A***	**Module A***	**Module B***	**Module C***	**Module D***
				separately					material • - closed loop approximation method: system expansion including the benefits and loads of recycling • No specification on the substitution approach
DCF (Levasseur et al. (2010)	Dynamic CF	New LCA approach	• It can be used to characterize the impact of any time explicit C uptake but does not differentiate between fossil and biogenic carbon (i.e. same CF regardless of the origin of the fluxes)	• It can be used to characterize the impact of any time explicit C flux from land use change but does not differentiate between fossil and biogenic carbon (i.e. same CF regardless of the origin of the fluxes)	• It can be used to characterize the impact of any time explicit C flux from land use change but does not differentiate between fossil and biogenic carbon (i.e. same CF regardless of the origin of the fluxes)	• Any temporal explicit forest C fluxes profile can be characterized with this method	• Yes, when timing of C fluxes are explicitly considered; the storage effect is also characterized (i.e. CF for C uptake bigger than CF for emissions occurring later in time)	• It can be used to characterize the impact of any time explicit C emission but does not differentiate between fossil and biogenic carbon (i.e. same CF regardless of the origin of the fluxes)	
Vogtländer et al. (2013)	C storage accounting method	New LCA approach	• Yes, using IPCC Tier 1 or 2 approach to estimate the C	• Yes, consider effect of afforestation and reforestation as	• Not considered	• Looks at landscape level carbon dynamic	• No	• Yes	• Suggests the use of the avoided burden

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	**Module A***	**Module A***	**Module A***	**Module B***	**Module C***	**Module D***
			fluxes of forests	well as C density of existing forests					approach when wood is burnt at EoL
GWPbio (Cherubini et al 2011)	CF for biogenic C	New LCA approach	• Yes, any growth function can be used to estimate it	• Not considered	• Not considered	• Any stand level carbon profile can be used (C neutral or not)	• Yes, CF changes based on assumed lifetime and decay function	• Yes, CF changes based on assumed lifetime and decay function	
GWPnetbio (Pingoud et al. 2012)	CF for biogenic C	New LCA approach	• Yes, any growth function can be used to estimate it	• Not considered	• Not considered	• Similar to GWP bio, but also considers the lost uptake due to harvest (i.e. lost uptake if forest was left growing)	• Yes, CF changes based on assumed lifetime and decay function	• Yes, CF changes based on assumed lifetime and decay function	• Substitution applied to consider avoided burdens due to the displacement of functional equivalent, fossil-based products. Substitution is assumed to happen at time of harvest
GWPbio-product (Helin et al. 2016)	CF for biogenic C	New LCA approach	• Yes, any growth function can be used to estimate it	• Not considered	• Not considered	• Similar to GWP bio, but also considers the lost uptake due to harvest (i.e. lost uptake if forest was left growing)	• Yes, CF changes based on assumed lifetime and decay function	• Yes, CF changes based on assumed lifetime and decay function	
WF method (Väisänen et al.	Simplified forest C	New LCA	• Yes, simple linear growth is	• Not considered	• Not	• C stock of a 100 years	• Not	• Assumed instantaneous	

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
2012)	method	approach	assumed		considered	old forest	considered	oxidation at the time of harvesting	
de Rosa et al. (2016) method	Parametric forest C flux model	New LCA approach	• Yes, considered dynamically for (potentially) all C pools also considering management	• Not considered	• Not considered	• It can be simulated from this method at stand level	• Not considered	• Assumed instantaneous oxidation at the time of harvesting	
TAWP (Kendall 2012)	Dynamic CF	New LCA approach	• It can be used to characterize the impact of any time explicit C uptake but does not differentiate between fossil and biogenic carbon (i.e. same CF regardless of the origin of the fluxes)	• It can be used to characterize the impact of any time explicit C flux from land use change but does not differentiate between fossil and biogenic carbon (i.e. same CF regardless of the origin of the fluxes)	• It can be used to characterize the impact of any time explicit C flux from land use change but does not differentiate between fossil and biogenic carbon (i.e. same CF regardless of the origin of the fluxes)	• Any temporal explicit forest C fluxes profile can be characterized with this method, but	• Yes, when timing of C fluxes are explicitly considered also the storage effect is characterized (i.e. CF for C uptake bigger than CF for emissions occurring later in time)	• It can be used to characterize the impact of any time explicit C emission but does not differentiate between fossil and biogenic carbon (i.e. same CF regardless of the origin of the fluxes)	
UNFCCC Good Practice Guidance for the LULUCF sector (IPCC, 2019)	C storage accounting method	Dynamic approach considering tree growth before wood harvest	• C stocks and fluxes included by choosing Tier-3 methodology. Harvested biomass is assumed as an	• Yes, harvest from Deforestation is not eligible to be included in the HWP	• The land use of the whole country is reported, so indirect land use changes within the country are	• All forest carbon pools are reported for the country as a whole	• New inflow of HWP is "recaptured" from the atmosphere. Release is based on assumed	• Release is based on assumed lifetime and decay function; different product categories; only	• Included in the energy sector, not in the LULUCF sector

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
			immediate emission		included; however, these are not made explicit, there is no tagging of wood that causes indirect land use change		lifetime and decay function; different product categories; only for domestically produced roundwood	for domestically produced roundwood and from Forest land that remains Forest land or from Afforestation	
Moura-Costa (Moura-Costa & Wilson, 2000)	C storage accounting method	Calculation of an equivalence factor for projects	• General methodology, not specifically oriented at forest and/or products	• Not specified, generic method	• Not specified, generic method	• Not specified, generic method	• Not specified, generic method	• Not specified, generic method	• Not specified, generic method
Lashof (Fearnside et al., 2000)	C storage accounting method	Dynamic approach to quantify effect of (delayed) emissions	• Included	• Included; focus of the method	• Not considered	• Included (before deforestation/conversion) as difference in carbon stock between land uses	• Not mentioned	• Instantaneous oxidation when harvested	• Not considered
GWPsoil (Brandão et al., 2011)	CF for biogenic C in soils	Method to include soil C changes into LCA	• Not considered	• Not considered (plot of land with a certain crop is the focus)	• Not considered	• Not considered	• Not considered (aimed at bioenergy)	• Immediate oxidation	• Not considered
CRP (Muller-Wenk & Brandao, 2010)	CO_2 lifetime in atmosphere	Calculation of a relative residence time compared to fossil fuel	• Average stock of carbon in current land use compared to average	• Included; focus of the method	• Not considered	• Included in carbon stock of current land use	• Average stock of carbon in current land use compared to average stock in PNV; may	• Only explicitly when changing the landcover type; implicitly in calculating average carbon	• Not considered

Method	Method type	Type of approach	Biogenic carbon uptake	Direct land use and land use change	Indirect land use change	Forest carbon sink effect	Biogenic carbon storage	Biogenic carbon emissions	Benefits and loads related to reuse, recycling and energy recovery
			Module A*	Module A*	Module A*	Module A*	Module B*	Module C*	Module D*
		if land will grow back to Potential Natural Vegetation	stock in PNV				include carbon stored in HWP but no methodology mentioned	stock in current land use	

* Applicable only to LCA standards

5.2. Biogenic carbon assessment

Plant biomass absorbs CO_2 from the atmosphere during photosynthesis and this is re-emitted to the atmosphere as a result of oxidation of the biomass via e.g. combustion, digestion, composting, and landfilling. This section focuses on evaluating how methodological aspects relevant for measuring the biogenic carbon content of wooden construction products are dealt with in the literature concerning LCA standards, other innovative methods and LULUCF accounting.

5.2.1. LCA standards

As described in Hoxha et al. (2020), two types of static approaches are used in LCA standards to assess the biogenic carbon uptake and release:

0/0 approach- In this approach, there is no accounting of biogenic CO_2 uptake (0) and release (0). It is based on the assumption that the net balance between the emitted biogenic CO_2 from bio-based products at the end of their life and that sequestered during the biomass growth equals zero. The release of any biogenic methane, however, is accounted for at the end-of-life

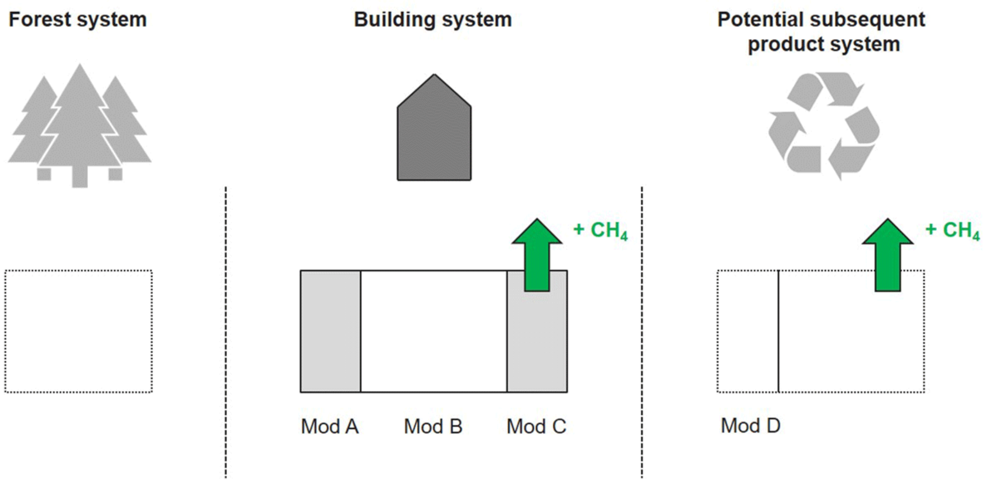


Figure 26: The 0/0 approach to biogenic carbon emissions and removals. The building system is subdivided according to the modular structure presented in Figure 1 and dotted lines indicate the building system boundaries. From Hoxha et al. (2020)

-1/+1 approach- In this approach, both biogenic carbon removals and releases are accounted for as an uptake (-1) and a release of CO_2 (or CO or CH_4) (+1).

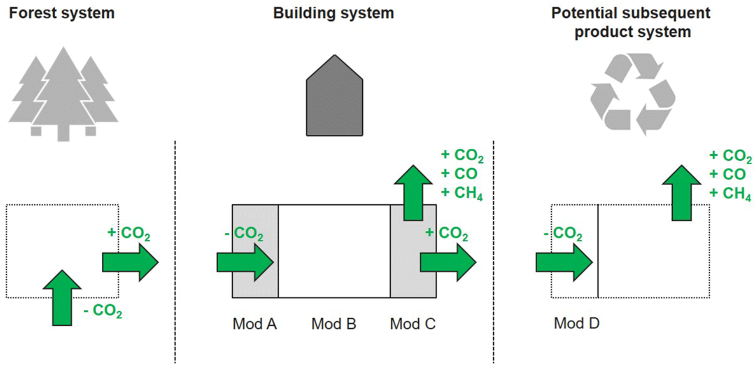


Figure 27: The -1/+1 approach to biogenic carbon emissions and removals. The building system is subdivided according to the modular structure presented in Figure 1 and dotted lines indicate the building system boundaries. From Hoxha et al. (2020)

These two LCA approaches have 2 main criticisms: (1) they do not consider the timing of the carbon fluxes and (ii) they assume the carbon neutrality of forests either implicitly (0/0 approach) or as a requirement over the whole building life cycle (-1/+1 approach). Both aspects represent a limitation of these methods when assessing the impact of bio-based products.

As well as biogenic carbon uptake and release, the effect of biogenic carbon storage can also be assessed. Carbon storage can be defined as the sequestration of carbon in products for a certain period of time resulting in a (temporary) reduction of the CO_2 concentration in the atmosphere (Brandão et al. 2013).

In most LCA standards, there is a distinction between temporary carbon storage (of less than 100 years) versus permanent carbon storage (more than 100 years). Nevertheless, the effect of carbon storage is generally not considered in LCA standards. In some cases, it may be reported as additional information. In the British Publicly Available Specification (PAS) 2050 (BIS, 2011) and the European Commission's ILCD handbook (European Commission, 2010), the temporary carbon storage may be calculated based on linear discounting, which is used as an approximation for the non-linear atmospheric decay of CO_2. The PAS approach differentiates between the carbon stored for less and more than 25 years. The ILCD handbook, on the other hand applies a credit proportional to the number of years of storage.

5.2.2. Innovative methods

To overcome the shortcomings of the static approaches discussed above, some methods which allow consideration of the temporal dynamics of the carbon fluxes and the temporal influence of forest growth have been developed. These dynamic LCA methods can be grouped into those considering tree growth happening before wood harvest (Figure 5) and those considering tree growth happening after wood harvest (Figure 6).

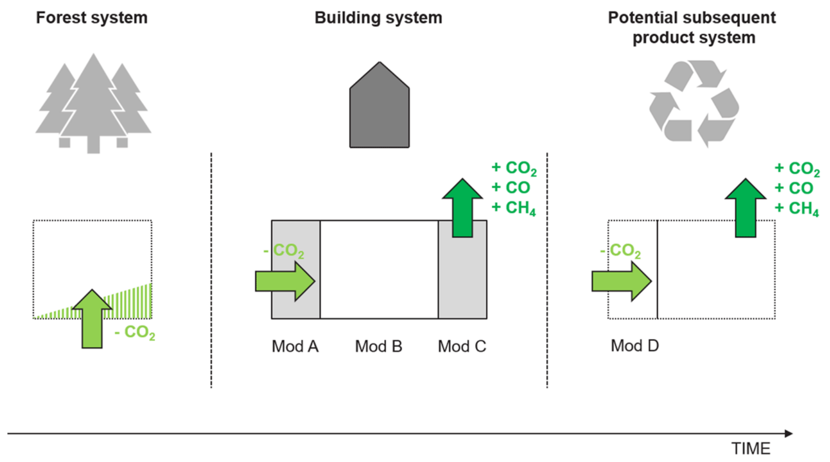


Figure 28 Dynamic approach considering tree growth before wood harvest (also backward-looking). The building system is subdivided according to the modular structure presented in Figure 1 and dotted lines indicate the building system boundaries. From Hoxha et al. (2020)

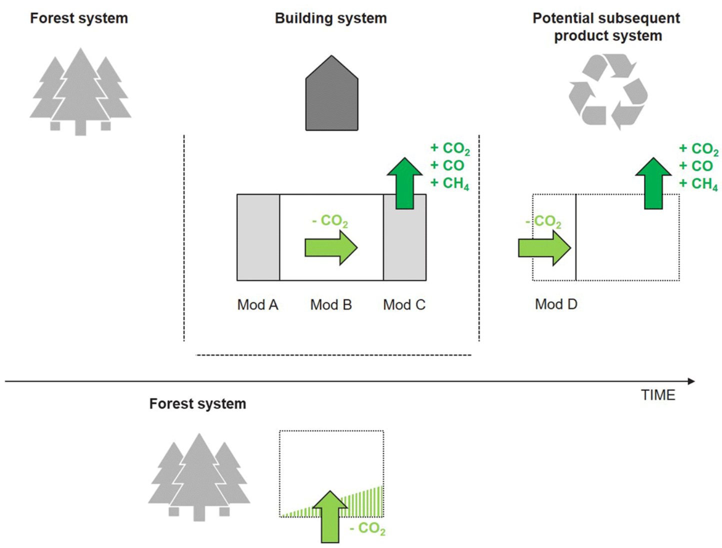


Figure 29 Dynamic approach considering tree growth after wood harvest (also backward-looking). The building system is subdivided according to the modular structure presented in Figure 1 and dotted lines indicate the building system boundaries. From Hoxha et al. (2020)

Levasseur et al. (2010) proposed a dynamic method to consider time in LCA. Their method is based on the use of time-dependent characterization factors (DCF) that can be applied to a dynamic life cycle inventory (dLCI). It can be used for any given time horizon, does not differentiate between fossil and biogenic carbon and can be applied to consider tree growth happening before and after wood harvest.

Another similar approach to deal with the timing of greenhouse gas fluxes is that developed by Kendall (2012), who proposed the Time Adjusted Warming Potential (TAWP). This metric found its mathematical foundation in the GWP calculation equation. In the traditional calculation of the GWP of a gas, the selection of the time horizon for calculating the cumulative radiative forcing (CRF) is fixed e.g. at 100 years; in the TAWP the timing of the emission is considered by integrating the CRF only for the number of years that the gas is in the atmosphere within the time horizon considered.

Vogtländer et al. (2013) used an approach based on the global carbon cycle and land-use change. They started from the rationale that the methods in ILCD and PAS 2050 lead to an overestimation of the benefits of temporary carbon sequestration, as discounting of delayed CO_2 emissions results in an overestimation of benefits of temporary fixation of biogenic CO_2 and should be avoided. In their approach credits for carbon sequestration can only be allocated to wood products when there is both a global growth of forest and a growth of application of wood in buildings. In this method, delayed emissions are not discounted, but accurate information on land transformation processes are needed.

Cherubini et al (2011) proposed an approach to consider biogenic carbon impact based on specific characterization factors for biogenic CO_2 (GWP_{bio}), which take into account the rotation period of the forest. This method was improved in Cherubini et al. (2012) to also take into account the effect of delayed CO_2 emissions from biomass storage. Guest et al. (2013) further extended the method to also include the effect of using this biomass as energy at the end-of-life. In these methods, the GWP_{bio} impact depends on the rotation period of the forest and the lifetime of wood products. The shorter the rotation period and the longer the lifetime of the products, the lower the biogenic GWP.

It must be noted that all these applications are forward-looking and that, as they were applied in the original work of Cherubini et al (2011) and in all its derivations listed below, the forest is assumed to be carbon neutral. The method, nevertheless, allows to avoid the carbon neutrality assumption when the regrowth pattern of forest stands is known, as already done in other works (see e.g. Holtsmark, 2015)[387] and also have a backward-looking approach with regards to forest growth.

The method proposed by Cherubini et al (Cherubini & Strømman, 2011) was extended by Pingoud et al. (2012) who developed the GWP_{netbio} factor. This indicator also considers the potential effect of both the lost uptake of CO_2 when the biomass is harvested, the biomass use, and the temporal dynamic of its growth. The lost uptake is embedded in the GWP_{netbio} by taking into account the CO_2 that would have been taken up if the trees had been left standing, which is basically an implicit way to consider the impact of land occupation. To include the use of the biomass, the GWP metric is modified to also consider the avoided burdens due to the displacement of functionally equivalent, fossil-based products using the displacement factors[388] developed by Sathre & O'Connor (2010).

Helin et al. (2016) proposed the $GWP_{bio\text{-}product}$ as an alternative to the $GWP_{netbio.}$ This does not consider the displacement effect but does include the temporary storage effect, as well as the impact of harvest. The impact of harvest is established by considering the impact due to the changes in the atmospheric carbon concentration between the harvest- and no-harvest-case.

Another child of the GWP_{bio} approach is the WF (weighting factor) method proposed by Väisänen et al. (2012). The WF method is essentially a streamlined version of the GWP_{bio} method, and is calculated in the same way but with the carbon uptake of forests modelled as a simple linear function. In addition, the temporal dynamic of the biogenic carbon fluxes is not considered explicitly but assumed to cumulatively happen at the time of felling as a

[387] In the remaining of the report what is referred to GWPbio includes also all the modification to the original work of Cherubini et al (2011) reported in this paragraph.

[388] Displacement factors are used to describes how much GHG emissions would be avoided if a wood-based product is used instead of another product to provide the same function - be it, for example, a chemical compound, a construction element, an energy service or a textile fibre.

unique pulse emission. (Brandão et al., 2011) applied the GWP method to energy crops, but focussing on the accumulation of carbon in the soil (GWP_{soil}), without taking into account the carbon stored in the biomass. (Muller-Wenk & Brandao, 2010) focus on the carbon impact of land use, specifically on land use where the original forest cover is removed completely. When clearing the land, an amount of carbon is released equal to that stored in the original vegetation. When the new land use is terminated, the carbon will be captured back again by the re-growing (forest) vegetation. They compare the time this carbon stayed in the atmosphere to the average residence time of CO_2 in the atmosphere as emitted by fossil fuels and thus argue that emissions from land use should be weighted differently than fossil fuel emissions. Application of this method for forestry purposes would probably be possible, but would require a specific methodology on how to take into account the storage of carbon in HWP, and its release over time.

5.2.3. LULUCF accounting

Parties to the UNFCCC have to regularly report their greenhouse gas emissions and CO_2 removals. The type and frequency of reporting depends on the country. Currently developed countries that are listed under Annex 1 of the convention need to annually report GHG emissions and CO_2 removals in a National Inventory Report (NIR). For countries that have committed to emission reductions under the Kyoto Protocol the NIR also needs to include monitoring information related to the Protocol.

Reporting is done for a range of different sectors, according to IPCC guidelines that are regularly updated by the IPCC. See Table 2 with information on the IPCC guidelines that need to be applied under the various Monitoring, Reporting and Verification (MRV) schemes under the UNFCCC. Currently under the UNFCCC Annex 1 countries need to apply the 2006 IPCC Guidelines (IPCC 2006). Reporting under the Kyoto Protocol (up to 2020) additionally requires the application of the 2013 revised supplementary methods and good practice guidance arising from the Kyoto Protocol (IPCC 2014). Under the Paris Agreement (first reporting on emission and removals from 2021 onwards in 2024) all parties that have ratified the agreement need to report according to the Modalities, Procedures and Guidelines[389] (UNFCCC, 2019) of the Enhanced Transparency Framework (ETF). Under this framework the reporting and requirements will be the same for all parties. Decision 18/CMA1 (UNFCCC 2019) requires the use of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and encourages parties to use the 2013 wetland supplement to the 2006 IPCC guidelines.

[389] UNFCCC, 2019. Decision 18/CMA.1 Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, (March), 1–65. https://unfccc.int/sites/default/files/resource/cma2018_3_add2_new_advance.pdf

Table 26 Overview of the HWP approach and IPCC guidelines to be applied in the various UNFCCC MRV schemes. Adapted from Sato & Nojiri (2019).

Scheme	HWP approach	Applied IPCC guidelines
GHG inventory before Paris Agreement		
For Annex I	Production approach, stock-change approach, atmospheric-flow approach, Simple-decay approach	2006 IPCC guidelines (IPCC 2006)
For non-Annex I	No specific rule	Revised 1996 guidelines (IPCC, 1996), but GPG-LULUCF (IPCC, 2003) encouraged
Kyoto Protocol accounting		
1st commitment period	Instantaneous oxidation	GPG-LULUCF
2nd commitment period	Production-based approach/instantaneous oxidation	2006 IPCC Guidelines, 2013 KP supplement (IPCC 2014)
REDD+	No specific rule	Most recent IPCC guidelines
Paris Agreement		
GHG inventory	Production approach (or instantaneous oxidation) - as common information	2006 IPCC Guidelines and any subsequent IPCC guidelines
Nationally Determined Contributions Accounting	Any approach, to be defined by the country. EU Member States need to follow the EU LULUCF regulation (EU) 2018/841, which requires the use of the "production approach", excluding accounting of imported HWP by the importing country.	IPCC guidance (= all IPCC guidelines and guidance). EU Member States need to follow the requirements in the EU LULUCF regulation 841/2018, which currently has the 2016 IPCC guidelines mandatory.

In the meantime a 2019 refinement to the 2006 IPCC guidelines is available. This does not revise or replace the 2006 guidelines, but rather updates and supplements them. While it is not yet compulsory to use these refinements Parties may use these refinements in inventory preparation.

Forests and carbon stored in Harvested Wood Products (HWP) are reported in the Land Use, Land Use Change and Forestry (LULUCF) sector. Gains and losses of carbon stocks in the forest biomass pool, as well as in the pools litter, deadwood and soil are estimated annually. Carbon in wood harvested from the forest is transferred from the living biomass carbon pool to the HWP carbon pool, based on production quantities per product category. This implies a loss in the carbon stocks in forested land. The carbon is then stored in the HWP pool for a certain amount of time. If a country applies a second order decay function, the carbon is gradually released from the HWP pool (as CO_2 emissions) depending on the half-lives of the product category. For instance, the carbon stored in sawnwood that is used in construction has a longer half-live than paper. Woody biomass used for energy is usually accounted for assuming instantaneous oxidation, i.e. meaning that the carbon in the wood is deducted from the forest biomass carbon pool and does not enter a HWP pool, resulting in an instant emission. Under the guidelines for accounting under the Kyoto Protocol, and also in the EU LULUCF regulation ((EU) 841/2018) that provides the accounting rules to be applied by EU Member States under the Paris Agreement, wood originating from deforestation events is reported as instantaneous oxidation (i.e. no carbon from wood from deforestation events will enter the HWP carbon pool).

The 2006 IPCC guidelines detail various approaches to calculate emission and removals from HWP. These approaches differ for instance in how to deal with imports and exports of HWP and hence determine where (location, country) the emissions and removals are reported (see Table 2 for an overview of approaches that can be used under the different schemes, and see Sato and Nojiri (2019) for more detailed information). Under the KP accounting and the EU LULUCF regulation the production approach is specified, which means that only wood that has been harvested domestically is accounted for. The inflow into the HWP module is derived from the production quantities as reported by the industry. The outflow is calculated using a decay function calibrated with the half-lives of each product group and considered to be oxidised instantaneously. These emissions can be recaptured again in the Waste sector if the wood is landfilled. Any benefits from using the wood to replace energy-intensive materials are not allowed for in the LULUCF sector but should be seen as lower GHG emissions visible in the Energy or Industry sector if the wood product is replacing domestically produced materials.

To overcome lack of data known to be encountered by LCA practitioners, de Rosa et al. (2016) proposed a simplified time-dependent modelling method to model forest carbon fluxes in LCA. The method has been validated with the CO_2FIX models (Masera et al., 2003). The method allows choices to be made for four key parameters:

(1) carbon pool considered (above and below-ground, only above-ground or only in the stems);

(2) biomass growth dynamic (sigmoidal or linear dynamic);

(3) biomass decomposition of aboveground and below-ground dynamic (sigmoidal, negative exponential or linear dynamic)

(4) the characteristic of the forest management (rotation length, stand type, thinning frequency and intensity).

The boundary in this method is the forest, and carbon storage effects of wood forest products cannot be accounted for within it.

The Moura-Costa (Moura-Costa & Wilson, 2000) and Lashof (Fearnside et al., 2000) methods were developed to consider the potential benefits of temporary carbon storage in the context of forestry sequestration credits (Figure 7). Both methods find their basis in the ton-year method (IPCC, 2000) aiming at calculating a credit in kg CO_2-eq for keeping carbon out of the atmosphere for a given number of years. The baseline for these methods is the cumulative radiative forcing caused by a one-ton pulse-emission of CO_2 at time zero, integrated over a 100 year time horizon, which results in approximately 48 tonne-years of CO_2 (Figure 7a). Moura-Costa uses this value to generate an equivalency factor of 48 years, which means that storing one ton of CO_2 for 48 years is equivalent to avoiding the impact of a ton pulse emission of CO_2 (Figure 7b). The credits are then distributed evenly over time, meaning that storing one ton of CO_2 for one year can fully compensate for the impact of an emission of 0.02 ton (1/48) of CO_2. The Lashof method, that has also been proposed for LCA-related applications (Courchesne et al., 2010), is based on the rationale that temporary storage is equivalent to delaying an emission until the end of the storage period. In this approach, the benefit is represented by the area of the tail of the second curve that is pushed beyond the end of the time horizon as a result of the emissions delay (Figure 7c).

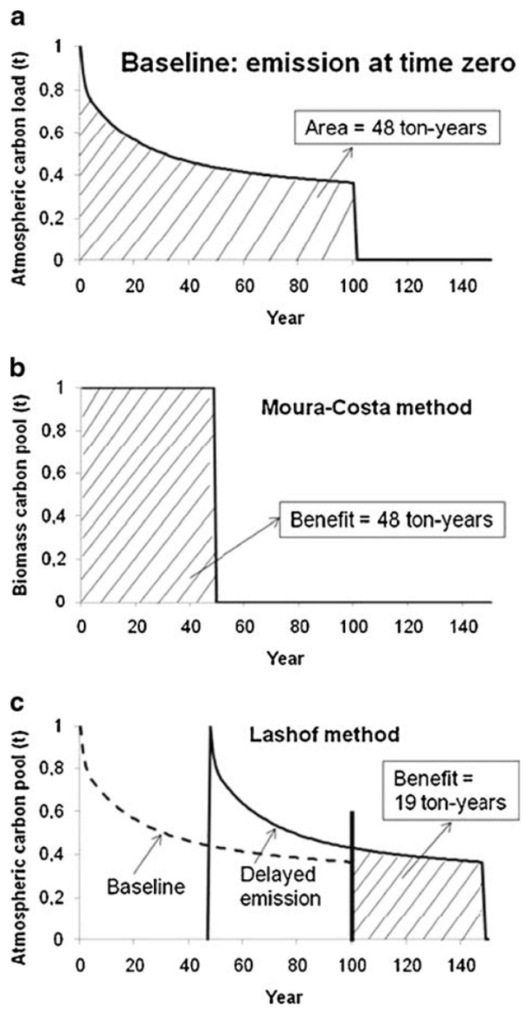


Figure 30 Graphical representation for a 100-year time horizon of the ton-year approach (a) the Moura-Costa (b) and the Lashof method (c), both of which is based on the cumulative radiative forcing of 1 t of carbon. From Levasseur et al., (2012)

5.3. Biomass sustainability and sink/source effect

None of the reviewed standard and methodologies explicitly require the origin of the harvested biomass to be sustainable when applying the standard to biobased materials. Nevertheless, some of the reviewed standard and methodologies include a differentiation based on the sustainability of forest management to disincentivize the use of wood that cannot be proved to be sustainable. In ISO 21930 (ISO, 2017) and EN 16485 (ISO, 2014), the CO_2 sequestration by forests is characterised by -1 kg CO_2eq / kg CO_2 in wood solely in the case of sustainably managed forest; for other (non-sustainably managed forests) the value is 0 kg CO_2eq / kg CO_2 in wood. By default forests located in a country that has decided to account for the article 3.4 of the Kyoto Protocol (e.g., additional human-induced activities from the management of existing forests) are regarded as sustainable. Alternatively, sustainable management can be demonstrated for those forests subject to the certification for sustainable forest management (e.g. FSC or PEFC).

In EN 15804+A2 a similar but weaker approach to account for the sustainability of wood used is followed based on a distinction between native and non-native forests. In that case, CO_2 sequestration is only characterized for non-native forests (i.e. -1 kg CO_2eq / kg CO_2 in wood harvested). This means that (i) all native forests are implicitly considered non-sustainable not being characterized (0 kg CO_2eq / kg CO_2 in wood harvested) and (ii) there is no distinction about the sustainability of non-native forests meaning that all they are assumed by default sustainable.

Concerning the forest carbon sink/source accounting, this aspect is still relatively poorly addressed. The ISO 14067 (ISO, 2018) asks for explicit accounting, stating that the GHG fluxes occurring as a result of land use through changes in soil and biomass carbon stocks that is not the result of changes due to management of land, should be assessed in accordance to the UNFCCC reporting guidelines (IPCC, 2019). They should be reported separately and, if not reported, justification as to why should be given. The GHG protocol (WBCSD/WRI, 2011) asks for the sink effect to be accounted for when it is the direct result of extraction or production of the biogenic material under study.

Several of the innovative approaches take into account in one way or another the in-situ carbon stock and sink effects. Examples are the method of Vogtländer et al. (2013), which looks at the problem from a landscape level, and the methods of de Rosa et al. (2016), Cherubini et al (2011) and Pingoud et al. (2012) which look at it from a stand-level.

Notably, most of the standards ask for the accounting of land use change impact.

5.4. Biomass end-of-life

At the end-of-life, wooden products may be landfilled, incinerated (with or without energy recovery), recycled or reused. In LCA standards, the impact of landfilling and incineration (without energy recovery) is fully assigned to the building system. In case of reuse, recycling and incineration with energy recovery, the benefits (i.e. the avoided use of virgin materials or fuels) and loads (i.e. the impact of the recycling process) should be shared between the building system and the potential subsequent product system following a clear allocation approach that avoids double counting of loads and/or benefits. Three main types of allocation approaches can be applied.

A first approach, referred to as recycled content or the cut-off approach, allocates the benefits and loads to the life cycle of the product system that uses the recycled material. This approach is followed by the ISO 21930, EN 15804+A2 and EN 16485 standards where reuse, recycling and energy recovery are reported in module D, which fall outside the system boundary. In practical terms this means that, for example, if wood is incinerated with energy recovery at the end-of-life, both the impact of the incineration (i.e. loads) and avoided impact due to the saving of primary fuels (i.e. benefits) do not contribute to the life cycle impact of the building, although they are reported in module D for transparency.

In a second approach, referred to as closed-loop approximation, benefits and loads are fully allocated to the building system. In PAS 2050 and the GHG protocol, a choice can be made between the recycled content and closed-loop approximation methods. The closed-loop approximation method is mainly used for recycled materials that retain the same inherent properties as the virgin materials. For example, if a wooden beam would be disassembled and reused (without downcycling) in another building after the end-of-life, the avoided impact for the production of the new wooden beam is, in that approach, subtracted from the life cycle impact of the first building.

A third approach consists in sharing the benefits and loads of recycling between the first and second life cycle. This approach is used in the PEF standard (European Commission, 2013) and related PEFCR (European Commission, 2018) where allocation factors are applied following the circular footprint formula. As an example, if wood is incinerated with energy recovery at the end-of-life, the impact of the incineration and the avoided impact of primary fuels contribute partly (depending on the allocation factor) to the life cycle impact of the building.

Concerning the calculation of the benefits related to reuse, recycling and energy recovery, few standards include recommendations for the substitution approach which should be adopted[390]. EN 15804+A2 and EN 16485 mainly recommend the calculation of benefits based on the substitution of current average technology and energy mix such as, for example, heat from fossil fuels.

In the innovative methods, Vogtländer et al. (2013) suggests the use of the substitution approach when wood is burnt at end-of-life while Pingoud et al. (2012) consider avoided burdens due to the displacement of functionally equivalent, fossil-based products using displacement factors.

6. Calculation of the embodied carbon and biogenic carbon content for a selected wood construction product

There is a fundamental difference between the way carbon in wood products is considered in the IPPC methodology for LULUCF accounting and in LCA, In the former the methodology is applied at a broad geographical scale (e.g. country), whereas in LCA the methodology is applied at the level of a single product or building. In LULUCF accounting a probabilistic approach is used to estimate the carbon remaining in the harvested wood products pools. Based on an assumed half-life the amount of carbon still stored in the pool is estimated using a first-order decay function. This approach aims to provide an estimate that is valid at the product pool level, and, as such, presents some clear limitations when applied to a single product. In LCA a reference service life for each product/building is assumed and, as such, the carbon storage dynamic of each specific product/building can, in principle, be more precisely considered. For buildings, assumptions about service life vary, normally ranging from 30 to 100 years, with 50 years representing the most commonly assumed value shown in (Trigaux et al., 2021). The same authors also suggest to use 50 years as service life for building LCA, and this value has been considered in the work of this chapter, although any other service life can be considered based on the specific (realistic) case under study.

Figure 8 compares how the carbon storage effect for wood products is modelled in the UNFCCC LULUCF methodology for both a half-life of 35 years (default value for long-living products) and 50 years (commonly used reference study period for buildings in literature). It also shows how carbon storage for a product with a 50 year lifetime is modelled in LCA using a traditional static approach (st) and in LCA using a dynamic inventory (dynamic) (before applying DCF).

[390] Substitution (also called avoided burden) is often used in LCA to allocate benefits or burden of recycling/reuse/using as energy. In determining the overall impact of a product a "credit" is given for the potential recycled/reused/used as energy material included. For instance, If a wood products at end-of-life is chipped to produce particle board ,this particleboard may be given a credit for virgin wood saved by using recycled wood. This credit is termed "avoided burden" because it refers to the impact of virgin material production that is avoided by the use of recycled material. In the same way of the same wood at end-of0life was incinerated to produce energy, the impact of the fossil energy saved can be credited to the product.

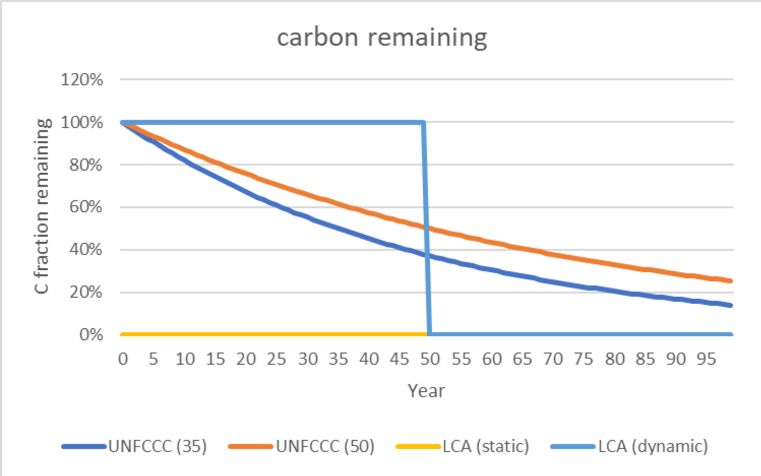


Figure 31 Comparison of how the carbon stored effect in wood products is modelled in the UNFCCC methodology and LCA approaches

The more precise carbon storage accounting approach which can be used in LCA is not however necessarily translated into the accounting of its mitigation benefits and it depends on the method used. Current LCA methodologies are not suited to giving a value to temporary carbon storage. This is not only because of the carbon neutrality issue discussed earlier, in which the amount of sequestered carbon, even when accounted for explicitly (i.e. in -1/+1 approach) is subtracted from the emission occurring at the end of the storage period, but also because traditionally LCA is static. This means all emissions and sequestrations are assumed to happen at the same year (i.e. the year of production). The difference in timing between the moment in which the biogenic carbon is sequestered during forest growth and the subsequent emissions at the end of life of the wood products (i.e. the temporary carbon storage) is not considered (Agostini et al., 2013; Breton et al., 2018), thus precluding any incentive for the temporary storage of carbon in wood products (Ellison et al., 2011). This lack of the time dimension is of particular relevance for biogenic carbon in the building context, due to the relatively long life cycles involved (Cardellini et al., 2018). This issue can be solved by performing dynamic LCA that has both a temporal explicit inventory and uses time dependent characterisation factors (DCF) that can give a value to the temporary mitigation impact of carbon storage (Levasseur et al., 2013). The methodology has been outlined in detail in Levasseur et al. (2010) and consists first in the construction of a dynamic life cycle inventory (dLCI), where also the timing of the GHGs fluxes is explicitly reported, and then in the application of DCF, characterization factors that are dependent on the moment when the emissions happen. Contrarily to what happens traditionally in LCA where static characterization factors are used (i.e. any flux has the same impact regardless of when it happens), with this approach fluxes happening closer to the end of the time horizon considered are given less weight compared to those happening at the beginning.

Table 3 shows Dynamic Characterization Factors (DCF) calculated following the methodology outlined in Levasseur et al. (2010, see from equation 1 to equation 6) using the ‘‘Dynamic Carbon Footprinter” (DynCO2) excel tool developed from the same authors. The DCF are calculated for the main GHGs over a time horizon of 100 years, the standard time horizon in LCA, for fluxes happening at year 0 (i.e. year of wood harvesting), 25, 50 (i.e. the assumed lifetime of the building in this work) and 75 years.

Table 27 Dynamic Characterization Factors (DCF) for emissions in different years calculated following the methodology outlined in Levasseur et al. (2010) see from equation 1 to equation 6).

Year	CO_2	CH4	N2O	CO
0	1,0	30,9	264,9	1,6
25	0,8	30,3	219,6	1,3
50	0,6	29,3	162,0	0,9
75	0,3	25,5	91,1	0,5

This method has already been used to assess the climate change impact of biogenic carbon in buildings (Breton et al., 2018; Fouquet et al., 2015; Head et al., 2020; Peñaloza et al., 2016) and more generally of wood-based products (Demertzi et al., 2018; Faraca et al., 2019; Levasseur et al., 2013). Levasseur et al. (2012) showed its superiority over the other methods developed to assess the impact of temporary carbon storage (i.e. the Moura-Costa and Lashof methods) due to its flexible approach, its explicit consideration of every life cycle step and the opportunity given to use different time horizons if needed. Hoxha et al. (2020) identified this dynamic approach as the most pertinent and transparent to be applied in the context of construction bio-based products and materials.

To show how this method can account for the carbon storage effect in wooden products used in buildings, the cradle-to-grave GWP impact of a typical wooden beam (section 100x100 mm – length 1m)[391], was calculated for two cases, one following *in toto* the guidelines of the standard (i.e. using a static approach) and another one using the same data and assumptions but creating a dynamic LCA based on dLCI and DCF.

Wood construction products encompasses both traditional and innovative engineered wood products[392]. The most common traditional and engineered wood products used as structural building materials are Sawnwood and glued laminated timer (glulam henceforth) (Hildebrandt et al., 2017) respectively. These have therefore been modelled as representative for the two aforementioned classes of wood construction products. The growing stock of European forests is dominated by pines (scots, black, maritime, stone etc.) (29.6%), Norway spruce (23%) and beech (11.9%) (Forest Europe, 2020). Beech and Norway spruce represent thus the most abundant single species in Europe. Also due their commercial importance (EC-JRC, 2016) they were taken as representative species for hardwood (Beech) and softwood (Norway Spruce). Four products variants were thus modelled, namely sawnwood and glulam made from both beech Norway spruce.

It was assumed that all activities included in module A happen at year 0 (equivalent to the year of wood harvest) and activity in module C at year 50 (i.e. the assumed end-of-life of the building). Since the overall goal of the project is to focus on the effect of carbon storage in wood products, the temporal dynamic of carbon fluxes in the forests was excluded by assuming that all forest carbon sequestration occurred at year of harvest (i.e. year 0). This assumption can be considered valid for wood products made from raw wood coming from sustainably managed forests (see section 4.1.2). This approach would further allow taking an implicit neutral position on the growth before/regrowth after harvesting debate, which is not relevant for this project, where the forest examined at landscape (i.e. large scale e.g. regional or country level) rather than stand-level (cfr. with section 4.1.1). Concerning the

[391] The dimensions are based on a typical wooden beam as defined in the Belgian LCA tool TOTEM (www.totem-building.be)

[392] Cfr. with report from Task 1.1 “Market Analysis” of the same project “Evaluation of the climate benefits of the use of harvested wood products in the construction sector and assessment of remuneration schemes”

end-of-life treatment, wood incineration without energy recovery was assumed meaning that the full carbon content was released at year 50.

All the data for the LCA were taken from the ecoinvent database version 3.6 (Wernet et al., 2016), and Gabi the most complete LCA databases on building materials (Martínez-Rocamora et al., 2016) and the market-leading LCA database[393]. A carbon content of 50% was assumed and densities of 450 and 800 kg/m³ for Norway spruce and beech respectively . A moisture content of 10% was assumed for sawnwood and of 12% for glulam. The relative life cycle inventory is reported in .

Table 28 dLCI with the GHG emissions of the four wooden products studied (section 100x100 mm – length 1m)

Product	Stage (year)	CO_2 bio (kg)	CO_2 foss(kg)	CH4 (g)	N2O (ng)	CO (g)
Glulam hard	A1-A3 (0)	13,10	1,95	3,95	11,73	32,09
	C3-C4 (50)	13,10	1,31	1,93	1,06	22,98
Glulam soft	A1-A3 (0)	7,37	1,71	3,43	10,46	25,32
	C3-C4 (50)	7,37	0,74	1,08	0,60	12,92
Sawnwood hard	A1-A3 (0)	13,33	0,37	0,84	11,44	12,33
	C3-C4 (50)	13,33	0,05	0,18	0,08	2,12
Sawnwood soft	A1-A3 (0)	7,50	0,36	0,98	11,40	15,55
	C3-C4 (0)	7,50	0,03	0,10	0,05	1,19

The climate change impact of producing the same product can greatly diverge depending from the product under consideration and the methodology used (Figure 9). Looking at the contribution analysis of Figure 10, it can be clearly seen how the temporary carbon storage in wood products is not considered in the -1/+1 approach. In fact, the climate benefits of biogenic carbon in stage A1-A3 (i.e. C sequestration in forests) is cancelled out by the subsequent emission of the same biogenic carbon in stage C3-C4 at the end-of-life of the wooden product. This is a consequence of the climate neutral assumption of the 1/+1 approach. This means that the global warming impact is solely due to the global warming impact caused by the fossil GHG emissions.

For glulam (both sawnwood and hardwood) production (A1-A3) the cause of impacts are the use energy (37% of the total) and of formaldehyde (15% of the total) for the production of the glulam and the production and sawing of the wood used[394] (17% of the total). For sawnwood softwood production, the emissions due to forestry activities (sawing and skidding) contributes to 46% of the impacts, and the transportation to 24%. For sawnwood hardwood production, the emissions due to forestry activities (sawing and skidding) contributes to 26% of the impacts, and the transportation to 42%, since in ecoinvent it assumed that 15% of the wood used is imported for this product. The end-of-life (C3-C4) impact of glulam 0,8 softwood kg $CO_{2\ eq}$/m , 1,4 kg $CO_{2\ eq}$/m hardwood) is higher than those of sawnwood (0,04 kg $CO_{2\ eq}$/m softwood, 0,07 kg $CO_{2\ eq}$/m hardwood) being a composite material that generates hazardous waste for which the treatment is more GHG intensive.

[393] https://www.ipoint-systems.com/blog/success-factors-for-life-cycle-assessment-data-data-data/

[394] Which includes impact of raw wood production, transportation to the sawmill, the sawmilling activities and the sawmill infrastructure

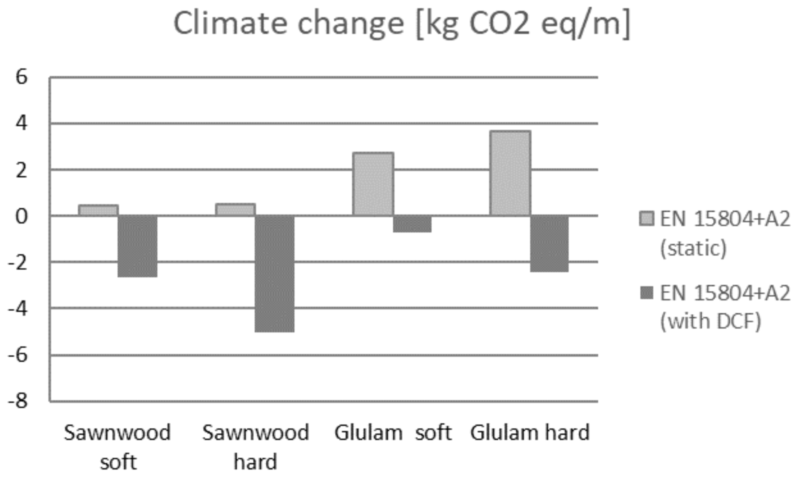
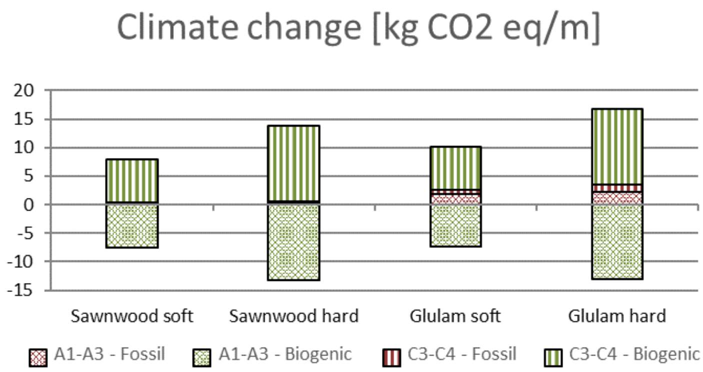


Figure 32 comparison of GWP impact (kg CO2 eq per metre of product) using the static method (i.e. -1/+1) and the dynamic (i.e. -1/+1 with DCF)



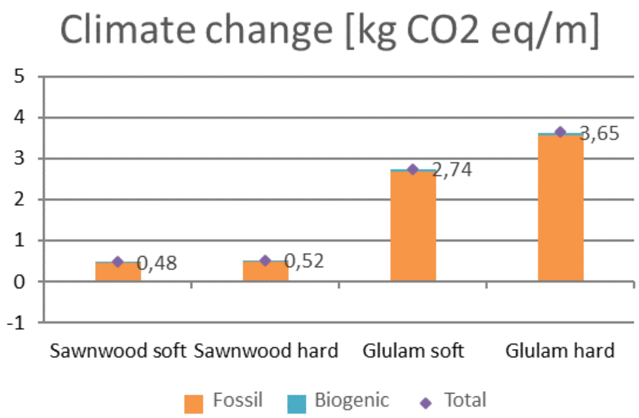


Figure 33 Contribution analysis for the (static) analysis performed following the standard EN 15804+A2

When the timing of the emissions is considered the results change sensibly since here the benefits of the temporary storage of biogenic carbon in wood product is acknowledged and weighted (light blue bars in Figure 11).

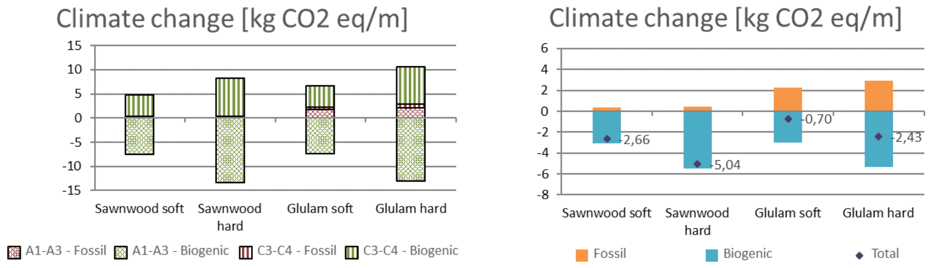


Figure 34 Contribution analysis for the analysis performed following the standard EN 15804+A2 and using a dynamic approach.

The global warming impact of fossil emissions shows negligible changes: the global warming impact of the production phases (A1-A3) is unchanged and the end-of life (C3-C4) impact is about 40% lower due to the lower global warming impact given by the use of the DCF (cfr. Table 3). The global warming benefits of biogenic carbon storage range from 3,0 kg CO_2 $_{eq}$/m beam for both softwood products up to 5,5 kg CO_2/m for sawnwood made from hardwood species. In all cases, these benefits are bigger than all other fossil emissions making the product a net climate mitigator when the temporary storage benefits are considered and estimated with a dynamic approach. It is also clear that these results are highly dependent on assumptions such as the lifetime chosen (the higher the lifetime, the higher the climate change benefits due to carbon storage) and the time horizon over which the DCF is calculated (to longer the time horizon, the lower the difference between the static and the dynamic approaches).

7. Recommendations for a single methodology for measuring embodied carbon and biogenic carbon content of wood products used in construction

Based on the review performed in section 2, the strengths and weaknesses of each methodology when used in the context of wood products are summarized in Table 5. Some clear conclusions can be drawn from these strengths and weaknesses:

- LCA standards:
    - provide the most comprehensive approaches to considering the climate change impact/benefits of (wood) products thanks to their focus on the full value chain of the product,
    - allow, due to their clear and detailed description of the modelling approach which must be followed, avoidance of potential inconsistencies (and consequentially incomparability) in the results and double counting,
    - do not have a specific focus on bio-based materials and the tracking of biogenic C in terms of carbon sink/source effect in the forest and carbon storage in wood products; these aspects are either only considered in a rudimentary way or are completely neglected.
- LULUCF accounting:
    - allows detailed tracking of the forest carbon sink/source effect and consideration of the wood products carbon storage effect,

  - only looks at biogenic carbon,
  - has a poor level of detail at the product-level; all wooden products are generally aggregated into macro families of semi-finished products.
- Innovative methods:
  - address some of the specific limitations of the previous two methods,
  - only look at specific aspects and are thus not suitable for use in a stand-alone way.

Table 29 Pros and cons of each method when used in the context of wood-based products

Method	Pros	Cons
ISO 21930:2017 Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services	• Tracking of biogenic CO_2 flows • Differentiation based on forest management (Biogenic carbon uptake only for sustainably managed forests)	• Carbon neutrality assumed over the whole life cycle • Only consideration of land use change impacts (no impact of land use) • No consideration of the effect of temporary carbon storage (may be reported separately) • Benefits and loads from reuse, recycling and energy recovery at the end-of-life fall outside the system boundary
14067:2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification	Tracking of biogenic CO_2 flows • Consideration of both land use and land use change impacts • Benefits and loads from reuse, recycling and energy recovery at the end-of-life are fully allocated to the product system (closed-loop allocation) or shared between the first and second life cycle (open-loop allocation)	• Carbon neutrality assumed over the whole life cycle • No consideration of the effect of carbon storage (may be reported separately)
EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products	• Tracking of biogenic CO_2 flows • Differentiation between native and non-native forests (Biogenic carbon uptake only for non-native forests) • Consideration of both land use and land use change impacts	• Carbon neutrality assumed over the whole life cycle • No consideration of the effect of carbon storage • Benefits and loads from reuse, recycling and energy recovery at the end-of-life fall outside the system boundary
EN 16485 Round and sawn timber - Environmental Product Declarations - Product category rules for wood and wood-based products for use in construction	• Tracking of biogenic CO_2 flows • Differentiation based on forest management (Biogenic carbon uptake only for sustainably managed forests)	• Carbon neutrality assumed over the whole life cycle • Only consideration of land use change impacts (no impact of land use) • No consideration of the effect of temporary carbon storage (may be reported separately) • Benefits and loads from reuse, recycling and energy recovery at the end-of-life fall outside the system boundary

Method	Pros	Cons
Product Environmental Footprint (PEF) guide (2013)	• Tracking of biogenic CO_2 flows • Benefits and loads from reuse, recycling and energy recovery at the end-of-life are shared between the first and second life cycle (circular footprint formula)	• Only consideration of land use change impacts (no impact of land use) • No consideration of the effect of temporary carbon storage (may be reported separately)
PEFCR Guidance - Product Environmental Footprint Category Rules Guidance version 6.3 (2017)	• Easy to implement (no allocation of CO_2 content between multiple products, no tracking of biogenic CO_2 flows) • Benefits and loads from reuse, recycling and energy recovery at the end-of-life are shared between the first and second life cycle (circular footprint formula)	No tracking of biogenic CO_2 flows (carbon neutrality as starting assumption) • Only consideration of land use change impacts (no impact of land use) • No consideration of the effect of temporary carbon storage (only permanent carbon storage of more than 100 years)
PAS 2050: 2011 - Specification for the assessment of the life cycle greenhouse gas emissions of goods and services	• Tracking of biogenic CO_2 flows • Benefits and loads from recycling at the end-of-life are fully allocated to the product system when the recycled material maintains the same inherent properties (closed-loop approximation method)	• Only consideration of land use change impacts (no impact of land use) • No consideration of the effect of temporary carbon storage (only permanent carbon storage of more than 100 years) - credit for temporary carbon storage may be calculated separately based on linear discounting • Benefits and loads from recycling at the end-of-life fall outside the system boundary when the recycled material does not maintain the same inherent properties (recycled contend method)
International Reference Life Cycle Data System (ILCD) Handbook -- General guide for Life Cycle Assessment -- Detailed guidance (2010)	• Tracking of biogenic CO_2 flows • Benefits and loads from recycling at the end-of-life are shared between the first and second life cycle	• No consideration of the effect of temporary carbon storage (only permanent carbon storage of more than 100 years) - credit for temporary carbon storage may be calculated separately based on linear discounting
GHG protocol - Product Life Cycle Accounting and Reporting Standard (2011)	• Tracking of biogenic CO_2 flows • Consideration of both land use and land use change impacts • Benefits and loads from recycling at the end-of-life are fully allocated to the product system (closed-loop approximation method)	• No consideration of the effect of temporary carbon storage • Benefits and loads from recycling at the end-of-life fall outside the system boundary (recycled contend method)
DCF (Levasseur et al. (2010)	• Accounts for effects of temporary storage/delayed emissions • Avoid temporal inconsistency of impact assessment	• Requires temporal explicit inventory (can be time consuming)

Method	Pros	Cons
Vogtländer et al. (2013)	• Integrates landscape-level carbon-cycle and land use change	• Complex and data intensive
GWPbio (Cherubini et al 2011)	• Accounts for stand-level impact of forest C dynamic/regrowth • Considers also effect of C storage in HWP	• In its standard form assumes C neutrality (can be avoided this assumption but making it more complicated to be calculated)
GWPnetbio (Pingoud et al. 2012)	• Considers avoided burdens (i.e. displaced fossil emissions if the same product had been produced from a fossil resource) • Considers also effect of C storage in HWP • Considers impact of land occupation	• Requires assumptions on the displaced fossil fuels and land use reference scenario, which can influence sensibly its value • Risk of double counting when not used properly
GWPbio-product (Helin et al. 2016)	• Considers also effect of C storage in HWP • Considers impact of land occupation	• Requires assumptions on land use reference scenario, which can influence its value
WF method (Väisänen et al. 2012)		• Unrealistic (linear) forest growth dynamic • C storage of HWP effects not considered • Not considers timing of fluxes
de Rosa et al. (2016) method	• Consider all C pool dynamic • Consider also effect of forest management	• Data intensive • C storage of HWP effects not considered
TAWP (Kendall 2012)	• Accounts for effects of temporary storage/delayed emissions • Avoid temporal inconsistency of impact assessment	• Requires temporal explicit inventory (can be time consuming)
UNFCCC Good Practice Guidance for the LULUCF sector (IPCC, 2019)	• Accounts for carbon stored in the products; includes carbon balance in the forest	• No avoided emissions through substitution
Moura-Costa (Moura-Costa & Wilson, 2000)	• Includes re-capture by vegetation recovery, favouring biogenic carbon over fossil-based carbon emissions	• General methodology, not specifically oriented at forest and/or products carbon accounting
Lashof (Fearnside et al., 2000)	Considers a dynamic “ton per year accounting” for global warming mitigation action such as: temporary C sequestration from forest plantations, avoided deforestation , clearance and fossil fuel emission reduction,	Does not consider the product. Once the wood is harvested is account as carbon emissions.
GWPsoil (Brandão et al., 2011)		• Focus on soil carbon
CRP (Muller-Wenk & Brandao, 2010)		• Focus on landcover change as compared to PNV, not so much on use of the land; time horizon very long, favouring

Method	Pros	Cons
		short-term biogenic emissions over fossil fuel emissions; carbon stored in products is not explicitly considered

The analysis reveals that while none of the methodologies is perfect for measuring both the embodied carbon and biogenic carbon content of wood products used in construction, good elements exist in each family of methods, and a good methodology can be created by taking their best elements without having to reinvent the wheel.

It is evident that, by their very nature, and because they are already widely accepted in the building sector, the use of LCA standards should represent the starting point of any methodology aiming at measuring the embodied carbon and biogenic carbon content of wood products used in construction. This is because this type of analysis, namely the comparison of a wood-based building with its functionally equivalent solid building, clearly falls into the so-called comparative attributional LCA analysis.

To make this general consideration functional to the goal of estimating the mitigation benefits of wood-based buildings, the following decisions must be made:

- how to identify the benchmark building against which the wood-based one is compared,
- whether to restrict the analysis solely to biogenic carbon or to also include fossil emissions,
- which specific LCA standard should be used as a starting point.

For the first aspect, it is clear that a highly simplified approach based on the identification of a single EU reference building for each building type is too coarse due to the big differences existing in the European building practices. For example, the consumption of wood in construction in Nordic countries is relatively high compared to southern European countries. However, bearing in mind the need to keep the procedure relatively simple, the identification of the benchmark building based on certain rational criteria, and the subsequent assessment of its life cycle impact, should not be left to the applicants. The approach should rather be based on the identification of representative benchmark building for (macro) regions and building typologies (residential, commercial, industrial etc.), for which the life cycle impact per square meter is pre-calculated. This way the applicant would be relieved of the burden of identifying the competing solid building himself (even if based on some clear and rational guidance) and calculating its life cycle impact, Instead they would just focus on the calculation of life cycle impact of the wood-based building for which the benefits are to be estimated.

In the building sector, benchmarking systems and values are being developed in a number of different European countries. As an example, in France, reference values for the life cycle GWP impacts of buildings have been defined in the context of the E+/C- labelling system which will serve as a basis for future environmental regulation[395]. Trigaux et al. (2021) gives an exhaustive overview of the existing benchmarking systems in the building sector of European countries, and we recommend starting from these benchmark values developed in the different European countries. In the work of Trigaux et al. (2021), 23 European

[395] http://www.batiment-energiecarbone.fr.

benchmarking systems[396] for the building sector were analysed, including benchmarks from regulations, labelling systems, sustainability ratings tools and research studies. Choices related to the methodologies and their application, and the strengths and weaknesses of the various approaches were explored, and the environmental impact results of the 23 reviewed benchmarks were statistically analysed. The results of this statistical analysis are shown in Table 6. Based on the overall analysis, specific recommendations are formulated for the development of environmental benchmarks.

The approach could be streamlined even more by providing pre-calculated life cycle impacts for the wood-based building as well. In this case, the applicant would just need to demonstrate, based on some rational and clear guidelines, that the wood-based building he intends to construct can be considered similar to one of those pre-calculated. This way, simply by knowing the building typology, the region where it will be built, and by demonstrating the its similarity to the pre-calculated wooden building, the applicant would readily know the carbon benefits of its project without having to spend further time and resources in LCA calculations. This principle would essentially shift the burden of the benefits estimation from the applicant to the carbon crediting scheme implementer.

Table 30 Statistical analysis of the climate change impact reported in the benchmarking systems evaluated in Trigaux et al. (2021).

Unit	Residential buildings				Non-residential buildings				All-buildings			
	Interquartile range			std	Interquartile range			std	Interquartile range			std
	0.25	0.5	0.75		0.25	0.5	0.75		0.25	0.5	0.75	
GWP impact (kg CO_2 eq / m^2.a)	4.5	5.7	7.5	2.5	6.8	8	9.1	4.0	4.9	6.9	8.6	4.2

With regard to point (ii) the GHGs to consider, it is advisable to include both biogenic and fossil carbon fluxes. This is because, while the goal is mainly to reward the benefits from temporary carbon storage, production of (innovative) wood products still emits fossil GHG, as also shown in chapter 3. Not considering these emissions might generate unwanted leakage effects and overestimate the benefits of wood products.

Concerning the most suitable LCA standards, the EN 15804+A2 (and its corresponding building level EN 15978) standard is the LCA standard typically used to estimate the environmental performance of construction products. It is also the basis for Environmental product declarations (EPD) of construction products. The PEF method was developed in 2011 and adopted in 2013 as a harmonized and cross-sectorial approach for the assessment of the environmental performance of products. It is applicable to products in the construction sector and its applicability has also been tested at building level (see PEF4Buildings research project). With the publication of the latest PEF method and the revised EN 15804+A2 the two standards have been deeply (but not completely) harmonised, for example in terms of system boundaries, end-of-life allocation, LCIA etc. Durão et al.(2020) made a detailed comparison of the two standards which showed that, despite this

[396] Following the definition given in PEF a benchmark is a standard or point of reference against which any comparison can be made

in-depth harmonization, results from both methods cannot be compared yet. For what concerns the functional unit definition, for example, while in the EN 15804+A2 there may be a declared unit not depending on the product's function, also the magnitude, the expected level of quality and the lifetime of the product need to be indicated in PEF.

It must be also noted these, as all standards, are constantly updated. Zampori & Pant (2019) have already suggested updates to the current PEF, although the same authors highlight that being a working document their work does not modify the PEF method as outlined in the recommendation 2013/179/EU on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations[397]. Durão et al.(2020) highlighted that if the modifications suggested by Zampori & Pant (2019) are implemented, both methods will get closer and their integration in the context of construction will be facilitated. At the moment the EN 15804+A2 is the de-facto standard for the construction sector (see also its use in the European framework for sustainable buildings Level(s)), and the situation is not expected to change in the near future. It can thus be considered as the starting methodology to be used. However, its applicability in this context still presents some issues related to:

- If and how to account for the carbon fluxes in the forest and how to ensure that wood is sourced from sustainably managed forests.
- How to include the benefits of carbon storage in wood products.
- How to deal with end-of-life considering its relatively high uncertainty.

These three macro-issues and any potential solutions must obviously be considered in the context of creating a methodology that, despite being scientifically robust, does not become practically unfeasible for its final users. Risks exist in creating a resource-intensive methodology that might disincentivize the involvement of the actors in the carbon credit scheme. A proposal on how to address all these aspects is made in the following sub-sections.

7.1.1. Proposal for a feasible safeguarding of the forests sink effect and their sustainability

For a methodology that has as a main focus the accounting of the carbon storage effect of wood construction products, the detailed accounting of the forest carbon dynamic in the forests is discouraged for essentially two reasons. The first is that the accounting for forest carbon fluxes might become complex and time consuming, making its accounting a disincentive to the adoption of the standard. Moreover, this information will be very difficult to obtain for the end user, because it needs to be collected at the forest sourcing area. The second is that other certification schemes (like PEFC and FSC) and sustainability criteria (like those in RED2) , are being put in place that directly target forest owners and aim to protect and increase the forest carbon sink. Nevertheless, the proposed methodology for the quantification of the net carbon storage effect in wood construction products should take into account any effects from the way the wood is produced and harvested from the forest. Such an approach should give an incentive for sustainable forest management, optimise the carbon performance of the forest (soil and remaining forest), avoid improperly harvested wood from being credited, avoid leakage, be transparent, and should be feasible and cost-effective to implement. Trade-offs exist between these demands and no single methodology

[397] https://eur-lex.europa.eu/eli/reco/2013/179/oj

can fulfil them all. To be able to answer the questions about the origin of the wood, how sustainably the forest was managed, especially in terms of carbon impact, and how this can be determined, four options are presented.

Option 1: assessment of the country situation based on general reporting. The amount of carbon that accumulated in Europe's forest has increased by 50% over the last 30 years (Forest Europe, 2020), and forests in all regions in Europe are currently carbon sinks. Based on such reporting, countries could be put on a "green list". If wood is sourced from one of these countries, no additional proof of sustainability is needed. The advantage of this option is that the assessment can be done at a higher level with relatively low cost, and no new certification scheme is required. A disadvantage is that this option will not exclude wood harvested from within a country that was subject to non-sustainable or less sustainable forestry operations, as long as the country as a whole is judged to be managing its forests sustainably, or at least if the forest is judged to be an overall sink. Moreover, the general reporting in Forest Europe only covers the biomass carbon and does not include the soil carbon.

Option 2: assessment of the situation per country based on UNFCCC reporting. A more in-depth picture of the effect of management on the carbon balance in forests in a country can be gained from the UNFCCC inventory reports submitted by countries. Currently these reports are available on an annual basis only for the Annex I countries, but under the Paris Agreement all countries will provide reports annually. These reports provide more details on important parameters like gross deforestation, and carbon development in soil, litter and deadwood. These reports are reviewed by independent reviewers, giving them a higher credibility than voluntary reporting. Still, this option is at the country level, allowing for possible local unsustainable practices to be included but averaged out with the rest of the country.

Option 3: use of certification schemes. This option makes it mandatory for any of the wood sourced to be certified by a certification scheme. Forest management certification systems were created to allow buyers to ensure that their product was sourced from a sustainably managed forest, but certification schemes can be designed for more specific purposes as well. This option includes both the use of existing schemes, as well as new schemes that can be specifically targeted at the carbon implications of the management. Certification can be done by a forest owner or by groups of owners, but all owners have to comply to the rules, and are checked, which is an advantage compared to the country-level options. The judgement as to whether a forest owner or operator complies to the certification rules or not is done by the certification provider, based on the rules as given by the specific certification scheme. Many of the existing schemes focus on sustainability in general terms, and have no or little specific attention to carbon balance effects. Examples of such forest management certification systems are:

Forest Stewardship Council (FSC)

Endorsement of Forest Certification (PEFC)

Sustainable Forestry Initiative (SFI)

Canadian Standards Associations (CSA)

Every certification system has its own rules, and rules can differ between countries even within one certification scheme. FSC is used here as an example, but more certification schemes are available, also outside the above-mentioned ones. For FSC certification, a separate policy is determined per country. Once FSC has established the standards for the country policy, it is determined whether the owner meets the country policy. Being FSC Forest Management certified means that the certified entity is verified by a third party to be in compliance with the basic FSC Principles and Criteria as outlined in the applicable National, Regional or Generic Forest Management Standard[398]. The FSC issues three different types of certificates: Forest Management (FSC-FM), Chain of Custody (FSC-COC) and Controlled Wood (FSC-CW). The different certificates relate to different stages of production and subsequent progress of forest products through the value chain. Verification against all FSC requirements ensures that materials and products are from responsibly managed forests. In 2017, FSC started the FSC-Ecosystem Services Procedure (FSC-ES) [399] a tool that can be used to verify and communicate positive impacts of forest management. This tool incentivises the restoration and conservation of forest ecosystem services. It focuses on five types of ecosystem services: biodiversity conservation, carbon sequestration and storage, watershed services, soil conservation and recreational services. FSC-ES supports FSC-FM certificate holders to promote any verified impacts (towards sustainability, reduction of deforestation and forest degradation) and seek rewards from customers, investors, financial sponsors, users, etc. Additionally, FSC-ES improves the access of FSC-FM holders to ecosystems services payments, carbon funds, impact and supply chain investments. In the case of FSC, only the FSC-ES certification and specifically ES2.1 (Conservation of forest carbon stocks) explicitly mentions carbon, stating the following:

"3.5 Forests are identified to be protected due to their carbon stocks, according to FSC-GUI-30-006 FSC Guidance for Demonstrating Ecosystem Services Impacts.

3.6 Management activities maintain, enhance, or restore carbon storage in the forest, including through forest protection and reduced impact logging practices for carbon, as described in FSC-GUI-30-006 FSC Guidance for Demonstrating Ecosystem Services Impacts."

Some countries have already introduced certification requirements, focussing on carbon aspects for woody (or solid) biomass for generation of bioenergy, e.g. Better Biomass based on NTA 8080[400]. These could be extended to wood for construction purposes as well. Other possibilities under this option include for example certifying owners that receive subsidies for specific measures in their terrain to protect and enhance carbon pools (carbon farming).

Option 4: full accounting of the carbon effects. This option goes beyond a general statement of sustainable forest management, by quantifying the carbon effects in an LCA type of analysis. This would require a comprehensive analysis of the carbon effects at the specific forest (parcel) level, comparable to carbon crediting schemes for example for afforestation projects. This would increase the costs significantly. The purpose of this option is that only the most beneficial options (in terms of carbon) to provide construction wood will be selected. This may lead to leakage if only for the parcel itself evidence is given about the harvesting methods and carbon effects, and other parcels of the same owner can still be harvested in a detrimental way, providing wood for other purposes than construction. This method should therefore be applied to all forests of the specific owner. This option gives a very high administrative burden to the owner, which they may not be willing to take. In the worst case, this may lead to the situation that an owner cannot sell his high-quality logs to the construction sector because he does not have the required label, and has to sell it for

[398] https://fsc.org/en/forest-management-certification
[399] https://fsc.org/en/document-centre/documents/resource/316
[400] https://www.betterbiomass.com/

lower-quality purposes, which could be counter-productive in terms of climate change mitigation.

The options presented above require increasing level of details in the information required and thus in the guarantees they give for appropriate management. These options could be used in a Tier approach, with higher rewards granted for more detailed options which give a better guarantee of appropriated management, i.e. a higher Tier level. The maximum amount of credits that can be rewarded is the amount calculated to be generated by the use of wood as construction material in the LCA analysis. This amount can be lowered using a *reduction factor*, which expresses the risk that the wood credited is harvested using practices that do not take into account carbon effects in the forest. A higher Tier level would mean better guarantees of safeguarding the carbon functioning of the forest, and a lower (or no) reduction of the generated credits to be received.

Determination of the appropriate reduction levels is difficult and will depend on the perceived level of risk of unwanted management practices, and the risk-avoidance strategy of the body that grants the credits. A possible reasoning for the determination of reduction factors could be the following.

Option 1 only gives a general impression about the sustainability and the carbon sink function of the country as a whole, in most cases for biomass only. Reporting is voluntary. Risk factors are that local practices deviate from the average of the country, not all carbon pools are included (carbon in soil and litter), and reported numbers are not verified. This could be translated to a reduction factor of 80%.

Option 2 is still at the country level, but provides more certainties because UNFCCC reporting has to include all pools, and is independently reviewed. A general reduction factor of 60% could be applied, possible mediated in a country-specific way, taking into account for example extra penalties linked to gross deforestation in relation to the total forest area, and bonuses if reported carbon accumulation exceeds the Forest Reference Level as specified in the National Forestry Accounting Plan, or if soil carbon is reported based on measured values rather than reporting a general “not a source”, etc.

Option 3 practically eliminates the risk that the wood is sourced from an area that does not comply to the average conditions as in option 1 and 2, because the certification rules apply to the whole certified area. However, a general sustainability certificate gives no absolute guarantees about the carbon implications of the management. General certification schemes could therefore be awarded a reduction factor of 30%, while explicit carbon certification schemes (like FSC-ES2.1) could be awarded a 0% reduction factor.

Option 4 also gives good guarantees if applied at the forest owner level and could receive a 0% reduction factor.

Table 7 gives a summary of the proposed reduction factors. These factors are meant for illustration purposes only, and can be refined considering the uncertainties and reliability of the respective methods

The Renewable Energy Directive (RED2) 2018/2001 also sets sustainability requirements on biomass sources, in this case if the biomass is used for generation of energy. Comparable to our approach, this includes evidence of sustainable management on the country level as a whole (article 29(6) option a) or at the level of the forest sourcing area (article 29(6) option b). In addition, sourcing countries have to be a Party to the Paris Agreement and have submitted their Nationally Determined Contribution (NDC) to the UNFCCC or have plans in place, applicable in the area of harvest, to conserve and enhance carbon stocks and sinks, and provide evidence that reported LULUCF-sector emissions do not exceed removals (article 29(7)a). If this evidence is not available, management systems should be in place at the forest sourcing area level to ensure that carbon stocks and sinks levels in the forest are maintained or strengthened over time (article 29(7)b). These requirements have parallels to the options presented here, with evidence provided either at the country level (a) or at the forest sourcing level (b), and relating to sustainability in general (article 129(6)) and more specific on protection of the carbon balance (article 29(7)). While we propose a reduction factor to express different levels of guarantees, the RED2 Directive only accepts or rejects a certain batch of wood given the evidence provided.

Table 31 Proposal for application of tier-based approach into carbon credits

Option	Description	Reduction Factor (%)	Total Credit Obtained (%)
1	General country reporting	80	20
2	UNFCCC reporting	60	40
3	Certification scheme	0-30	70-100
4	Case-specific evidence	0	100

In order to guarantee that the wood used in construction purposes is really the wood harvested under the specified Tier level, a “Chain of Custody” (CoC) certificate would be required. Every trader or (processing) company that comes into contact with the wood has to be certified for this CoC, ensuring essential information about the wood is passed down the supply chain from source to consumer. Essential information usually refers to the (accredited) sustainability of the forest management, but could also be information on measures to maintain the carbon stocks and sink function of the forest, as would be the case here. A similar requirement for a CoC certificate is set in the EU Timber Regulation, to ensure wood is not sourced from illegal logging operations. In the Netherlands a CoC is for example already applied in practice as a requirement for usage of solid biomass for energy production [401]. In the case of usage of wood for construction purposes, a similar CoC should be in place to trace the origin of the wood and ensure guarantees about the carbon impact of the logging and forest management operations.

7.1.2. Proposal for the crediting of the temporary carbon storage effect in wood products

In section 2 it has been shown how current LCA standards fall short in considering the temporary carbon storage effect of wood products. In the same chapter, it has been demonstrated how this limitation can be overcome using a dynamic approach that explicitly takes into account the timing of GHG fluxes using a dLCI and applying DCF. This is the approach we recommend to use to account for the temporary carbon benefits due to carbon storage in wooden buildings. Our recommendations are in line with those of other authors such as Hoxha et al. (2020) who found the same limitations for LCA standards, that we reported in section 2. They also identified the dynamic approach as the most pertinent and transparent approach to be applied in the assessment of the climate change impact of construction bio-based products and materials. There are three important methodological aspects to decide upon in the suggested dynamic approach presents:

[401] https://english.rvo.nl/sites/default/files/2018/02/Guidance-Chain-of-Custody-EN.pdf

- how to address the timing of forest carbon fluxes,
- which time horizon to consider for the development of the DCF factor
- which temporal resolution to use.

As highlighted in section 2.2.2, tree growth, and its temporal dynamics, can be considered to happen before or after wood harvest. The main goal of the proposed methodology is to credibly quantify the carbon storage in wood construction products. Therefore ,in line with the proposal in the previous section foreseeing the exclusion of forest carbon fluxes from the methodology, it is suggested to not explicitly consider the temporal dynamic of forest carbon fluxes but simply assume that all these fluxes happen at the year of harvesting (i.e. year 0) for all forests. This approach would further allow taking an implicit neutral position on the growth before/regrowth after harvesting debate and keeping the methodology simple.

Concerning the second methodological aspect, it is suggested to maintain the 100 years' time horizon for the development of the DCF to keep consistency with current LCA practices.

Lastly, bearing in mind that the overall goal is to find a scientifically robust but still feasible methodology, it is suggested to keep the methodology relatively simple by assuming that

- all activities of stage A (production and construction) occur at year 0,
- all activities of stage B (i.e. repair, replacement etc.) occur at a year corresponding to half of the estimated lifetime of the building
- all stage C (end-of-life) activities occur at the year corresponding to the estimated lifetime of the building,

There might be some temporal delay between all the activities in one stage, but this would only have a negligible effect on the results. For example, between the moment of wood harvesting and its actual use in the building, there might be a temporal delay due to the drying, processing, installation in building etc. Although these activities are spread over time, the temporal gap between them will be at maximum a few years and as such have a negligible impact on results. Adopting the assumptions above would drastically simplify the creation of dLCI and the calculation of default DCF for the main GHG to be considered.

7.1.3. Proposal for the management of the uncertainty of End-of-life

How to deal with the end-of-life management of the building is a critical point which needs to consider several aspects. One is the high uncertainty of estimating the impacts/benefits of an activity that will occur far into the future. To do so with any certainty would require knowing the waste management practices taking place decades after the buildings are constructed for all the materials used. Ideally, to have a robust estimation, this would need to also consider the carbon intensity of producing such a material in the future. For example, recycling rates for steel in 50 years' time are expected to be significantly higher than current recycling rates for steel, and the carbon footprint of producing virgin steel can be expected to be lower in future due to increased use of renewable energy sources. If one wants to estimate the (hypothetical) benefits of the end-of-life management practice of a wood-based building vs a steel-based one, one would need to make at least assumptions on how it will be in 50 years from now, concerning (i) the end-of-life management of the wood-based building, (ii) the end-of-life management of the steel-based building, (iii) the carbon intensity of producing virgin steel and (iv) the carbon intensity of energy (if some of the wood is incinerated with energy recovery). It is clear how the uncertainty is proportional to the number of assumptions to be taken. It must be highlighted that if or not to account for all these end-of-life related hypothetical effects (i.e. the application of more climate friendly and circular wood-waste management practices) is more a policy than a scientific decision. This means that, once the overall goal is decided, the best methodology to achieve this goal can be identified. In this specific case this is reflected in the choice of the most suitable end-of-life allocation method (cfr. discussion in chapter 2.4) which best reflect the underlying policy objective.

Taking the two aforementioned LCA standards candidates, PEF uses the circular footprint formula. This is a PEF specific allocation rule that was developed to share burdens and benefits between both the supplier and user of recycled materials in the case of open-loop recycling. The approach was developed with the underlying goal of stimulating, and thus rewarding, circular practices. The circular footprint formula is parametrized, depends on certain specific conditions indicated in the standard, In cases where there is a limited demand for the wate material (e.g. wood), the formulae is parametrized so that it rewards the user of recycled material, with the aim of stimulating the market uptake of the recycled material. In cases where there is a higher demand for the wate material (e.g. steel) the supplier of those waste materials is rewarded, with the aim of stimulating design for recyclability. In contrast, EN 15804+A2 solves the same allocation issue with a simple cut-off approach (see chapter 2.4), and to encourage the use of sustainable practices stipulates that the results from module D (benefits and loads beyond the system boundary) shall be reported separately. Eventually module D just gives environmental “points”, while the circular footprint formula adds credits to the LCA results reducing the GWP impact of the product/building under study (see also Mirzaie et al., 2020 for an in depth and clear exposition on how these two standards deal with end-of-life). In principle, if the goal is to reward climate friendly and circular end-of-life practices, the use of the circular footprint formula would be more suitable, although its application is more complex. Furthermore, asking the sector to use a different approach to End of life from that used in the main LCA standard for the sector, might be a barrier to adoption of the overall methodology.

One aspect, from a methodological point of view, is nevertheless independent from the policy goal and must be set unequivocally. The temporary benefits from carbon storage, when accounted for, must solely be allocated and considered for the life cycle of the building under consideration: this means that any circular/cascading practices that extend the lifetime of wood, postponing the emission of biogenic carbon into the atmosphere, has to be allocated to the life cycle of the next building/product so to avoid any double counting[402]. Taking the glulam beam of chapter 3 as an example to explain this issue. Assuming that it was used in a building for 50 years and, at the end-of-life, chipped to produce particleboard that would, in turn, be used in another building for another 50 years. If the temporary carbon storage benefits were calculated over 100 years (glulam + particleboard lifetimes), this would create a double counting since the storage benefits of particle board would be counted twice (100 years in total instead of 50).

[402] It must be stressed that service-life is different from circularity/cascading. The former consists in using the same product (i.e. same life cycle) for longer time and can be considered modelling a longer lifetime for the product/building under consideration. the latter means producing multiple (temporally subsequent) products (i.e. different life cycles) from the same wood.

C. Quantify and Remunerate Net Carbon Credits for Harvested Wood Products for Construction

8. Introduction

8.1. Background and objectives

The objective of this task is to investigate the policy options to incentivise the use of wood in construction by focusing on the material's climate benefits. This study compared various schemes for the development of a **market-based scheme** and an accompanying methodology that quantifies and remunerates the volumes of carbon emissions savings by employing wood-based materials in construction. The mechanism here put forward intends to be a stepping stone to progressively moving to a larger and full fledged market-based carbon removal system for the built environment, where carbon neutral buildings must become the norm. This requires an approach that takes into account the complexities involved with determining the **net climate benefits of wood-based construction products (WCPs)**. Most critically, with the issues revolving around sustainable forest management and products' end-of-life. This approach shall involve, first, a **solid and feasible methodology** for the calculation of the tons of carbon stored for specific building types, the **guarantee of origin** from sustainably managed forests, and the development of a process that creates value for the **quantity of carbon saved**.

This study contributes to a growing momentum around **carbon-dioxide removal technologies**. With the commitments stemming from the Paris Agreement on the limiting of increased average temperatures to well below 2°C, preferably 1,5°C, as well as the EU 2030 emission targets, carbon removals are identified as a valuable addition to an increasingly urgent climate strategy. These policy objectives are enhanced by growing concerns in scientific literature regarding the avoidance of irreversible "tipping points" in the evolution of the Earth's climate. This work intends to be **a first step in the implementation of carbon removal instruments**, by focusing on the climate benefits of wooden materials. While the scope of this exercise remains within the context of wood-based construction materials, the LCA methodology developed in the study intends to lay the ground to inform other policies and strategies for advancing other carbon removal policies across the EU.

The present task builds on the previous components of this study by:

1. addressing the **market characteristics of WCP** as identified in task 1, while including the lessons learnt in the elaboration of a market-based scheme;
2. building on the findings of task 2 on the **methodology** on the embodied carbon of a building; and
3. borrowing from the results of the **Monitoring, Reporting and Verification (MRV) approach**.

The task builds on the previous tasks of this study, which form the empirical and knowledge basis for the task. The following section specifically highlights the main points from the previous tasks, in an attempt to triangulate and cross-reference the findings. **Chapter 2** provides a background and application of LCA methodologies in the building sector. **Chapter 3** explores the various options for policy instruments, highlighting advantages and disadvantages of the instruments with regards to the development of a system that incentivises the use of wood in construction. **Chapter 4** delves into the market of WCP, with the aim of identifying the relevant actors constituting the target stakeholders of the proposed system, as well as the point of entry for the methodology into the market. In **Chapter 5**, the findings are brought together to propose a remuneration scheme, putting forward a set of guidelines to implement such a system, from **policy tools employed**, to the **verification systems**, and the **marketing and the management** of the tradeable credits. **Chapter 6** concludes the task by reflecting on the applicability and limitations of the proposed scheme, as well as the opportunities it presents with regards to other relevant policy domains.

8.2. Triangulation of information from other tasks

8.2.1. Task 1 - Insights on market barriers and existing policies

The aim of task 1 was to conduct an in-depth scoping of the market for WCPs in Europe, as well as of the existing policies and market initiatives that aim at their promotion.

The findings point to **a limited potential of EU forests to increase supply**, which corresponds to an increase of around 10-15 percent of supply of wood for building materials compared to current levels. Nevertheless, there are large variations in this potential between Member States. About 80-90% of the additional harvest would be of species suitable for construction, while comprising more broadleaves than the current harvest. This additional harvest from broadleaves or lower-quality timber currently used in other applications (such as energy, pulp/paper, fencing, pallets) could be mobilised for construction, specifically if the material is used to manufacture Cross-Laminated Timber (CLT). The mobilisation of this potential will require additional investments into sawmills as well as training and research. Regarding the trade of wood, the study finds that in almost all EU Member States, the **consumption of wood comes primarily from local production**, with the remainder coming from imports.

Next to a description of the current market characteristics, the task also explored existing policies that encourage the use of WCPs at national level, taking the case studies of Finland and France as examples. The two areas of regulation where public policy appears to be most effective are (1) **fire safety**, using simple rules to allow multi-storey buildings while guaranteeing safety levels; (2) **the construction code**, by attributing building permits only to the buildings with a demonstrated low environmental impact over their life-cycle.

Finally, the landscape of market-based schemes to reduce the GHG emissions associated with the construction of buildings can be regrouped into three categories: 1. **voluntary labelling and certification systems**; 2. **tools and metrics** quantifying emissions removed or sequestered in construction materials; and 3. schemes developing a **market for carbon removal credits**. The first category of the schemes offers a reputational incentive based on the general sustainability of buildings with limited attention given to carbon emission savings. The schemes identified under the third category have revealed the **challenges of developing a market-based carbon credit scheme** that has enough players on the demand and supply sides to create a stable value for carbon credits. Finally, the approach of quantifying and certifying GHG removals provides an insightful model, by concentrating on a reliable assessment of climate benefits, based on which market players can make **environmental claims**, obtain **public funding**, or seek third parties interested in **compensating their own GHG emissions**.

8.2.2. Task 2 – Insights on carbon content of wood products used in construction

A literature review of existing methodologies has identified the strengths and weaknesses of available methods to calculate the carbon storage of materials. The main findings point to **LCA standards** as the most comprehensive approaches to consider the climate benefits of materials, while not providing a specific focus on bio-based materials. **LULUCF accounting** allows for detailed tracking of forest carbon sink and wood products' carbon storage effect. On the other hand, it narrowly focuses on biogenic carbon and has a poor product-level detailedness, with all wooden products being generally aggregated into one category of semi-finished products. Finally, **innovative methodologies** exist that address the limits of established frameworks; however, they only look at specific aspects and therefore are not usable stand alone.

The task has led to the conclusion that accounting for the carbon storage effect of wood construction products should avoid the detailed accounting of the **carbon dynamic in the forest**. This is due to the complexity of forest carbon fluxes, which would act as a **disincentive to adopt the standard**. Moreover, existing certification schemes – like the Program for Endorsement of Forest Certification (**PEFC)** and the Forest Stewardship Council (**FSC**) - and sustainability criteria (for example, as formulated in the Taxonomy Regulation (Regulation 2020/852) and its delegated act containing technical screening criteria) directly target forest owners and aim to protect and increase the forest carbon sink. Nevertheless, the proposed methodology should take into account the effects of the way the wood is produced and harvested from the forest. This is done as to **promote sustainable forest management** and the optimal carbon performance of forests and avoid improperly harvested wood from being credited.

It was found that **current LCA standards** fall short of considering the temporary carbon storage effect of wood products. This limitation can be overcome by using a dynamic approach that explicitly takes into account the timing of GHG fluxes using a dynamic Life Cycle Inventory (dLCI) and applying a dynamic characterization factors (DCF) method. This approach accounts for the **temporary carbon benefits** due to carbon storage in wooden buildings. Moreover, it is suggested to not explicitly consider the temporal dynamic of forest carbon fluxes but simply assume that all these fluxes happen at the year of harvesting (i.e. year 0) for all forests. This approach would further allow taking an implicit neutral position on the **growth before/regrowth after harvesting** debate and keeping the methodology. Moreover, it is suggested to maintain the 100 years' time horizon for the development of the DCF to keep consistency with current LCA practices.

9. Estimating the Carbon Savings of Wood-based Construction Products

This subtask provides a background and an application of the methodology proposed to quantify the volumes of carbon emissions savings, to accompany the market-based scheme for the promotion of WCPs in construction. The aim is to put the proposed methodology into context, by assessing the available Life Cycle Assessment (LCA) methods based on scientific literature. This is done to scope the volumes reached by the scientific studies, identify variations and distributions of LCA the results, and assess the factors that affected these variations. This scoping is developed in the first section of this chapter, in which 17 studies are reviewed. Despite a significant level of variability in the amounts of carbon saved, the findings identify the methodology used and the estimations on the volumes of carbon saved, in line with the scientific studies. While some studies reviewed deviate from these estimations by much, these are identified as outliers, leading to questions regarding the methods used and the validity of some of their parameters and assumptions.

The second section is concerned with the testing of the proposed methodology on a building type, in the form of a case study. Specifically, the section carries out an LCA that assesses the greenhouse gas emissions of different structural versions of a multi-storey office building, using the methodology described in Task 2 of this project. The latter is therefore tested in light of its intended use by construction sector practitioners that choose to apply for certification and remuneration for their activity.

The proposed methodology is compared to the static calculation methodology recommended in the guidelines of the European standard (EN15804+A2), namely the -1/+1 approach (more on this approach in the following sections). In particular, this exercise is necessary to evaluate the accuracy, effectiveness, and most crucially, the feasibility of the chosen approach to the calculation of the volumes of carbon saved. As shown in detail in the remainder of this chapter, the implementation of the methodology is judged straightforward and simple, as long as the necessary data, as well as a basic LCA knowledge are available. The section is concluded by a sensitivity analysis, by which a series of reflections on the choices and limitations of this approach are put forward.

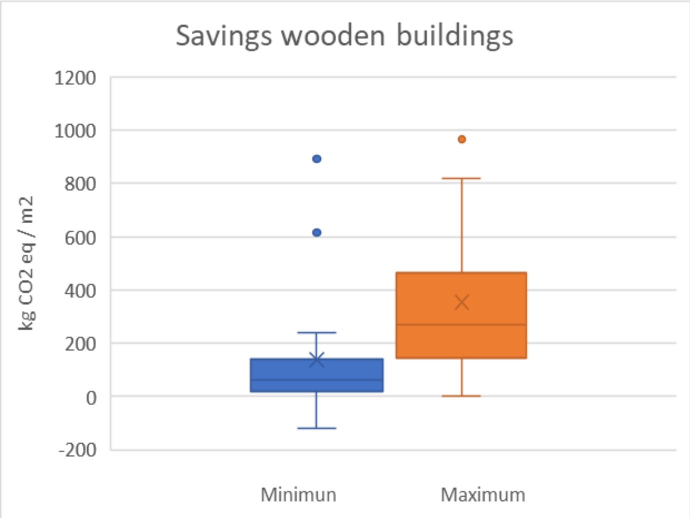
9.1. Achievable carbon savings from the literature

Although LCA standards exist, so do variations in the methodological approaches taken in LCA studies, as well as differences in the assumptions they use. All these are factors that can have substantial impacts on individual study results. The variation between individual studies can also arise from context specific parameters, such as resource availability and transportation distance. To get an idea about the achievable savings of using wood-based materials in the construction sectors, 17 studies were reviewed comparing the climate change impact of wood-based buildings with mineral-based buildings (concrete, steel and brick based). The aim is to compare the carbon savings findings under this methodology to other studies and approaches available in the scientific literature.

The findings are listed in Table 1 below. The results show that **the median minimum savings reported in the literature equal to 64 kg CO_2/m^2**, and the **maximum to 270 kg CO_2/m^2**. The variation in estimates are reported in Figure 1 that demonstrate the inherent complexity of these studies and the difficulty of finding default figures usable to estimate the achievable savings of different wooden buildings typologies but also of buildings of the same typology.

NB There are several metrics that can be used e.g. $kgCO_2/m^2$ or per m^3. As most of the literature is using $kgCO_2/m^2$, the same metrics is used in the study to make facilitate comparisons.

Figure 35. Boxplot with minimum and maximum Global Warming Potential (GWP) savings reported in the literature analysed



There are many factors that influence the estimates of the carbon savings and their variability. As highlighted by Moncaster et al.[403], the choice of life cycle stages can have an important influence on the results, which differs from study to study reviewed, as seen in Table 1. The same authors further stress that the variability of the embodied carbon coefficients used for the structural materials, as well as the physical building elements included in the life cycle analysis, are important sources of variability. These three factors solely can change the results of the assessment by a factor of 10. The results can also be impacted by the energy mix used since using energy with low carbon footprint reduce the GHG emission gap between of producing wood vs other energy intensive material such a steel[404]. A positive, although weak correlation between building height and embodied carbon impact also exists, since heavier columns at the lower levels are required for taller buildings.[405] This positive correlation is stronger for steel and concrete buildings, meaning that, at least in theory, higher buildings produce higher savings from using wood. Lastly, an important source of variability is also how and if at all the role of biogenic carbon is accounted for. Due to the relative benefits of temporary carbon storage in wood products, studies considering the role of biogenic carbon tend to show higher climate change mitigation potential for wood-based buildings.

[403] Moncaster, A. M., Pomponi, F., Symons, K. E., & Guthrie, P. M. (2018). Why method matters: Temporal, spatial and physical variations in LCA and their impact on choice of structural system. Energy and Buildings, 173, 389-398.

[404] Cabeza, L. F., Boquera, L., Chàfer, M., & Vérez, D. (2021). Embodied energy and embodied carbon of structural building materials: Worldwide progress and barriers through literature map analysis. Energy and Buildings, 231, 110612.

[405] Hart, J., D'Amico, B., & Pomponi, F. (2021). Whole-life embodied carbon in multistory buildings: Steel, concrete and timber structures. Journal of Industrial Ecology, 25(2), 403-418.

Table 32. Overview of the reviewed studies assessing the CO_{2eq} savings of using wood in construction

Study	Building type	Compared material	Minimum savings	Maximum savings	Unit	LCA Stages [406]	Standard used (if any)	Building lifetime	Biogenic C included
Hafner, A., & Schäfer, S. (2017). Comparative LCA study of different timber and mineral buildings and calculation method for substitution factors on building level. Journal of cleaner production, 167, 630-642.	single/two-family-houses	concrete/brick	77	270	kg CO_2 eq / m^2 gross external area (GEA)	A+C	EN 15978/15804	50	no (1+1)
Hafner, A., & Schäfer, S. (2017). Comparative LCA study of different timber and mineral buildings and calculation method for substitution factors on building level. Journal of cleaner production, 167, 630-642.	multi-storey residential building	concrete/brick	18	178	kg CO_2 eq / m^2 gross external area (GEA)	A+C	EN 15978/15804	50	no (1+1)
Gong, X., Nie, Z., Wang, Z., Cui, S., Gao, F., & Zuo, T. (2012). Life cycle energy consumption and carbon dioxide emission of residential building designs in Beijing: a comparative study. Journal of Industrial Ecology, 16(4), 576-587.	multi-unit residential building	concrete/steel	240	268	kg CO_2 eq / m^2 floor area	A+B6+C (not explicitly mention-ed)	not mentioned	50	no (0/0)
Rebane, K., & Reihan, A. (2016). Promoting building materials that have lower embodied carbon and energy in public	partially two storied and partially four storied	concrete	30	399	kg CO_2 eq / m^2 floor area	A (not explicitly mention-	not mentioned	not mentioned	yes, statically as C storage

[406] Following the EN 15840 definition. A refers to the "production stage", B to the "use stage", C to the "end of life stage" and D to the "Benefits and loads beyond the system boundary" of the building. See task 2 for an in-depth explanation of what is included in each stage.

Study	Building type	Compared material	Minimum savings	Maximum savings	Unit	LCA Stages [406]	Standard used (if any)	Building lifetime	Biogenic C included
procurements. Management of Environmental Quality: An International Journal.	building					ed)			
Chen, Z., Gu, H., Bergman, R. D., & Liang, S. (2020). Comparative life-cycle assessment of a high-rise mass timber building with an equivalent reinforced concrete alternative using the Athena impact estimator for buildings. Sustainability, 12(11), 4708.	multi-storey residential building	concrete	53		kg CO_2 eq / m^2 floor area	A+B2+B4 +B6+C	EN 15978/15804	60	no (1+1)
Peñaloza, D., Norén, J., & Eriksson, P. E. (2013). Life cycle assessment of different building systems: The Wälludden case study.	multi-storey residential buildings	concrete	75	112	kg CO_2 eq / m^2 living area	A+B1+B2 +C	EN 15978/15804	100	no (1+1)
Caruso, Maria Chiara, et al. "Methodology for life-cycle sustainability assessment of building structures." ACI Structural Journal 114.2 (2017): 323.	multi-storey residential building	concrete/steel	22	105	kg CO_2 eq / m^2 gross floor area	A+B2+C	not mentioned	50	no (0/0)
Moschetti, R., Brattebø, H., & Sparrevik, M. (2019). Exploring the pathway from zero-energy to zero-emission building solutions: A case study of a Norwegian office building. Energy and Buildings, 188, 84-97.	multi-storey office building	concrete	2		kg CO_2 eq / m^2 gross internal floor area	A+B4+B6	not mentioned	60	no (0/0)
Peñaloza, D., Erlandsson, M., & Falk, A. (2016). Exploring the	2-storey residential	concrete	202	457	kg CO_2 eq / m^2	A+B6+C	not applicable for dynamic	50	yes, dynamically,

Study	Building type	Compared material	Minimum savings	Maximum savings	Unit	LCA Stages [406]	Standard used (if any)	Building lifetime	Biogenic C included
climate impact effects of increased use of bio-based materials in buildings. Construction and Building Materials, 125, 219-226.	building				living area		model		but C neutrality assumed
Fouquet, M., Levasseur, A., Margni, M., Lebert, A., Lasvaux, S., Souyri, B., ... & Woloszyn, M. (2015). Methodological challenges and developments in LCA of low energy buildings: Application to biogenic carbon and global warming assessment. Building and Environment, 90, 51-59.	single-family-house	concrete	615	820	kg CO_2 eq / m^2 floor area	A+B5+B6 +C	EN 15978/15804	100	yes, dynamically, but C neutrality assumed
Dodoo, A. (2019). Lifecycle impacts of structural frame materials for multi-storey building systems. Journal of Sustainable Architecture and Civil Engineering, 24(1), 17-28.	multi-storey residential building	concrete	120	222	kg CO_2 eq / m^2 floor area	A+C+D	not mentioned	50	yes
Guo, H., Liu, Y., Meng, Y., Huang, H., Sun, C., & Shao, Y. (2017). A comparison of the energy saving and carbon reduction performance between reinforced concrete and cross-laminated timber structures in residential buildings in the severe cold region of China. Sustainability, 9(8), 1426.	multi-storey residential building	concrete	892	967	kg CO_2 eq / m^2 floor area	A+B6+C	not mentioned	50	yes
Padilla-Rivera, A., Amor, B., & Blanchet, P. (2018). Evaluating	multi-storey residential	concrete/steel	51	167	kg CO_2 eq / m^2	A	not mentioned	not	no (0/0)

Study	Building type	Compared material	Minimum savings	Maximum savings	Unit	LCA Stages [406]	Standard used (if any)	Building lifetime	Biogenic C included
the link between low carbon reductions strategies and its performance in the context of climate change: a carbon footprint of a wood-frame residential building in Quebec, Canada. Sustainability, 10(8), 2715.	building				floor area			mentioned	
Pierobon, F., Huang, M., Simonen, K., & Ganguly, I. (2019). Environmental benefits of using hybrid CLT structure in midrise non-residential construction: An LCA based comparative case study in the US Pacific Northwest. Journal of Building Engineering, 26, 100862.	commercial building	concrete	117	123	kg CO_2 eq / m^2 floor area	A	not mentioned	not mentioned	no (0/0)
Skullestad, J. L., Bohne, R. A., & Lohne, J. (2016). High-rise timber buildings as a climate change mitigation measure–A comparative LCA of structural system alternatives. Energy Procedia, 96, 112-123.	multi-storey residential building	concrete	29	358	kg CO_2 eq / m^2 gross floor area	A	not mentioned	60	yes
Hart, J., D'Amico, B., & Pomponi, F. (2021). Whole-life embodied carbon in multistory buildings: Steel, concrete and timber structures. Journal of Industrial Ecology, 25(2), 403-418.	multi-storey residential building	steel/concrete	121	460	kg CO_2 eq / m^2 gross external area (GEA)	A+B1/5+C	EN 15978/15804	50	no (0/0)
Ajayi, S. O., Oyedele, L. O., & Ilori, O. M. (2019). Changing	multi-storey office	steel/concrete	105	626	kg CO_2 eq / m^2	A+C	not mentioned	30	no (0/0)

Study	Building type	Compared material	Minimum savings	Maximum savings	Unit	LCA Stages [406]	Standard used (if any)	Building lifetime	Biogenic C included
significance of embodied energy: A comparative study of material specifications and building energy sources. Journal of Building Engineering, 23, 324-333.	building				gross floor area				
Chastas, P., Theodosiou, T., Kontoleon, K. J., & Bikas, D. (2018). Normalising and assessing carbon emissions in the building sector: A review on the embodied CO2 emissions of residential buildings. Building and Environment, 130, 212-226.	Various residential buildings	steel/concrete/brick	30	470	kg CO_2 eq / m^2 floor area	A+C	EN 15978/15804	50	no (0/0)
Proposed methodology	**Multi-storey generic building frame**	**concrete**	**5**	**85**	**kg CO_2 eq / m^2 gross floor area**	**A+C**	**EN 15978 and proposed methodology**	**50**	**yes**

The results highlighted above present the findings of the proposed methodology, allows for comparison with other existing methodologies. This methodology is tested in the next section by the TU Graz on a building case study.

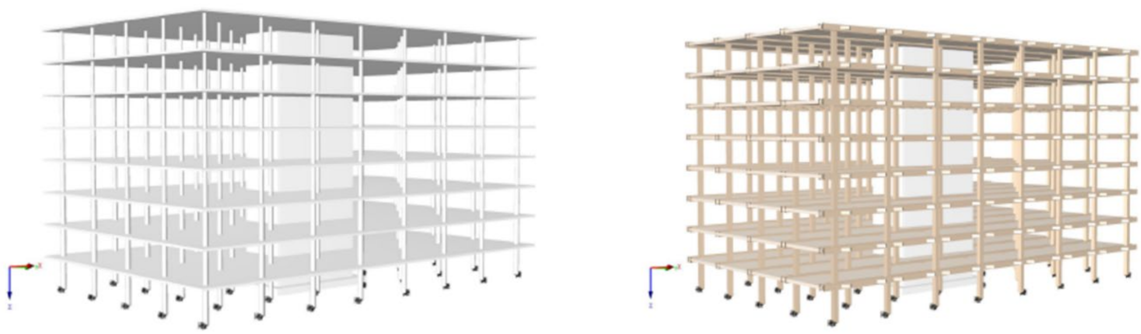
9.2. Testing the proposed methodology: comparing traditional reinforced concrete building structure with a functional equivalent wood-framed version

This modelling exercise was designed to demonstrate and test the methodology to account for and monitor the (potential) carbon benefits of wood buildings under the methodology proposed in task 2. The assessment aims to test and discuss the feasibility of the methodology and give recommendations on the level of detail and/or the possible simplifications the monitoring scheme should have to ensure its robustness but, at the same time, its feasibility for the targeted applicants. In line with the scope of the project, namely wood construction products with a capacity to sustain structural loads in construction, only the building frame was modelled. It is well documented in the specialized literature that the structural system is the major contributor to a building's total GWP (Heeren et al 2015, Hoxha et al 2017, Meneghelli 2018), therefore this scope delimitation does not harm the relevance of the conclusions. To support the calculations herein described, we used the "cut-off" system model of the ecoinvent database 3.6, and the software SimaPro v.8.

9.2.1. Case study description

The case study adopted to test the methodology is based on the master thesis developed by Gierlinger (2020). The thesis contains a design of various structures for a 7-storey building, adapting parameters for each version such as the structural design and the building material used . All necessary calculations and simulations to prove the reliability and the integrity of the designs were performed in Gierlinger (2020). The structural simulations also predicted a variation on the span of the structure i.e. the distance between the different load-bearing elements, to assess the potential differences in results that would come from varying spans. Within this report, we discuss the methodology application to the two different spans: 5.5m and 7.5m. The average span value most traditionally adopted in constructions today is from 5.5m to 6m.

Figure 36. Reinforced concrete version (left) and wooden version (right) of the case study. Source: Gierlinger (2020).



Both reinforced concrete and wood versions have seven floors in addition to the ground floor which accumulates to a total gross floor area (GFA) of 9,792 m^2. A central reinforced concrete core is located in the two versions for structural integrity. The foundations for both structures are entirely built with reinforced concrete.

For the reference building frame, the reinforced concrete floor slabs are supported by reinforced concrete columns. The concrete class is C30/37 XC1, which means that its compressive strength is 30 MPa. For the reinforcement, a steel of class S500 and sections 5.24 cm^2/m and 7.54cm^2/m for the 5.5m and 7.5m spans, respectively, are employed.

The wooden version of the building still has its foundations, base floor slab and central core conceived with reinforced concrete. While a foundation in wood would not be possible, in some special cases one might be able to design a mid-rise building with a wooden core. Still, that does not represent the typical practice - due to seismic hazard and fire safety issues, elevator and stairs shafts are typically made of concrete. In the future, a wooden core might be an option, however this would need to be further investigated. The type of concrete and reinforcing steel used for the foundations and the central core are the same as the one implemented in the reference concrete building. The floors of this building are constructed with cross-laminated timber (CLT). These are supported by glued-laminated timber (GLT) beams, which are themselves supported by glued-laminated timber columns. The junction of these elements is accomplished with a steel element. To allow for the wider span, the 7.5m building's flooring system (in CLT) requires the insertion of glued-on ribs to improve the vibration behaviour. These ribs allow for reduced width of floors, which led to a proportionately smaller consumption of wood in that system.

Even though the foundation and the core of the wooden building are in concrete, the reduction in concrete consumed between the reinforced concrete and wood version was significant. For the 5.5m span, there was a 67% reduction in concrete quantity take-off for the whole structure, and for the 7.5m span the reduction was a 73%. The detailed bill of quantities for both structural systems can be found in Tables 2 and 3.

Table 2: Bill of quantities for reinforced concrete building (Gierlinger, 2020)

Building element	Material	Span width of 5.5m		Span width of 7.5m	
		Quantity	Unit	Quantity	Unit
Floors/roof	Concrete	1880	m^3	2741,8	m^3
	Reinforcing steel	217	to	329,5	to
Foundation	Concrete	571,2	m^3	903,6	m^3
	Reinforcing steel	58,9	to	80	to
Central core	Concrete	240,9	m^3	229,1	m^3
	Reinforcing steel	19,2	to	18,1	to
Supports (columns)	Concrete	132,8	m^3	153,4	m^3
	Reinforcing steel	35,7	to	34,1	to
Total (whole structure)	**Concrete**	**2824,9**	**m^3**	**4027,9**	**m^3**
	Reinforcing steel	**330,8**	**to**	**461,7**	**to**

Table 3: Bill of quantities for wooden building (Gierlinger, 2020)

Building element	Material	Span width of 5.5m		Span width of 7.5m	
		Quantity	Unit	Quantity	Unit
Floors/roof	Concrete	106,5	m^3	99	m^3
	Reinforcing steel	10,1	to	9,4	to
	Wood (CLT)	2060,4	m^3	1443,2	m^3
Foundation	Concrete	539,5	m^3	531,6	m^3
	Reinforcing steel	57,7	to	52,8	to
Central core	Concrete	277,4	m^3	262,2	m^3
	Reinforcing steel	21,9	to	20,7	to
Supports (columns)	Wood (GLT)	171,1	m^3	172,4	m^3
	Construction steel	43,4	to	57,9	to
	Wood (GLT)	379,9	m^3	1376,4	m^3

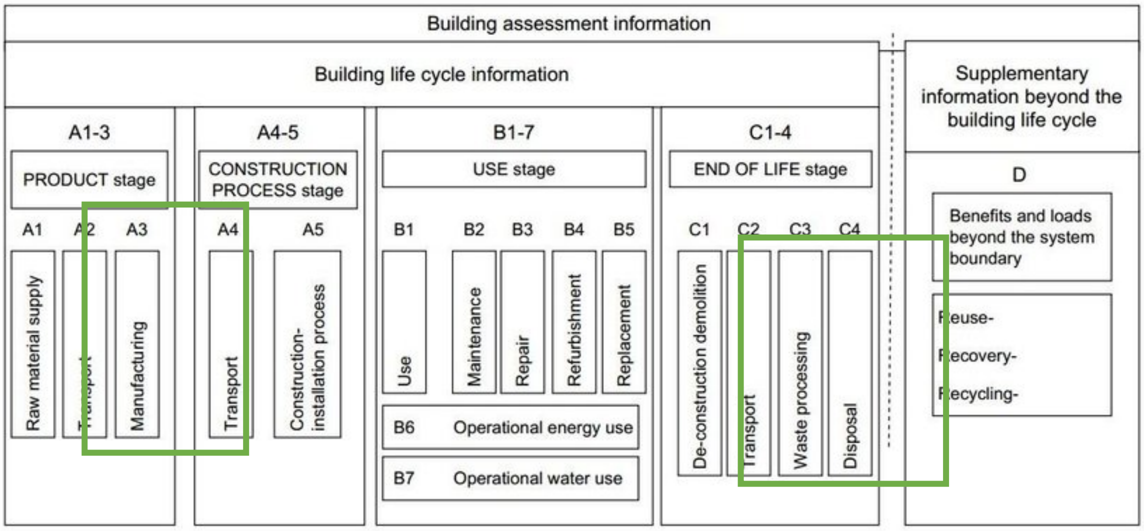
Total (whole structure)	**Concrete**	**923,4**	**m³**	**892,8**	**m³**
	Reinforcing steel	**89,7**	**to**	**82,9**	**to**
	Construction steel	**43,4**	**to**	**57,9**	**to**
	Wood (GLT+CLT)	**2611,4**	**m³**	**2992**	**m³**

9.2.2. Life Cycle Assessment: general methodological approach

This study is performed in compliance with the European norms overseeing LCA of buildings and construction products (EN 15978 and EN 15804). As mentioned, the goal of this LCA is to assess and compare the greenhouse gas emissions of different structural versions of a multi-storey office building. The building's reference service life is considered to be 50 years, and results are presented in relation to the whole structure. While in some cases a 50 years reference study period might seem low, this is the average value most widely adopted for building LCA in specialized literature (Marsh 2017, Röck et al 2020), which allows for proper comparability and potential benchmarks definition (however, for sensitivity, we have also tested with 60 and 100 years (see section 2.2.4)).

The life cycle phases of a building are divided in modules according to the EN 15978 norm. A cradle-to-grave analysis is performed, and the modules included in this study are highlighted in green in Figure 3. Operational emissions are excluded from the LCA because they are out of the scope of this task. Replacement is not necessary as the entire structure is assumed to have a minimum reference service life of 50 years. Datasets from ecoinvent database v3.6 were adopted for all construction materials and activities. Regarding the demolition of the building (module C1), a representative reference ratio for this type of building was used (Lützkendorf and Balouktsi, 2016). Module C1 is considered to represent 2% of the environmental impacts generated in modules A1-A3. The implemented distances for module C2 and the predictions for the end-of-life scenarios of steel and concrete were taken from Debacker et al (2013). All wood was assumed to be incinerated once its end-of-life was reached.

Figure 37. Modules considered in the LCA (as defined in the EN 15978 norm)



9.2.3. Collection of data for proposed methodology application

To apply the time dependent characterization factors for the main greenhouse gases defined in the proposed methodology, an LCA practitioner must have access to (i) life cycle databases, such as ecoinvent (Wernet et al 2016) – the one adopted for this exercise – and to (ii) a software or a tool that will support the combination of the emissions from all processes involved either in the manufacturing of the materials or in a certain activity (e.g. demolition of a building), providing a final list of greenhouse gas emissions that arose from that material or activity. This processing of the data is called a computational structure of Life Cycle Assessment, thoroughly described by Heijungs and Suh (2002). Once in possession of the list of greenhouse gases emitted to manufacture a certain volume or mass of material, or to perform a certain activity, the practitioner can multiply the amount of carbon dioxide, carbon monoxide, methane and nitrous oxide (the greenhouse gases handled by the proposed methodology) by the respective characterization factors developed for the time the emission took place. This calculation provides the results of the global warming effect in kg of CO_{2eq}, which then allows for a combination of all calculated effects at different times, to portray the life cycle global warming potential of a building.

It is noteworthy, however, that typical life cycle databases do not include detailed, mass-balanced information on the biogenic CO_2 content absorbed by biobased materials during its growth. To take that into consideration, the LCA practitioner must calculate the biogenic carbon content separately, relying on Equation 1. The amount of CO_2 stored in the wood products calculated by that equation is considered to be equal to the amount of biogenic CO_2 uptake during the forest growth and to the biogenic CO_2 release during the incineration at the building’s end-of-life.

$$P_{CO_2} = \frac{44}{12} \times cf \times \frac{\rho_\omega \times V_\omega}{1 + \frac{\omega}{100}} \qquad \text{Equation 1}$$

With:

P_{CO_2}= amount of stored CO_2

cf = carbon fraction of woody biomass (oven dry mass), default = 0.5

ω = moisture content of the wood product

ρ_ω = density of woody biomass of the product at that moisture content (kg/m³)

V_ω= volume of the solid wood product at that moisture content (m³)

An important final disclaimer to the intended methodology users is that due to the lack of mass balance in biogenic carbon accounting in the ecoinvent database, in performing the calculations we ignored the biogenic CO_2 flows indicated in the list of greenhouse gas emissions (the output from the LCA software) previously mentioned. The biogenic flows were gathered exclusively from the calculation described in Equation 1. It is however expected that in the near future the most used life cycle databases will contain the necessary biogenic carbon flows to allow for a swift calculation.

9.2.4. Results of methodology application

The proposed methodology is compared to the static calculation methodology recommended in the guidelines of the European standard (EN15804+A2), namely the -1/+1 approach. Figure 4 below shows the results obtained from a cradle-to-grave LCA of the building frame in concrete and in wood, following the mentioned standard, whereas Figure 5 shows the results obtained when applying the proposed time-dependent characterization factors.

In the figures' legends, A1-A3 refers to the so-called "production stage" of the building, covering raw material extraction, transport to factory and manufacturing of the construction material. C1-C4 refers to the "end of life stage" of the building, encompassing the demolition activities, transport of construction waste, waste processing and final disposal. The biogenic CO2 uptake is accounted for at stages A1-A3, whereas all the wood is assumed to be burned during the stages C1-C4, incurring in the emissions of the total amount of absorbed CO2. The figure also separately indicates biogenic CO2 uptake and emissions - associated to wood growth and oxidation, and fossil CO2 emissions - associated to materials manufacturing and end of life, construction, transport and demolition activities.

Figure 38. Cradle to grave Global Warming Potential (GWP) of the building frame in reinforced concrete and in wood, using the guidelines proposed by the EN15804+A2 standard.

When following the EN15804+A2 approach, the adoption of wooden elements for the building structure with a 5.5m span implicated in a reduction of roughly 43 tons of CO2eq in comparison to its concrete counterpart, while the wooden building with a 7.5m span led to a reduction of approximately 287 tons of CO2eq. The significant difference in absolute reduction when adjusting the span of the building underscores the sensitivity of the results to certain structural parameters. Changing the building span require structural changes in the building that changes also the material consumption.

The rather modest reduction observed for the wooden building is mostly related to CLT's non-negligible impact in comparison to that of concrete. While sawn-wood is knowingly far more carbon efficient than concrete, due to CLT's energy-intensive production process and glue incorporation, a direct comparison between 1m^3 of concrete and 1m^3 of CLT yields reductions in GWP of around 30%[407]. The design of a mid-rise building in wood is currently only possible by relying on the use of engineered wood products, such as CLT.

Much higher carbon storage potential would be expected for small family houses not using CLT but made of sawn-wood only. However, the considerations for applying the above calculations to small family houses have been provided in Box 1 below.

Box 6 The case of small family houses

In this research we have concentrated on the use of laminated timber beams for construction in larger buildings. In the case of a smaller building - like family houses - it is possible to use massive timber. Massive timber has a better carbon footprint than laminated timber.

A few considerations are therefore necessary in case of massive timber: first, the tree-to-wood conversion is much less efficient; moreover, the constructional properties are far lower than for laminated timber, which results in the need for more trees. On the other hand, smaller buildings don't need a concrete or steel core and can be built entirely from a wooden construction. Current trend in wooden construction leans more strongly towards the use of laminated timber and less so to massive timber.

Figure 39. Cradle to grave Global Warming Potential (GWP) of the building frame in reinforced concrete and in wood, using the proposed methodology.

On the other hand, when applying the proposed methodology, the GHG emission reduction observed for the wood building with a 5.5m span vs the concrete one was of approximately 828 tons of CO2eq, while for the building with a 7.5m span the reduction was over 1170 tons of CO2eq. The life cycle negative value for GWP obtained with the time dependent characterization factors seems to indicate that the benefit of growing the wooden products outweighs the onus of the emissions arising from manufacturing other needed materials and

[407] This was the case for the European datasets present in the life cycle inventory database selected for this calculation, namely ecoinvent 3.6.

from the end-of-life activities. Still, this happens specifically because of the lower characterization factors for emissions happening at a later life cycle stage of the buildings, as outlined in the proposed methodology.

To briefly illustrate the sensitivity of these potential emissions reductions to the adopted reference study period (i.e. 50 years), the same assumptions were tested for a 60-year reference period. In the latter case, the reduction observed for the wooden vs concrete building with a 5.5m span would be of around 1019 tons of CO_{2eq}, while for the wooden vs concrete building with a 7.5m span the reduction would be of 1396 tons of CO_{2eq}. If the reference study period was increased to, e.g. 100 years, there would be no effect of the end-of-life emissions accounted for, since the time of observation of the global warming effect proposed in the methodology is also 100 years (i.e. the global warming potential of all end of life emissions would be left out, biasing interpretation).

To properly interpret how the simplifications of deriving time dependent characterization factors from a fully dynamic model (as proposed by Levasseur et al (2010)) lead to the identified reduction, a series of sensitivity analyses were performed, which are detailed in the next section.

In conclusion, after the adoption of the proposed methodology, we conclude that its application is straightforward and simple, as long as the requirements for data collection mentioned in the previous section – namely access to a life cycle database and to a software/tool that would calculate the life cycle inventory – are guaranteed. While the level of expertise in Life Cycle Assessments does not need to be high, a basic LCA knowledge is required for the implementation of the approach.

9.2.5. Sensitivity analyses and potential risks due to simplification

Simplifications of complex modelling tools are many times necessary to allow for the adoption of certain methods by non-experts. With the proposed methodology, the time dependent characterization factors for emissions happening at different moments in time were deprived from the so-called “dynamic modelling of Global Warming Potential” (Levasseur et al 2010). This method was proposed as an adjustment to the typical (static) calculation of GWP. When considering the environmental consequence of an emission 100 years after it took place, the proposed method would always show the resulting effect at different times in the future. In other words, the effect of an emission happening today is calculated for 100 years from now, whereas the effect of an emission happening in 50 years, is calculated for 150 years from now. The proposal by Levasseur et al (2010) allows one to select when in the future he or she would like to identify the resulting effect on the global warming due to emissions happening at different moments, all the while assuring that one would see the consequences of those emissions at that “year of observation”.

In theory, assuming that an LCA practitioner understands the calculation approach behind GWP factors,[408] the dynamic model can be adopted by any LCA expert that has detailed yearly data of uptakes and emissions of GHGs. The greatest benefit of using the model with that comprehension is the freedom to set certain important parameters as one wishes, and to perform sensitivity analyses, to properly identify which of these factors should be handled and selected with care.

[408] In very simple terms, the connection between the decay equation of each GHG and their radiative efficiency, providing the instantaneous radiative forcing curves which are later integrated to portray the cumulative effect (see more in IPCC (2013)).

Considering that all simplifications bear the risk of leaving important parameters out, we here illustrate our observations on those potential risks when adopting the methodology proposed in Task 2, which can be summarized in three points:

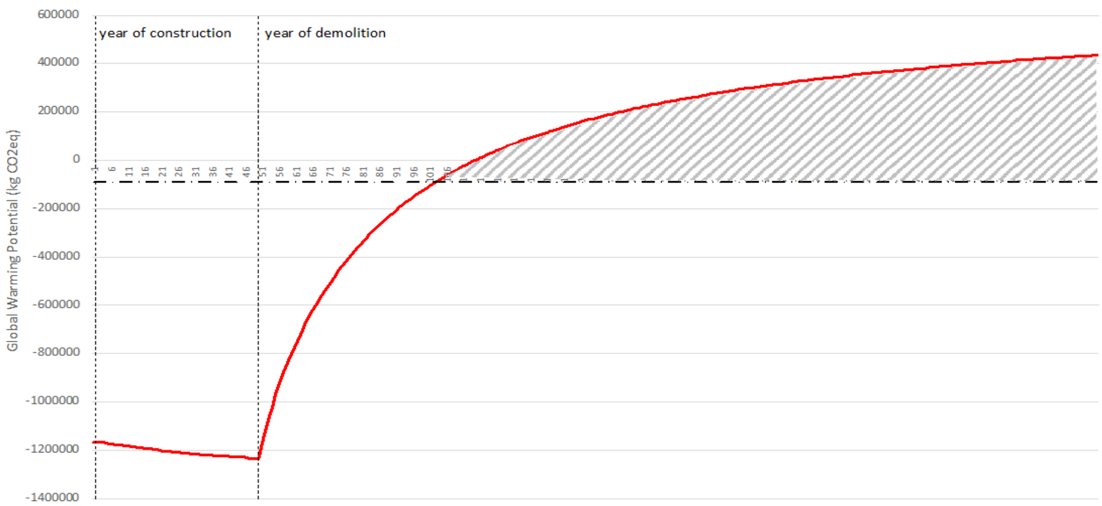
- The “importance” of emissions happening at the end-of-life after year 100 is disregarded. Some might argue that upon applying the simplified proposed methodology, one would shift the environmental burden to next generations.
- The principle of the dynamic calculation is followed for one specific time horizon, and for one “year of observation”. The freedom to set important parameters previously mentioned is lost, and any forest growth specificities are disregarded.
- All uptake is considered to happen during one year (at the same year of construction), which shows a different outcome in the total cumulative radiative forcing effect when compared to a slow gradual uptake.

The following paragraphs and figures further illustrate the above-mentioned observations.

The importance of end-of-life GHG emissions after 100 years

To illustrate the global warming effect of the end-of-life emissions dynamically, without setting a fixed “year of observation” at 100 (as in the proposed methodology), we applied the detailed yearly GHG emissions and uptake data for the wooden building with a 5.5m span to the “full” (i.e. non-simplified) dynamic model. Result is shown in Figure 6.

Figure 40. Dynamic global warming effect of wooden building with 5.5m span. Red curve indicates fully dynamic calculation, black dashed line indicates the result obtained with the proposed methodology. Dashed area indicates the disregarded effect.



The dashed grey area below the red curve is ignored when fixing the year of observation of the effect at 100.

To better illustrate the consequences of adopting a different fixed time horizon (higher than 100 years), or, in other words, to set a different year of observation of the global warming effects for the development of the proposed methodology, Figure 7 and Figure 8 below show

how the results for the reference concrete building and the wood frame would alter if the year of observation was fixed at 200 and 500 years, respectively.

Figure 41. Cradle to grave Global Warming Potential (GWP) of the building frame in reinforced concrete and in wood, using the proposed methodology with a time horizon (or year of observation) set to 200 years after construction.

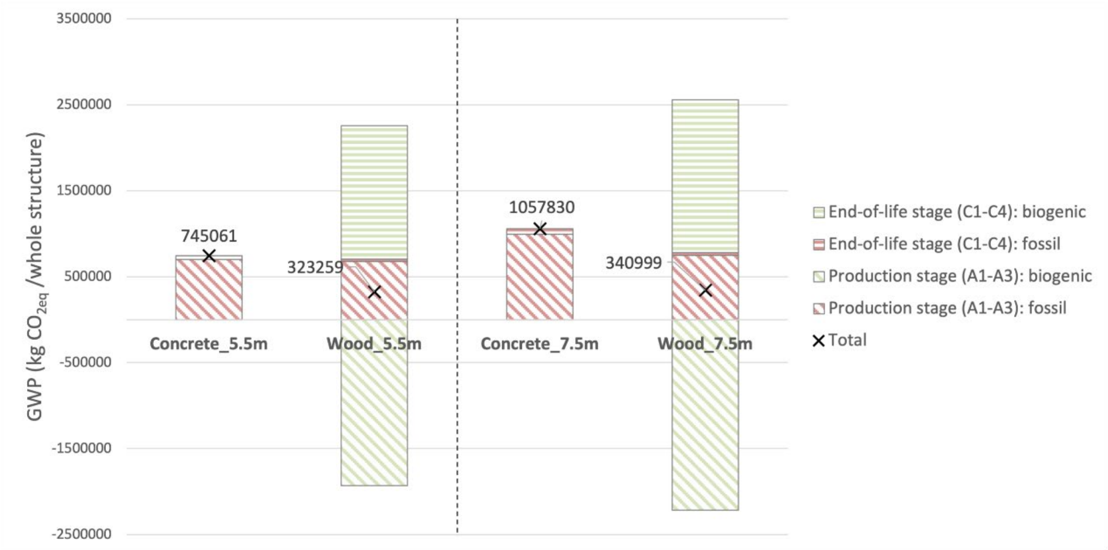


Figure 42. Cradle to grave Global Warming Potential (GWP) of the building frame in reinforced concrete and in wood, using the proposed methodology with a time horizon (or year of observation) set to 500 years after construction.

Box 7 Circularity and the modelling of the building end-of-life in Life Cycle Assessment

Circular economy policies aiming at the extension of buildings' service life (e.g. via refurbishment processes) and reuse/recycling of building's components is making the modelling of end-of-life (EoL) in LCA context of particular relevance. The scientific literature about the modelling of EoL in LCA of the building sectors is rich (see e.g. Allacker et al. 2014, 2017 Mirzaie et al. 2020), with discussions that are still ongoing (see e.g. Malabi Eberhardt et al 2020).

Without entering into the technicalities of the LCA methodology, there are two important aspects that can have an important influence on the results when circular practices are considered in the context of LCA of buildings. The first is the LCA methodological choices made when performing the analysis (essentially the allocation approach). The second concerns the assumption made in the analysis about the EoL practices (e.g. if the product is landfilled, recycled, incinerated etc. and in which percentage).

For the former aspect, as explained in task 2, whatever is the allocation approach that is chosen, the eventual benefits of circular practices are not lost, since the allocation method chosen just defines who gets the benefits, making sure that double counting is avoided.

In the EN15804+A2 EoL allocation procedure (so-called *cutoff or recycled content approach*) follows the polluter pays principle, based on which the (eventual) benefits of circular practices are allocated to the primary user of that material and included in module A**.** For example, if the components of a construction built at *t0* are reused at (e.g.) *t50* in a new construction, the latter will get the environmental benefits of the reused components since less virgin material will be used in module A. The opposite happens with the so-called *avoided burden approach* (or end of life recycling approach) *with credit for avoided virgin production*, in which the total credit *C* benefits would be fully allocated to the *t0* building. In the middle there is the Product Environmental Footprint approach, in which the same credit C is distributed between the construction of t0 and that of t50 with a relative share that is calculated using the Circular Footprint Formula (see task 2 for details). As explained in depth by Frischknecht (2010), the risk-seeking attitude of the end of life recycling approach serves the weak sustainability approach, since environmental loans from future generations are borrowed for the potential future reuse or recycling of man-made capital. On the contrary, the risk-averse attitude of the recycled content approach, in which burden are not shifted to future generations, makes it aligned to the strong sustainability concept.

Regarding the assumptions, LCA does not pose any limitation to the modelled system and the assumptions/scenario behind the EoL fate modelled, which is solely dependent on the scope of the analysis. For example, the assessment of the life cycle impact of an existing building should be based on current situation and reflect the realty. On the contrary, when LCA is applied in the context of a scenario analyses (e.g. what could be the impact of a building built in 50 years from now) one could use assumptions on the future evolution of the society (e.g. for what concerns energy mix, EoL practices etc.).

The allocation and assumptions choices made in the LCA modelling can also be used to stimulate and incentivize a specific behavioural change (see Box 1 for an example relevant for this work). Whatever choices are made, it is important that they are coherent with the scope of the analysis

The loss of freedom to set important parameters

The following figures illustrate the differences in results (and conclusions) that would arise from considering a variation in important parameters in wood building LCAs (Hoxha et al 2020; Peñaloza et al 2016), such as (i) the timing of the CO2 uptake – if it is considered to happen before the construction of the building or after (usually referred to as "regrowth"), and (ii) the rotation period of the forest.

To model the gradual uptake of biogenic CO2 by the forest, we started from the biogenic carbon content calculated via Equation 1 and assumed that the obtained amount was absorbed following a linear trend, with the same quantitative uptake of CO2 happening yearly. In reality, the uptake does not follow a linear trend, but we consider this simplification to be acceptable for the objective of the sensitivity analyses herein performed.

To allow for the comparison of the curves, one must set the “time zero” of the analysis in a uniform way for all alternatives. The curves in blue, green and purple in Figure 9 and Figure 10 are therefore comparable. Figure 9 indicates the differences in GWP results that arise from selecting different parameters for when the uptake of CO2 should be accounted for, for a fixed rotation period of 50 years. Analogously, Figure 10 also indicates the same nature of differences, but assuming a rotation period of the forest of 100 years. Absolute results varied significantly between the curves in the same figure (same rotation period, different consideration of uptake timing) and between the separate figures (different rotation periods).

Figure 43. Dynamic global warming effect of wooden building with 5.5m span. (i) blue curve: the uptake of CO2 was assumed to have started 50 years before the construction, (ii) purple curve: the uptake of CO2 was assumed to have started at the year of construction, in what is called the “tree regrowth approach” in wood buildings LCA, and (iii) the green curve illustrates the consideration of the methodology proposed in Task 2, assuming all uptake happened in the year of construction.

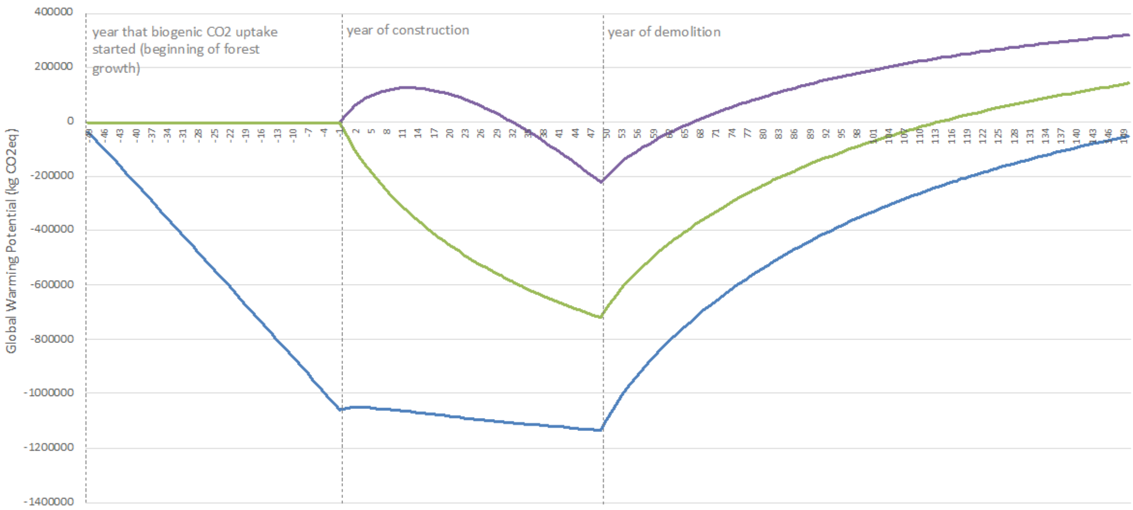
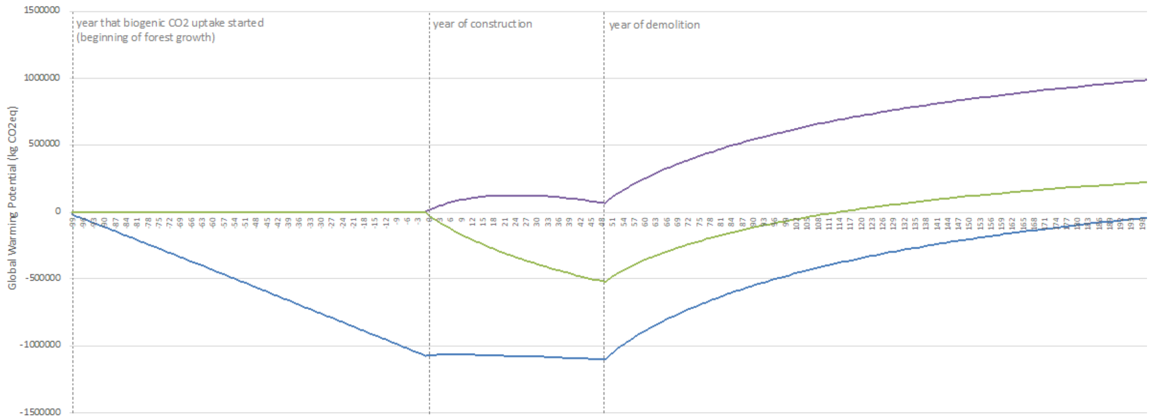


Figure 44. Dynamic global warming effect of wooden building with 5.5m span. (i) blue curve: the uptake of CO2 was assumed to have started 100 years before the construction, (ii) purple curve: the uptake of CO2 was assumed to have started at the year of construction, in what is called the “tree regrowth approach” in wood buildings LCA, and (iii) the green curve illustrates the consideration of the methodology proposed in Task 2, assuming all uptake happened in the year of construction.



When assuming a tree regrowth (purple curve in both figures), if the building lasts less than the time it takes the forest to grow, it does not “receive” the full credit for forest growth. That is why when assuming a rotation period of 100 years, and keeping in mind that the building in this case study was assumed to last 50 years, the global warming resulting effect was much higher in Figure 10.

Forest rotation periods, growth specificities and the selection of when the uptake should happen (a methodological choice in LCAs of wooden buildings without consensus) play a big role in the final results.

All uptake assumed to happen during one year versus slow gradual uptake

To calculate the global warming potential, one must determine how much a certain greenhouse gas can increase the radiative forcing (measured in Watts per unit of area) in the atmosphere. It is the increase in radiative forcing that leads to an increase in temperature. When calculating the effect of global warming using the CO2 as a reference (with the typical results in kg of CO2eq), a practitioner divides the cumulative radiative forcing caused by a certain amount of GHG at a certain time by the effect caused by the same amount of CO2 at the same time. In Figure 11, due to the use of the “fully dynamic” model, we can illustrate the cumulative radiative forcing effect, one step before showing the results in kg of CO2eq. The blue curve indicates the cumulative radiative forcing of a generic assumption: 50kg of CO2 absorbed in one year, namely the first year of the analysis. The red curve indicates the effect of the same amount of CO2 being absorbed throughout 50 years (resulting in 50kg of CO2 in total at year 50). The green curve indicates the effect of the same 50kg of CO2 uptake, happening throughout 100 years. Finally, in Figure 12 and Figure 13, the dashed blue curves illustrate the effect of 50kg of CO2 absorbed in one year (analogously to the full blue curve), while adjusting the first year considered in the dynamic calculation (year zero of the analysis) to 50 or 100 years before, respectively, to represent the growth of the forest happening 50 or 100 years before the building construction.

Figure 45. Cumulative radiative forcing of a generic uptake of 50kg of CO2, happening (i) all at once: blue curve, (ii) during 50 years, 1 kg per year: red curve, and (iii) during 100 years, 0,5kg per year: green curve.

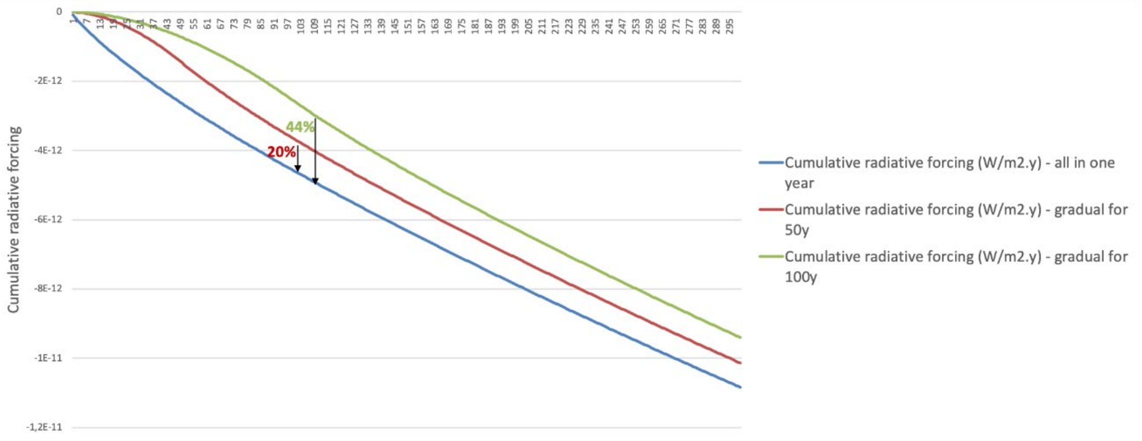


Figure 46. Cumulative radiative forcing of a generic uptake of 50kg of CO2, happening all at once, with an adjustment of the first year considered in the dynamic calculation: while the uptake is assumed to happen at the year of construction, the calculation also accounts for 50 years before building was constructed (assuming the forest would have taken 50 years to grow, analogously to the red curve in figure 9).

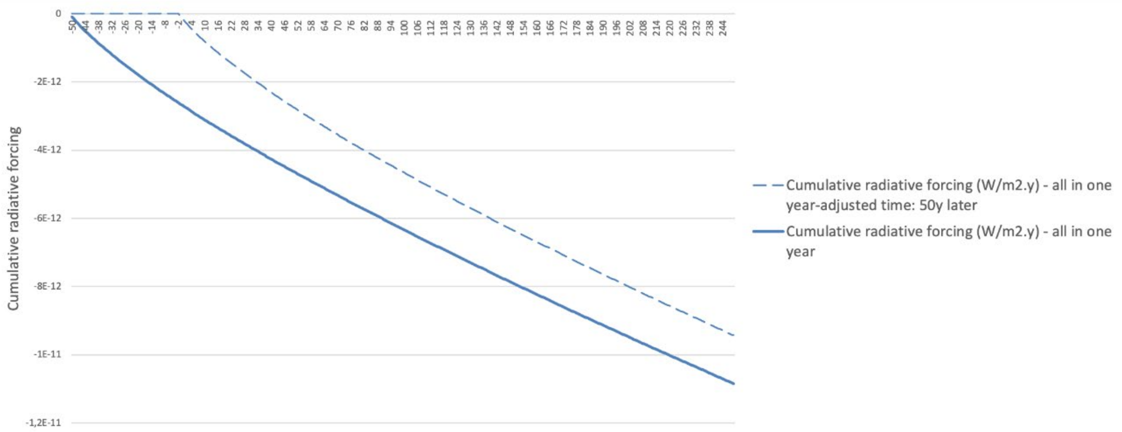
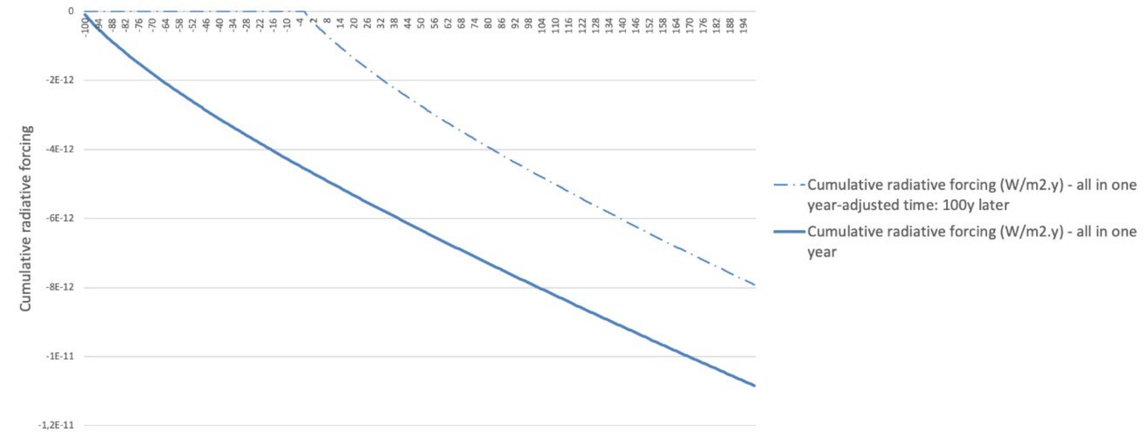


Figure 47. Cumulative radiative forcing of a generic uptake of 50kg of CO2, happening all at once, with an adjustment of the first year considered in the dynamic calculation: while the uptake is assumed to happen at the year of construction, the calculation also accounts for 100 years before building was constructed (assuming the forest would have taken 100 years to grow, analogously to the green curve in figure 9)



It can be seen that assuming that all the uptake happen in one year (namely the first year of the analysis, as shown in Figure 11), the “benefit” is overestimated – note that all results in the graph are negative. However, if one adjusts the first year of the analysis to when the forest started to grow, the overestimation is not observed (as shown in Figure 12 and Figure 13). Still, the intended users of the proposed methodology are expected to assume that the first year of the analysis is the year of construction, therefore accounting for the uptake at that same year (as in the full blue curve).

A certain amount of emissions or uptake happening during one year or divided amongst a greater number of years will have varying effects in the potential increase in temperature in the atmosphere. The simplifications necessary to derive the proposed methodology disregard this effect.

9.2.6. Conclusions and discussions

From the applicability point of view the proposed methodology require an effort that is similar to that of a life cycle analysis done following the EN 15804 standard. The only differences relate to the knowledge of:

The timing of the emissions;

The dynamic characterization factors (DCF).

Both requirements are easily manageable as explained in task 2. For the former, knowing the lifetime of the building is enough. For the latter the DCF have already been provided in and, if other DCFs are needed, can be easily calculated using the “Dynamic Carbon

Footprinter" (DynCO2) excel tool.[409] Although the calculations are marginally differing from those required from the EN 15804 standards, of course calculations need to be performed . This is something that can be done with a little effort by, for example, building products producers. They would have available both data and expertise necessary to perform such LCA analysis, which are the same required for the (mandatory) environmental product declarations. This would not however be the case for building owners, who are not expected to have the necessary engineering and LCA related expertise. There are, in any case, ways to simplify the procedures, and consequentially augment the chances of success of a carbon crediting initiative. One option might be, for example, to create a dedicated self-service software/tools that would guide the applicants, step-by-step, through self-calculation of the life cycle impact of their buildings. By knowing the bill of building materials, the applicants would be able to perform the calculations. An interesting example has been presented by the Athena Impact Estimator for Buildings,[410] a free LCA software tool designed to evaluate the environmental impact of buildings. Another option could be to provide pre-calculated life cycle impacts for pre-defined wooden buildings typologies. In this case, the applicants would need to demonstrate, based on some rational and clear guidelines (e.g. building typology, number of floors, area and other technical characteristics, geography and local climate), that the wood-based building they intend to construct can be considered similar to one of the buildings, where the impacts have been pre-calculated. This principle would essentially shift the burden of the estimation of benefits from the applicants to the authority responsible for implementing the carbon crediting scheme, who provide the pre-calculated life cycle impacts.

Concerning the temporary carbon storage assessment, it has been shown that the choice of some key parameters can also have an important influence on its estimated benefits and, consequently, the overall LCA results. The choice of the time horizon is, more than a scientific decision, a value judgement, and "explicit and justified value choices by decision-makers should govern the selection of an appropriate time horizon, to make robust and consistent choices".[411] The set time horizon influences the results since the importance given to the delays in emissions due to the temporary carbon storage effect is greater, where a shorter time horizon is chosen for the assessment. On the contrary, when an (hypothetical) infinite time horizon is set, no benefit from temporarily storing carbon is found. Temporary carbon-sequestration is not a permanent solution, but solely a way to postpone climate change and to prevent reaching tipping points in case CO_2 concentrations in the atmosphere go beyond irreversibility thresholds. The choice of short time horizon, giving higher importance to the temporary carbon storage effect, should only be justified when this is seen as a way to buy time for technological progress and changes in production and consumption patterns allowing for the mitigation of climate change (e.g. large scale deployment of renewables and carbon capture and use, circular economy, changes in food diets).

Postponing emissions should never be seen as the same as avoiding fossil-fuel emissions since carbon is not removed from the atmosphere permanently. Not giving excessive value to temporary carbon storage is also important to avoiding conflicts with the principle of intergenerational equity governing the sustainability concept. One potential solution to still credit temporary mitigation activities and reducing the risk of unsustainable postponing of emissions to future generations might consist of moving away from the traditionally used 100 year time-horizon for GWP in LCA, which is more an "inadvertent consensus" rather than a scientifically grounded decision.[412] The use of longer time horizons, such as 200 or even 500

[409] Freely downloadable at: https://ciraig.org/index.php/project/dynco2-dynamic-carbon-footprinter/

[410] https://calculatelca.com/software/impact-estimator/

[411] Levasseur, A., Brandão, M., Lesage, P., Margni, M., Pennington, D., Clift, R., & Samson, R. (2012). Valuing temporary carbon storage. Nature Climate Change, 2(1), 6-8.

[412] Shine, K. P. (2009). The global warming potential—the need for an interdisciplinary retrial.

years, should be considered. As shown above, this way the climate mitigation role of temporary carbon storage in wooden building would still be acknowledged, but the relative weight given to temporary carbon storage effect is lower.

In conclusion, bearing in mind the sensitivity analysis presented above, and comparing it with the results of previous studies (cfr. section 2.1), **the proposed methodology is deemed effective for quantifying the net carbon storage of construction wood products in a way can be reliably reported by operators and verified by an accredited body.** . In particular, compared to the -1/+1 method (in line with current European standards), yielding 5kg CO_{2eq}/m^2 of gross floor area, the proposed methodology reaches the following outcomes for the reference building selected for the analysis as provided in section 2.2.1:

- Time horizon for GWP fixed at 100 years: 85 kg CO_{2eq}/m^2 of gross floor area;
- Adjusting time horizon for GWP to 200 years: 43 kg CO_{2eq}/m^2 of gross floor area;
- Adjusting time horizon for GWP to 500 years: 19 kg CO_{2eq}/m^2 of gross floor area.

The outcomes from the methodology are reasonable and in line with the previous LCA literature, while providing a solid and feasible approach for its application in the construction sector. This methodology constitutes a strong starting point for formalising a standardized method, which can be used by European Commission within a broader scope of objectives in the field of carbon removals. The methodology is therefore taken forward in the remainder of this task, which informs on the policy design characteristics of the proposed remuneration scheme.

10. Discussion and Design of a Remuneration Scheme

Following the development of a proposed methodology for the calculation of the volumes of carbon saved in using wood in construction in Task 2 and its application in Task 3.1, this subtask is responsible for the design of a scheme that applies this methodology within a policy framework. The section provides an assessment of a variety of policy instruments available to regulators to impact the behaviour of market actors.

10.1. Introducing the variety of policy instruments

There is a **variety of policy instruments** to incentivise the uptake of certain technologies and appliances, or to tweak sector behaviour. These include command-and-control policies, taxes and remuneration schemes. Even within the latter, the set of options remains large: subsidies, tax-cuts, market-based credit schemes (e.g. cap and trade systems, baseline-and-credit systems) and voluntary programmes, such as green labels or voluntary carbon trading schemes. This chapter provides an **overview of these available options**, in an attempt to compare the advantages and disadvantages that each presents in light of the objectives set out in this exercise. Based on available policy and economic literature, the study provides a **critical assessment of each option** by building on the empirical findings on measures promoting WCPs, developed in subtasks 1.2 and 1.3.

Specifically, the following measures are included in this assessment:

- **Command-and-control policies,** setting binding requirements;
- **Taxes,** addressing negative externalities;
- **Remuneration schemes**, changing behaviour of market actors by affecting their economic incentives, including:
    - **Tax incentives and subsidies**;
    - **Market credit schemes**;
    - **Voluntary remuneration and trading schemes**.

10.2. Conditions under which different policy instruments can thrive

10.2.1. Command-and-control policies

Command-and-control policies take a form of **legislative regulations or standards**, by which public authorities set binding requirements. When these are not complied with, they are followed by sanctions or penalties. The requirements can either be **prohibitive**, by forbidding a certain behaviour or attribute, or be **prescriptive**, requiring the fulfilment of a certain requirement. Previous studies conducting extensive policy reviews in environment and resource management domains have concluded that the overall majority of regulations in the EU are based on legislative and regulatory instruments.[413]

Command-and-control policies have a number of **advantages**. They provide a high degree of enforceability, as they allow to overcome the lack of cooperation from targeted stakeholders. Moreover, since these policies take place within a regulatory framework, they guarantee equal treatment to all actors, based on the rule of law. They allow the regulator to directly influence market behaviour, in a top-down manner. On the other hand, command-and-control policies also present important **disadvantages**, among which the most cited one is the **amount of resources** (i.e. financial and administrative) that these measures require. The costs apply not only to the regulator, which needs to mobilise sufficient resources in monitoring and enforcing capacity, but also to the targeted stakeholders, which often have to bear significant **compliance costs**.[414] Moreover, several accounts of command-and-control policies criticise their **little flexibility and adaptability** to changing situations and outcomes, a particularly critical shortcoming in the field of environmental regulation, often demanding adaptable, understandable and enforceable measures. The latter issue most sharply applies in the field of ecosystem service management and biodiversity conservation, where the **complexity** inherent to ecosystems and biogenetic processes outpace regulatory efforts.[415]

Several considerations can be drawn when applying this regulatory framework to the policy issue at hand, namely the uptake of WCP in the construction sector. In this context, command-and-control regulation may take various forms, each addressing specific aspects and steering the increased use of WCP in different ways. **Land use policies** have been highlighted as one of these approaches. **Sustainable forest management**, coupled with an intensification of harvest targeting wood suitable for construction, constitutes one of these options. These policies, nonetheless, need to be put in perspective with regards to the current state of play in Europe, particularly the one emerging from the previous tasks of this study: the potential for **increased wood harvest in Europe appears rather limited**, with wood consumption coming mostly from local (i.e. national) production. Intensified harvest could be replaced by an increased sourcing of wood from outside EU borders, albeit bearing the risk of uncertainty regarding wood quality certification, as well as potentially looser checks on their sustainable origin.

Alternatively, a regulation may target the **uptake of WCP**, setting binding targets for renewable or sustainable materials share in a building or in a city / region. This option would constitute the most explicit understanding of the command-and-control regulation, whereby specific materials would be given priority and this priority be implemented by means of **enforceable standards in building regulations**. In this regard, the previous tasks of this study have informed on the feasibility, challenges and current developments of this type of policies. In particular, subtask 1.2 investigated the regulatory environment in Finland and France, providing useful insights into the current state of play in these countries. In Finland, the **revision of fire codes** has been highlighted as an impactful (indirect but very relevant) measure for the uptake of WCP, particularly in multi-storey constructions, where wood represents so far a marginal share of building materials.[5] While constituting an indirect form of regulation, by affecting the uptake of wood on the grounds of **safety** norms, these measures are recognised as a major barrier for the development of WCP. Moreover, as highlighted in the interviews carried out in the context of subtask 1.1, concerns over safety

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[413] Bouwma, I. M., Gerritsen, A. L., Kamphorst, D. A., & Kistenkas, F. H. (2015). Policy instruments and modes of governance in environmental policies of the European Union: past, present and future.

[414] Cole, D. H., & Grossman, P. Z. (1999). When is command-and-control efficient-institutions, technology, and the comparative efficiency of alternative regulatory regimes for environmental protection. *Wis. L. Rev.*, 887.

[415] Holling, C. S., & Meffe, G. K. (1996). Command and control and the pathology of natural resource management. *Conservation biology*, *10*(2), 328-337.

are often based on preconceptions and "old traumas", rather than on actual technical assessments.

France has attempted to force the usage of wood in construction in a very direct way, with a decree setting a binding share of biobased materials for building construction. This decree was legally challenged, and eventually withdrawn, on the grounds of discrimination.[416] While not including such level of prescription, the newly developed RE2020 law in France constitutes a strong attempt in the promotion of biobased and wooden materials in construction. New ways of promoting biobased materials in construction are investigated in the ongoing RE2020 revision.

To circumvent the legal challenge, a regulation in the form of setting **normative carbon limits for buildings** has been suggested as a viable option, by promoting low-carbon constructions, without favouring any specific building material (see subtask 1.3). This is the approach used when **revising Finnish building code** to adopt a material-neutral and life-cycle approach, where building permits would only be granted to projects where the overall environmental and climate impact over the building's life cycle lies below a threshold. Under these conditions, WCPs are expected to acquire a competitive advantage.

All in all, command-and-control policies, while providing several enforceability advantages, present also important limits when it comes to their implementation. Current and past experiences at national level show the difficulty for regulators to implement hard standards to favour the usage of wood in construction. This is likely to be even more the case at the EU level, where these challenges are exacerbated by the **heterogeneity in national legislation** concerning building codes and requirements.

However, the urgent need for reducing carbon in building constructions might soon prompt this most stringent path. In fact, this approach is expected to bring the most effective carbon reductions in construction, by stimulating innovation, specifically if a material-neutral approach is taken, based on requirements placed on the lifecycle climate impact of the building at the time of granting the building licence.

10.2.2. Taxation

Environmental taxes constitute a solid policy instrument globally as they are particularly effective in covering (i.e. internalizing) **environmental externalities** of certain economic activities. This is the basic principle of a Pigouvian tax, a well-established concept in environmental economics.[417] The advantage of taxation instruments is that they can correct **market failures**, in particular regarding common goods or activities for which there are no markets. Taxes, charges and fees are a useful policy tool in influencing private behaviour in order to meet public objectives. They generally work by placing a monetary charge per unit of emissions or waste to reduce the overall quantity. However, while taxes discourage certain harmful activities by imposing a charge on them, they do not guarantee their cessation. Therefore, taxes **do not ensure the achievement of a pre-set target** (e.g. CO_2 emission reductions). Moreover, another drawback which has been extensively addressed, is the **regressive impacts** of environmental taxes. Low-income households are potentially vulnerable to environmental taxes because they spend proportionately more of their income on emission or intensive items, such as energy bills and fuels. These groups, therefore, tend to bear a disproportionate share of the costs of environmental taxes. Measures can be put in

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[416416] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000030401733/#:~:text=2010%20relatif%20...,D%C3%A9cret%20n%C2%B0%202015%2D340%20du%2025%20mars%202015%20abrogeant,du%20bois%20dans%20certaines%20constructions

[417] Pigou, A. C. (1920). The Economics of Welfare. London: Macmillan.

place to mitigate the regressive effects of environmental taxes, which can take various forms, according to the activity in question, as well as the target group.

In the context of the given policy issue, to incentivise the uptake of WCP at the EU level, taxes present several challenges. First, and most importantly, any harmonisation of fiscal legislation of EU Member States regarding indirect taxation shall be the purpose of a special legislative procedure requiring the unanimity in the Council[11]. This creates a very important obstacle to the imposition of a tax on conventional building materials (i.e. cement, bricks, steel) in favour of biobased and wood-based products. Moreover, **no such tax is currently present at national level**, hence the absence of similar measures to draw lessons from. The implementation potential of this policy is therefore considered rather low, inadequate for the regulatory context this study is concerned with. Finally, similarly to the point raised with regards to command-and-control policies, a tax on conventional building materials is expected to face a **fierce opposition by the industries concerned**, with the likelihood of being legally challenged and disputed.

10.2.3. Remuneration schemes

Tax incentives and subsidies

Tax incentives can be used to promote private R&D and innovation in low carbon technologies and practices. It has been proven that the **knowledge spill-overs** from patents for low-carbon technology are among the highest.[418] Large spill-overs suggest low-carbon innovation has positive effects in the economy, but it does not imply that targeted tax incentives are justified in every circumstance.[419] For instance, tax incentives may work best for near-to-market products, but not so much for other stages up the supply chain. In the latter case, **direct R&D or technology deployment** is thought to enhance innovation more successfully. On the other hand, direct support requires expertise in selecting and executing the projects. The policy should also be based on the principle of **additionality**, whereby the tax incentive should create additional environmental benefits that would not have occurred otherwise. Tax incentives can also support investment that would have been made even in the absence of the tax incentive. In addition, just like with taxation, tax incentives may have **regressive impacts**.[420]

Subsidies are forms of public financial support for certain activities that are deemed beneficial for the society. Rather than charging activities based on their emissions, a subsidy **rewards efforts of emission reductions**. Examples of subsidies include grants, low-interest loans, favorable tax treatment and procurement mandates. Environmental subsidies offer the same environmental benefits as environmental taxes. The main difference compared to taxes is that subsidies do not generate additional government revenues but are actually **government expenditures**. Disadvantages are the costs associated with the subsidies, but also some administrative costs deriving from coordination programs to distribute and collect the resources.

Policy instruments in the form of subsidies, grants and tax incentives could be part of a programme promoting the use of wood in construction. It could take the form

[418]https://www.researchgate.net/publication/259974557_Knowledge_spillovers_from_clean_and_dirty_technologies_A_patent_citation_analysis

[419] Ibid.

[420] Appelt et al, 2016; Greene and Braathen, 2014.

of **procurement guidelines** for public building projects, involving the measurement and assessment tools to establish the carbon storage and carbon footprint in wood building projects. Moreover, the use of **grants** could be explored, by means of subsidies to R&D and skill development across the WCP supply chain. These subsidies would support the acquisition of scientific and technical knowledge and professional competence necessary to process the alternative sources of wood (e.g. from broadleaved trees, from lower-quality timber) from which to produce Wood-based Construction Products (specifically: Cross-Laminated Timber). The R&D and skill development subsidies would also support the skills of engineers, architects and construction companies to use wood-based construction products in their daily work. The latter points have been extensively raised throughout the market policy scoping performed in the previous tasks of this study. Indeed, lagging knowledge and skills development have been identified as major obstacles to the development of the wood supply chain and its involvement in the construction sector. This type of policy is also represented at national level, as it was found from the two case studies performed in subtask 1.2. Indeed, both France and Finland have implemented strategies involving direct and indirect support to the wood supply chain, targeting skills development, but also technical advancement. Examples of these measures are, in France, **Filiere Foret Bois - Plan Recherche Innovation**; **Fonds Bois & Plan de relance de la compétitivité des scieries, "Plans bois" (Wood Plans) I, II and III (2009 – 2020),** and in Finland, **Aid Scheme for Growth and Development from Wood** and the **Wood Building Programme (2016-2022).** These encouraging measures consisting of research grants and funding already also take place at EU level, through a number of schemes. The latest and the most relevant example of this is the Horizon 2020 funded project Build in Wood,[15] focusing on the innovative development of materials and components for multi-storey wood buildings.

Mandatory carbon markets

Compliance markets for the issuing and trading of carbon credits were firstly designed with the Kyoto Protocol in 1997 by the United Nations Framework Convention on Climate Change (UNFCCC). Project-based mechanisms were introduced in the form of Joint Implementation (JI) and Clean Development Mechanism (CDM), covering emission reduction projects in developed and developing countries, respectively. Emission reductions through the projects are verified, upon which carbon credits are issued; these can be sold to other organisations that need to offset their emissions in line with pre-set emission reduction targets. Emission reduction projects are usually referred to as carbon offset projects.

The issuance of credits under the project-based mechanisms is conditional on a series of strict requirements, which have later been adopted as a standard by other emission trading systems. These are namely:

Additionality: the emission reductions associated with a given project could not have occurred without the project;

Leakage: leakage occurs when an emission reduction project leads, directly or indirectly, to the other emissions elsewhere, in presence of which the given project is not eligible for accreditation;

Permanence: relevant for projects involving carbon sequestration, the emissions sequestered need to be permanent, meaning that these emissions should be certified to be captured for an enough long timespan;

Double counting: carbon credits require their registration in a database to avoid the multiple (i.e. double) accounting of the same emission reductions.

Market-based credit schemes are considered effective instruments given their advantages – if designed and administered correctly – with regards to **cost effectiveness** and **ability to drive innovation**. Yet, for a market-based instrument to be used at its full potential, various necessary conditions must be met to assure a minimum level of competition, such as:

Homogenous products – Homogeneity of products is a necessary condition for a market to function well and for producers to compete. In the context of climate policies and credit schemes for greenhouse gas emissions, this is slightly different. The products as such do not need to be homogenous, but the extent to which they contribute to the overall policy objective (CO2 reduction) should be measurable and comparable.

Sufficient market players – For a market-based credit scheme (and for any regular market) to function well, it must have sufficient players (both buying and selling) to assure that individual actors do not possess market power. In markets without sufficient players, market power can lead to sub-optimal situations as the actor with market power (actor A) can force other market players to act in the interest of actor A, as other actors may not have decent alternatives, as there are not enough actors.

Sufficient market volume – Aside from a minimum amount of market players to prevent any market player from having market power, a market-based credit scheme must cover sufficient market volume too, if trading is an element within the credit scheme. The combination of sufficient market players and sufficient market volume should lower transaction costs for individual participants to find a buyer/seller and therefore increase a market's liquidity.

A carbon pricing scheme is already operational in the EU, in the form of the **Emissions Trading Scheme** (ETS). Established now since several years, it is the object of an ongoing debate regarding several of its characteristics, its successes and shortcomings. Under the recently launched 'Fit for 55' package the ETS will be further tightened. This will likely lead to further decrease in the carbon content of concrete and steel for construction.

The proposal for a revised Emission Trade System (ETS)[421] lowers the overall emission cap and increase its annual rate of reduction, phases out free emission allowances for aviation, and includes shipping emissions in the scope of the ETS. The proposal also set up a separate emission trading system for road transport and buildings. Finally, the proposal increases the size of the Innovation and Modernisation Funds, inter alia giving more prominence to renewable sources and energy efficiency investments.

Voluntary remuneration programmes and trading schemes

Voluntary carbon market and remunerations schemes allow for private entities to offset their carbon emissions from projects that reduce or capture emissions, by either applying for a certification system, or, when these are issued, participating in the trade of carbon credits. This occurs on a voluntary basis, hence beyond legislative or regulatory frameworks. While not being bound to normative requirements, like in cap-and-trade schemes, private entities participate in voluntary carbon markets out of social corporate responsibility, marketing and reputational purposes. Voluntary markets and remuneration programs have evolved in the recent years to gain an increasingly solid certification and accreditation mechanisms, borrowing from market credit schemes the conditions e.g. additionality, permanence and leakage. To do so, most of these schemes rely on third party audit and certifications. This applies equally to voluntary carbon markets as well as to certification standards and labels,

[421] COM (2021) 551 final.

which are also increasingly taken up by private companies to enhance their image and socio-environmental awareness.

The standard setting and accreditation organisation are a crucial element of the certification scheme. The standard setting and accreditation organisations define the standards and allow (accredit) third parties to control against the set standard (= certification). A well-established voluntary remuneration scheme is the Gold Standard[422] developed by the World Wildlife Fund (WWF). In these types of voluntary remuneration schemes projects can apply to be certified under the remuneration scheme in which case individuals and companies can opt to offset their carbon emissions by investing in a certified product. Standard setting bodies dwell between the seemingly opposing objectives of, on one hand, developing a strict and reliable standard, and on the other, to avoid overly costly and complex standards. Moreover, certification standards require third party audit and verification, necessary to enhance their impartiality and reliability.

As a result of increased interest from both citizens and companies, the demand for carbon offsetting has risen significantly over the past years. This has led to an increase in the number of voluntary remuneration schemes (e.g., American carbon registry[423], climate care[424], carbonfund.org[425], my climate[426] and carboonfootprint.com[427]). Storing CO_2 in a building for longer period could become part of such schemes and could be a way to buy and sell this stored carbon.

The findings from subtask 1.3 are particularly relevant, as they concern existing market-based schemes incentivising the use of wood in construction. In particular, the study reviewed existing schemes operating both in the EU and globally, at national, regional and international levels. These experiences led to a set of conclusions. To date, voluntary market schemes can be divided into **labelling and certification schemes**, **schemes allowing for the trade of credits**, and **sustainability assessment tools**. This horizontal variation is coupled by a diversity in a vertical, methodological dimension. While some of the reviewed schemes provide a thorough and established method for the calculation of the carbon stored in wooden materials specifically, other rely on more generic frameworks, which tackle broader dimensions of the sustainability of buildings (e.g. acoustics, air quality, energy efficiency).

Concerning the labelling and certifying schemes (i.e. Level(s)[428], BREEAM[429], HQE Bâtiment Durable[430], BES 6001[431]), the subtask 1.3 findings suggest that the accreditation methodologies the schemes employ – mostly based on qualitative frameworks assessing several sustainability dimensions of buildings – do not offer as of now the granularity that is here sought, and do not provide significant attention to the climate benefits of wood specifically. Two initiatives (Label Bas-Carbone[432] and BenchValue[433]) focus on the quantitative evaluation and certification of the benefits in terms of saved GHG emissions of a broad range of actions (Label Bas-Carbone) and more specifically of the substitution of

422 https://www.goldstandard.org/
423 https://americancarbonregistry.org/
424 https://climatecare.org/
425 https://carbonfund.org/
426 https://www.myclimate.org/
427 https://www.myclimate.org/
428 https://ec.europa.eu/environment/levels_en
429 https://www.breeam.com/
430 https://www.certivea.fr/offres/certification-hqe-batiment-durable
431 https://www.bsigroup.com/en-GB/bes-6001-responsible-sourcing-of-construction-products/
432 https://www.ecologie.gouv.fr/label-bas-carbone
433 http://benchvalue.efi.int/

mineral-based construction materials with wood-based alternatives (BenchValue). These two schemes create a technical base for a market in carbon credits, but do not develop such a market. Finally, two initiatives aim at the establishment of a full-fledged market for carbon offset are: Puro.earth[434], a functioning voluntary carbon market (at very limited scale) operating internationally, and CARBOMARK[435], a similar market system though operating at local level.

In the latter cases, the creation of a market with a sufficient number of players on both sides and projects involved has not been achieved. It is likely that the difficulties encountered by these two frontrunners remain relevant and that a fully-fledged market for the carbon credits created by substituting mineral-based materials with Wood-based Construction Products remains a challenging target. On the other hand, the approaches adopted by Label Bas-Carbone and BenchValue, appear as the most successful systems in combining the accuracy of measurement for carbon embodied materials, and issuing a reliable certification. These schemes concentrate on the essential operation consisting of providing a reliable, quantified assessment of climate benefits. Based on this quantitative assessment, market players can make environmental claims (as a reputational tool), obtain public funding (as illustrated in the Dutch adaptation of BREEEAM[436]) or seek third parties interested in compensating their own GHG emissions, in peer-to-peer or intermediated transactions.

10.3. Selection of the policy instrument

Table 2 summarises the main points regarding the suitability of various policy instruments as ways to incentivise the use of wood in construction.

[434] https://puro.earth/

[435] https://pdc.minambiente.it/it/area/temi/clima/progetto-carbomark

[436] https://www.breeam.nl/

Table 33: Summary table of available policy instruments

Policy instrument	Advantages	Disadvantages	Favourable conditions
Command-and-control	Strong enforceability Assurance of outcomes	Costs for regulator and compliance Rigid approach	Need for strong regulating authority
Taxes	Address market failures	No ensured achievement of pre-set targets Regressive impacts	Requires unanimity in EU Council
Subsidies	Promote socially positive activities Address market failures	Source of government expenditure	Already in place at both national and European levels
Compliance market-based credit schemes	Cost effective Allows for innovation	Necessitate sufficient market liquidity and number of actors	Product homogeneity Sufficient market volume Sufficient number of trading actors
Voluntary carbon remuneration and trading schemes	Provides flexible guidelines Competition-driven structure Allows for innovation	Large pool of certifications existing Varying quality of methodologies employed	Product homogeneity Sufficient market volume Sufficient number of trading actors Reliability of verification system

All instruments present advantages and disadvantages regarding the feasibility and effectiveness in achieving climate objectives. In line with the Terms of Reference, this study puts forward a accreditation **methodology that ultimately informs the development of a voluntary remuneration scheme for the use of wood in construction**. However, this methodology is seen as a valuable tool for any of the policy instruments explored above. Indeed, while a voluntary remuneration scheme is seen as the most suitable option in terms of political acceptability and feasibility of implementation, based on the legal and political difficulties highlighted previously involved with command-and-control regulations, the methodology and approach to quantify and reward carbon saved lay the ground for other policy instruments for carbon removal and their further exploration as well. In particular, this approach and methodology could be applied in the context of a more ambitious strategy involving more stringent measures, such as command-and-control or taxation measures, especially in regard to carbon neutrality.

In subtask 1.3, a review of existing market-based instruments yielded relevant insights into the effectiveness of the design of some instruments compared to others. Voluntary remunerations schemes that focus on the development of a strong methodology for the measurement of embodied carbon emissions, with a certification mechanism that allows for varying benefits and remunerations, are put forward in this task. Based on the existing experience at national and international levels, voluntary remuneration schemes provide the level of **accuracy** in the remuneration methodologies they propose, but also the **flexibility** of a market-based scheme, which has been highlighted as an important characteristic. They offer opportunities for innovation and provide various possibilities in terms of the remuneration offered, be it reputational or monetary. This type of policy is therefore taken forward in this study and will be further detailed throughout the following sections of this task.

11. The market of wood-based construction

11.1. Market actors

Several different actors operate in the market of WCPs. As shown in subtask 1.1 of this study, the sector is both highly diverse and fragmented. The actors can be divided in the following categories:

Sourcing:

Forest owners/other actors in the forestry sector;

Production of Wood-based Construction Products:

Saw-mill operators;

Producers and traders of WCPs;

Construction of buildings:

Architects, construction engineers and construction firms (including those specialised in building renovation);

Project owners (in the construction phase);

Usage of the building:

Long-term owners of the buildings (landlords);

End of life:

Demolition and recycling firms.

Despite this fragmentation, the sector presents also some degree of vertical integration across the value chain. This integration occurs through market players that are active across different stages of the chain (e.g. forest owners that also act as sawmill operators and producers and traders of WCP, or project owners that also remain long-term owners of the building). In addition, external actors play an important role at some crucial stages of the process, such as insurance companies and banks for project owners.

11.2. Climate gains

11.2.1. Forestry perspective

Beyond wood production, forests perform many different functions, such as biodiversity conservation, protection of water and soil (and of the massive carbon stocks embedded in the soil[437]), various ecosystem services, as well as leisure and recreation. Achieving a positive balance among all these different functions, meaning one that guarantees the sustainability of forests and of their soils, represents a challenge, with frequent issues stemming from **overexploitation of the land**. The Forest Europe[438] process defined sustainable forest management as "*using forests and forest land in a way, and at a rate, that*

[437] https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter11.pdf
[438] Forest Europe. (2020). *State of Europe's Forests 2020*.

maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems". This definition has been operationalized though various indexes and criteria. Also, Joint Research Centre of the European Commission (JRC) has assessed[439] the potential climate benefits and relevance of good forest management and wood in construction.

The climate benefits associated with WCP are indissoluble from the sustainable management of the forest. An assessment, as the one that is here pursued, quantifying the climate benefits of wood, needs to integrate an account of the wood sourcing from the forest. The latter is no easy task: as highlighted in subtask 1.1, data on third party certification sourced from all MS is not available. However, based on performed estimations, it is possible to use the percentage of wood areas available for wood supply under third party certification, as a proxy for the share of wood products produced by each MS which is certified. The estimation yielded that besides Croatia, all of the MS with a high share of wood sourcing under third party certification have large forest cover. While there is a sensitive level of variation between MS, the consumption of wood in the EU comes primarily from local (i.e. national) production, and to a smaller extent from imports. EU-level data shows that the EU imports more timber than it exports, but that imports represent roughly 15% of its total consumption, with the remainder being sourced domestically.

As part of the assessment of the climate benefits of wood in construction, an essential aspect is therefore the assurance that the woody mass comes from forests that are managed in a way that maintains or enhances the forest carbon sink in the long term. Task 2 of this study was concerned with the development of a methodology evaluating the net GHG content of wood-based construction materials. The task aimed at the inclusion of all carbon embodied in the material, all additional GHG emissions that may be necessary in order to achieve full functional equivalence with traditional materials, as well as the materials' end-of-life. Following an in-depth literature review of available methodologies and LCAs, the task reached important conclusions for this study, particularly for the account of the forests' perspective. It was concluded that a detailed accounting of the carbon dynamic in the forests is discouraged, for two reasons: (1) the acquisition of data and the accounting for the forests carbon fluxed might become complex and time consuming, making its accounting a disincentive to the adoption of a standard; (2) existing certification schemes already target forest owners to protect and enhance the forest carbon sink. However, the approach developed for this study includes the essential aspect of sustainable forest management, by designing an incentive system for sustainable forest management, avoiding improperly managed wood from being credited and leakage, while being feasible and efficient to implement. A set of options were formulated to tackle this issue:

Option 1. Assessment of the country situation based on general reporting. Countries could be put on a "green list", guaranteeing the sustainability of their forest management. Reporting is voluntary, and an important risk factor is that local practices deviate from national average. This option also presents important limitations in terms of third-party verifications.

Option 2. Assessment of the situation per country based on UNFCCC reporting: the UNFCCC reports by country provide a more accurate picture of the effect of management on the carbon balance in forests. While still at country level, therefore allowing for internal variation, this option provides more certainty as its reporting includes more pools and it is independently certified.

[439] https://ec.europa.eu/jrc/en/science-update/forest-based-bioeconomy-and-climate-change-mitigation-trade-offs-and-synergies

Option 3. Use of certification schemes: this option would involve the obligation to source the wood that is certified by a third-party certification scheme. This option envisages both the use of existing certification systems, as well as new schemes that are specifically targeted at the carbon implications. Examples of these forest certifications schemes are the Forest Stewardship Council (FSC), Endorsement of Forest Certification (PEFC), Sustainable Forest Initiative (SFI) and Canadian Standard Associations (CSA). This option is identified as one that practically eliminates the risk of the wood being sourced from areas with unsustainable management practices.

Option 4. Full accounting of the carbon effects: this option goes beyond a third-party certification and develops its estimations for carbon content, based on a type of LCA analysis. Such an approach, while guaranteeing a high-level guarantee of carbon accounting, would significantly bring up the costs for the scheme.

NB Both the Taxonomy Regulation as well as RED 2[440] sustainability criteria are alternative options to describe acceptable forest management levels. These were not included previously but will be addressed in the renumeration system described in 5.2.1.

As articulated in task 2, these options, and the respectively increasing level of detail in their assessment, could translate into a tiered system. The latter provides incremental levels of guarantee on the carbon functioning of the forest, with a corresponding increasing level of accreditation offered by the system. Chapter 4 provides a more detailed overview on the functioning of this system.

11.2.2. Construction perspective

Following an account of the ways the carbon implications of the woody mass can be included in the assessment of the climate benefits of WCP, from a forestry perspective, this section addresses the assessment of the climate benefits of construction projects including wood in their structural materials. With this aim, subtask 3.1 implemented the methodological considerations developed in task 2 by testing them under the proposed MRV scheme in Task2 of this study. Lying at the heart of this exercise, assessing the carbon benefits of WCP is confronted with a double challenge: providing an accurate methodology that depicts to the most accurate extent possible the temporary GHG emissions storage and resulting climate benefit of wooden constructions, while designing a system that can be easily understood and applied by the targeted users.

The LCA provided in the previous subtask 3.1 (chap. 2 above) assessed and compared the greenhouse gas emissions of different structural versions of a multi-storey office building. Structural simulations were performed on varying assumptions concerning the span of the structure, i.e. the distance between the different load-bearing elements, to assess potential differences in results that would come from varying spans. Within this report, we discuss the methodology application to two different spans, 5.5m and 7.5m, which can be identified as standard span measurements, with intention to show the contextual variability of the simulation.

The results seem to indicate that the benefit of growing the wooden products outweighs the onus of the emissions arising from manufacturing other building materials and from all end-of-life activities. Varying assumptions on the lifetime of the buildings did not have a large impact on the outcomes. The difference between sawn-wood and CLT did have a great

[440] https://www.vie-publique.fr/consultations/279651-projet-de-decret-red-ii-durabilite-ges-bioenergie

impact, calculations are based on CLT as this is currently the only way of constructing larger wooden buildings. So far, we have not included end-of-life alternatives for the carbon stored as this is scientific standard. However, we can imagine that in the future, with more standardized CLT construction elements and proof of their longer physical lifetime, end-of-life can become an issue that needs to be reconsidered.

Box 8 Alternative mechanism based on a liability system

> An alternative system could be further explored, whereby the climate benefits of the WCPs in a building could be computed and attached to the building as a liability system, similarly to a mortgage; it would be permanently ‘attached’ to the building in physical units (tonnes of CO_{2eq}). The liability would decay – meaning the owner of the building would not be obliged to repay the CO_{2eq} credits (at the price per tonne of CO_{2eq} valid at that time) – upon proof that the wood embedded in the building has been reused in an acceptable circular manner, safeguarding the long term carbon storage and transferring the liability to the owner of the building incorporating the re-used wood. The advantage of such a system would be to incentivize the reuse of the wood for another long-term application, and solve the uncertainty related to the fate of the wood at end of life. On the other hand, the practical and economic viability of such a system is very uncertain.

The results of the tested MRV approach, together with the considerations elaborated previously on the forestry perspective, are of fundamental importance for the following chapter of this study, the final one, which ultimately proposes a market-based scheme for the incentivization of WCP. It is tasked with the important goal of incorporating and adapting the proposed methods to the practical policy and economic aspects which define the context of this study. After introducing the intended objectives of the policy, chapter 5 brings together the multitude of considerations elaborated throughout this study and this task: composing the design of the policy instrument, the application of the MRV methodology and its practical implications for the regulatory environment.

12. The remuneration scheme

This study puts forward a policy scheme and a supporting remuneration methodology that intends to incentivize the use of wood in construction. Stemming from WCP climate benefits in storing carbon emissions throughout their lifecycle, **the proposed scheme rewards market actors that voluntarily opt for these materials**. The previous sections of this task aimed at laying the ground for the development of such scheme, analyzing, respectively, the most suitable policy design - given the previously identified policy and economic barriers - as well as past and existing experiences in this policy domain. Next, the market and policy scoping provided the tools to determine the targeted market players, in other words, **the point of entry of the scheme**. Finally, the methodology and MRV testing provided a scientific basis for the design of the remuneration method underpinning the scheme.

Direct remuneration from the scheme, in the form of a price mechanism dependent on the quantities of CO_2 stored in the wooden material has been explored by the study. In order to have an effective price-incentive, the volume of carbon multiplied with the unit price of the carbon saved (V x P) needs to give a **financial incentive that is significant enough** - in relation to overall construction cost - **to change the key decision maker to opt for more WCP in the building**. Based on the assessments performed in the elaboration of the quantification methodology, and the testing through the MRV study, it was found that the magnitude of emissions saved in wooden **buildings is of a limited level, and likely not enough to give a strong enough price signal for the project developer**. Table 3 reports the findings from the application of the methodology from task 2 and shows the estimated level of remuneration per saved volume of carbon, in the two cases of a **single-family house** and a **multi-storey office building**.

Estimates of future carbon-prices vary strongly. Current prices on the voluntary carbon market are between €3-10/tCO_{2eq}, and certain market players are paying an additional amount for their "compensation schemes". A few considerations on the current and future developments of ETS prices: currently, these are around €50/ton, and the high end for the ETS price in 2030 is estimated at €65/ton,[441] according to the EU's own impact assessment. Voluntary prices will – logically – always be below the prices in a formalized system. Towards 2050 it is to be expected that a higher CO_2 price is required, as eliminating the last tons of carbons in society is more costly. We have therefore also included a fictive €200/ton price. It is likely that for this price level, or even less, also the steel and concrete sectors can reach carbon neutrality. For the voluntary market it is important to realize that in a substantial market the buyers will try to find the lowest cost and most likely can find options far below the €200 across the globe.

[441] https://www.europarl.europa.eu/RegData/etudes/IDAN/2021/662927/IPOL_IDA(2021)662927_EN.pdf

Table 34. Estimated volume saved and respective remuneration per price level

Building type	Construction costs[442] (EUR)	GHG emissions saved (tonnes CO_{2eq}, with savings estimated at 5 - 85 $kgCO_2/m^2$)	Economic incentive (EUR, with current price level of €10/$tCO_{2eq}tCO_2$)	Economic incentive (EUR, with future potential price level of €50/$tCO_{2eq}tCO_2$)	Economic incentive (EUR, with future potential price level of €200/tCO_2)
Single-family house 150m^2	€150.000-€300.000	0,75 – 12,8 tCO_{2eq}	€7,5 - €128	€ 37,5 - €640	€150 – €2.560
Five-storey building (office building) 9,792m^2	€9.792.000-€19.584.000	48,9 - 832 tCO_{2eq}	€489 - €8.320	€2.445 - € 41.600	€9.780 – €166.400

In the decade to come, a monetary remuneration for project developers based on the volumes of carbon saved does constitute only a weak signal in relation to both the cost magnitude and margins of the building project. While this could constitute an element of attraction for customers investing in and building their own dwelling, it is not deemed a convincing enough economic argument to switch to WCPs. For professional project developers, an anticipated margin is around 15-20%. For a five-storey building the additional margin would be well below 1% under the most optimistic scenario. This will likely be outweighed in the first phase by the increased risk and cost due to lower familiarity with working with WCPs. Margins, on the other hand, are much lower for the construction companies or the companies actually making the WCPs. By moving the carbon benefits to the producers of WCPs there might be an impulse in the market, as it becomes more interesting for the suppliers to switch to certified WCPs.

If, in the years after 2030, the CO2 price would happen to increase drastically, and as companies get acquainted with working with WCPs, the renumeration through a carbon price might have a little bit more impact on the project developers' decision. However, with much higher carbon prices, alternative products such as concrete and steel will also reach carbon neutrality.

Based on these considerations, it is inferred that **in the decade to come the renumeration for the carbon storage is unlikely to change the uptake of WPCs in the construction of houses or buildings.** It is much more likely that both private house builders and professional developers will choose for more WPCs for other reasons, such as **marketing**, **aesthetics** or concerns over the materials' **sustainability**. Nevertheless, it is not to be excluded **that in later years, with CO_2 prices well over €100/ton, the financial incentive will become more attractive for project developers.** Once the premises for the expansion of WCPs to structural building elements are reached, the overall benefits can further increase.

Having that said, it is important and urgent to store carbon in the immediate future, as every ton stored today is more important than any ton stored in 25 years from now. Therefore, options have been sought which would guarantee a quicker impact on the use of WCP's.

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[443] In future also secondary wood could be included at this point in the system. This has not been developed in this research.

There are two possible, more positive, incentives that can be achieved with regards to rewarding the temporary carbon storage in the WCPs, namely:

- The proposed methodology could **incentivize the constructor of wood-based construction products**.
- The proposed methodology for a credible measurement / calculation of carbon removed would allow the **project developer to use this claim in a variety of other relevant situations like e.g. permitting** or **green building labelling schemes.**

More specifically, the first option envisages the transformation of the certified trees into a beam with a long lifespan. In this scenario, the monetary remuneration, as mentioned before, could create a **positive incentive for producers of wood-based construction products**. This remuneration would most likely **cover the administrative costs involved with guaranteeing the sustainable origin of the wood used**, and the carbon content of the beam produced. It is thus likely to encourage the manufacturer of wood-based construction products to use only wood from certified sources in its processes, and thus prevent the manufacturing process from having detrimental environmental and climate impacts (e.g. due to LULUCF considerations).

The second option entails the use of the certified WCP by project developers in their buildings. The scheme would thereby create a quantifiable and certified estimate of the carbon removal volume at building level. In this context, the project developer purchases the wood from a WCP supplier that can guarantee the sustainable origin and the volumes of carbon content of its products, i.e. the beams. The agreed methodology as put forward by this study is therefore applied to calculate and certify the volume of carbon removed. This can be used for reputational and regulatory incentives for the building owner: a much more valuable incentive than the monetary reward. These points will be further explained in detail in the following sections.

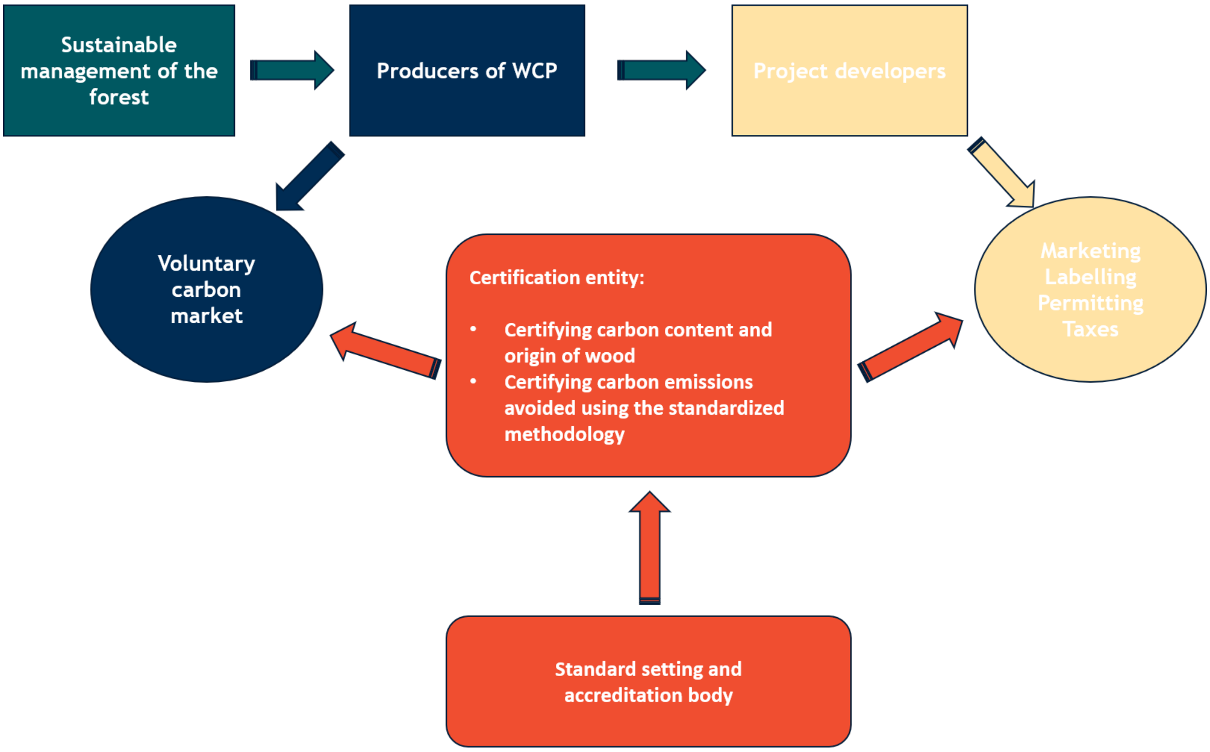
NB: By giving one party the right to use the credits in the market and the other to use the underlying non-tangible claim, there is a form of double counting in the strict sense. But this is also true for any other sustainable forest promotion scheme. As there is no financial double counting, we believe this is the most effective and realistic option to make the system work.

Therefore, **the methodology for quantifying volume of carbon removed would work on two levels**:

1. remunerating the beam producer for participating in the scheme by certifying their WCP, representing the point of entry of the scheme;
2. supporting the project developer in carbon reduction claims for labels, marketing or public authorities.

This next section presents the design of the proposed policy instrument. It elaborates on the functioning of the scheme, by indicating the targeted beneficiaries, the functioning and accreditation of the scheme, and the role of the regulatory authorities within the scheme.

12.1. Overall design of the system:



12.2. Different elements in the system:

The study now delves into the individual components of the proposed scheme, providing insights into the proposed functioning of the system, as well as the critical points that need to be addressed. Specifically, the following elements are analyzed:

1. **The wood used from sustainable managed forest;**
2. **The WCP/Beam producer;**
3. **The project developer;**
4. **The standard setting and accreditation body;**
5. **The certification party.**

12.2.1. The wood used from sustainable managed forest

As presented and argued previously in this study, there are various ways to prove the sustainable origin of wood. These different methods come with their own advantages and shortcomings. These need to be included in the scheme in order to account for the quality and sustainable dimension of the wood. Based on these and other considerations, as well as the specific findings from task 2 of this study, a four-tier system is proposed as the most comprehensive way forward. Table 4 below presents the major elements of this system:

Table 35. Four-tier system on the sustainable origin of wood

Tiers	Description	Reduction factor
Assessment of the country situation based on general reporting	Countries could be put on a "green list", guaranteeing the sustainability of their forest management.	80%
Assessment of a non-decreasing forest sink situation per country based on UNFCCC reporting	The UNFCCC reports by country provide a more accurate picture of the effect of management on the carbon balance in forests.	60%
Use of certification schemes	This option would involve the obligation to source the wood that is certified by a third-party certification scheme.	0-30%
Full accounting of the carbon effects	This option goes beyond a third party certification, and develops its estimations for carbon content, based on a well-developed type of LCA analysis.	0%

As mentioned above, the four-tier system was developed based, among others, the considerations put forward in task 2 of this study, proposing several options for the qualitative assessment of the origin of wood. Each option is associated with a reduction factor that reflects the quality of the information on the wood. Therefore, the reduction factor increases as the quality of certification quality of the wood decreases. However, given the arguments raised on the volumes of carbon saved and market-prices for that carbon, **there are doubts on whether all four tiers should be included in the system from the beginning** of its implementation. Particularly, the volumes and monetary values for tiers 1 and 2 are very limited and they increase the risk for the credibility of the system, given the reduction factors associated with them. Therefore, it is suggested to initially start with tiers 3 and 4 only, allowing the full 100% of the carbon volume reflected in the remuneration price. At a later stage, when the overall WCP volumes are developing as well as the demand for those in the market and the participation in the scheme, it can be decided to expand to the two first tiers as well.

Box 9 Advantages and disadvantages of including all four tiers

The currently envisaged system foresees the adoption of only tiers 3 and 4 to account for the certification quality of the wood, therefore the two most stringent sets of requirements. As an alternative, all four tiers could be implemented, at least initially. This option would slim down certification requirements, and hence become more attractive to a larger number of potential users of the scheme, especially at an initial stage of deployment. However, the trade-off resulting from this option on the quality of the certification, and therefore the credibility of the system as a whole, is considered too critical. For this reason, the proposed scheme puts forward the two more stringent tiers, to ensure the certification quality of the wood employed.

Furthermore, a few considerations are due concerning the **country of origin of the wood**. Several options are available to deal with wood coming from outside of the EU/EEA. The crucial aim here is balancing between **practicality**, **relevance** and **credibility** of the system. A substantial part of the imported wood is hard-wood or other tropical woods with less relevance for the production of WCP. Therefore, the relevance of non-European wood is not very large (with the exception of Russian and Ukrainian wood). Another important element is that the credibility of the labelling systems within Europe are more similar than those outside Europe. Also, the additional carbon emissions due to transport could play a role. Based on these considerations, two options are proposed for dealing with wood coming from outside the EU:

1. Weigh and select existing standards (like FSC, PEFC or other) for wood from outside the EU/EEA;
2. No wood from outside the EU/EEA is accepted in the system.

It important to bear in mind that the fourth tier, involving an individual credible accountant declaration against a certain standard, is always acceptable, thus providing enough security with regards to avoiding trade barrier issues. Overall, it is believed that the first option might bear the risk of raising strong arguments from environmental NGOs on the credibility of the system; option two has the risk of the argument of global trade distortion but we think it can be formulated in a WTO conform way. From a practical and carbon-impact point of view we would suggest the last option, however we can understand that there are political arguments for option 1 as well.

12.2.2. The producer of the WCP or Cross-Laminated Timber beam

At this point in the process, the wood[443] is transformed into a WCP or Cross-Laminated Timber beam, designed for a certain building with the aim of replacing steel or concrete in the construction design. It is thus the stage at which the carbon in the wood is stored for a

[443] In future also secondary wood could be included at this point in the system. This has not been developed in this research.

substantial period of time, as it is included in the methodology to calculate the carbon emissions avoided. **It is the beam producer who can substantiate the origin, weight, density and the type of wood used.** Although the financial renumeration for the carbon saved is limited for the project developer compared to the overall investment, it is a much more substantial contribution for a beam producer, and could therefore trigger a desired change in behaviour at this level towards sourcing from reliably sustainable sources. The estimates show that it will largely cover the administrative costs as well as potential additional remuneration, as an incentive to change the behaviour. It must be noted though that the carbon credits are originating from the storage and only for a lesser amount to the avoided GHG emissions from the production of steel and concrete and therefore it has no value without the overall calculation of the climate benefits for a certain designed building through the developed methodology. **The certification body will then give the WCP producer the right to sell a certain amount of carbon credits on the voluntary market**, based on the volumes of carbon saved, as well as the origin of the wood. The prices on the voluntary market can fluctuate but are likely to increase over time, thus increasing the benefits for the WCP producer.

12.2.3. The project developer

As elaborated earlier in this study, **it is up to the project developer to decide whether to invest in a wooden construction with climate benefits**. Certainly, other actors are involved, e.g. the architects have to design the building, the construction companies have to purchase the material and buy the wood-based construction products, but they will be working on the instructions of the future owner or project developer, so that this actor is the one to be targeted.

It has been highlighted that the benefits for the project developer are too narrow in financial terms, however, other, more interesting options have been identified based on the certified carbon removal. The options can exist in parallel or will mature over time, based on the local and national circumstances.

Marketing value

Adding extra points in labelling schemes for green buildings

As basis for tax benefits or cuts in levies

As basis for national, regional or local regulation

Concerning the **marketing value**, there is an increasing number of claims that are made on the sustainable composition of buildings. Building with wood, as seen in task 1, is gaining momentum as an attractive practice, and is already used in marketing strategies. However, these claims are often hard to sustain when challenged. Using this certification system gives the project developer a certified claim and that has a value in marketing. On the **labelling scheme option**, there is a range of green labelling schemes for buildings already in the market, both at national and international levels, many of which have been considered in Task 1.3. This system will make it possible for these schemes to have a certified value for the volume of carbon removed, which can be used to feed into a labelling system. A higher score in the labelling systems would translate into a higher value in the market for selling or renting out the building. Following the implementation of the scheme, a discussion needs to be put in place with existing labelling schemes for buildings on how best to include the certified carbon removed in these labels.

Using the scheme to feed tax benefits and incentives can be envisaged in coordination with national/local authorities that want to promote green buildings and less carbon emissions from construction materials. This would take the form of tax benefits or lower levies for permits when the certified carbon removal is proved. As far as this study has found, this does not yet exist, but there are a growing number of areas where only green buildings are allowed.

The last option probably represents the most interesting in long term as it is to set legal limits for the carbon embodied in the construction of a building, which would condition the award of a building / renovation permit. This could be a technology neutral measure (also steel or concrete are reducing their carbon emissions) with a declining percentage over time. It is suggested that this option has the most potential as it focusses entirely on the climate benefits and the goal of carbon neutral construction by 2050. It is to be seen if this can take the form of a European standard[444] or national standards.

12.2.4. The standard setting and accreditation body

This body will have to perform **several key tasks** to enable the system to function:

1. Decide on the methodology to be used to calculate the carbon emissions;
2. Decide on what is accepted as sustainable source of wood (the tier-system / labels/ countries);
3. Design accreditation criteria;
4. Accredit certification parties;
5. Promote and communicate about the label options.

The methodology developed in this project to calculate the carbon emissions could be the basis for the standardised methodology to be used in this accreditation and certification scheme. Nonetheless, it is the new standard setting body that is responsible for such a new standard, being the legal owner of the standard. This involves developing the guidelines on how to use and to perform the calculations. In this regard, it is not uncommon to use an advisory board, technical experts or scientific committee to advise the board on such matters.

Similarly, concerning the tier system, it is up to the standard setting body to weigh the advantages and disadvantages of the existing labels, the different countries of origin, the tier-system and also the acceptable individual "sustainable management" criteria as mentioned under tier 4. The standard setting body will most likely first decide on a basic set of minimum criteria for sustainable forest management that is safeguarding the carbon stock in the forest. From there the existing labels and countries can be evaluated. This must be clearly described in guidelines, which can be adapted over time. Third parties will most likely be executing the certification against the developed standards. The accreditation is the process where the accreditation body will set the standards that a certifying organization must meet.

On the level of the accreditation criteria, when requested by potential certification organizations the accreditor can allow, after thorough control, the right to certify to

[444] Included in building-related policies, including the Renovation Wave Strategy and its 2050 roadmap for reducing whole life-cycle carbon emissions in buildings, the Construction Product Regulation or the European Performance of Building Directive.

certification organizations. Most likely a monitoring and reporting obligation is included in the accreditation criteria. The organization will be responsible for the promotion activities for the overall system as well as setting standards related to how the certifiers and the users of the system are allowed to communicate on the results.

Concerning the practical question over what organization will be responsible for the system is still unsettled, though several options are available:

- An official EC institute responsible solely for this system;
- An official EC institute responsible for a set of carbon removal standards;
- A European Standardisation Body (most likely: CEN) to define the standard and the accreditation bodies in the Member States to implement it;
- An NGO type of organization/foundation with broad societal back up;
- An industrial standard organization like ISO.

At this stage we think it is too early to decide on the advantages and disadvantages of the different options as this is clearly embedded in the wider 'carbon removal' discussion within the EC.

12.2.5. The Certification Party

A certifying party is necessary to ensure the consistency and integrity of the system. However, this can take a variety of forms. A certification party can be a company or an NGO that meets the criteria as set by the accreditation body. They are only allowed to certify against the standard after being accredited. They are the ones that in the field have to fulfill the certification and who will check the calculations. Preferably, this should be constituted of a third-party certification that has the expertise and legal stance to produce such certification.

13. Conclusion and policy advice

The objective of this task was to address the uptake of wood in the construction sector, based on the climate benefits associated with wood as a construction material. The aim was to develop a policy that incentivises the use of WCP as storing GHG emissions, temporarily, but still over long durations (several decades). This was done by building on the previous findings of this study, related to the current state of the market for WCP in Europe, the current policies in place to promote their use, and the development of a solid methodology for the quantification of carbon stored in a given volume of wood. Specifically, this task's aim was to elaborate a market-based scheme to reward the use of WCP, based on the climate benefits. The scheme developed here envisages a certification scheme that rewards market actors for the volume of carbon saved through their activity. Acting on two levels, the scheme remunerates WCP producers through transferable carbon credits, and project developers by means of a labelling certificate, which in the future could be used for permitting purposes. The elaboration of this task has led to a series of conclusions regarding the effectiveness of this type of schemes in the context of the use of wood in construction, as well as its limitations.

This study points at the **limited financial benefits associated with a market-based carbon credit system with regards to wood in construction, especially in the first decade to come**. It is likely that the identified carbon saving levels are not of enough significance to prompt a major market signal to increase the uptake of WCP. Following the quantification methodology, the volumes of carbon saved are not enough to trigger, in themselves, a financial incentive in the form of tradable carbon credit, as far as project developers are targeted. This might change over time with much higher carbon prices (well over €100/ton), and as more wooden building elements are integrated in the system. While this issue has been overcome in the present scheme, it points at broader concerns with the use of such an instrument in this specific context. The announcement by the EC on the development of an ad hoc carbon market for transport and built environment could represent an opportunity to strengthen the present tool, by locating it within a wider market system, such as the EU ETS. It is suggested for this option to be further explored. Further work is encouraged that will incorporate the ongoing methodological debates in LCA research on end of life into future policy frameworks for the building sector. Looking forward to 2050 when also steel and cement are almost without emissions it is difficult to assess if a much higher carbon price would then make such a scheme more attractive.

However, it is sensitive enough to assert that the proposal for a carbon credit scheme, in light of the low volumes of carbon claims available, **should not limit the search for other regulatory frameworks**, as it was conveyed throughout this study. Indeed, a multitude of policy tools are available, with their inherent advantages and shortcomings. The choice over which to employ unfolds from one's economic and political priorities. It is even possible that both direct product regulation and renumeration are organized side by side. This study constitutes a significant first step in this direction, in a number of ways. Firstly, the methodology for the assessment of the carbon content of WCP developed here and tested is not bound to any specific policy instrument. Instead, it constitutes a versatile method that runs across policy tools. Integrating this methodology within a system of building permitting, hence requiring compliance to the scheme, is regarded as a potential option to explore.

Moreover, the previous tasks of this study informed on the several barriers, particularly with regards to building codes and regulations, as well as the unavailability of scientific / technical knowledge and of professional skills, that inhibit the development of WCP. Regardless of the market-based scheme, these barriers will persist, unless addressed by means of further integration of and harmonisation of national rules and guidelines, and of appropriate support and funding.

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15. Annexes

15.1. Annex 1: Datasets with relevant data on wood and WCPs

	Name of dataset	Species	Quality	Type of product	Economic value	Caveats
Eurostat Forestry database - Removals, production and trade	Roundwood removals by type of wood and assortment (for_remov)	Coniferous and non-coniferous	Under bark; over bark	Roundwood; industrial roundwood; sawlogs and veneer logs; pulpwood; other industrial roundwood	N/A	
	Industrial roundwood by species (for_irspec)	Coniferous and non-coniferous, as week as a few specific species.	N/A	Industrial roundwood	Data in EUR and in units of national currency	Only shows imports and exports; data not available for some countries
	Industrial roundwood by assortment (for_irass)	Three coniferous types (fir/spruce, pine, non-specified) and one non-coniferous species (birch)	N/A	Industrial roundwood split in two categories	Data in EUR and in units of national currency	Only shows imports and exports; data not available for some countries
	Sawnwood and panels (for_swpan)	Coniferous; non-coniferous; and non-coniferous tropical	N/A	Sawnwood; wood-based panels; and a variety of wood-based panels (incl. OSB, fibreboard, MDF/HDF, etc.)	N/A	Only shows imports and exports
	Sawnwood trade by species (for_swspec)	Coniferous and non-coniferous; two coniferous sub-types (fir/spruce, pine), seven non-coniferous species	N/A	Sawnwood	Data in EUR and in units of national currency	Only shows imports and exports; data incomplete for some countries
	Secondary wood products (for_secwp)	Coniferous; non-coniferous; and non-coniferous tropical	N/A	Secondary wood products of relevance: builder's joinery and carpentry of wood; prefabricated buildings (of wood)	Data in EUR	Only shows imports and exports
Eurostat Forestry database - Economics	Monetary supply and use of wood in the rough (for_emsuw)	Wood in the rough	N/A	N/A	Data in EUR for supply of forestry and logging	Data for six EU MS only; data incomplete for some countries
	Physical supply and use of wood in the rough over bark	Industrial roundwood split in coniferous, non-coniferous,	N/A	Roundwood; industrial	N/A	Data for six EU MS only; data incomplete

	Name of dataset	Species	Quality	Type of product	Economic value	Caveats
	(for_epsuw)	and non-coniferous tropical		roundwood		for some countries
	Output of forestry by type (for_eoutput)	N/A	N/A	N/A	Data in EUR	
	Economic accounts for forestry - values at current prices (for_eaf01)	Coniferous and non coniferous	N/A	Industrial timber	Production value at basic price; production value at producer price; subsidies; taxes	Latest year available is 2005; data incomplete for some countries
	Economic accounts for forestry - values at n-1 prices (for_eaf02)	Coniferous and non coniferous	N/A	Industrial timber	Production value at basic price; production value at producer price; subsidies; taxes	Latest year available is 2005; data incomplete for some countries
	Economic accounts for forestry - indices: volume, price, values (for_eaf04)	Coniferous and non coniferous	N/A	Industrial timber	Production value at basic price; production value at producer price; subsidies; taxes. Price adjustment available.	Latest year available is 2005; data incomplete for some countries
Eurostat Forestry database - Forest resources	Volume of timber over bark (for_vol_efa)	N/A	N/A	Timber over bark	Data in EUR	Data incomplete for some countries
Eurostat PRODCOM database	Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data	Coniferous and non coniferous for some products	N/A	Several products beginning with product code 16	Export value; import value; production value	Data incomplete for some countries
UNECE Statistical database	Forest resources: Forest area by forest type (Indicator 1.1b.)	Predominantly coniferous; predominantly broadleaved; mixed	N/A	N/A	N/A	Latest year available is 2010
	Forest resources: Growing stock per forest type (Indicator 1.2b.)	Predominantly coniferous; predominantly broadleaved; mixed	N/A	N/A	N/A	Latest year available is 2010
	Forest resources: Growing stock	24 species	N/A	N/A	N/A	Latest year available is

	Name of dataset	Species	Quality	Type of product	Economic value	Caveats
	composition by species (Indicator 1.2c.)					2010
	Forest resources: Age class distribution (area of even-aged stands) (Indicator 1.3a1.) and volume of even-aged stands (Indicator 1.3a2.)	Predominantly coniferous; predominantly broadleaved; mixed	Development phase: Regeneration; Intermediate; Mature, Unspecified	N/A	N/A	Latest year available is 2010
	Diameter distribution and total area (uneven-aged stands) (Indicator 1.3b.)	N/A	Volume by diameter	N/A	N/A	Latest year available is 2010; data incomplete for some countries
	Forest Health and Vitality: Forest area with damage (Indicator 2.4.)	N/A	Damage caused by: biotic agents (2 categories; human (2 caterories); abiotic agents; fire (2 categories)	N/A	N/A	Latest year available is 2010
	Productive Functions: Removals (Indicator 3.2.)	N/A	N/A	Industrial roundwood; marketed industrial roundwood	In EUR	Latest year available is 2012; data incomplete for some countries
	Socio-economic functions: Gross Added Value (Indicator 6.2.)	N/A	N/A	Forestry (ISIC/NACE 02); Manufacture of wood and articles in wood (ISIC/NACE 16); (ISIC/NACE 17)	Data in EUR; % of total GVA	Latest year available is 2010
	UNECE/FAO price series	Several species, among which Birch, Pine, Spruce, Beech, Oak, Alder	N/A	Several types of roundwood; sawnwood	In EUR or index value	Data available for a limited number of EU MS.
Forest Europe (2020) State of Europe's Forests	Reports on the main indicators from the UNECE Statistical database (including those mentioned above)	See above	See above	See above	See above	Report shows sub-regional figures for 2015 (rather than per MS)
FAO Forestry Statistics	Forestry Production and Trade	N/A	N/A	Several types of roundwood, sawnwood, wood-based panels, and	Data in USD	

	Name of dataset	Species	Quality	Type of product	Economic value	Caveats
				fibreboards.		
FAO Euroean Forest Sector Outlook 2020 (2005)	Reports on: production and consumption of raw, intermediate and processed wood products; trade; prices	Coniferous and non coniferous	N/A	Several types of roundwood, sawnwood, wood-based panels, and fibreboards.	Data in EUR	Latest year available is 2000, with projections until 2020; data aggregated at regional level (supra-national)
Forest Information System in Europe (FISE)	**Bioeconomy dataset under construction*					
JRC Bioeconomy knowledge centre	Bioeconomics database	N/A	N/A	Forestry; wood products	Data in EUR, including value added at factor cost and turnover	Generic sectoral categories.
EU greenhouse gas (GHG) inventory	Harvested Wood Products (HWP) (CRF 4G) (Gains, losses, and net CO_2 balance)	N/A	N/A	Solid wood	N/A	

15.2. Annex 2: List of main market players in the WCP value chain

Name of organisation	Category	Geographic coverage
Technical University Graz, Institut für Holzbau und Holztechnologie	10. wood schools and wood trainers/technical institutes	Austria
HS Timber Group	2. saw-mill operators 3. producers and traders of WCP	Austria, Germany, Romania
Association for the Quality of the Economic Indicators of the Construction Industry	12. expert/industry associations	Belgium
VIA University College	10. wood schools and wood trainers/technical institutes	Denmark
VTI Vinderup Træindustri	3. producers and traders of WCPs	Denmark
Build in Wood	13. other	EU
C.F. Møller Architects	4. architects and construction engineers	EU

Name of organisation	Category	Geographic coverage
Confederation of European Forest Owners (CEPF)	1. forest owners/players in the forestry sector	EU
Euroconstruct	12. expert/industry associations	EU
European Confederation of Woodworking Industries (CEI-Bois)	12. expert/industry associations	EU
European Forest Institute	12. expert/industry associations	EU
European Panel Federation	3. producers and traders of WCP	EU
European Property Federation	12. expert/industry associations	EU
KLH Massivholz GmbH	2. saw-mill operators 3. producers and traders of WCP	EU
Laboratory for Timber Constructions IBOIS	10. wood schools and wood trainers/technical institutes	EU
The European Trade Timber Federation	3. producers and traders of WCPs	EU
Timber Construction Europe	12. expert/industry associations	EU
Delete	9. demolition and recycling firms	Finland
Federation of the Finnish Woodworking Industries	3. producers and traders of WCP 6. construction firms12. expert/industry associations	Finland
Finnish Forest Industries Federation	1. forest owners/players in the forestry sector2. saw-mill operators3. producers and traders of WCP	Finland
Junnikkala	2. saw-mill operators	Finland
KK Fire Consulting	4. architects and construction engineers	Finland
Metsähallitus	1. forest owners/players in the forestry sector	Finland
Ministry of the Environment, Department of the Built Environment	13. other	Finland
Natural Resources Institute Finland (Luke)	10. wood schools and wood trainers/technical institutes	Finland
OOPEAA Office for Peripheral Architecture	4. architects and construction engineers	Finland
Westas	2. saw-mill operators	Finland
Allin	3. producers and traders of WCP	France
Compagnie de Phalsbourg; (Engie)	5. project owners (in the construction phase)	France
ÉCOLE SUPÉRIEURE DU BOIS	10. wood schools and wood trainers/technical institutes	France
Eiffage	6. construction firms	France
FCBA	10. wood schools and wood trainers/technical institutes	France
Federation Nationale du Bois	1. forest owners/players in the forestry sector2. saw-mill operators3. producers and traders of WCP	France
FIBois Ile-de-France	12. expert/industry associations	France

Name of organisation	Category	Geographic coverage
ICAWOOD	7. insurance companies, banks and creditors	France
Office national des forêts (ONF)	1. forest owners/players in the forestry sector	France
Reseau GRETA Normandie	10. wood schools and wood trainers/technical institutes	France
Bavarian State Forest Enterprise (Bayerische Staatsforsten)	1. forest owners/players in the forestry sector	Germany
best wood Schneider	3. producers and traders of WCP	Germany
Frickingen municipality	5. project owners (in the construction phase)8. long-term owners of the building (landlords)	Germany
German sawmill and wood industry	2. saw-mill operators	Germany
German Wildlife Foundation	5. project owners (in the construction phase)8. long-term owners of the building (landlords)	Germany
Holz-recycling	9. demolition and recycling firms	Germany
Main Association of the German Wood Industry	3. producers and traders of WCP 6. construction firms12. expert/industry associations	Germany
Rosenheim University of Applied Sciences	10. wood schools and wood trainers/technical institutes	Germany
National Technical University of Athens	10. wood schools and wood trainers/technical institutes	Greece
Allianz	7. insurance companies, banks and creditors	International
AREP Group	4. architects and construction engineers	International
Balfour Beatty	6. construction firms	International
Danzer	1. forest owners/players in the forestry sector2. saw-mill operators3. producers and traders of WCP	International
dRMM	4. architects and construction engineers	International
Ergodomus	4. architects and construction engineers	International
EuroChêne	2. saw-mill operators	International
European Wood Corporation	3. producers and traders of WCPs	International
Foreco	3. producers and traders of WCP 4. architects and construction engineers	International
Gruppo Mauro Saviola	9. demolition and recycling firms	International
Latvia Timber International	3. producers and traders of WCP	International
Lendlease	4. architects and construction engineers 6. construction firms	International
Mace Group	4. architects and construction engineers 6. construction firms	International
Rubner Group	2. saw-mill operators 3. producers and traders of WCP	International

Name of organisation	Category	Geographic coverage
SCA	1. forest owners/players in the forestry sector2. saw-mill operators3. producers and traders of WCP	International
Skanska	4. architects and construction engineers 6. construction firms	International
Södra	1. forest owners/players in the forestry sector2. saw-mill operators	International
Stora Enso	2. saw-mill operators 3. producers and traders of WCP11. modular building elements	International
World Green Building Council	13. other	International
General Smontaggi SpA	9. demolition and recycling firms	Italy
TU Delft, research group on Biobased Structures and Materials	10. wood schools and wood trainers/technical institutes	Netherlands
Voll Arkitekter	4. architects and construction engineers	Norway
The State Forests National Forest Holding (LASY PAŃSTWOWE)	1. forest owners/players in the forestry sector	Poland
Tree Grupa	9. demolition and recycling firms	Poland
Romsilva	1. forest owners/players in the forestry sector	Romania
Slovak University of Technology	10. wood schools and wood trainers/technical institutes	Slovakia
Slovak University of Technology	10. wood schools and wood trainers/technical institutes	Slovakia
CORWIN	4. architects and construction engineers	Slovakia, Slovenia
MAPFRE	7. insurance companies, banks and creditors	Spain
Bostadsrättföreningen Trummens Strand	8. long-term owners of the building (landlords)	Sweden
Exli	4. architects and construction engineers 6. construction firms	Sweden
HSB Stockholm	5. project owners (in the construction phase)	Sweden
Renova Group	9. demolition and recycling firms	Sweden
Sjöklint Agenturer	8. long-term owners of the building (landlords)	Sweden
Slättö Förvaltning	5. project owners (in the construction phase)	Sweden
Sveaskog	1. forest owners/players in the forestry sector	Sweden
Swedish Federation of Wood and Furniture Industry	3. producers and traders of WCP	Sweden
Swedish Forest Industries Federation	2. saw-mill operators 3. producers and traders of WCP	Sweden
Swedish Wood	2. saw-mill operators 3. producers and traders of WCP	Sweden

15.3. Annex 3: Private forests owned by individuals and families (in thousand ha).

	Private ownership (2015)	Private ownership by families (2015)	Proportion (in %)
Belgium	354	268	75.71
Bulgaria	474	418	88.19
Croatia	556	545	98.02
Czechia	626	513	81.95
Finland	15474	13099	84.65
France	12911	9925	76.87
Ireland	339	317	93.51
Lithuania	866	783	90.42
Netherlands	193.3	77.5	40.09
Poland	1686	1587	94.13
Portugal	3140	2826	90.00
Slovakia	668	206	30.84
Sweden	20635	13276	64.34

15.4. Annex 4: Employment in forestry and forest-based industry.[445]

	Forestry and logging (thousands)	Manufacture of wood and wood/cork products; and articles of straw and plaiting materials (thousands)	Overall (thousands)	Change in forestry and logging (in %)	Change in manu-facture (in %)	Total change (in %)

[445] Eurostat (2021) Employment in forestry and forest-based industry. Available here.

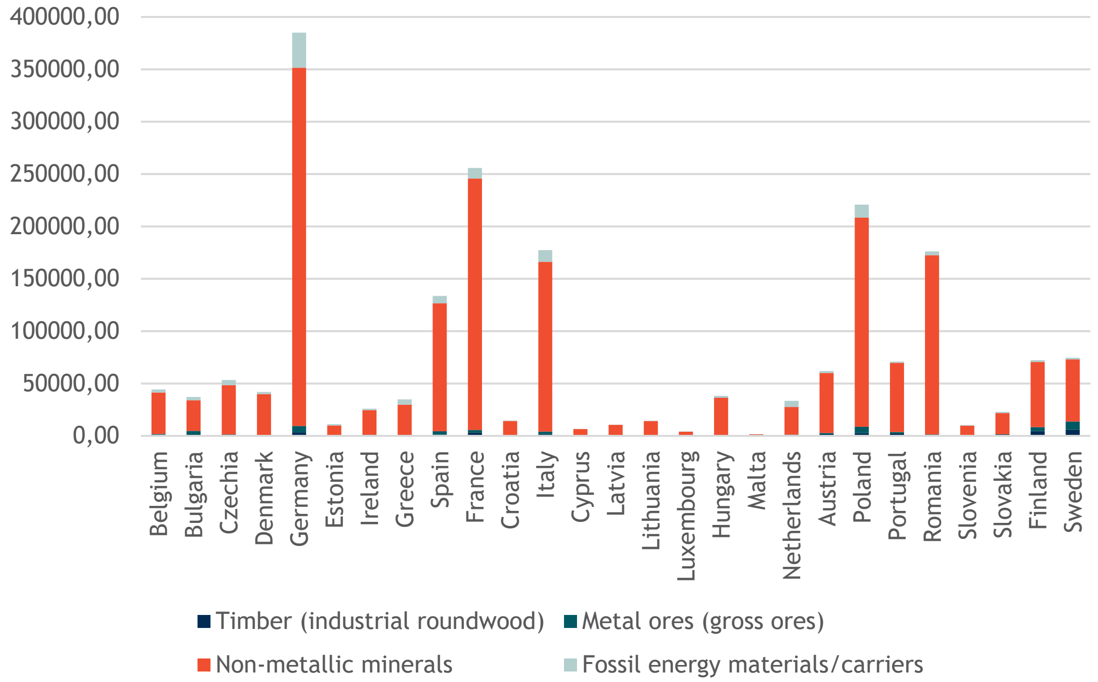
	2015	2019	2015	2019	2015	2019	2015-2019	2015-2019	2015-2019
EU 27	510.0	493.8	945.0	974.9	1,455.0	1,468.7	-3.2	3.2	0.9
Belgium	:	2.2[446]	14.1	12.5	:	14.7	:	-16.7	-14.5
Bulgaria	28.6	28.5	17.5	18.7	46.1	47.2	-0.3	6.9	2.4
Czechia	30.1	26.4	46.9	46.2	77.0	72.6	-12.3	-1.5	-5.7
Denmark	3.5	4.4	8.6	8.0	12.1	12.4	25.7	-7.0	2.5
Germany	36.5	33.1	105.0	104.1	141.5	137.2	-9.3	-0.9	-3.0
Estonia	7.4	7.0	19.3	16.8	26.7	23.8	-5.4	-13.0	-10.9
Ireland	2.0	2.4[447]	3.9	3.4	5.9	5.8	20.0	-12.8	-1.7
Greece	6.0	6.9	11.5	10.1	17.5	17.0	15.0	-12.2	-2.9
Spain	26.1	28.0	57.7	65.5	83.8	93.5	7.3	13.5	11.6
France	31.7	27.6	69.5	61.4	101.2	89.0	-12.9	-11.7	-12.1
Croatia	15.1	13.0	16.2	29.0	31.3	42.0	-13.9	79.0	34.2
Italy	50.5	51.8	105.9	114.6	156.4	166.4	2.6	8.2	6.4
Cyprus	0.8	0.9	2.2	1.4	3.0	2.3	12.5	-36.4	-23.3
Latvia	18.6	19.3	23.5	22.2	42.1	41.5	3.8	-5.5	-1.4
Lithuania	13.8	12.1	21.5	22.4	35.3	34.5	-12.3	4.2	-2.3
Hungary	25.3	20.0	22.5	27.7	47.8	47.7	-20.9	23.1	-0.2
Netherlands	:	1.8	14.5	13.8	0.0	15.6	-18.2	11.3	6.8
Austria	8.4	13.1	28.2	29.2	36.6	42.3	56.0	3.5	15.6
Poland	72.7	63.2	159.5	172.7	232.2	235.9	-13.1	8.3	1.6
Portugal	12.9	12.1	36.5	34.4	49.4	46.5	-6.2	-5.8	-5.9
Romania	51.6	58.0	80.2	72.2	131.8	130.2	12.4	-10.0	-1.2
Slovenia	4.0	3.4	7.3	9.7	11.3	13.1	-15.0	32.9	15.9
Slovakia	18.4	17.9	21.7	25.8	40.1	43.7	-2.7	18.9	9.0
Finland	21.0	21.5	21.4	19.7	42.4	41.2	2.4	-7.9	-2.8
Sweden	21.9	21.0	29.3	33.1	51.2	54.1	-4.1	13.0	5.7

[446] 2017 data

[447] 2018 data

15.5. Annex 5: Domestic material consumption by the construction sector, per MS

Domestic material consumption by the construction sector, per MS, 2010-2018 average (in thousand tonnes). Adapted from: Eurostat Material Flow Accounts (MFA) database.[448]

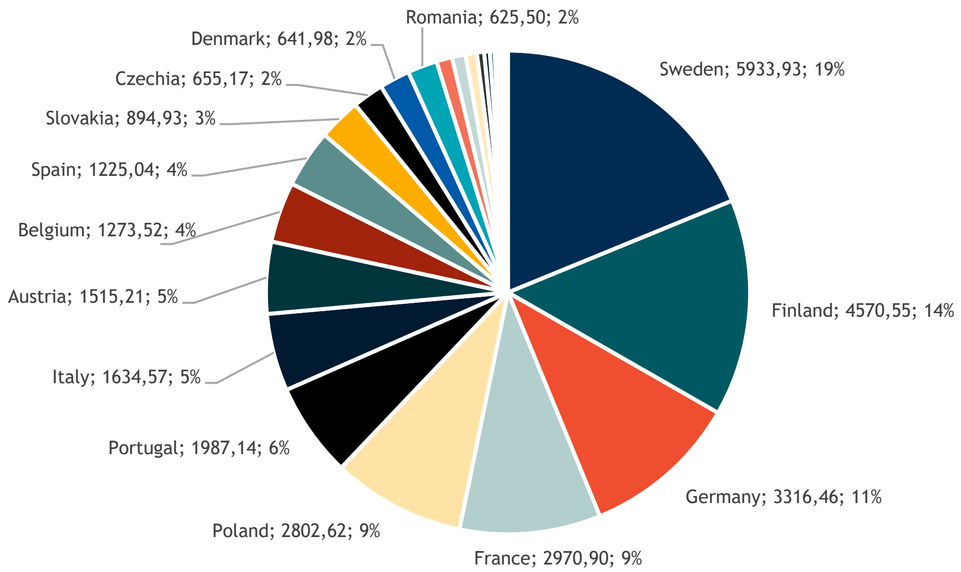


15.6. Annex 6 : Domestic material consumption of timber (industrial roundwood) in the construction sector, per MS

Domestic material consumption of timber (industrial roundwood) in the construction sector, per MS, 2010-2018 average (in % of total timber use in the construction sector across EU26 and in thousand tonnes). Adapted from: Eurostat Material flow accounts database.[449]

[448] EUROSTAT (2020) Material flow accounts. Available here.

[449] EUROSTAT (2020) Material flow accounts (env_ac_mfa). Available here.



15.7. Annex 1 Forest area, FAWS, and proportion of third party certified forests, per MS.

	Total forest area in km^2 [450]	% of forest under 3rd party certification scheme[451]	Total forest area under cert. scheme	Total forest area AWS[452]	% wood area available for supply certified
Belgium	6834.00	47.10	3218.81	6702.80	48.02
Bulgaria	38230.00	34.00	12998.20	22130.00	58.74
Czechia	26674.10	70.50	18805.24	23007.90	81.73
Denmark	6122.30	30.00	1836.69	5722.30	32.10
Germany	114190.00	78.20	89296.58	108880.00	82.01
Estonia	22319.50	65.60	14641.59	19937.50	73.44
Ireland	7540.20	56.30	4245.13	6320.10	67.17
Greece	39030.00	0.00	0.00	35946.60	0.00
Spain	184178.70	13.40	24679.95	147111.20	16.78
France	169890.00	46.80	79508.52	160180.00	49.64
Croatia	19220.00	92.00	17682.40	17400.00	101.62

[450] UNECE (2015). UNECE Statistical database - Forest area (Indicator 1.1a.). Available here.

[451] Forest Europe (2020) State of Europe's Forests. Available here.

[452] UNECE (2015). UNECE Statistical database - Forest area (Indicator 1.1a.). Available here.

	Total forest area in km² [450]	% of forest under 3rd party certification scheme[451]	Total forest area under cert. scheme	Total forest area AWS[452]	% wood area available for supply certified
Cyprus	1727.00	0.00	0.00	411.20	0.00
Italy	92970.00	9.20	8553.24	82164.70	10.41
Latvia	33560.00	N/A	N/A	31510.00	N/A
Lithuania	21800.00	51.10	11139.80	19240.00	57.90
Luxembourg	867.50	47.00	407.73	861.00	47.35
Hungary	20691.30	11.00	2276.04	17787.70	12.80
Malta	3.50	0.00	0.00	N/A	N/A
Netherlands	3760.00	47.00	1767.20	3010.00	58.71
Austria	38690.00	79.50	30758.55	33390.00	92.12
Poland	94350.00	77.00	72649.50	82340.00	88.23
Portugal	31821.00	15.30	4868.61	20881.60	23.32
Romania	68610.00	38.50	26414.85	46270.00	57.09
Slovenia	12480.00	24.00	2995.20	11390.00	26.30
Slovakia	19400.00	71.60	13890.40	17850.00	77.82
Finland	222180.00	87.40	194185.32	194650.00	99.76
Sweden	280730.00	63.00	176859.90	198321.30	89.18

15.8. Annex 2 Production, imports, exports, and total consumption of industrial roundwood, EU27 and per MS

Production, imports, exports, and total consumption of industrial roundwood, EU27 and per MS, 2018 (in m³). Adapted from: FAO Forestry Production and Trade database.[453]

Country	Production	Imports	Exports	Net trade balance	Total consumption
Austria	13,948,840	10,112,884	947,804	-9,165,080	**23,113,920**
Belgium	4,319,390	4,132,994	1,770,447	-2,362,547	**6,681,937**
Bulgaria	3,679,901	17,603	289,343	271,740	**3,408,161**

[453] FAOSTAT (2020). Forestry Production and Trade. Available here.

Country	Production	Imports	Exports	Net trade balance	Total consumption
Croatia	3,449,083	56,779	291,043	234,264	**3,214,819**
Cyprus	2,111	3,166	0	-3,166	**5,277**
Czechia	21,443,000	1,422,000	8,309,000	6,887,000	**14,556,000**
Denmark	1,781,000	652,419	536,618	-115,801	**1,896,801**
Estonia	7,353,031	270,509	2,927,493	2,656,984	**4,696,047**
Finland	60,530,434	6,935,095	1,471,881	-5,463,214	**65,993,648**
France	25,720,647	1,143,433	4,065,609	2,922,176	**22,798,471**
Germany	52,873,678	8,909,855	5,363,681	-3,546,174	**56,419,852**
Greece	455,120	27,198	8,079	-19,119	**474,239**
Hungary	3,038,027	352,622	547,040	194,418	**2,843,609**
Ireland	3,329,801	308,180	49,590	-258,590	**3,588,391**
Italy	2,523,354	3,859,704	92,504	-3,767,200	**6,290,554**
Latvia	10,742,170	1,228,879	2,651,872	1,422,993	**9,319,177**
Lithuania	5,153,000	214,994	2,028,045	1,813,051	**3,339,949**
Luxembourg	363,380	805,150	359,236	-445,914	**809,294**
Malta	0	22	0	-22	**22**
Netherlands	766,406	261,000	516,000	255,000	**511,406**
Poland	41,352,719	1,070,720	5,327,864	4,257,144	**37,095,575**
Portugal	12,767,000	2,010,074	500,218	-1,509,856	**14,276,856**
Romania	10,436,100	1,264,647	90,614	-1,174,033	**11,610,133**
Slovakia	3,921,157	992,326	2,494,376	1,502,050	**2,419,107**
Slovenia	3,951,568	347,877	2,298,236	1,950,359	**2,001,209**
Spain	15,457,140	637,608	1,578,723	941,115	**14,516,025**
Sweden	68,300,000	9,479,356	755,474	-8,723,882	**77,023,882**
Total (EU27)	**377,658,057**	**56,517,094**	**45,270,790**	**-11,246,304**	**388,904,361**

15.9. Annex 3 Total domestic material consumption of selected WCPs, per MS, latest year available (from 2015 to 2019). Adapted from Eurostat (2021)454

Wood product	Country	Consumption for latest year available (in thousand ha)	Year
Sawnwood (including sleepers)	European Union - 27 countries (from 2020)	88049.97	2019
Sawnwood (including sleepers)	Belgium	2128.14	2017
Sawnwood (including sleepers)	Bulgaria	597.66	2019
Sawnwood (including sleepers)	Czechia	1777.29	2019
Sawnwood (including sleepers)	Denmark	1728.76	2016
Sawnwood (including sleepers)	Germany	20190.31	2019
Sawnwood (including sleepers)	Estonia	2067.25	2018
Sawnwood (including sleepers)	Ireland	520.81	2018
Sawnwood (including sleepers)	Greece		
Sawnwood (including sleepers)	Spain	3863.74	2019
Sawnwood (including sleepers)	France	9105.18	2019
Sawnwood (including sleepers)	Croatia	682.8	2019
Sawnwood (including sleepers)	Italy	5091.55	2019
Sawnwood (including sleepers)	Cyprus	49.64	2019
Sawnwood (including sleepers)	Latvia	1013.74	2016
Sawnwood (including sleepers)	Lithuania	1433	2019
Sawnwood (including sleepers)	Luxembourg		
Sawnwood (including sleepers)	Hungary	1130.51	2019
Sawnwood (including sleepers)	Malta	13.57	2019
Sawnwood (including sleepers)	Netherlands	2728.6	2019
Sawnwood (including sleepers)	Austria	6285.03	2019
Sawnwood (including sleepers)	Poland	5343.75	2019
Sawnwood (including sleepers)	Portugal	1301.55	2019

[454] Eurostat (2021) Sawnwood and panels. Available here.

Wood product	Country	Consumption for latest year available (in thousand ha)	Year
Sawnwood (including sleepers)	Romania	3928.33	2019
Sawnwood (including sleepers)	Slovenia	718.77	2019
Sawnwood (including sleepers)	Slovakia	1103.46	2019
Sawnwood (including sleepers)	Finland	3016.6	2019
Sawnwood (including sleepers)	Sweden	6636.07	2019
Veneer sheets	European Union - 27 countries (from 2020)		
Veneer sheets	Belgium	59.13	2017
Veneer sheets	Bulgaria	43.85	2019
Veneer sheets	Czechia	36.56	2019
Veneer sheets	Denmark	123.06	2016
Veneer sheets	Germany (until 1990 former territory of the FRG)	145.86	2019
Veneer sheets	Estonia	138.04	2018
Veneer sheets	Ireland	4.23	2017
Veneer sheets	Greece	1041.02	2015
Veneer sheets	Spain	193.97	2019
Veneer sheets	France	166.53	2019
Veneer sheets	Croatia	20.45	2019
Veneer sheets	Italy	259.21	2019
Veneer sheets	Cyprus	0.63	2019
Veneer sheets	Latvia	121.61	2016
Veneer sheets	Lithuania	27.96	2019
Veneer sheets	Luxembourg		
Veneer sheets	Hungary	184.65	2019
Veneer sheets	Malta	0.72	2019
Veneer sheets	Netherlands	22.6	2019
Veneer sheets	Austria	46.39	2019
Veneer sheets	Poland	106.82	2019
Veneer sheets	Portugal	40.75	2019
Veneer sheets	Romania	86.15	2019

Wood product	Country	Consumption for latest year available (in thousand ha)	Year
Veneer sheets	Slovenia	8.83	2019
Veneer sheets	Slovakia	26.32	2019
Veneer sheets	Finland	-45.92	2016
Veneer sheets	Sweden	3.88	2019
Plywood	European Union - 27 countries (from 2020)		
Plywood	Belgium	154.64	2017
Plywood	Bulgaria	79.35	2019
Plywood	Czechia	150.81	2019
Plywood	Denmark	274.23	2016
Plywood	Germany (until 1990 former territory of the FRG)	1215.9	2019
Plywood	Estonia	128.26	2018
Plywood	Ireland	64.8	2017
Plywood	Greece		
Plywood	Spain	423.32	2019
Plywood	France	631.53	2019
Plywood	Croatia	36.17	2019
Plywood	Italy	557.63	2019
Plywood	Cyprus	20.88	2019
Plywood	Latvia	58.26	2016
Plywood	Lithuania	123.14	2019
Plywood	Luxembourg		
Plywood	Hungary	451.61	2019
Plywood	Malta	9.8	2019
Plywood	Netherlands	520.9	2019
Plywood	Austria	-91.67	2019
Plywood	Poland	601.53	2019
Plywood	Portugal	122.5	2019
Plywood	Romania	227.62	2019
Plywood	Slovenia	77.83	2019

Wood product	Country	Consumption for latest year available (in thousand ha)	Year
Plywood	Slovakia	394.89	2019
Plywood	Finland	289.96	2019
Plywood	Sweden	307.99	2019
Particle board, oriented strandboard (OSB) and similar board	European Union - 27 countries (from 2020)		
Particle board, oriented strandboard (OSB) and similar board	Belgium	1642.74	2017
Particle board, oriented strandboard (OSB) and similar board	Bulgaria	695.51	2019
Particle board, oriented strandboard (OSB) and similar board	Czechia	738.31	2019
Particle board, oriented strandboard (OSB) and similar board	Denmark	902.46	2016
Particle board, oriented strandboard (OSB) and similar board	Germany (until 1990 former territory of the FRG)	7280.95	2019
Particle board, oriented strandboard (OSB) and similar board	Estonia	224.76	2018
Particle board, oriented strandboard (OSB) and similar board	Ireland	-129.5	2017
Particle board, oriented strandboard (OSB) and similar board	Greece		
Particle board, oriented strandboard (OSB) and similar board	Spain	1646.17	2019
Particle board, oriented strandboard (OSB) and similar board	France	2648.14	2019
Particle board, oriented strandboard (OSB) and similar board	Croatia	222.86	2019
Particle board, oriented strandboard (OSB) and similar board	Italy	3962.94	2019
Particle board, oriented strandboard (OSB) and similar board	Cyprus	56.91	2019
Particle board, oriented strandboard (OSB) and similar board	Latvia	197.14	2016
Particle board, oriented strandboard (OSB) and similar board	Lithuania	1206.43	2019
Particle board, oriented strandboard (OSB) and similar board	Luxembourg		
Particle board, oriented strandboard (OSB) and similar board	Hungary	652.83	2018
Particle board, oriented strandboard (OSB) and similar board	Malta	9.73	2019

Wood product	Country	Consumption for latest year available (in thousand ha)	Year
Particle board, oriented strandboard (OSB) and similar board	Netherlands	489.5	2019
Particle board, oriented strandboard (OSB) and similar board	Austria	910.03	2019
Particle board, oriented strandboard (OSB) and similar board	Poland	7300.99	2019
Particle board, oriented strandboard (OSB) and similar board	Portugal	777.18	2019
Particle board, oriented strandboard (OSB) and similar board	Romania	2372.78	2019
Particle board, oriented strandboard (OSB) and similar board	Slovenia	179.67	2019
Particle board, oriented strandboard (OSB) and similar board	Slovakia	250.89	2019
Particle board, oriented strandboard (OSB) and similar board	Finland	87.6	2016
Particle board, oriented strandboard (OSB) and similar board	Sweden	1087.59	2019
Hardboard	European Union - 27 countries (from 2020)		
Hardboard	Belgium	1.77	2017
Hardboard	Bulgaria	-15.73	2016
Hardboard	Czechia	57.37	2019
Hardboard	Denmark	656.45	2016
Hardboard	Germany (until 1990 former territory of the FRG)	-940.35	
Hardboard	Estonia	27.36	2018
Hardboard	Ireland	-32.16	2017
Hardboard	Greece		
Hardboard	Spain	10.56	2019
Hardboard	France		
Hardboard	Croatia	11.53	2019
Hardboard	Italy	140.9	2018
Hardboard	Cyprus	1.29	2019
Hardboard	Latvia	13.65	2016
Hardboard	Lithuania	101.96	2019

Wood product	Country	Consumption for latest year available (in thousand ha)	Year
Hardboard	Luxembourg		
Hardboard	Hungary	354.94	2017
Hardboard	Malta	0.45	2019
Hardboard	Netherlands	54.2	2019
Hardboard	Austria	44.78	2019
Hardboard	Poland	-162.37	2019
Hardboard	Portugal	105.32	2019
Hardboard	Romania	116.92	2019
Hardboard	Slovenia	-0.44	2019
Hardboard	Slovakia	17.36	2019
Hardboard	Finland	-15.64	2016
Hardboard	Sweden	65.72	2019
Medium/high density fibreboard (MDF/HDF)	European Union - 27 countries (from 2020)		
Medium/high density fibreboard (MDF/HDF)	Belgium	221.91	2017
Medium/high density fibreboard (MDF/HDF)	Bulgaria	56.29	2016
Medium/high density fibreboard (MDF/HDF)	Czechia	43.33	2019
Medium/high density fibreboard (MDF/HDF)	Denmark	0	2016
Medium/high density fibreboard (MDF/HDF)	Germany (until 1990 former territory of the FRG)	2376.65	2019
Medium/high density fibreboard (MDF/HDF)	Estonia	18.37	2018
Medium/high density fibreboard (MDF/HDF)	Ireland	-339.35	2017
Medium/high density fibreboard (MDF/HDF)	Greece		
Medium/high density fibreboard (MDF/HDF)	Spain	1082.2	2019
Medium/high density fibreboard (MDF/HDF)	France	1304.7	2019
Medium/high density fibreboard (MDF/HDF)	Croatia	59.22	2019
Medium/high density fibreboard (MDF/HDF)	Italy	1590.15	2019
Medium/high density fibreboard (MDF/HDF)	Cyprus	13.19	2019
Medium/high density fibreboard (MDF/HDF)	Latvia	14.23	2016
Medium/high density fibreboard (MDF/HDF)	Lithuania	104.93	2019
Medium/high density fibreboard (MDF/HDF)	Luxembourg		

Wood product	Country	Consumption for latest year available (in thousand ha)	Year
Medium/high density fibreboard (MDF/HDF)	Hungary	-75.72	2019
Medium/high density fibreboard (MDF/HDF)	Malta	5.29	2019
Medium/high density fibreboard (MDF/HDF)	Netherlands	269.5	2019
Medium/high density fibreboard (MDF/HDF)	Austria	246.2	2019
Medium/high density fibreboard (MDF/HDF)	Poland	3624.85	2019
Medium/high density fibreboard (MDF/HDF)	Portugal	293.1	2019
Medium/high density fibreboard (MDF/HDF)	Romania	-296.17	2015
Medium/high density fibreboard (MDF/HDF)	Slovenia	18.15	2019
Medium/high density fibreboard (MDF/HDF)	Slovakia	93.7	2019
Medium/high density fibreboard (MDF/HDF)	Finland	120.6	2016
Medium/high density fibreboard (MDF/HDF)	Sweden	179.91	2019
Other fibreboard	European Union - 27 countries (from 2020)		
Other fibreboard	Belgium	1.37	2017
Other fibreboard	Bulgaria	4.85	2019
Other fibreboard	Czechia	34.12	2019
Other fibreboard	Denmark	111.63	2016
Other fibreboard	Germany (until 1990 former territory of the FRG)	2178.17	2019
Other fibreboard	Estonia	35.64	2018
Other fibreboard	Ireland	0	2017
Other fibreboard	Greece		
Other fibreboard	Spain	47.32	2019
Other fibreboard	France		
Other fibreboard	Croatia	4.06	2019
Other fibreboard	Italy	67.3	2018
Other fibreboard	Cyprus	2.12	2019
Other fibreboard	Latvia	0.49	2019
Other fibreboard	Lithuania	30.84	2019
Other fibreboard	Luxembourg		
Other fibreboard	Hungary	460.06	2019

Wood product	Country	Consumption for latest year available (in thousand ha)	Year
Other fibreboard	Malta	0.52	2019
Other fibreboard	Netherlands	94.75	2019
Other fibreboard	Austria	138.52	2019
Other fibreboard	Poland	266.45	2019
Other fibreboard	Portugal	-0.06	2019
Other fibreboard	Romania	16.54	2016
Other fibreboard	Slovenia	6.24	2019
Other fibreboard	Slovakia	86.74	2019
Other fibreboard	Finland	23.47	2016
Other fibreboard	Sweden	14.43	2019

15.10. Annex 4 Member States assessment of the potential of forests to increase supply of wood for construction purposes

Austria

Austria reports an increase in the felling/increment ratio from 85% in 2001-2009 to 88% in the period 2007-2018 (BFW 2019). The average felling level in 2007-2018 was 26.2 million m3 overbark, of which about 84% was conifers and 16% broadleaves. The difference between fellings and increment amounts to 3.5 million m3, of which the majority is owned by owners having less than 200 ha of forest. In general it is more difficult to reach the category small(er) owners and to convince them to harvest more. However, the felling/increment ratio in these forests has increased since the previous inventory, indicating a higher mobilisation, but no information is given on how realistic it is to expect the full amount to be mobilised.

Austria reports a tendency towards more growing stock in diameter classes >30 cm, a general tendency for an increase in the share of broadleaves (mainly beech) in the growing stock, and a disproportional increase in the share of broadleaves especially in the larger diameters. An increase in wood harvest would therefore likely consist of a larger share of broadleaves (mainly beech) in diameters classes >30 cm than is the case nowadays.

A rough estimate would be that an additional 1.8 million m3 could be harvested annually (assuming half the apparent potential cannot be mobilised due to ownership issues), consisting of 0.9 million m3 spruce and 0.9 million m3 beech (assuming beech will be more prevalent based on above observations), in diameter classes above 30 cm.

Belgium

The current felling/increment in Belgium is ratio is 99%, and thus no additional mobilisation can be expected. However, recent results suggest that the increment in at least part of Belgium seems higher than previously expected (Govaere and Leyman 2020). Until more information is available, we assume this does not constitute a real potential.

Bulgaria

Bulgaria harvests around 7 million m3 per year, while the increment is reported at about 14 million m3. We didn't find national projections, but an analysis by the Boshnakova (2017) gives an overview of the forest resources and indications for the possibility to increase harvests. About 38% of the forest area is classified as timber producing forests, while 62% is located in protective, recreational and protected territories. The expansion of the share of protected forests "has reduced the potential for more intensive timber production and made sourcing of local timber more challenging and expensive" (Boshnakova 2017). Furthermore, the road network is not very well developed, causing an unequal harvesting pressure, depending on accessibility. Harvesting is labor intensive due to the mountainous terrain and outdated equipment. Modernisation would allow at least some of these obstacles to be overcome if increased mobilisation is desired. Forest management planning foresees an annual harvest of 8.46 million m3 per year. The share of conifers in the total area has decreased from 33% to 31% in the last 15 years, but its share in the total harvest is 44%. Almost half of the harvested wood is used as fuelwood, mainly consisting of broadleaves. 75% of the broadleaves is being used as fuelwood and only 11% is used in the furniture and construction sector.

Barriers for increased mobilisation are the protection status of a large share of the forest, underdeveloped infrastructure and logging equipment and a lack of quality in especially the broadleaves. If we assume a 90% felling/increment ratio in the timber producing forests and 50% in the protected forests, a total felling/increment ratio of 65% would be achieved. This would equal an increase by 2 million m3 per year, most likely consisting of broadleaved species.

Croatia

No wood supply projections for Croatia were found. An important barrier for increased mobilisation is presumably the fact that there are many "new" forest owners after the restitution process, that have no experience with forest management. About 23% of the forest is privately owned, and many owners do not actively manage their forests (Beljan et al. 2020). Given the large share of broadleaves in the country, it is likely that any increase in harvest will consist of broadleaves.

Cyprus

Cyprus has a forest area available for wood supply of 41 thousand ha. The felling/increment ratio is currently 20%. No information is present on the likelihood of increasing this share, but at the scale of the EU the impact would be minimal.

Czech Republic

Synek et al. (2014) projected the allowable harvest level for the Czech Republic for the period 2013-2033, based on the current management plans and regulations. They found an allowable cut of 15.5 million m3 per year, which is lower than the reported felling for 2015 of 18.2 million m3. They attributed a similar difference in earlier years to incidental fellings (salvage logging). In their projections, the harvest of spruce would decrease by about 1 million m3, in favour of broadleaves. Given the current situation with an enormous amount of volume of dead spruce trees, it is likely that at short term the harvest level will be higher due to salvage logging, but at longer term lower, at the expense of spruce. We therefore assume no additional potential for Czech Republic, and apply a planned felling/increment ratio of 71% under normal conditions, based on the allowable cut level as presented.

Denmark

For Denmark no projections of future (potential) wood supply were found.

Estonia

The National Forestry and Accounting Plan for Estonia (Lesta 2019) presents three scenarios of calculation the allowable cut for the period 2021-2025. In scenario A, all stands that have reached the age or diameter limit for regeneration felling are harvested in the next 10 years. Scenario B is a business as usual scenario, seeking an optimum between the current age structure and the one in 40 years' time and a long-term uniform wood harvest. In scenario C a constant area is harvested annually. The current harvest level is 10.2 million m3. Scenario A features a harvest level of 19.8 million m3, B of 11.8 million m3 and C of 8.6 million m3 annually. Scenario A demonstrates the existence of a relatively large share of mature forests, theoretically available for harvesting. Scenario B is just below the increment of 12.3 million m3, which we take as the maximum potential. No indication is given on the feasibility of this scenario, nor on the species or size distribution of the additional harvest.

Finland

Finland has a felling/increment ratio of 80%, with the 2015 felling level at 77 million m3, and a reported increment of 96 million m3. Detailed outcomes of 4 scenarios projected with the MELA model are available from the web (http://mela2.metla.fi/mela/tupa/index-en.php). The three most interesting scenarios are the business as usual scenario, the maximum economic removal scenario and the maximum sustained yield scenario. The business as usual scenario shows a stable level of 85 million m3 drain (= fellings plus mortality) and an increment that increases from 105 million m3 in 2016-2025 to 109 million m3 in 2036-2045. The increment is higher than reported in Forest Europe (2020), possibly because Forest Europe reports net increment and the MELA model reports gross increment. The difference of Forest Europe fellings level (77 million m3) and MELA business as usual drain (85 million m3) would be explained by mortality of 8 million m3, more or less equal to the difference in increment reported by both sources (96 vs 105 million m3). The maximum economic removal scenario assumes all forests to be harvested that have reached or exceeded their optimal economic rotation at a 5% discount rate without considering sustainability considerations. In the first projection period (2016-2025) the drain is 121 million m3, which is 120% of the increment. After that it decreases to about 95 million m3, more or less equal to the increment. The maximum sustainable yield scenario uses a 4% discount rate and has the additional constraint that the removals should not decrease over time. The drain increases from 92 million in the first decade to 100 million thereafter, which is 96% of the increment. If we assume the mortality to be constant in all scenarios, we can infer that the felling level could be increased by about 15 million m3 without exceeding the 100% felling/increment ratio. No analysis is available what barriers exist to reach this level. At short term an even higher level could be achieved, but this would lead to temporary exceedance of the increment, and a lower increment level in the next decades.

France

The forest area in France currently covers 16,800,000 ha (31%) and is still expanding (Institut National de l'Information Géographique et Forestière, 2019). Broadleaved forests are most abundant, covering 67% of the total forest area (9,900,000 ha). Coniferous forests cover 21% of the total forest area, while mixed forests cover 12%. Broadleaved species account for 64% of the total volume, of which 44% is oak (Quercus spp.). Coniferous species account for 36% of the total volume, of which 43% is Norway spruce (Picea abies) or silver fir (Abies alba). Above 40 cm diameter, the volume is more or less equally distributed between conifers and broadleaves, while at lower diameters broadleaves clearly dominate.

The average felling volume per year in the period 2009-2017 was 48.0 million m3, of which 23.3 million m3 from broadleaved species and 24.7 million m3 from coniferous species. The species with the largest share in the total felled volume is maritime pine (Pinus pinaster, 6.9 million m3 yr-1).

Projections for the SIMWOOD regions Haute Loire and Vosges reveal a significant mobilisation potential for French forests. The felling rate increased from 3.2 m3 ha-1 yr-1 initially to 8.0 m3 ha-1 yr-1 averaged over the 20 year simulation period in Haute Loire (increment at 9 m3 ha-1 yr-1) and 4.5 m3 ha-1 yr-1 to 6.9 m3 ha-1 yr-1 in Grand Est (increment at 10 m3 ha-1 yr-1). However, it is unclear how much of this potential can really be mobilised. In Haute-Loire, 40% of the forest area is classified as “difficult to work in”, and 22% features estimated skidding distances of more than 500 m. In addition, a large share of the forest is located on steep slopes, and the ownership is very fragmented. Also in Vosges the forest area is very fragmented, with a mean size of 2 ha for private forest properties. Another barrier is that many soils are considered to be fragile, with limited experience in the region of mechanised logging on such sites. A lot of the unused potential is located in broadleaved forests.

Roux et al. (2017) sketch three possible scenarios for the French forest sector: 1) extensification and reduced harvesting, 2) territorial dynamics and 3) intensification and active replanting. The first scenario features a reduction in the felling/increment ratio from 50% to 42% in 2035 and 37% in 2050. The second scenario aims at a continuation of the current felling/increment ratio of 50%, while the third scenario aims to increase the felling increment ratio to 70%. The latter does not come by itself but involves major investments in the sector: “This scenario assumes an economic and political context favouring a rapid transition toward a new “bioeconomy.” Use of hardwoods is facilitated by technological innovations, investments in forestry and timber industry infrastructure, changes in consumer behaviour, training and education programs, strong public incentives for property consolidation, increased use of contracts, and simplification of planning policies.”. We assume a maximum potential ratio of 70% of the increment, of which 75% broadleaves.

Germany

Germany has about 11.5 million ha of forests (Forest Europe 2015). The standing stock is high with 336 m3 ha-1, as well as the productivity with over 11 m3 ha-1 yr-1 (Oehmichen et al. 2017). Conifers make up about 58% of the area and broadleaves 42%. As a consequence of the restorations after the Second World War, a large share of the area has an age between 40 and 80 years. The WEHAM scenario study (Oehmichen et al. 2017) shows a baseline scenario, a high wood use scenario and a nature conservation scenario. Under the baseline scenario, the removals will remain constant at about 78 million m3 yr-1, but the increment will show a decline. The growing stock increases to 364 m3 ha-1 by 2050. The wood use scenario has a removals level of 105 million m3 yr-1, which is higher than the projected increment. As a consequence, the average growing stock is projected to decrease to 289 m3 ha-1 by 2050. Under the nature conservation scenario, wood removals are comparable to the baseline scenario, but the average growing stock will increase to 374 m3 ha-1 by 2050. All scenarios show higher potential removals of oak, beech and pine compared to the realised harvesting level in the period 2003-2012. No indications are given on the likelihood of these scenarios, nor on the barriers that exist. We here assume that half of the projected increase in the wood use scenario can be realised, equally distributed over oak, beech and pine.

Greece

For Greece no projections of future (potential) wood supply were found.

Hungary

For Hungary no projections of future (potential) wood supply were found. An overview of the primary management objectives is given in Levente (2018). The share of forest dedicated to protection has increased from 23% in 2000 to 37% in 2016, with a corresponding decrease in forest with an economic purpose. The reported felling/increment ratio of 66% in 2015 corresponds rather well to the 62% of forests that have no special protection status. Although these forests are still available for wood supply, it is very likely that constraints will apply. If we assume a 90% ratio in production forests and 50% in protected forest, we get a felling level of 75% of the increment.

Table 7-36 Distribution of forest area by primary management objective (Levente 2018)

Name	2000	2016
Economic purpose	74.5	61.6
Protection purpose	23.2	37.3
Other purpose	2.3	1.1
Altogether	100.0	100.0

Ireland

Irish forests cover 11% of the total land area and are steadily expanding (Department of Agriculture, Food and the Marine, 2017). Forest area has increased from 697,842 ha in 2006 to 770,020 ha in 2017. The increase in area is a result of afforestation and the inclusion of pre-existing forests for the first time during the third NFI cycle. About half of the forest area is in public ownership and half is in private ownership. Coniferous species are dominant, representing 71.2% of the forest area, with Sitka spruce (Picea sitchensis) as main tree species (occupying 51.1% of the total forest area). Broadleaved species occupy 28.7% of the total forest area, with the species group ‘other short lived broadleaves’, which encompasses e.g. willow and hazel, as main contributor (7.9%). Birch occupied 7.0% of the total forest area.

Overall, the forests are young, with nearly half (44.9%) of the stocked forest estate less than 20 years old. Gross mean annual volume increment between 2013 and 2017 was 8.5 million m3 per year, while the mean annual standing volume felled within this period was 4.9 million m3 per year. The area thinned and clearfelled increased by 11% and 17% respectively, between 2013 and 2017. Estimates for wood harvest on the whole island of Ireland range from 3.5 million m3 (Knaggs & O’Driscoll, 2015) to 4 million m3 (Phillips et al. 2016).

In their roundwood production forecast for 2016-2035, Phillips et al. (2016) anticipate that wood production on the island will increase from 4 million m3 to close to 8 million m¬3. The main part of this mobilisation potential lies in privately-owned, grant aided forests in the Republic of Ireland. Especially the harvest volume of spruce will increase compared to other species. In terms of diameter classes, especially the harvest volume in trees with diameters >=20 cm will increase.

In the framework of the SIMWOOD project (Orazio et al., 2017), the wood mobilisation potential in the case study region South-Eastern Ireland was simulated, on a forest area of 375,000 ha. Under the baseline scenario, the fellings increased from 1.6 million m3 in the period 2013-2016 to 2.8 million m3 in 2029-2032 . A full mobilisation scenario would lead to an estimated felling level of almost 4 million m3 yr-1 in the period 2029-2032. If we scale this up to the whole island, using 770,000 ha of forest for the Republic of Ireland and 52,900 ha of forest for Northern Ireland (EFISCEN database), we have an estimate of a baseline felling level of 6.1 million m3 yr-1 in 2029-2032 and a maximum felling level of 8.6 million m3 yr-1 at full mobilisation. This is comparable to the 8 million m3 roundwood production by Philips et al. (2016), which is probably the removals from the forest, excluding harvest losses like stumps and tops. The majority of this additional potential was located in privately owned grant-aided forests, often situated such that new access roads would need to be built. This group of owners are “new” forest owners and usually have no experience with managing and harvesting forests, and it is unclear how many of them will really engage in harvesting Even under the mobilisation scenario the ratio between harvest and increment remained under 100%, due to a large share of young forests, inaccessible soils (wet peat soils) and broadleaved species that are not in demand.

Italy

Italy reports a low felling/increment ratio of 39%. No national supply or forest resource projections were identified. Pettenella et al. (no year) gives an analysis of the competitiveness of the Italian forest sector. They identify the main barriers for the development for enterprise development to be the low profitability and the attitude of the forest owners. The low profitability is connected with limitations regarding the infrastructure, and limitations by the fact that 95% of the forests are located in mountainous areas. Furthermore, the wood demand is low because many industries have been relocated outside the country. On the social side, many forest owners or managers are aged, working only part-time in their forest, and not very open for innovations or joining associations. We have no estimates how much these factors contribute to the low felling/increment ratio, how effort is needed to overcome these barriers and what would be a realistic expectation for wood mobilisation in Italy.

Latvia

Wood harvesting in Latvia recovered very quickly after the recession in 2007, with an increase of more than 40% between 2008 and 2010. The increase of the felling level was hugely debated in the media, most of all because of the use of clearcuts (Kingsbury 2011). The timber was FSC certified, but the certificate was revoked after a new inspection. Apparently this did not affect the timber sales (Kingsbury 2011). In the period 2010-2015 the harvests gradually decreased again but the last years show another increase. The felling level in 2015 was 12.8 million m3 in 2015 (Forest Europe 2020).

Latvia's NFAP presents an ”even-aged” scenario, aiming at a stable age-class structure, to be reached after two rotations. In this scenario, the harvest level would initially increase from 18 to 30 million m3, declining to about 20 million m3 after 2030. This scenario is not deemed realistic due to the expected inelasticity of demand at short term. It would also mean a felling/increment ratio of about 150% in the short term, leading to a reduction in average growing stock. However, this scenario demonstrates an unbalance in the current age class structure, and the presence of a relatively large share of mature forests. Beķeris (2016) mentions a maximum allowed felling volume for the period 2016-2020 of 23.4 million m3 per year. This is still above the current increment of 19.7 million m3. Nothing is mentioned why this maximum is not reached. However, history shows that an increase even within the limits of increment can invoke public protests. Any increase in felling level would require very good communication and very careful forest management. Here we assume that the felling level can be increased from the current 65% to 75% at maximum, mainly due to public concerns.

Lithuania

The felling level in Lithuania has increased slightly over the last two decades. Fluctuations are mainly caused by private owners reacting on price developments, while the state forest service fells more or less the same volume every year (Jurevičienė and Kulbokas 2018). According to Forest Europe (2020), the current felling/increment ratio is 70%. Brukas et al. (2011) state that the felling level could be increased from the 61% it was back then to potentially 70-80%, but that this would be inhibited by “rigid forest management planning routines, involving inflexible rotation ages and cutting norms”. Jurevičienė and Kulbokas (2018) state that the maximum felling level allowed in State Forests is 85% of the increment. Calculations by Kuliesis et al. (2011) confirm that a felling level of 83% of the gross annual increment is feasible for the state forests. This would consist of 54% conifers, 44% soft broadleaves and 2% hard broadleaves. We assume the felling level will at maximum reach 80%, both for state forests and private forests.

Luxembourg

The total increment in Luxembourg is about 0.76 million m3. The total estimated harvestable volume is estimated at 0.52 million m3, with reductions mainly caused by difficult terrain conditions and nature protection (Administration de la nature et des forêts 2020).

Malta

For Malta no projections of future (potential) wood supply were found, and no data was available in Forest Europe 2020.

Netherlands

The Netherlands has a forest area of about 370,000 ha (Schelhaas et al. 2014). In the period 1900-1960 a lot of heathlands and inland drift sands were afforested with Scots pine, while after that there was more attention towards broadleaves. As a consequence, the share of broadleaved and mixed forests has gradually increased over the past decades. The harvest level is around half the increment. A case study for the province of Gelderland (100,000 ha) (Vural Gursel et al. 2021) looked into the possibilities to increase the future supply. Due to the current diameter class structure (most volume in 30-40 cm) and the relatively low harvest level, there is a considerable theoretical potential. However, about one third of the area has nature conservation as a primary objective, with a subsidy scheme that limits harvests to 20% of the increment. It is unlikely that this area will be harvested more intensively, and current policy is to increase the nature conservation share by with 10% points. Forests managed by the large organisations and without nature conservation goals showed potential for increased harvesting, but would reach felling levels that are higher than the increment already quite quickly. The largest potential was available in the forests of the larger private owners, but this is a very heterogenous group and not all of them may be willing to harvest more. In conclusion, it is not very likely that the harvest level will increase substantially in future.

Poland

The felling/increment ratio in Poland was 75% in 2015. Fellings have been rising steadily over the years up to 2015 (Kobuszynska 2017). No projections were found, and no analysis on potential barriers for a further increase. Given the trend of the last years and a favourable age class distribution, it seems likely that the felling level can be increased further in the future. We assume a maximum ratio of 85%.

Portugal

The main species in Portugal are maritime pine, cork oak and eucalypt, together covering 75% of the forest area. Especially eucalypt is in demand for the pulp and paper industry. The pine area has decreased over the last decades due to forest fires and fighting of the pine wood nematode (Barreiro and Tomé 2017). Wood mobilisation is hampered by the fragmented ownership, a decrease in the population in rural areas, lack of interest of owners in forest management, and lack of organisation of owners (Kerr et al. 2017). No national projections were found. We assume no increase in felling level in Portugal.

Romania

In Romania, each individual management plan calculates an allowable cut, based on the current state of the forest in terms of age class distribution, rotation lengths, growth rates and management objectives (Ciceu et al. 2019). The total of these individual plans add up to the national allowable cut. In practice only 80-90% of this allowable cut is really harvested. No future supply scenarios are available because this would require a change in the way the allowable cut is calculated (Ciceu et al. 2019). In line with the distribution of species, 37% of the total fellings are from conifers. About one third of the total fellings is labelled as timber, where conifers have a share of 78% (Ciceu et al. 2019). This clearly indicates the preference of the industry for conifers, while much of the broadleaves are used for lower quality applications. If the full allowable cut would be realised, a felling/increment ratio of 53% would be reached. Dobrescu (2017) mentions poor transport infrastructure and outdated harvesting technology as obstacles for increased mobilisation of wood. A matter of concern is illegal logging, which is according to some sources even of the same size as the legal amount of fellings (Rodina and Iordachescu 2019).

Slovakia

The felling/increment ratio in Slovakia is usually in the range of 70-80%, with incidental fellings (salvage felling) the major driver of the fluctuations (Ministry, 2020), mainly caused be the European spruce bark beetle (Ips typographus). The increase in felling volume in the early years of the 21st century is attributed to the age structure, with a large proportion of stands >70 years (Ministry 2020). According to Ministry (2020), the area and volume of mature forests has now stabilised, and a reduction in the planned felling volumes are to be expected in future.

Assumptions on the level of future incidental fellings are the driver for three scenarios as published by Moravčík et al. (2009).

62% of the area is broadleaved, with the share of conifers decreasing due to a high incidence of natural disturbances.

Slovenia

The forest policy in Slovenia has for decades been aiming to increase the growing stock volume and the increment, with the optimal growing stock volume set at 300-330 m3/ha, and an expected corresponding increment of 7.2-8 m3 ha-1 yr-1 (NFAP Slovenia 2018), to be reached by 2030. This would allow for a felling level of 6-7 million m3 per year. The annual allowable cut for subsequent periods in the past was derived from this long-term objective, and was thus relatively low. For the period 2001-2010 for conifers a felling/increment ratio of 67% was applied and for broadleaves 55%, leading to an allowable felling level of about 4.2 million m3 in 2004. For the period 2011-2020 the allowable cut is set at 6.55 million m3 per year. In state forests the allowed cut was generally realised, but in privately owned forests only about two thirds of the allowable cut was really harvested. Main reasons are the fragmented ownership structure, unfavorable parcel sizes, joint ownership, many owners with just a few hectares of forest (average ownership size 2.3 ha), and owners not willing to carry out thinnings that are not cost effective. Moreover, high harvesting costs are reported, among others due to the low density of forest access roads.

Spain

Of the total land area in Spain, 37% is covered by forests (Alberdi et al., 2017). The forest area in Spain is about 18.5 million ha. Private forest owners own 70.9% of the total forest area, 29.1%. is state-owned. Broadleaved forests are most abundant, covering 46% of the total forest area (8.6 million ha). Coniferous forests cover 35% of the total forest area, mixed forests cover 19%. The most abundant broadleaved species are holm oak (Quercus ilex), followed by Pyrenean oak (Q. pyrenaica) and pubescent oak (Q. pubescens). The most abundant coniferous species is Aleppo pine (Pinus halepensis), followed by maritime pine (Pinus pinaster). Spanish forests are on average not very productive, due to warm and dry conditions in large parts of the country. Forest Europe indicates a total increment in 2010 of about 35.5 million m3 yr-1, which gives an average increment of 1.9 m3 ha-1 yr-1. The low productivity makes harvesting unattractive, which explains the rather low felling/increment ratio of 56%. Cooler and more humid regions such as along the Atlantic coast (Galicia) and in the Pyrenees have a higher productivity, and are thus more profitable for forestry. About 40-50% of the total harvested volume in Spain is produced in Galicia.

SIMWOOD projections for Catalonia confirm the general picture, with a current increment level of 2.7 m3 ha-1 yr-1, and a harvest of 0.7 m3 ha-1 yr-1. The current growing stock is 58 m3 ha-1, with the majority of the volume in diameter classes below 40 cm. Harvesting is done in cycles of 20 years, usually by means of selective cutting. A large share of the forest is privately owned and managed very extensively or not at all. In the mobilisation scenario, harvests could be increased from 1.23 million m3 yr-1 to 2 million m3 yr-1, but it remains unclear how this should be realised in an economically attractive way. We therefore assume no increase in harvesting for Spain.

Sweden

According to Forest Europe (2020), the felling/increment ratio in Sweden was 94% in 2015. Felling data for 2015-2020 indicate felling levels even a bit higher, in the range of 90-94 million m3 per year[455] , which is 95-100% of the increment. All future scenarios as presented in Ministry for the Environment and Energy (2019) show a stable harvest level for the next decade, and we conclude there is no further room of increasing the harvest level in Sweden.

15.11. Annex 5 List of organisations which participated in consultation activities

Type of stakeholder	Organisation	Contultation method	Date of consultation
Forest owner/player in the forestry sector	Södra Building Systems	Written feedback	18/12/2020
	Stora Enso	Interview and written feedback	18/01/2021; 18/12/2020
	Confederation of European Forest Owners	Interview	06/01/2021
Sawmills	Swedish Wood	Interview and written feedback	15/12/2020; 18/12/2020
	Finnish sawmills	Written feedback	18/12/2020
Producers and traders of WCPs	Svenska Cellulosa Aktiebolaget	Interview	10/12/2020
	Derome	Written feedback	18/12/2020
Architects and construction engineers	OOPEAA	Interview	16/12/2020
	KK Fire Consulting	Interview	22/12/2020
Industry associations (cross-cutting)	European Panel Federation	Interview	04/12/2020
	European Confederation of Woodworking Industries	Interview and written feedback	17/12/2020; 18/12/2020
	Centrum Hout	Written feedback	18/12/2020

455 Skogsstyrelsen Statistical database https://www.skogsstyrelsen.se/en/statistics/statistical-database/

Type of stakeholder	Organisation	Contultation method	Date of consultation
	Swedish Forest Industry Federation	Interview	16/12/2020
	Finnish Woodworking Industries Federation	Written feedback	18/12/2020
	Asfor	Written feedback	18/12/2020
	FI Bois Ile-de-France	Interview	20/01/2021
	Main Association of the German Wood Industry (Holzindustrie)	Interview	20/01/2021
	Association of the German Sawmill and Timber Industry (Säge Industrie)	Written feedback	29/01/2021
Project owners	Slättö Förvaltning	Interview	18/01/2021
Demolition and recycling firms	Renova	Interview	13/01/2021
Wood schools, technical institutes, and wood trainers	Danish Technological Institute	Interview	26/11/2020
	Institut Technologique Foret Cellulose Bois-construction Ameublement	Interview	21/12/2020
	Natural Resources Institute Finland	Interview	13/01/2021
	VIA University College	Interview	19/01/2021
Research and consultancy organisations	Research organisation (did not wish to be named)	Interview	18/01/2021
Government bodies	Finnish Ministry of Environment	Interview	21/12/2020
	French Ministry of the Ecological Transition	Interview	16/02/2021

15.12. Annex 12 – Mapping of political priorities in relevant national strategies and plans

The table below presents the mapping of political priorities regarding the use of wood in construction in national long-term strategies (LTSs) and national energy and climate plans

(NECPs), as published on the relevant European Commission websites. This scan of strategies and plans contributed to the selection of case studies for the present subtask (see Step 1a in Section 2). Countries that were selected for Step 1b have been highlighted in pink. Political priorities were assessed as follows:

- Low priority = the LTS/NECP only provides brief information on wood-based products for construction purposes;
- Medium priority = the LTS/NECP provides some information on wood-based products for construction purposes;
- High priority = the LTS/NECP provides relatively detailed information on wood-based products for construction purposes;
- N/A = wood-based construction products are not referenced in the LTS/NECP.

More information on what was found in the LTSs and NECPs is included in the comments column below.

Table 5-37 Mapping of political priorities in LTSs and NECPs

Country	LTS	NECP	Comments	Market share of wood-based construction products
Austria	Medium priority	Medium priority	One of the scenarios in the Austrian **LTS** describes the use of wood and wood products in construction, and mentions that such products will be promoted through direct support, changes in building codes and development work towards new technologies - resulting in an increased use of wood in the construction sector. Austria aims to become a technology leader in wood products and to encourage the use of bio-based materials. However, it is unclear to what extent this priority focuses on the construction sector. The **NECP** refers to wood use quite frequently, mostly in relation to the energy industry, but shows consideration for wood in construction: Creating appropriate conditions for an increase in domestic wood use for material purposes (e.g., building regulations) and for wood to be an optimal substitute for nonsustainable raw materials.	7%
Belgium	Low priority	N/A	According the Belgium's **LTS**, the country uses biomass according to the cascade principle, meaning that it allocates as much biomass as possible to the production of long-lived products (e.g., construction materials, furniture, raw material for sustainable chemicals). Belgium also aims to reduce non-energy emissions from the industrial sector by using more low-carbon materials, with an emphasis on wood and biomass. However, wood is often discussed in the context of heating and cogeneration. The **NECP** talks about the storage of carbon in wood products; it focuses on implementing timber production monitoring. No direct mention of HWPs for construction purposes.	8%
Bulgaria	Not available*	N/A		1%

Country	LTS	NECP	Comments	Market share of wood-based construction products
Croatia	Not available*	Low priority	The **NECP** indicates awareness of wood into new products, but does not directly link to construction or buildings. It also refers to renovation of buildings and a general appraoch to reaching nearly zero energy buildings. Notable mentions: "In the sector of building construction, the Republic of Croatia is strongly committed to achieving an energy-efficient and decarbonised building stock by 2050. For the purposes of mobilising all stakeholders in the process of building and renovating buildings to achieve the long-term target of reducing CO2 emissions by 80% in the building construction sector by the end of 2050, the Ministry of Construction and Physical Planning has initiated a Charter of Cooperation for the Decarbonisation of Buildings by 2050" and "Encourage the use of wood products in traditional and new products in order to increase outflows and reduce greenhouse gas emissions in the wood storage facility."	2%
Cyprus	Not available*	Low priority	The **NECP** highlights a Greece-Cyrpus collaboration, Project AYTONOM, which is described as " The project aims at the development of a common strategy between the two countries for addressing the common challenges associated with the renovation and construction of more efficient buildings. The project intends to develop a guide (template) describing all steps required for a building to convert to a Green, Intelligent and Zero Energy building". Otherwise, no specific targets are set or information provided.	1%
Czechia	Low priority	Low priority	According to its **LTS**, Czechia aims to increase its carbon sinks of greenhouse gases in the LULUCF sector by either continuing to increase the stock of wood in its forest ecosystems or increasing its production of harvested wood products (HWPs). The Ministry of Agriculture's 2030 strategy will, inter alia, be geared towards the objective of increasing the competitiveness of the forest-based value chain, creating the conditions for increased domestic use and consumption of wood and wood products. All this should lead to the greater use of wood as a renewable carbon-binding raw material and the substitution of other materials whose production is associated with high CO2 emissions. The **NECP** provides no direct mention of increasing wood-based products in the construction sector, but does higlhlight its commitment to replacing products using raw materials with high CO2 footprint, with lower emission raw materials: "The Strategy of the Ministry of Agriculture with a view to 2030 under Objective D.2 'Competitiveness of the forest management-based value chain' aims, inter alia, to: (iv) promote research and development towards better use of wood mass and explore new product opportunities with the use of wood. All this should lead to increased use of wood as a renewable carbon-binding raw material and a substitutefor other materials whose production is associated with high CO2 emissions. Reducing exports of raw wood and its processing (especially to cut timber and timber boards) in the Czech Republic will positively contribute to the Czech Republic's emission balance."	4%
Denmark	Low priority	Low priority	Denmark's **LTS** does not mention the use of wood in construction but mentions the development of sector-specific climate action plans, as well as a national strategy for sustainable construction. There is a brief acknowledgement to the benefits of HWPs in constructions, as well as their commitment to sustainable buildings, but it is not further elaborated or mentioned throughout the **NECP**: "on biomass, one stakeholder stresses that bioenergy accounts for a significant share of overall energy, but that this role could be further increased through the use of wood in construction of buildings, thereby contributing to storage of CO2" and "the climate action plans will, amongst other things, include energy efficiency measures, including energy saving requirements for public sector buldings and a national strategy for sustainable construction".	4%

Country	LTS	NECP	Comments	Market share of wood-based construction products
Estonia	Low priority	N/A	One of the objectives highlighted in the **LTS** is the use of wood (particularly domestic production and use) to increase carbon stocks in wood products and buildings, thus replacing non-renewable resources. Priority will be given to research, development and innovation, which help increase carbon sequestration and find alternative uses for wood.	2%
Finland	N/A	N/A	Although wood products play an important role in the **LTS**'s scenario-building and modelling, and great emphasis is placed on the forestry sector, there is no description of what implications this would have on the construction sector. However, responses to the OPC in support of the LTS mentioned the need to promote wood in construction and to focus on emission-reducing wood products.	16%
France	High priority	High priority	The country highlights the use of bio-based materials in construction and renovation work in its **LTS**. The latter mentions that the use of wood (obtained from forests) as a product/material is encouraged, as opposed to the use of wood as an energy source. It is expected that long-lived wood products (particularly in construction) is expected to triple between 2015 and 2050. The **NECP** shows a strong committment to wood as a low-carbon alternative resource, mobilising forests as a resource, developing end markets. The NECP features a section on Strategy implementation in the forestry and wood sector as well as the The Strategic Wood Sector Contract (2018-2022), signed by industry professionals and the Government, which is aimed at promoting the use of wood and boosting the sector's competitiveness. The Strategic Wood Sector Contract represents a building block in the implementation of a circular economy; its objectives include sustainable production, reduced raw material waste and higher rates of wood waste recycling and recovery (NECP defined Challenge 3). It also provides for the increased use of wood for construction, resulting in long-term carbon storage (NECP defined Challenge 4). Addtionally, there is the The National Biomass Mobilisation Strategy (SNMB) which aims to develop positive externalities related tothe mobilisation and de facto use of biomass, especially for the purposes of mitigating climate change, including in the construction sector.	3%
Germany	High priority	High priority	In Germany's **LTS**, avoided emissions from the production of materials and energy from wood (directly related to the raw material supplied by the forestry sector) are reflected in the energy sector, construction and housing, transport and industry and business sectors or source groups. Wood is considered a renewable raw material that can store carbon over the long term when used as a material (e.g., in the building sector) and can replace materials with more detrimental footprints. Wood should be used according to the cascading principle. The LTS mentions that the Federal Ministry of Food and Agriculture plans to develop measures to enhance the contribution made by the sustainable use of wood to achieving climate action targets. The Strategy advocates for lower barriers to the use of durable wood products (e.g., building regulations) and for more R&D to encourage the use of wood products. The **NECP** clearly highlights the committment to conservation and sustainable use of wood and timber, including in its plans the following statement: The Federal Government will therefore be funding the protection of these carbon sinks. The extreme weather of the past year has shown that the forest needs help to enable it to continue to fulfil its climate protection function. At the same time, the Federal Government will promote the sustainable and resource-efficient use of timber. This includes, for example, increased use of wood as a climate-friendly building material. Additionally, the NECP sets out committments for funding of relevant research: increased funding for research and development projects, specialist and consumer information,competitions of ideas, model / demonstration projects aiming at climate-friendly and innovative timber usage, especially in the area of building with wood, and in relation to the re-use of	3%

Country	LTS	NECP	Comments	Market share of wood-based construction products
			hardwood timber, the circular economy and cascading use. Section 3.5 furthermore focuses on "Innovation and Competitiveness" in which a chapter is dedicated to new construction techniques and materials for a low-emission industry.	
Greece	N/A	Low priority	The **LTS** only references wood in the context of energy demand/use. It also states that renovations are of higher priority than new constructions. There is a brief mentioning of interest in climate adaption in construction standards, but neither wood nor low-carbon alternative materials are discussed in the **NECP**: The necessary climate change adaptation measures include interventions aimed at the preservation of biodiversity, more efficient use of water resources, forest management, adjustment of building and infrastructure construction standards	1%
Hungary	Low priority	N/A	Hungary's LTS encourages the wood industry to improve the quality of its products and its processing capacities, with the aim to increase the use of wood products and to substitute other materials that generate more greenhouse gas emissions. Wood is considered a renewable resource.	2%
Ireland	Not available*	Medium priority	The NECP sets out promoting the increased use of domestic harvested wood in longer lived products, to enhance the storage of carbon in these products and act as a substitute for materials with a higher carbon intensity as a key measure of Ireland's plan. However, no specific targets nor elaboration on HWP in the construction sectors is avaiable.	1%
Italy	Not available*	Low priority	The NECP notes the importance of circular economy and waste in the construction sector, but does not specify wood-based product incorporation or sustainable building constructions initiatves.	3%
Latvia	Low priority	Low priority	According to the **LTS**, Latvia's forest area is expected to increase in the future. It is stated that wood resources in Latvia are obtained to produce and export various wood products (wood and wood products, wooden furniture, wooden constructions, paper and cardboardwood) and wood by-products. Latvia aims to promote the bioeconomy (e.g., by developing wood resources and encouraging the use of wood products with high added value), in pursuit of climate neutrality. The **NECP** sets a target for 2030 "Wood use volumes in construction have increased." It points out the importance of wood stored carbon in buildings that construct with timber, and supports the promotion of wood based products on a wider scale. However, there are no targets or commitments mentioned.	N/A
Lithuania	Low priority	Low priority	Lithuania's **LTS** aims to increase stored organic carbon stocks in forests and wood products and develop sustainable forestry that ensures forest productivity. The country aims to increase forest cover to 35% by 2030. The **NECP** specifically states one of the planned policy measures under the LULUCF as "Introducing additional environmental criteria for public procurement to promote the use of wood and wood articles/products in the construction sector". It also notes the potential for wood based products in being a low-carbon alternative, however no specific targets are provided nor strategic plans.	5%

Country	LTS	NECP	Comments	Market share of wood-based construction products
Luxem-bourg	Not available*	Medium priority	The **NECP** mentions increased use of wood products in the construction sector and improved cascading use of wood will prolong the CO2 storage effect, as well as implementing climate support measures in the construction sector. The move towards a sustainabel construction and circular economy in that sector specifically focuses on the use of wood-based products: "There will be continued efforts to increase timber construction. Due to its potential for cascading use, the possible regional nature and the reduced climate impact, this building material in particular has potential which should be further exploited." However, no specifics on these plans nor targets are provided.	5%
Malta	Not available*	N/A		1%
Nether-lands	Low priority	Low priority	The Dutch **LTS** states that there is significant potential to retain the CO2 captured in vegetation beyond the harvest. This could be achieved through the use of wood as a building material. In the built environment, innovation programmes will be used to allow the building sector to develop concepts and products that will enable large-scale, rapid and cheaper sustainability improvements. The **NECP** briefly mentions the use of biomass increasingly being used as an organic raw material to replace fossil raw materials in sectors such as construction. However, it does not mention a committment or targets in relation to increasing specifically HWP in the sustainable construction plans.	3%
Poland	Not available*	N/A	Although the **NECP** sets out specific targets to reduce CO2 emission in the construction sectors, those primarily relate to energy consumption and have no mention of HWP as a potential low-emission material.	4%
Portugal	Low priority	Low priority	In addition to the use of 'empty' built public spaces, passive buildings with a zero energy balance, and multifunctional and shared buildings, the Portuguese **LTS** promotes the reuse of construction components and reclaimed/recycled materials, and the use of durable and renewable materials with a smaller carbon footprint (e.g., wood and cork). The **NECP** sets out commitments to investing in innovation and research regarding woody products and their integration in the the market. In separate context it also sets out targets for promoting sustainable techniques in construction and sustainable buildings, but does not refer to wood and HWP in relation to it.	7%
Romania	Not available*	N/A		1%
Slovakia	Low priority	Low priority	As per its **LTS**, the country aims to increase the proportion of harvested wood products (HWP) used for construction purposes. However, no target is mentioned. The **NECP** recognizes that material replacement in the construction sector is required for steps towards a circular economy but makes no mention of wood or HWP as a potential alternative source of materials.	10%
Slovenia	Not available*	Low priority	The **NECP** notes an interest in raising the country's profile in relation to sustainable construction.	1%
Spain	Not available*	N/A		3%

Country	LTS	NECP	Comments	Market share of wood-based construction products
Sweden	Low priority	Low priority	The LTS mentions the uptake of wood in construction as a means to replace more climate-damaging materials. Furthermore, the housing stock is expected to increase and must be done in accordance with climate and sustainability considerations. There is also an environmental target system in place for increased resource management in the construction sector, meaning that efforts must be made to prepare for reuse, recycling and other material recovery of non-hazardous construction waste to meet the relevant EU targets. The NECP notes that an initiative to focus on building in wood and sustainable architecture and design ran from 2018-2020, indicating that the nation is already taking preliminary steps towards integrating wood in construction. However, the report does not elaborate on future targets or plans to continue the integration and expansion of HWP in the construction sector.	20%

Notes: * signals that the document was not available on the European Commission website at the time of research (i.e., November 2020). In the LTS and NECP columns, the relevant documents are linked (where available).

15.13. Annex 12 – Preliminary review of five Member States

The brief overview of policies in selected Member States (Step 1b, as indicated in Section 2) is presented below.

Table 5-38 Brief analysis of Estonia

Member State	Estonia
Forest coverage (FAO, in 2016)	51%
Timber imports (FAO, Task 1.1, in 2018)	6%
Market share of timber (Task 1.1, average 2010-2018)	2%
Key policies, strategies, and plans promoting the use and production of wood and wood-based products	• The Estonian Forest Policy focuses on sustainability in forestry management and efficient production and effective utilisation of valuable forest-based products and services • The manufacturing of wooden houses in Estonia represents a large market, with more than 8,000 wood construction companies operating in the country (90% of which are micro enterprises) • The Estonian Forestry Development Program until 2020 provides the policies to safeguard the productivity and viability of forests in the long term, focusing on industrial use combined with reforestation • To support innovation and increase in use of timber in construction, a cluster of wood construction stakeholders has been set up, bringing together the the Estonian Forest Industries Association, timber construction firms and universities to increase the competitiveness and improvements of the wood sector in construction • Estonia has an innovation strategy, but the R&D of wood-based products, and specifically in construction, are not directly mentioned
Comments on the relevance and added value of selecting the country as a case study	Almost no policies directly aimed at increasing the uptake of HWPs were found in Estonia in this first screening. Generally, it appears that policies that support green infrastructure and growth are still lacking. However, the indicated that

	the use of wood will be a means to increasing carbon stocks in buildings.

Table 5-39 Brief analysis of Finland

Member State	Finland
Forest coverage (FAO, in 2016)	73%
Timber imports (FAO, Task 1.1, in 2018)	11%
Market share of timber (Task 1.1, average 2010-2018)	16%
Key policies, strategies, and plans promoting the use and production of wood and wood-based products	• In 2011, the Government set up the Strategic Programme for the Forest Sector • Wood Building Programme (2016-2021) (joint government undertaking), which aims to increase the amount of wood used in construction • Finnish Bioeconomy Strategy, supported by the Wood Building Programme • Aid Scheme for Growth and Development from Wood, providing for projects using timber in construction • In 2011, the Government set a target of increasing the market share of wood multi-storey constructions (WMCs) from 1% to 10% by 2015 • The Government also revised the fire regulations allowing WMCs of up to 8 storeys
Comments on the relevance and added value of selecting the country as a case study	Since 2011, Finland has a target in place to increase the market share of wood buildings. It is expected that since then, more targeted policies have been developed and their implementation can be explored through interviews.

Table 5-40 Brief overview of France

Member State	France
Forest coverage (FAO, in 2016)	31%
Timber imports (FAO, Task 1.1, in 2018)	5%
Market share of timber (Task 1.1, average 2010-2018)	3%
Key policies, strategies, and plans promoting the use and production of wood and wood-based products	• The country highlights the use of bio-based materials in construction and renovation work in their LTS • Buildings in France can receive a label certifying that they have used bio-based materials in their construction (label “Bâtiment Biosourcé”) • Art. 5 of Law no. 2015-992 (17/08/2015) regarding the energy transition and green growth highlights the benefits of using bio-based materials in the building sector • The forestry sector is an important pillar of France’s industrial strategy and has its own dedicated sub-strategy called “Contrat stratégique de Filière Bois 2018/2022” • National Forest Plan (2016-2026), which emphasises the use of wood in construction • France has established an inter-ministerial action plan for the forestry sector showing support for end-use markets, innovation, and the sustainable development of the sector • Several plans are in place to facilitate the uptake of wood in construction: I

	(20019-2015), II (2014-2017), and III (post 2017)
Comments on the relevance and added value of selecting the country as a case study	Compared to other MS, France appears to have one of the most developed agendas for further promoting the use of wood in construction.

Table 5-41 Brief overview of Slovakia

Member State	Slovakia
Forest coverage (FAO, in 2016)	40%
Timber imports (FAO, Task 1.1, in 2018)	41%
Market share of timber (Task 1.1, average 2010-2018)	10%
Key policies, strategies, and plans promoting the use and production of wood and wood-based products	• LTS objective to increase the % of HWPs in construction (no specific target set) • According to CORWIN, wooden constructions are limited to 12 meters due to strict legislation • National programme of utilization of wood potential (NPUWP) • Draft amendment to the Energy Performance of Buildings Act 555/2005 (Ministry of Transport and Construction), wanting to support the construction of houses with almost zero energy consumption • Residential Fund, Construction and Restoration, earmarked for EUR 40mn • Draft decree, which should support the construction of low energy-consumption wooden houses (Ministry of Agriculture and Rural Development), earmarked for EUR 1mn • Dedicated bioeconomy strategy under development
Comments on the relevance and added value of selecting the country as a case study	Few policies directly promoting the uptake of HWPs were found in this first screening, but R&D specific to wooden constructions and technologies is dominant. However, the LTS provides insight into the future ambitions of the country.

Table 5-42 Brief overview of Portugal

Member State	Portugal
Forest coverage (FAO, in 2016)	35%
Timber imports (FAO, Task 1.1, in 2018)	14%
Market share of timber (Task 1.1, average 2010-2018)	7%
Key policies, strategies, and plans promoting the use and production of wood and wood-based products	• In its LTS, Portugal mentions the reuse of construction components and reclaimed/recycled materials, and the use of durable and renewable materials with a smaller carbon footprint (e.g., wood and cork) • Dedicated bioeconomy strategy under development • Estratégia Nacional para as Compras Públicas Ecológicas (ENCPE 2020) requires materials and products to entail the lowest possible impact throughout all stages of their life cycle

Comments on the relevance and added value of selecting the country as a case study	Almost no policies directly aimed at increasing the uptake of HWPs were found in Portugal in this first screening. However, the country is still developing its bioeconomy strategy, which may explore the use of wood in the construction sector. The LTS provides a brief indication of the country's ambition to use more durable and renewable materials in the sector.

15.14. Annex 13: Task 4: Minutes of the Workshop

List of institutions represented and partaking in the workshop:

Association of Wood Industry -Prowood Romania

Canopee

CEI-Bois

CEI-Bois

Confederation of European Forest Owners

Danish Technological Institute

denkhausbremen

DREAL AURA

EOS & CEI-Bois

EPFL

Ergodomus Timber Engineering

European Commission

European Panel Federation

European Panel Federation (EPF)

European State Forest Association (EUSTAFOR)

European Wood-based Panels Federation (EPF)

FEP - the European Federation of the Parquet industry

Fern

FIEC

Finnish Association of Construction Product Industries RTT

Finnish Wood product Industry Federation

FSC Netherlands

FSC Netherlands

FutureVistas AB / SCA

General Directorate of the State Forests

General Directorate of the State Forests in Poland

Graz University of Technology

Graz University of Technology

Greenpeace

Greenpeace

Institue for Climat Economics

Karlsruhe Institute of Technology (KIT)

Karlsruher Institut für Technologie

Ministry of the Environment of Finland

Missaglia&Associati srl

Missagliaeassociati srl

National Technical University of Athens

Natural Resources Institute Finland

OOPEAA Office for Peripheral Architecture

PEFC International

TECHNOLOGICAL INSTITUTE FCBA

Timber Construction Europe

Timberr Construction Europe

Trinomics

UEF

UEF

The team presented task 1-2 and 3 to a group of 40-45 varied stakeholders.

There was ample time for feedback and discussions.

Below the main issues raised and the answers by the team.

Concerning Task 1 scoping:

- There were some doubts expressed over results of market share analysis. What parameters have been included? Different figures are suggested for Finland (much higher, 30%, probably not only for construction). Team replied that this was result of Eurostat.
- In general, market share has been pointed out as a complex object of analysis. The values one gets depend on the parameter chosen (weight, surface, economic value…). Point made that if weight is used then it yields biased results towards concrete, being more dense. Team answered that volume was used.
- Point made on wood-based panels, which next to structural use are also used as structural elements in new buildings, not only in renovation. Team answered that the current study is focused on WCP, but that later further extension is well possible (someone even suggested pulp and paper).
- Suggestion to look into the re-orientation of wood products from e.g. energy and industry to construction sector. This however lies outside the scope of our analysis. Considering that if increased use of wood products only comes from a harvest increase (and not from a more optimized use of wood products), it will probably cause a problem in terms of carbon balance, would it be possible to include in those types of methodologies this idea of products re-orientation? For example : only value the types of products that comes from this re-direction. Team answered that this is not the current road but interesting to hold on for the future.
- Need to be more specific in explaining the reasons behind the argument of limited potential for increased harvest. Team answered that this is build up bottom up, analysing each country, thus indeed very country specific.

- The study should provide some insight in the possible market distortions created by replacing conventional materials with cross laminated timber. Team replied that this will be addressed later in policy and remuneration.
- Large potential for more woody fibre to be produced on farms - partly in an agroforestry setting. Cannot be used for CLT but can be used for insulation.
- The point was stressed that 50 years is a too short life-cycle expectancy for the currently built or forthcoming building stock. Construction of new houses is less and less common compared to renovation. Focusing on renovation of existing building stock could increase the LCA time span.

Concerning Task 2 and 3, policy and remuneration:

- There have been several reactions on the idea that there would be rules applied only to wood as a material. Instead, the suggestion is to come up with carbon neutrality rules that apply to all materials.
- It has been also pointed out that in some circumstances, wood is just not the best material for construction, all materials should be incentivized when their use is the most suitable.
- Separating wood construction products in a crediting labelling scheme risks to involve huge transaction costs and cannot be separated from the rest of the wood-based value chain and circular bioeconomy
- There are doubts over the efficacy of certification schemes as these a) exist already in abundance, and b) they are complex systems. For carbon credits to work, the calculation needs transparency and credibility; to make it work in the market it also means simplicity and low cost for the system.
- On the point of which beneficiary should be targeted by this scheme, it has been argued that also the client and the designer should be encouraged to use wood, as they are the ones deciding over which material they prefer.
- Problem of end-of-life should be better tackled in the report, not only in methodology. It should come back in task 3 and potentially lead to policy recommendations on how to address it.
- Issue of double claiming/double counting: The difficulty of separating carbon credits and the associated green claim with regard to the principles to avoid double claiming and double counting was raised. A suggestion was to include the scheme within existing compliance markets (EU ETS), so have the same monetary value instead of a monetary value and a marketing value.
- Importance of end-of-life: it will influence the value of the remuneration, as it accounts for how long the wooden material will be storing carbon. This issue needs to be included better in the report.
- The remuneration scheme should include the carbon sequestration in the forest. There are methodologies that account for this. Team answered that other instruments are being developed for this purpose.
- In general, there is an increasing need to demand LCA’s for all kinds of materials
- The scheme should avoid being too voluntary, as other voluntary schemes already exist, and would result in accumulation of certifications.

Overall there was a constructive and positive discussion. Main take aways from our side:

- Need to consider other building lifetimes than 50 years.

- Need to better address the end-of-life stage.
- Need to better avoid the risk of double claiming and double counting
- Proposals to refine the conclusions on the incentive structure of the remuneration scheme, including reasoning in terms of marginal costs
- Think of a system that does not discriminate for materials
- Balance between credibility/robustness on the one hand and cost/simplicity on the other hand
- Except for some minor comments overall good acceptance of the outcomes of all three tasks

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