ARBETSRAPPORT 1187-2024

Manual for reporting corporate impact of wood-based products on the global climate

Overview of the Climate Effect Assessment and Reporting (CLEAR) model

Peter Holmgren & Monika Strömgren

skogforsk

The CLEAR model has applied principles, parts of which are now incorporated in the ISO standard series *Wood and wood-based products – Greenhouse gas dynamics* (ISO 13391), published in April 2025. For support to future assessments and reporting, please refer to ISO 13391, parts 1 to 3.

Contents

Preface **5**

Summary **6**

Sammanfattning **8**

Introduction **10**

Purpose of this manual 10

Processes in development of the methodology 11

The climate change challenge and the forest-based sector 11

The forest-based sector and the climate change challenge 13

Model scope **13**

Principles and system boundaries 13

Components 14

Methodology - the stepwise approach **17**

Introduction to the stepwise approach 17

Preparatory work 18

Component 1: Value chain emissions 20

Component 2: Prevented emissions 21

Note on factors not included in assessing prevented emissions 23

Component 3: Forest carbon storage 25

Component 4: Carbon storage in wood-based products (HWP) 26

Reporting results 27

References **28**

Annex 1. Concepts and definitions **33**

Annex 2. Establishment of Displacement Factor for a Product Category **34**

Annex 3. Establishment of HWP Coefficients **40**

Additional material supporting assessment of the climate impact of marketed wood-based products:

This document is accompanied by the following tools:

- A Microsoft Excel book that structures and guides each step of the assessment methodology, following the stepwise guide in this document.
- A Microsoft Excel book containing a database of displacement factors collected from the literature, providing indicative factors to be applied in the assessment work.

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Preface

This report is the result of a collaborative project in 2022-2023 involving expertise from Swedish forest-based corporations (Billerud, Derome, Holmen, Norra Skog, SCA, Setra, and Södra), Skogforsk, FutureVistas AB, and the Swedish Forest Industries Federation. It builds on experiences from corporate climate effect assessments by a number of Swedish forest-based corporations since 2019.

These assessments have been presented in corporate annual reports, providing a comprehensive picture of the climate benefits from a combination of long-term management and efficient value chains that deliver renewable wood-based products. By including impacts in the forest, as well as impacts of wood-based products, a more complete picture of the circular forest-based bioeconomy emerges – an important part of the climate solutions we need.

Over the past five years, the assessment methodology has evolved and increasingly converged with existing climate reporting protocols, as well as emerging reporting standardizations. An increasing body of knowledge from science and product assessments has been incorporated in the work.

The purpose of this report is to provide an updated manual that makes the methodology transparent and accessible to forest-based corporations and other stakeholders in Sweden and beyond. We expect that wider use will lead to further improvements, both from applications in corporate reporting, as well as through new science, additional product-level data, and development of international standards. We also anticipate that efficiency improvements in the value chains for both wood products and their counterfactual products over time will necessitate continuous development and updating of the methodology and the input factors.

The manual and accompanying material is maintained and updated by Skogforsk in collaboration with forest-based corporations and other stakeholders.

Stockholm and Uppsala, May 2024

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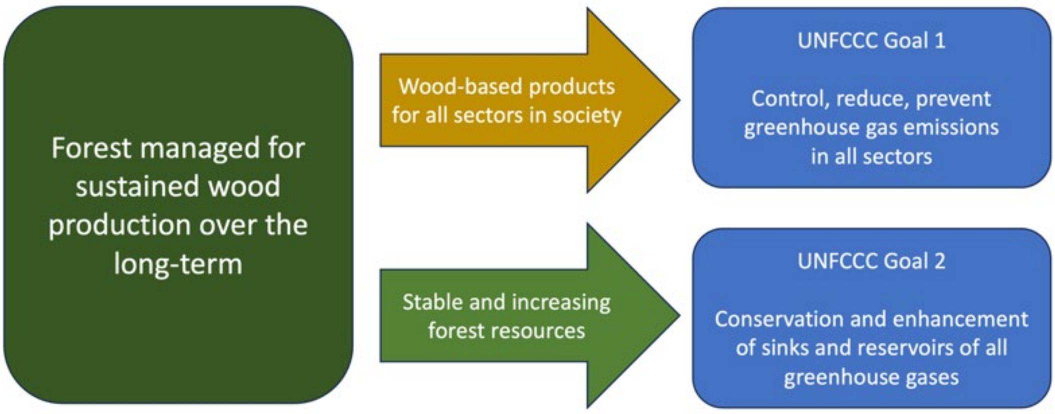
Summary

The purpose of this manual is to provide a reporting methodology for the climate effect of corporations in the forest-based sector for use in, e.g., annual financial and sustainability reports. Existing reporting methodologies, such as the IPCC Guidelines for National Greenhouse Gas Inventories and the Greenhouse Gas Protocol, give only a partial picture. They do not acknowledge that the forest-based sector contributes strongly to both principal climate change mitigation objectives stipulated by the United Nations Framework Convention on Climate Change (UNFCCC):

1. "[...] **control, reduce or prevent** anthropogenic emissions and of greenhouse gases in all relevant sectors [...]"; and
2. "[...] conservation and enhancement, as appropriate, of **sinks and reservoirs** of all greenhouse gases including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems".



The methodology comprises four components (1, 2, 3 and 4, see descriptions below). These components together provide a more complete picture of the corporation's climate effect in relation to the two principal climate change mitigation goals of the UNFCCC, as regards wood and wood-based products.

Each component builds on established methodologies/standards that each represent a long history of climate-related reporting. The novelty here is to assemble the four components into a complete climate effect assessment.

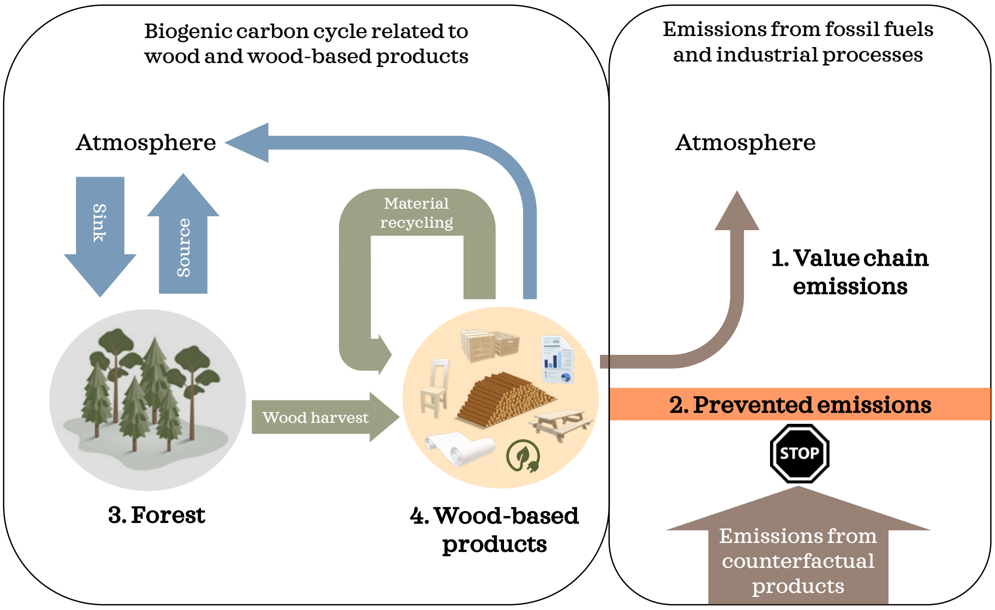
The four components are (see also figure below):

Related to the UNFCCC goal to control, reduce or prevent emissions:

1. **value chain emissions** for producing and placing wood-based products on the market, including recycling and final use; and
2. **prevented emissions** from counterfactual non-wood products, through the use of wood-based products, including final use;

Related to the UNFCCC goal to conserve and enhance sinks and reservoirs:

3. changes in **carbon stored in forests** where wood/material is sourced; and
4. changes in **carbon stored in wood-based products**.

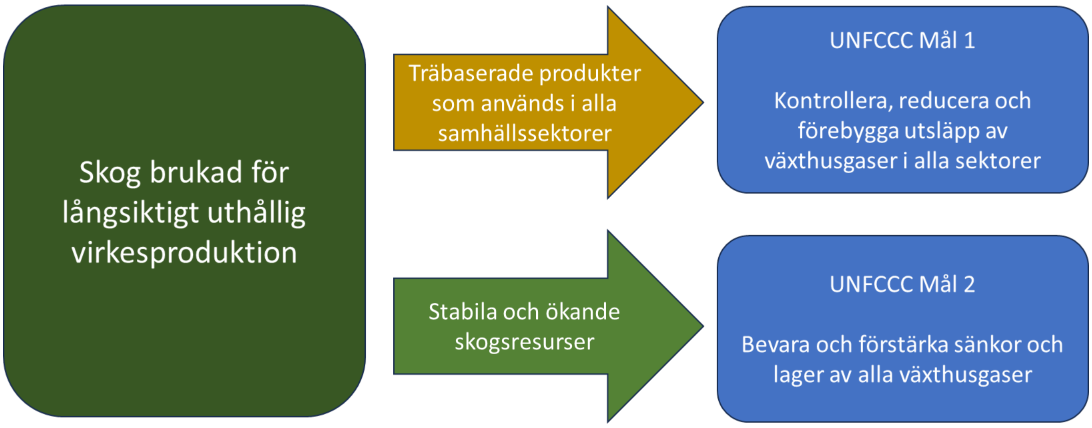


The manual provides a stepwise guide to assessments at the corporate level. Each step builds on existing and widely used standards for climate-related reporting, including the IPCC Guidelines, the Greenhouse Gas Protocol, and Life-cycle Assessments. It is complemented with an Excel sheet for calculation support, and a database of published data on displacement factors of wood-based products.

Sammanfattning

Syftet med denna manual är att tillhandahålla en metodbeskrivning för rapportering av klimateffekter orsakade av företag i skogssektorn, för att exempelvis använda i årsrapporter eller årliga hållbarhetsrapporter. Befintliga metoder, som ”IPCC Guidelines for National Greenhouse Gas Inventories” och ”Greenhouse Gas Protocol”, ger inte en helhetsbild då de inte inkluderar klimateffekter för båda de övergripande mål för minskning av människans klimatpåverkan som FN klimatkonvention (UNFCCC) lagt fast:

1. “[...] **control, reduce or prevent** anthropogenic emissions and of greenhouse gases in all relevant sectors [...]”; samt
2. “[...] conservation and enhancement, as appropriate, of **sinks and reservoirs** of all greenhouse gases including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems”.



Metoden har fyra komponenter som tillsammans ger en mer komplett bild av företagets klimateffekt vad avser trädråvara och träbaserade produkter gentemot de två övergripande målen enligt ovan.

Varje komponent bygger på etablerade metoder/standarder som var och en har använts i många år för klimatrelaterad rapportering. Nyheten här är att sammanställa komponenterna till en komplett beskrivning av klimateffekter för hela den träbaserade värdekedjan.

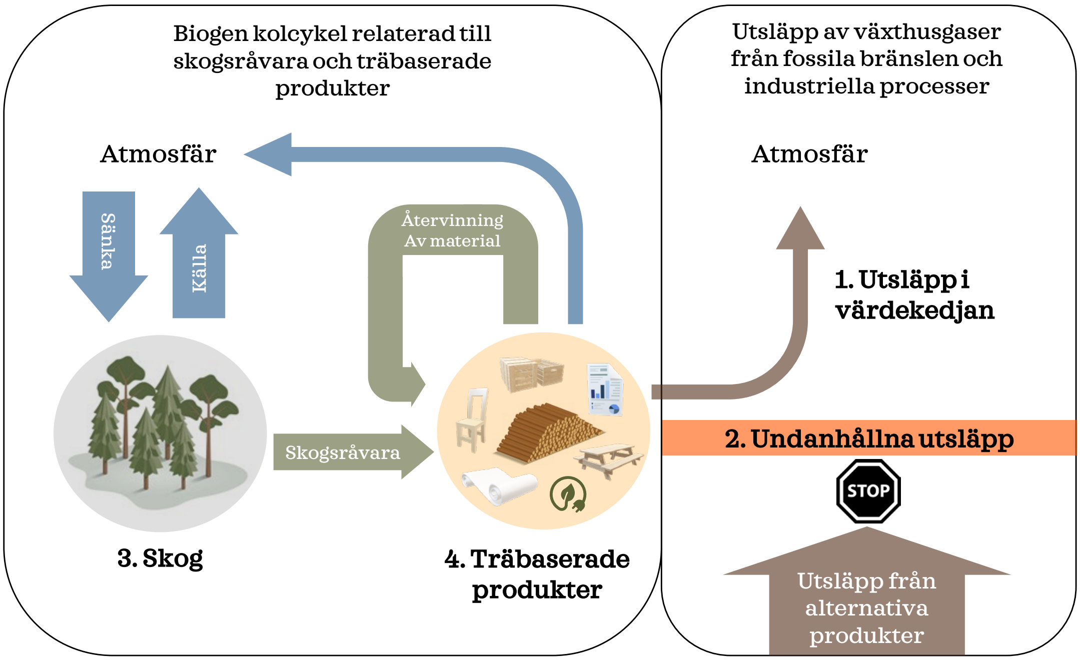
De fyra komponenterna är (se även illustration nedan):

Relaterat till UNFCCC målet att kontrollera, reducera och hålla undan utsläpp:

1. Klimatutsläpp i den **träbaserade värdekedjan**, inklusive vid återvinning och slutanvändning; och
2. **Undanhållna utsläpp** som skulle ha orsakats av kontrafaktiska produkter av fossil eller annat ursprung som skulle orsakat högre klimatutsläpp än de träbaserade;

Relaterat till UNFCCC målet att bevara och förstärka sänkor och lager (av biogent kol):

3. Förändring av **kollagret i den skog** där virke hämtats för att producera de träbaserade produkterna; och
4. Förändring av kollagret i **träbaserade produkter** som är i bruk i samhället.



Manualen innehåller en stegvis beskrivning av metoden för rapportering på företagsnivå. Varje steg bygger på befintliga och brett använda standarder för klimatrelaterad rapportering, som IPCC Guidelines, Greenhouse Gas Protocol, och metoder för livscykelanalys. Denna rapport kompletteras med en excelfil med en mall som ger stöd för beräkningarna, samt en databas med publicerade data för undanträngningsfaktorer, så kallade displacement-factors för träbaserade produkter.

Introduction

Purpose of this manual

The purpose of the manual is to provide a reporting methodology for the climate effect of corporations in the forest-based sector, for use in, e.g., annual and sustainability reports.

Climate change has emerged as one of the greatest challenges facing humanity. Numerous political initiatives have been launched, starting with the UN Framework Convention on Climate Change (UNFCCC) in 1992. While political decisions are key for initiating climate action, it is also clear that the climate challenge cannot be resolved without the contributions of corporations in the private sector, driven both by policy that regulates corporate activities and by corporation-driven business development. The Government-led initiative "Fossil-free Sweden" is an excellent example where the corporate sector is collaborating to spearhead the transition as part of their business development (Fossilfritt Sverige, 2023).

Over the past decades, climate reporting methodologies have evolved to trace emissions and facilitate actions to bring them down. One existing standard is the Greenhouse Gas Protocol, an initiative of the World Business Council on Sustainable Development and the World Resources Institute (WBCSD and WRI, 2023, p.17). The Greenhouse Gas Protocol is used by many corporations worldwide, including those in the forest-based sector. Other non-government initiatives seek to establish commitments by corporations to reduce emissions over time. Recent developments, e.g. Science-based targets (2023), also seek to include biogenic carbon in such reporting, which of course relates strongly to corporations in the forest-based sector.

Concerns are raised, however, that reporting methodologies are too generic and lack cross-sectoral impacts, so they may not address all aspects of wood-based value chains. In particular, the common beneficial climate effects of using wood-based products in other sectors are usually lacking. Such omissions mean that climate policy potentially misses out on opportunities for forest-related climate change mitigation. Corporations in the forest-based sector will not be appreciated for the full contribution they make in the climate field.

In recent years, a large number of scientific studies have brought forward the climate effect of wood-based products and the complexities arising from long and integrated value chains. Adding to the complexity, the effects of wood-based products are realized in other economic sectors, which is normally not recognized in existing climate reporting approaches. The current methodology has drawn from the emerging literature, including but not limited to the following contributions: Bentsen, 2017; Gustavsson et al., 2021; Harmon, 2019; Hurmekoski et al., 2021; Jonsson et al., 2021; Knauf et al., 2016; Leskinen et al., 2018; Leturcq, 2020; Lundmark et al., 2014; Rüter et al., 2016; Sathre and O'Connor, 2010; Skytt et al., 2021; Smyth et al., 2014; Soimakallio et al., 2021; Verkerk et al., 2022.

In addition to this manual, a database drawing from scientific and technical literature has been developed for the purpose of establishing a baseline knowledge on displacement factors under different conditions. As of December 2023, 164 references have been reviewed and data extracted.

The purpose of this manual is to provide a methodology for reporting on the climate effect of corporations in the forest-based sector, specifically for their wood-based value chains. The methodology is primarily designed for use in corporate financial and sustainability reports on an annual basis but can also be used for developing scenarios in line with business strategies. The reporting is intended to complement other sustainability reporting, noting that regulations may stipulate other forms and specifications of climate-related reporting.

Processes in development of the methodology

This manual has been developed as part of a project led by Swedish Forest Industries Federation in 2022-2023. Member corporations have participated actively, providing their own experiences and ambitions for climate action. The project builds on experiences from a number of Swedish forest-based corporations that have applied similar reporting methodologies, sometimes partial, in their annual reports (Billerud, 2022; Derome, 2023; Holmen, 2023; Norra Skog, 2023; SCA, 2023; Setra, 2023; Södra, 2023; StoraEnso, 2023; Sveaskog, 2023).

The first public reporting that used the present approach was that of SCA in its Annual and Sustainability Report for 2018. SCA has since reported their annual positive climate effect of about 10 million tons of carbon dioxide equivalents (10 Mt CO_2e) in a similar way. This first version of the methodology was described by Holmgren and Kolar (2019).

As other corporations picked up the reporting approach, new lessons were learned, and calculations refined. In a parallel process, an ISO standard is being developed that has brought in further perspectives and international considerations (International Organization for Standardization, 2024). In 2022, the Swedish Forest Industries compiled experiences gained. This manual is one of the main outputs of the project. The methodology has been developed in the English language to facilitate broader use by international corporations.

The Forestry Research Institute of Sweden (Skogforsk) is a partner in the project and the publisher of this report.

Further information about the project and methodology can be requested from

- Swedish Forest Industries at: https://www.forestindustries.se/about-us/contact-us/
- Skogforsk through email: skogforsk@skogforsk.se

The climate change challenge and the forest-based sector

The forest-based sector contributes strongly to both principal climate change mitigation objectives stipulated by the UNFCCC.

Forests and wood-based products have considerable potential for helping to address the climate change challenge and for providing fossil-free solutions to society. This is widely acknowledged in climate change assessments (IPCC, 2022) as well as climate-related policy at global, regional and national levels (European Commission, 2020, 2023a; IPCC, 2019a; Swedish Environmental Protection Agency, 2023; United Nations, 2015).

The United Nations Framework Convention on Climate Change (UNFCCC) defines two principal objectives for climate change mitigation (United Nations, 1992, Article 4.1):

1. "[...] control, reduce or prevent anthropogenic emissions and of greenhouse gases in all relevant sectors [...]"; and

2. "[...] conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems".

These dual objectives – reducing emissions and enhancing sinks – have since 1992 formed a basic structure for climate negotiations, agreements, and policy. At the global level, they feature in the Kyoto Protocol (UNFCCC, 1998, Article 3.3), and the Paris Agreement (United Nations, 2015, Articles 4.1 and 5). They provide a fundament for the European Green Deal through its Climate Law (European Union, 2021, Article 30) as well as for national climate law (e.g. Swedish Code of Statutes, 2017, Article 2.3). It is fair to say that this dichotomy has shaped climate action on all levels, often by approaching either of the two objectives in isolation.

Most policies take the dichotomy one step further by declaring that, in the future, emissions should be balanced by sinks, thereby achieving "net-zero" emissions. This appealing thought is formalized by the Paris Agreement, the EU Green Deal and national climate laws, such as in Sweden. As an example, the EU Green Deal includes a European Commission proposal that would, by 2030, "...increase the EU net removal target to -310 Mt of CO_2 equivalent, which will put the Union on track towards climate neutrality in 2050." (European Commission, 2022a). This means that emissions not eliminated under the first climate change mitigation objective are to be compensated by increased reservoirs, mostly in EU forests, under the second objective.

As a consequence, it is common that climate policies involving forests address only the second climate change mitigation objective – conserving and enhancing forest sinks and reservoirs of carbon. One example related to the EU Green Deal is the European Union regulation on Land Use, Land Use Change and Forestry (LULUCF), which aims at increasing the forest carbon stock in the European Union (European Commission, 2022b).

However, the forest-based sector also contributes strongly to the first goal by providing fossil-free and renewable material, products, and energy to all other sectors in the economy. With current reporting and policy structures, these contributions often fall between two stools. It is essential to establish a reporting model that addresses contributions to both mitigation goals – otherwise there is a risk of missing out on opportunities in mitigating climate change.

This manual provides a methodology for corporations in the forest-based sector to report the full contribution of their wood-based operations.

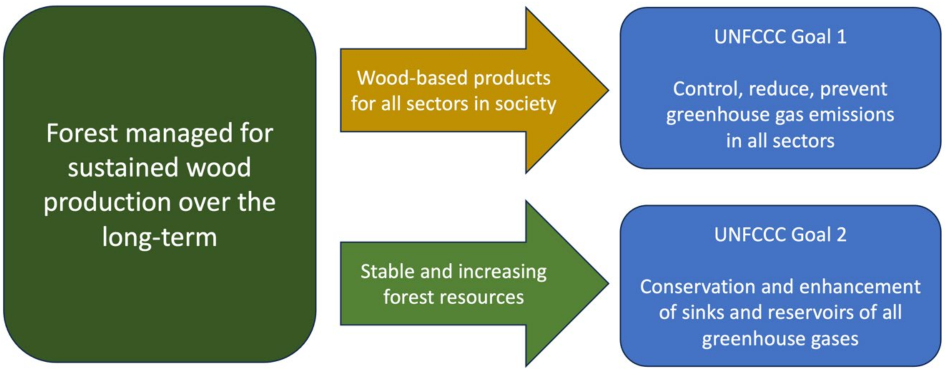


Figure 1. Managed forests can contribute to both principal goals for climate change mitigation as stipulated by the UN Framework Convention on Climate Change (UNFCCC).

The forest-based sector and the climate change challenge

Contributions to climate mitigation work is just one of many forest services that need to be balanced with other goals. For actively managed forest landscapes connected to wood-based value chains, a particularly important feature is the possibility of win-win between economic performance and climate action.

Supporting the climate change challenge is only one of many contributions of the forest-based sector. The Agenda 2030 framework makes it clear that the forest-based sector has an important role for most of 17 Sustainable Development Goals (United Nations, 2017). Climate can therefore never be a dominating objective for the forest-based sector; instead, balance needs to be sought between social, environmental, and economic dimensions.

In some instances, trade-offs between goals, for example between climate objectives and biodiversity conservation, may be identified (Verkerk et al., 2020). In other situations, win-win between objectives may be highlighted, such as between climate objectives and the economic performance of the sector (Swedish Forest Industries, 2022).

Both of these goal relationships are controversial in the policy dialogue on forests. While some argue that increased harvesting of wood reduces the climate benefits of forests (examples from the Swedish policy debate include Naturskyddsföreningen, 2023; WWF Sverige, 2023), it appears that such positions are based primarily on only one of the principal goals – conserving and enhancing sinks and reservoirs. This may be true in many situations, such as unmanaged tropical rainforests where harvesting is often a step towards deforestation. However, for actively managed forest landscapes that are connected to wood-based value-chains, it is not the complete picture (Verkerk et al., 2020).

Model scope

Principles and system boundaries

This manual provides methodology for an assessment of the overall climate effect of wood-based products achieved by a corporation under a specified time period ("the assessment").

The following principles and system boundaries apply for the assessment:

1. There is a defined time period for which the assessment is made. Normally the time period would be a specific calendar year, as the assessment would be used in the annual and sustainability reporting by a corporation. The purpose of the assessment is to calculate the climate effect within the time period. For some parameters, data that lie outside of the time frame need to be considered to facilitate the assessment.

2. The assessment is focused on the wood-based products that are put on the market by the corporation. Non-wood products or services (such as wind power or products outside of the wood-based value chain) are not included. This means that the assessment may not cover the entire business operations of the corporation.

3. All wood-based products put on the market by the corporation are included. The assessment is designed as a corporate reporting tool and does not replace

assessments of individual products or product categories. As a general rule, the set of product categories considered in the assessment should be short and reflect categories in financial or sales reports to establish a link with business operations.

4. As a rule, the interface between the corporation and the market in the assessment should be the same as for the corporation's financial reporting. This creates a clear link between the business operations and the corporate climate performance. One consequence is that joint ventures with other corporations or operations of subsidiary corporations that fall outside the financial report would also fall outside the climate effect assessment. In such cases, the assessment will include the delivery of wood-based products to such subsidiary entities.[1]

5. All forest management units where wood is sourced are included in the assessment. The corporation may choose to exclude the performance of some upstream forests, for example forests not owned by the corporation; however, such exclusions should be documented, including indications whether the upstream forest carbon reservoir can be assumed to be stable, increasing or decreasing.

6. The assessment calculates the climate effects (prevented emissions and product carbon storage) of products at the user stage, which may be after one or several refinement steps downstream from the corporation. This means that each actor along a wood-based product value chain may include the same climate effects in their assessments. As a consequence, the climate effect cannot be added along the value chain. This is a conscious approach and reflects the same considerations for upstream or downstream emissions (so-called Scope 3 emissions), which are also accounted for by several actors along the value chain.

7. In all, the assessment includes four components (see below). The assessment is complete only when all four components are included.

Components

The assessment comprises four components, each of which establishes a climate effect of a corporation that delivers wood and wood-based products. These components together provide a complete picture of the corporation's climate effect in terms of the two principal climate change mitigation goals of the UNFCCC, as regards wood and wood-based products.

Each component builds on established methodologies/standards and extensive experience of reporting. The novelty here is to assemble the four components into a more complete climate effect assessment.

The four components are:

Relating to the UNFCCC goal of controlling, reducing or preventing emissions:

1. value chain emissions for producing and placing wood-based products on the market including recycling and final use; and

[1] A special case of defining the corporate domain has been applied for Forest Owners Associations where the association is the owner of forest industries, while each individual forest owner is an independent business. In these cases, two assessments have been made, one for the collective land of forest owners (including the forest carbon balance and downstream effects of delivered wood), and one for the jointly owned industry corporation (including value chain emissions and the effects of delivered products). (Norra Skog, 2023; Södra, 2019)

2. prevented emissions from counterfactual non-wood products, through the use of wood-based products, including final use.

The difference between prevented emissions from non-wood products and value chain emissions from corresponding wood-based products is referred to as "displaced emissions".

Relating to the UNFCCC goal of conservation and enhancement of sinks and reservoirs:

3. changes of carbon stored in forests where wood/material is sourced, including biomass and soil; and

4. changes of carbon stored in wood-based products throughout the value chain, including recycling and final use.

See Figure 2 for a graphic illustration. Table 1 provides connections to established methodologies that form a base for the assessment.

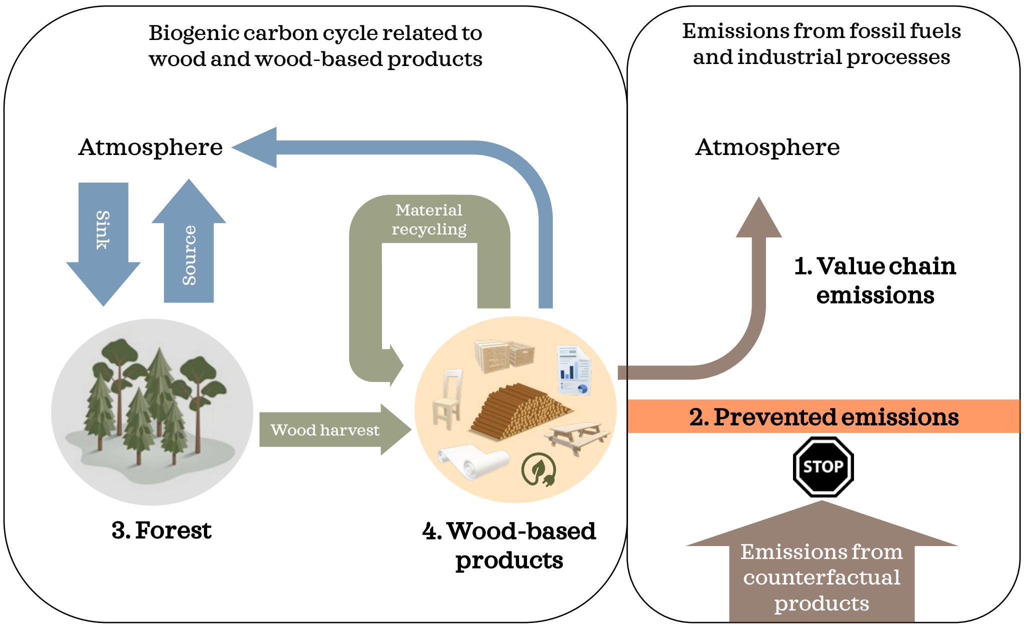


Figure 2. Illustration of the four components used in assessment of climate effect of a corporation's wood-based products. Components 1 and 2 relate to the UNFCCC goal to reduce, control and prevent GHG emissions (Article 4.1c). Components 3 and 4 reside within the biogenic carbon cycle of wood and relate to the UNFCCC goal for conservation and enhancement of sinks and reservoirs (Article 4.1d).

Table 1. The four components used in the assessment of a corporation's climate effect from wood and wood-based products

	Climate change mitigation goal (UNFCCC Article 4.1)			
	Control, reduce or prevent emissions		Conservation and enhancement of sinks and reservoirs	
Component in the assessment	Value chain emissions (1)	Prevented emissions (2)	Change of carbon stored in forest (3)	Change of carbon stored in wood-based products (4)
Main driver for assessment	Use of fossil fuels in wood-based value chain.	Types, volumes and uses of wood-based products delivered	Management of forest where wood is sourced	Types and volumes of wood-based products delivered
Key methodology applied in assessment	Greenhouse Gas Protocol	Comparative Life Cycle Assessments (LCAs)	IPCC Guidelines for National Greenhouse Gas Inventories	IPCC Guidelines for National Greenhouse Gas Inventories
Reference to methodology	World Resources Institute (2021)	International Organization for Standardization (2014)	IPCC (2019b)	IPCC (2019b)

Methodology - the stepwise approach

This section describes the method for assessing the climate impact for each of the identified four components. For each component, the background and context of the assessment is also provided.

Introduction to the stepwise approach

This section explains the assessment methodology using a stepwise approach as illustrated in Figure 3. The following sections provide details on each step. A separate Excel-based model is provided to facilitate the assessment.

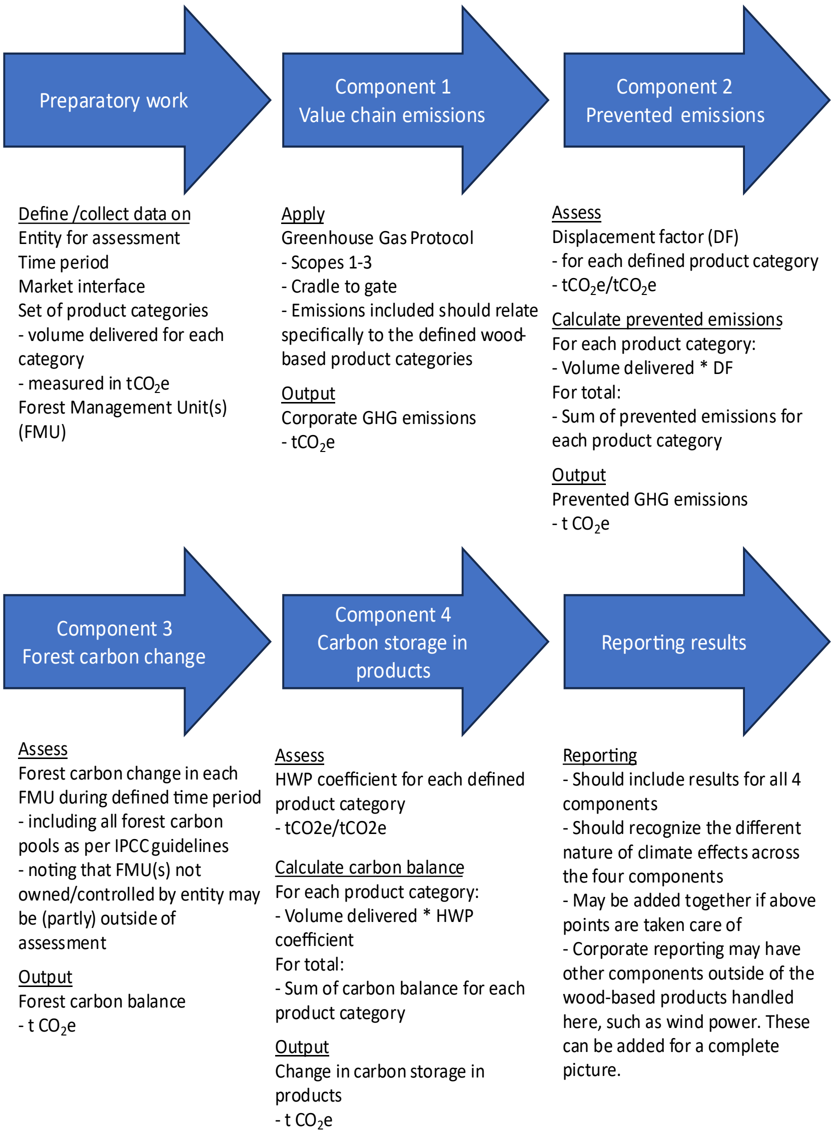


Figure 3. Overview of the stepwise assessment process. Each step is described in detail in the sections below.

Preparatory work

Preparatory work is needed to clarify the boundaries of the assessment and, to the extent possible, align the assessment with corporate financial reporting.

Before the climate impact can be assessed, the system boundary for the assessment must be set, including:

1. Identify the entity for which the assessment is made. This would normally be one corporation but can also be a set of corporations that operate jointly, but as separate legal entities. It can also be an association of forest owners where the assessment is aimed at the overall forest land owned by members.
    a) Under some circumstances, an assessment may be divided into several entities, for example one that considers the forest land owned by members of a forest owners association, and one that considers the forest industries owned by the same forest owners association. Combining these assessments requires attention to potential double-counting of, e.g., prevented emissions.
2. Identify time period for the assessment. This would normally be one year, corresponding to the period of annual financial reporting of the corporation(s). Subsequent annual assessments will then illustrate trends in the climate effect.
    a) The methodology allows for any time period to be used. If the assessment is not intended for annual reporting purposes a longer (or shorter) time period may be used.
3. Identify the market interface for the assessment. A focus of the assessment lies on the performance of wood-based products – both in terms of prevented emissions, and of carbon storage in the products. The assessment of value chain emissions is made from cradle-to-gate, which means that the end-point is delivery to customers (defined as the immediate next actors in the value chain). In other words, there are close ties between the assessment and the categories and volumes of products delivered by the entity/corporation to the market. The interface with the market is well defined in the financial accounting of the entity/corporation. The same interface should be used in the climate impact assessment, for the following reasons:
    a) It aligns the climate assessment with the financial domain of the entity/corporation.
    b) It facilitates the assessment, as data on product categories, volumes, specifications, and customer uses are already traced by the financial reporting and associated business strategies.
    c) It identifies any use of wood-based material within the entity/corporation (for example to generate heat for the pulp process or drying sawn wood) that is not part of the assessment, as this does not generate any external prevented emissions or carbon storage.
    d) It ties in with the "financial control criterion" of the GHG Protocol.

4. Identify the set of product categories that should be included in the assessment. This set should cover the full range of wood-based products put on the market by the entity/corporation. The list should preferably be short and correspond to how marketed products are reported for other purposes by the entity/corporation. The climate effect of each product category will be assessed, and the analyses may then include more details, for example on various uses of the product category by customers or customers' customers.
5. Identify the volumes delivered to the market for each product category during the specified time period. Volumes should be noted both in the unit of measure by which they are marketed, and converted to tons of carbon dioxide equivalents (t CO_2e), which is the unit applied in the assessment. Note that energy product volumes should also be converted to t CO_2e, corresponding to the biogenic material used for generating the energy.
6. Identify the forest management units (FMUs) that should be included in the assessment. These should cover all forests where wood/biomass is sourced by the entity/corporation, i.e., both forest owned by the entity/corporation and forests owned by others. Data from upstream forest owners may be difficult to obtain, yet these forests are impacted by the sourcing of wood and need to be recognized. The set of FMUs should be as short as possible without losing important variations between geographies where wood is sourced.

The above delineations of the assessment are illustrated in Figure 4.

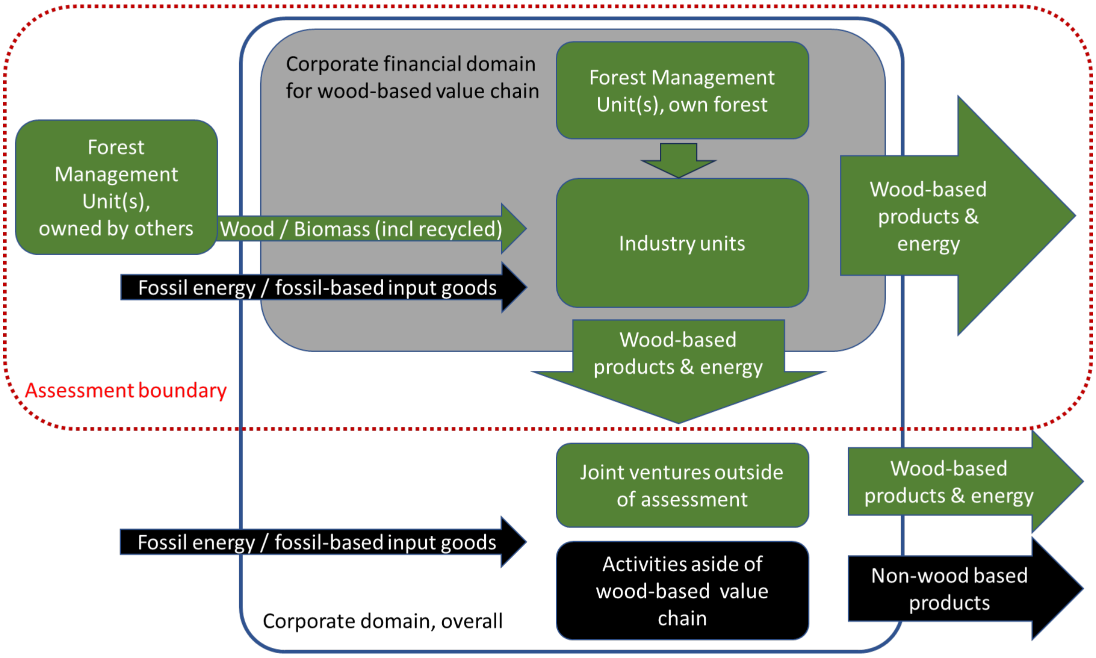


Figure 4. Illustration of the assessment boundary in relation to the assessed entity/corporation. The assessment covers the area within the dashed red line, which represents the wood-based value chain and includes upstream emissions and forest management units as well as downstream prevented emissions. The corporate domain may extend beyond the wood-based value chain: (1) through joint ventures for wood-based products that fall outside of the corporate reporting; and (2) through business activities outside of the wood-based value chain.

Component 1: Value chain emissions

Value chain emissions build on the established GHG Protocol and are assessed from cradle to gate for emissions by the entity/corporation that relate to its wood-based products.

Value chain emissions refer to the greenhouse gas (GHG) emissions from fossil fuels and industrial processes caused by the entity/corporation during the defined time period and related to the wood-based products included in the assessment. It does not include biogenic emissions, as the carbon balance of the biogenic cycle is covered by Components 3 and 4.

Value chain emissions are measured in tons of carbon dioxide emission equivalents (t CO_2e) and include a range of GHG gases, whose global warming potential is converted to CO_2 equivalents.

Many corporations already report their GHG emission using the GHG Protocol (World Resources Institute, 2021). The GHG Protocol has evolved into a standard for corporate reporting, even though it is a proprietary standard issued by two non-governmental organizations (World Resources Institute and the World Business Council on Sustainable Development).

The GHG Protocol includes review processes, but does not have the rigorous governance and decision processes of established standard organizations, such as ISO (International Organization for Standardization, 2024), or government-agreed reporting formats, such as the Corporate Sustainability Reporting Directive (European Commission, 2023b). Nevertheless, the GHG Protocol represents an established way of assessing GHG emissions, and is already used by many corporations.

Since the GHG Protocol is well documented, with many experiences of its use, this manual will not go into any details. Instead reference is made to WBCSD and WRI (2023) and supplementary documentation. The GHG Protocol is under continuous development, but the basic reporting structure of Scope 1, 2 and 3 emissions appears stable and is used in the assessment (Figure 5).

Scope 1 emissions relate to direct GHG emissions from the corporation, such as emissions caused by transporting logs from forest to industry by fossil-driven trucks, and Scope 2 emissions relate to indirect emissions, such as emissions from the purchased energy for the corporation's own use. Scope 3 emissions relate to indirect emissions caused upstream and downstream of the corporation, in particular provision of materials or services from other providers.

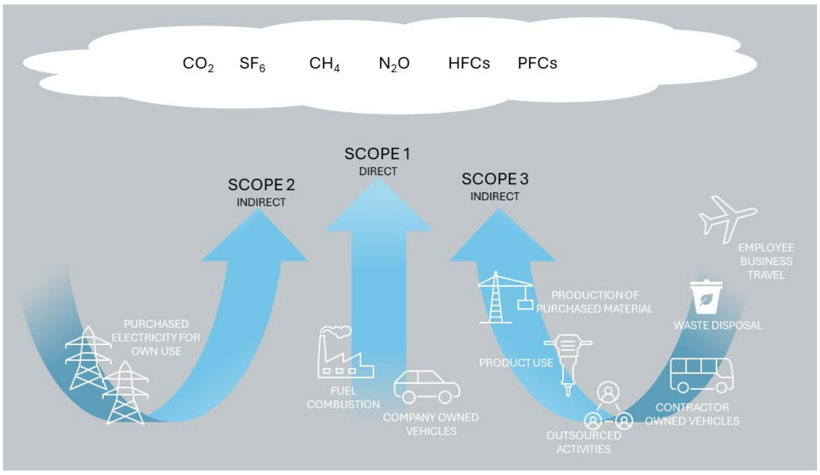


Figure 5. Illustration of Scopes 1, 2 and 3 as applied in the GHG Protocol (adopted from WBCSD and WRI, 2023, p.26).

The following aspects are considered in the assessment described in this document:

1. Only the value chain emissions related to the production and marketing of the entity's/corporation's wood-based products are included in the assessment. These emissions need to be deducted to the extent the entity/corporation has operations that do not involve production and marketing of wood-based products. In such cases it is important to recognize that the assessment is not a complete record of the corporation's climate impact.
2. For this assessment, the value chain emissions include cradle-to-gate emissions under the financial control criterion of the GHG Protocol. This includes all emissions from management and harvesting of forests (including upstream emissions by other actors), through transportation of raw material, industrial processing and transportation to the customer's gate.
3. Some entities/corporations also include downstream emissions in their GHG Protocol reporting, i.e., emissions caused in the onward value chain with customers and customers' customers, and eventually the use phase of the products. When such emissions (gate-to-grave) are included in this assessment methodology, they are handled in the prevented emissions component.

Component 2: Prevented emissions

Prevented emissions are those greenhouse gas emissions that would be caused by alternative products. Prevented emissions is a climate effect that is realized outside of the forest-based sector – in all other sectors. Conventional climate reporting guidelines such as IPCC and the GHG Protocol do not offer methodologies for such cross-sectoral effects. The assessment therefore relies on data obtained from Life Cycle Assessments and similar studies.

In many cases, the use of renewable wood material will lead to less emissions compared to alternatives that use fossil energy, steel, cement, or materials based on these. The effect is that fossil/process emissions are reduced, and this is referred to as prevented emissions. Sometimes the concept "substitution" is used synonymously, referring to the replacement of non-wood products by wood-based products. The concept "prevented emissions" is also closely related to "displacement (of emissions)", which here is understood as the net emission reduction taking into account both prevented emissions and the corporation's own value chain emissions. In the current methodology, however, prevented emissions and own value chain emissions are calculated and reported separately.

Displacement Factors (DFs) express the relative amount of emissions that are displaced or prevented. In the current methodology, prevented emissions are considered, as the corporation's own value chain emissions are reported separately. See also Annex 1 on concepts and definitions.

Wood-based products will also emit carbon dioxide both in the production process and at end-of-life. It is important to note that in the current methodology, these emissions (cradle-to-gate) are accounted for in Component 1. Prevented emissions refers to fossil/process emissions from counterfactual products. However, depending on the product and LCA methodology, the downstream balance between the wood-based value chain and the non-wood value chain may need to be considered.

Prevented emissions are assessed in tons of carbon dioxide equivalents (t CO_2e). It is important to note that the assessment results in the potential for prevented emissions, which is the aim in this methodology. Society may be more or less prepared to realize this potential, which is beyond the scope of this assessment of corporate climate performance, see more details below.

Prevented emissions (PE) by the entity/corporation during the identified time period are calculated for each identified product category and then added together. For each product category, the PE is calculated as the volume of products delivered to the market multiplied with a Displacement Factor (DF) for the product category (Equation 1)

$$(1) \quad PE = \sum_{i=1}^{n} DF_{pc}\, Q_i$$

where:

PE	Prevented emissions	t CO_2e
n	The number of product categories considered	
DF_{pc}	Displacement factor for product category *i*, including prevented emissions from first uses and prevented emissions at end-use of its material (see below)	t CO_2e/t CO_2e
Q_i	Quantity delivered to the market of product category *i*	t CO_2e

Consequently, the critical parameter for assessing displaced emissions is the Displacement Factor (DF), which needs to be assigned for each product category.

At a general level, a DF is simply defined as the quantity of emissions from fossil fuels and industrial processes that are avoided per quantity of wood-based products delivered to the market, considering the same functional unit of the alternative products (Equation 2).

$$(2) \quad DF = \frac{Emission_{non-wood} - Emission_{wood}}{WC_{wood} - WC_{non-wood}}$$

where for the same functional unit:

DF	Displacement Factor	t CO_2e/t CO_2e
$Emission_{non-wood}$	GHG emissions caused by the alternative, non-wood-based product	t CO_2e
$Emission_{wood}$	GHG emissions caused by the wood-based product. NB. For calculations under the current methodology, this is set to 0 to avoid double-counting, since value chain emissions are reported under Component 1	t CO_2e
WC_{wood}	Biogenic carbon content of the wood-based product	t CO_2e
$WC_{non-wood}$	Biogenic carbon content of the alternative, non-wood-based product (considering that also alternative, non-wood-based products can contain some wood, for example a house with a main structure of steel and concrete)	t CO_2e

Calculating the prevented emissions for an entity/corporation for the defined time period can therefore be summarized in the following steps:

1. Establish product categories and respective volume delivered to the market during the defined time period (this is part of the preparatory work above)
2. For each product category, establish a Displacement Factor and multiply by the volume delivered to the market to obtain the prevented emissions resulting from each product category.
3. Add the prevented emission for each product category to obtain the total prevented emissions by the entity/corporation for the defined time period.

However, there are several complex considerations when determining Displacement Factors. Annex 2 provides more detailed guidelines.

Note on factors not included in assessing prevented emissions

The methodology described in this document is defined around wood-based products that a corporation delivers during a defined time period. The system boundary of the assessment overall, and the calculation of prevented emissions, is therefore well defined. However, the concept of prevented emissions can be approached in different ways, and it is important to clarify some distinctions.

In the literature, a variety of system boundaries are applied when analyzing prevented emissions/displacement. To some extent these differences make it difficult to compare results across publications. One reason that discrepancies occur is that it is a cross-sectoral consideration not included in sector-oriented accounting methodologies, such as the IPCC Guidelines on National GHG Inventories.

The following considerations are sometimes included in the literature, but are beyond the scope of the current assessment methodology. In a number of cases, the referred literature likely underestimates the role of prevented emissions/displacement due to the considerations they introduce. These considerations can be important for other types of analyses, such as effects of broader climate policy interventions that go beyond the specific effects of wood-based products that are the focus of the current assessment methodology. The examples should therefore be read as additional information to the methodology provided, and illustrate how the results of assessments may be used in broader analyses.

Consideration	**Comment - Why beyond the scope of this methodology**	**Examples where consideration has been included**
Displacement factors will change over time, in particular the displacement factors of wood-based products will go down as fossil-free alternatives evolve.	Both wood-based products and fossil-based alternatives are developing over time, with current pressure to reduce impact on the climate. The effect of prevented emissions can therefore go either way over time. One example is that electricity on the European market over time reduces its climate footprint, partly due to more solar and wind power. This leads to lower displacement factors for biobased electricity. Another example is that innovation in paper-based products is rapid, with new applications replacing more fossil emissions. This leads to	(Harmon, 2019; Knauf et al., 2016; Skytt et al., 2021)

	higher displacement factors for the biobased products. This time factor is excluded from the assessment for two reasons: • The assessment concerns climate effects in a defined current time period • Available data would not be sufficiently accurate to make assessments of future displacement trends	
Prevented emissions will be less than anticipated, as more wood-based products on the market will stimulate consumption rather than reducing fossil-based alternatives.	Consumption patterns are a key concern in efforts to mitigate human climate impact. Reducing consumption is often argued as an important political focus, particularly in high-income societies. However, such considerations lie beyond the scope of this assessment of prevented emissions, which is limited to the climate impact of wood-based products compared with alternatives. An analysis of overall market-related consumer behavior would have to look broadly across product systems and product uses, and examine how these evolve over time. Results from this assessment methodology may inform such analysis, but it would be beyond the scope to evaluate how marginal additions of specific wood-based products would impact consumption patterns.	(Leturcq, 2020)
Prevented emissions should only be calculated for additional product volumes put on the market, not the volumes already on the market.	The methodology offered here attempts to quantify what the counterfactual fossil/process emissions would be if the quantities of wood-based products delivered by a corporation were not available and instead replaced by products based on other materials. This means that the entire volume delivered by the entity/corporation is considered. In other analysis situations, the question may be directed towards developments on the margin if product volumes were to change. These questions are both valid given the scope of each analysis. Comparing assessments over time for the same corporation(s) may be useful in this context.	(IPCC, 2022; JRC, 2021)
Prevented emissions that occur in the future should be discounted	The methodology offered here is for assessing the climate effect in a defined time period. The first use of the products is considered to fall within the defined time period. For final use energy recovery, only recovered material within the time period is considered. This recovery will be from products delivered at an earlier point in time. The logic applied for energy recovery is that recovery is made from a pool of existing products, which is the same logic as applied for carbon storage in wood products (HWP, Component 4).	(Skytt et al., 2021)

Component 3: Forest carbon storage

The carbon balance in the forest is assessed using the framework of IPCC Guidelines for National Greenhouse Gas Inventories. All forest area from which wood is sourced is included in the assessment.

The assessment includes the carbon balance of forests where wood is sourced by the entity/corporation. Carbon balance considers both the change of overall carbon stock in the forest and any emissions of N_2O and CH_4 from the beginning to the end of the defined time period.

Change in the carbon stock in the forest is assessed in tons of carbon dioxide equivalents (t CO_2e).

The first step is to identify the set of Forest Management Units (FMUs) to be included in the assessment. This was described as part of the preparatory work of the assessment (see above).

For FMUs owned by the entity/corporation, the complete carbon balance should be included in the assessment. For FMUs owned by others the assessment will be prorated against the total harvest from these FMUs – since part of the harvest may be delivered to other actors.

The entity/corporation can choose to set the balance to 0 for FMUs that are not under their ownership – provided that documentation is provided showing that the carbon balance of these forests is, with a reasonable level of certainty, not negative.

All forest area within the FMU is included in the assessment.

The carbon balance of a FMU is assessed using the framework of the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019c). These guidelines are also used for national reporting of carbon balance in forests (e..g. European Environment Agency, 2021; UNFCCC, 2022). By using the same framework as national reporting, the assessment of FMUs can build on the methodological approach, and also facilitate use of national level data when appropriate.

Calculation of the carbon balance for a FMU includes the net change for the identified time period for four carbon pools:

1. Living biomass (above and below ground)
2. Deadwood
3. Litter
4. Soil organic matter (SOM), including N_2O and CH_4 emissions, if any, from drained organic soils

The carbon balance of an FMU is the sum of carbon balances of the four pools.

When sufficient information is not available for one or several carbon pools for the forest management unit, secondary data may be used together with relevant documentation. Assumption of no change in a carbon pool may be applied, provided that documentation shows that the carbon balance of the carbon pool is, with a reasonable level of certainty, not negative. Table 1 provides general guidance for assessing the balance of each pool.

Table 1. Data sources and calculation methods for the four carbon pools.

Carbon pool	Data sources	General calculation methods	Alternative proxy variables or approaches, examples
Living biomass, above and below ground	Forest inventory data from sample plots and/or stand surveys representing the FMU	Geographically relevant allometric functions and biomass expansion factors applied to measured basal area and tree heights Time period results established through repeated measurements and/or growth and yield modelling	(a) Data from larger area inventories, such as national forest inventories, can be used to represent the FMU (b) If sufficient data for the time period is not available, change can be assumed to be 0. In this case, documentation verifying that sustainable forest management is applied must be provided
Deadwood	If included, same data sources as for living biomass above ground	Same as for living biomass above ground	(a) Data from larger area inventories, such as national forest inventories, can be used to represent the FMU and to establish time period results (b) If sufficient data for the time period is not available, change in deadwood can be assumed to be 0
Litter	Data from large area inventories, such as national forest inventories, can be used to represent the FMU	Results from larger area inventories applied to FMU	(a) If sufficient data for the time period is not available, change in litter can be assumed to be 0
Soil organic matter	Data from larger-area inventories, such as national forest inventories or national soil surveys, can be used to represent the FMU	Results from larger area inventories applied to FMU	(a) Data from scientific studies or established practices (b) If sufficient data for the time period is not available, change in soil organic matter can be assumed to be 0

Component 4: Carbon storage in wood-based products (HWP)

The changing (increasing) storage of carbon in wood-based products that are in use in society is a significant contribution to the assessed climate performance. Long-lived products make a greater contribution than short-lived ones.

The change in carbon storage in wood-based products is assessed in tons of carbon dioxide equivalents (t CO_2e) over the identified time period.

Annex 3 provides a methodological background for assessing the change in carbon storage in wood-based products, and how this can be applied to the assessment of climate effect by an entity/corporation under this methodology.

The general variable sought for the assessment of HWP carbon pool change is the HWP Coefficient, which expresses the proportional net increase of the HWP carbon pool for a given volume of a product category delivered to the market. With steadily increasing volumes on the world market, the HWP Coefficient is always a number between 0 and 1 (Equation 3).

(3) $$HWP_{coefficient} = \frac{HWP_{inflow} - HWP_{outflow}}{HWP_{inflow}}$$

where:

$HWP_{coefficient}$ = proportional increase of the HWP pool for a product category (unitless)

HWP_{inflow} = new quantity of the product category added to the HWP pool (t CO_2e)

$HWP_{outflow}$ = quantity of the product category exiting the pool due to decay or end-use (t CO_2e)

The following steps are applied to assess the change of carbon stored in wood-based products (HWP) for the entity/corporation during the identified time period:

1. For each product category in the assessment, establish a HWP Coefficient. Annex 3 explains how to assign HWP Coefficients.
2. For each product category in the assessment, multiply the HWP Coefficient by the volume delivered to the market during the identified time period, expressed in t CO_2e. The result is the net contribution to the HWP carbon pool for each product category.
3. Add together the contributions for the product categories. The result is the net contribution to the HWP carbon pool for the entity/corporation during the identified time period.

Reporting results

The final step in the assessment process is reporting the results. The assessment is primarily designed for regular updates in annual reports by corporations, but can be applied in other contexts.

In the section on Model Scope above, it is clarified that the assessment can only be considered complete if all four components are included, covering the value chain of all wood-based products delivered by the entity/corporation, according to the system boundary in Figure 4. Some parts of components may be left out of the assessment with justifications, as outlined in the above sections for each component.

Reporting results must therefore include all four components, including justifications where parts have been omitted.

The four components each result in a climate effect expressed in t CO_2e, where a minus sign denotes a net sink of CO_2 (less CO_2 in the atmosphere) and a plus sign denotes a net source of CO_2 (more CO_2 in the atmosphere).

Given that the components express climate effects in the same measurement unit, they can be added together to obtain a total climate effect of the wood-based value chain of the entity/corporation during the defined time period. However, it must always be noted in the reporting that the climate effects of the different components do not have the exact same characteristics and that the precision of results may vary between components.

As reporting is made for successive time periods, trends in the reported climate effect will become apparent. This is a valuable feature, as it enables tracking of progress, for example towards corporate climate goals. However, caution must also be applied, as assumptions and data availability and accuracy may also evolve over time. Such changes in underlying data may justify retroactive recalculations of previous reports so as to avoid presenting trends that are over- or underestimated.

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Annex 1. Concepts and definitions

Term/Concept	Definition/Explanation
CO_2e (carbon dioxide equivalent)	Unit for combining the radiative forcings of greenhouse gases to that of carbon dioxide.
t CO_2e, Mt CO_2e	Tons and million tons, respectively, of carbon dioxide equivalents.
Prevented emissions	Situation when greenhouse gas emissions from counterfactual non-wood products are not occurring due to delivery of wood-based products. Prevented emissions refer only to emissions of the counterfactual products and do not take into account emissions caused by the value chain of the wood-based product.
Displacement	Situation where the use of wood and wood-based products leads to avoided greenhouse gas emissions from fossil fuels and/or industrial processes, other than biogenic emissions. Displacement expresses the net reduction of greenhouse gas emissions, taking into consideration both emissions from counterfactual non-wood products and the emissions in the wood-based value chain.
Displacement factor	Quantity of avoided or prevented emissions relative to the quantity of biogenic carbon within the wood-based product(s) that is displacing the non-wood-based counterfactual. Measured in tonnes of avoided/prevented emissions per tonnes of carbon in the biogenic material (t CO2e/t CO2e). In cases where the wood-based value chain emissions are included in DF calculations, the DF refers to “avoided” emissions (a net measure of emissions reduction). In the CLEAR method the displacement factor refers to “prevented” emissions (emissions caused by alternative product(s)) as the wood-based value chain emissions as are calculated and reported separately.
Substitution	When a specific product, assembly, structure, or building is replaced by a specific wood-based product, assembly, structure, or building (with equivalent functional unit). Substitution is normally considered a narrower concept than displacement or prevented emissions, but is sometimes used synonymously.
Wood-based product or Harvested Wood Product (HWP)	Product wholly or partially derived from wood or wooden components.
Carbon pool	Component in the environment that has the capacity to accumulate carbon dioxide and store it in the form of carbon, and also has the capacity to release the carbon.
Forest management unit	Area of forest where wood is sourced for wood-based products.

Annex 2. Establishment of Displacement Factor for a Product Category

As shown in the main text, an overall Displacement Factor (DF) is determined for each defined product category. The DF expresses the quantity of emissions from fossil energy and industrial processes that are avoided by the use of a functional equivalent of wood-based products.

At a general level, a DF is defined as the quantity of emissions from fossil fuels and industrial processes that are avoided or prevented per quantity of wood-based products delivered to the market, considering the same functional unit of the alternative products (Equation 1).

$$(1) \quad DF = \frac{Emission_{alternative} - Emission_{wbp}}{BCC_{wbp} - BCC_{alternative}}$$

where for the same functional unit:

DF	Displacement Factor	t CO_2e/t CO_2e
$Emission_{alternative}$	GHG emissions caused by the alternative, non-wood-based product	t CO_2e
$Emission_{wbp}$	GHG emissions caused by the wood-based product. Note that this is reported as a separate component in this methodology and may then be set to 0 for the calculation of DFs	t CO_2e
BCC_{wbp}	Biogenic carbon content of the wood-based product	t CO_2e
$BCC_{alternative}$	Biogenic carbon content of the alternative, non-wood-based product (considering that also alternative non-wood-based products can contain some wood, for example a house with a main structure of steel and concrete).	t CO_2e

However, there are a number of considerations in the establishment of Displacement Factor for a Product Category. The steps involved are:

1. Identify list of intended first Product use(s) for the Product Category
2. Assess the Displacement Factor for each first Product use:
   a) assign the volume delivered for this purpose
   b) assign a Displacement Factor
   c) assess the proportion by volume that leads to displacement
3. Assess the Displacement Factor from energy recovery at final use for each first Product use
   a) assign the volume that leads to energy recovery at final use
   b) assign a Displacement Factor for the energy recovery
   c) assess the proportion by volume that leads to displacement at energy recovery
4. Calculate the overall DF for the Product Category across product uses and first/final uses

Note on first, recycled and final uses of wood-based products

Wood-based materials are recyclable, which means that avoided or prevented emissions can occur several times in the lifetime of a wood fibre, until it is either incinerated for energy or oxidized in other ways. With emerging BIO-CCS[2] and Bio-CCU[3] technology, we may also see additional phases as CO_2 is recovered.

This methodology includes two use phases for calculating prevented emissions:

- First use – the first product where the wood material is applied. This can range from house construction, to packaging, to hygiene products, to bioenergy in various forms.
- Final use for energy – unless the first use was for energy.

Note that when the first product use is energy, there cannot be any prevented emissions assigned for energy recovery at final use.

Due to complexity and lack of data, the assessment does not consider prevented emissions for downstream recycled use of wood material. However, the methodology does include wood-based products delivered in the specified time period that are partly or wholly produced using recycled wood-based material.

Step 1: Identify list of intended first Product use(s) for the Product Category

The product categories are defined for the assessment at an aggregated level, which means that each product will lead to a multitude of products and product uses at the consumer level. It is practically impossible to establish a complete list of these products and uses, and even more so the Displacement Factor for each combination.

The assessment must instead be based on a reasonably short list of products uses for the product category that together represent the overall uses of the product category. This is established through available market information and expert knowledge. For each first product use, a proportion of the product category volume delivered to the market is to be assigned. The total volume for product uses equals the total volume for the product category as a whole.

Example: A defined product category delivered from a sawmill may be simply "sawn wood". This can be subdivided into first Product uses "construction wood" and "wood pallets" with volumes assigned to each, see example below.

[2] Processes that include biomass with carbon, capture and storage
[3] Processes that include biomass with carbon, capture and utilization

Step 2: Assess Displacement Factor for first Product use(s)

For each product use, a DF is assigned based on Equation (1). This can be done in two ways:

1. Drawing a DF directly from the database developed in conjunction with this methodology that best corresponds to the Product use. See Table 1 for a set of available DFs, or
2. Calculating a specific DF based on available documentation in Life Cycle Assessments, Environmental Products Declarations, or similar. This can be justified if the product volumes are large and a more precise assessment of prevented emissions is required.

Step 3: Assess the proportion by volume that leads to prevented emissions at first Product use

While there is normally an intended first Product use (say paper packaging), it may be reasonable to assume that part of the volume will not lead to prevented emissions for a variety of reasons (waste during the process, actual consumer use does not replace any fossil-based alternative). Based on knowledge of the markets of products and their uses, a factor must therefore be set that indicates the proportion of the volume that leads to prevented emissions.

Example: Paper bags may directly displace plastic bags in most convenience stores, but may also be used for fashion product packaging where a plastic bag is not an alternative. Depending on the shares of the volume for either purpose, the proportion of volume leading to prevented emissions can be assigned.

Step 4: Assign a Displacement Factor for the energy recovery

As for first Product use(s), the DF for energy recovery can be obtained from the methodology database (Table 1) or calculated for the specific assessment.

Note: When comparing bio-based energy products with fossil alternatives, this assessment methodology accounts separately for (small) fossil emissions in the wood-based value chain (Component 1). When calculating the DF for energy products, emissions for the counterfactual fossil energy source throughout its value chain must be included. This means that emissions related to extraction, transporting and refining fossil energy products need to be considered. Consequently, a biobased fuel product will have a DF >1 when compared to an equally performing fossil-based product.

Step 5: Assess the proportion by volume that leads to energy recovery at final use

Energy recovery is an important part of prevented emissions, as fossil energy may be directly displaced. For this reason the volume of each first Product use that leads to energy recovery must be assessed based on market information. This is done with two considerations:

1. Biomass available in time period

The time factor needs to be considered. Prevented emissions are to be assessed for the defined time period, even though final energy recovery may not occur until several years later for many products. For this reason, the same pool logic applied for forest carbon storage and product carbon storage (Components 3 and 4) must be applied, i.e. a certain volume of products enters the pool during the time period, and a near-corresponding volume exits the pool and is available for energy recovery during the period.

The volume available for energy recovery in the defined time period must be set conservatively to mirror the increasing product carbon pool in society, as per the HWP coefficient (see Annex 3). For solid wood products, the HWP coefficient may be 0.3, indicating a 30% net increase in relation to the delivered volume. Consequently, the corresponding volume exiting the pool and being available for energy recovery would be 1-0.3 = 0.7. For paper/fibre products the corresponding proportion by volume available for energy recovery in the defined time period would be around 0.9. Note that these are only indicative numbers to assist the specific assessment case.

2. Proportion of available biomass in the time period leading to prevented emissions

As for first Product use(s), it is not obvious that all available biomass will lead to energy recovery with prevented emissions – it may, for example, end up as landfill or incinerated without recovering energy for the market. The proportion (0..1) of the available volume that leads to prevented emissions must therefore be assessed.

The proportion of the Product use volume leading to energy recovery with prevented emissions in the calculated as (a) × (b).

Example: DF calculation for product category

This example shows the data required for calculating the DF for the product category "Sawn wood", where two first Product uses have been identified: "Construction" and "Pallets".

Ninety percent of the volume is intended for construction, for which a DF of 1.2 is assigned, and 90% of this volume is assumed to actually displace fossil-based materials. For final energy recovery a displacement factor of 0.8 is assigned. It is assessed that 70% of the delivered volume is available in the time period and that the full volume will be used for energy that leads to prevented emissions, i.e., a proportion of 0.7×1 = 0.7 of the product use volume leads to prevented emissions through energy recovery during the time period.

Ten percent of the volume is intended for pallets, for which a lower DF, 0.5, is assigned, and 100% of this volume is actually used for pallets. For final energy recovery, the same parameters as for construction are applied.

This gives the following input table:

Product category	Product uses considered	Fraction by volume	First use		Final use (energy)	
			Displacement factor	Fraction leading to displacement	Displacement factor	Fraction leading to displacement
		0..1	t CO_2e/t CO_2e	0..1	t CO_2e/t CO_2e	0..1
Sawn wood	Construction	0.9	1.2	0.9	0.8	0.7
	Pallets	0.1	0.5	1.0	0.8	0.7

The DF for the Product category sawn wood as a whole can now be calculated as follows:

Construction:

First use: 90% of the overall delivered volume goes into construction, and a 90% fraction of this leads to prevented emissions at first use. The DF is 1.2 t CO_2e/ t CO_2e. The contribution to prevented emissions for sawn wood overall is then 0.972 t CO_2e/ t CO_2e:

$$0.9 \cdot 0.9 \cdot 1.2 = 0.972$$

Final use: In relation to the 90% of overall delivered volume, 70% is recovered for energy in the time period. The DF is 0.8 t CO_2e/ t CO_2e. The contribution to prevented emissions for sawn wood overall is then 0.504 t CO_2e/ t CO_2e:

$$0.9 \cdot 0.7 \cdot 0.8 = 0.504$$

Pallets:

First use: 10% of the overall delivered volume is used for pallets and all (100%) leads to prevented emissions at first use. The DF is 0.5 t CO_2e/ t CO_2e. The contribution to prevented emissions for sawn wood overall is then 0.05 t CO_2e/ t CO_2e:

$$0.1 \cdot 1.0 \cdot 0.5 = 0.05$$

Final use: In relation to the 10% of overall delivered volume, 70% is recovered for energy in the time period. The DF is 0.8 tCO_2e/ tCO_2e. The contribution to prevented emissions for sawn wood overall is then 0.056 t CO_2e/ t CO_2e;

$$0.1 \cdot 0.7 \cdot 0.8 = 0.056$$

Total DF for sawn wood is the sum of above contributions is 1.582 t CO_2e/ t CO_2e:

$$0.972 + 0.504 + 0.05 + 0.056 = 1.582$$

Table 1. Indicative Displacement Factors (DF) for key product uses. DFs build on the assumption that wood-based value chain emissions are reported as a separate component and are therefore not included here. The DF below and more detailed sets of uses can be provided in a separate excel database as part of this methodology.

Product category	Displaced product(s)	DF t CO_2e/t CO_2e	Remarks
Roundwood	Combination of marketed products after processing	0.5	For volume under bark. Assumes that roundwood is used as sawn wood to the extent possible, and the remaining biomass is used for fibre-based products and energy.
Sawn wood	Various non-wood construction materials	1.2	Can be used for general applications of first uses for sawn wood. Some uses lead to high DFs (e.g. windows, doors), some to lower (e.g. pallets)
Wood-based panels	Various non-wood materials	1	Can be used for general applications of panels for first use
Paper packaging	Packaging from plastic, glass or metal	1	Displacement of glass and metal packaging generally renders higher displacement factors, but are not distinguished here
Other fibre-based products	None identified	Depends on specific products delivered. Can be set to 0 if no specific product(s) are identified.	Many fibre-based products will render displacement sometimes with high DFs, but are not distinguished in this indicative list. Generally, final use for energy recovery will lead to displacement.
Bioenergy products	Corresponding energy product based on fossil fuels	0.8	Depending on the fossil fuel displaced, the displacement factor can be higher or lower, but this is not distinguished in this indicative set of DFs
Liquid biofuels	Corresponding liquid fossil fuel	1.2	Emissions from fossil fuel include emissions from upstream extraction and refining

Annex 3. Establishment of HWP Coefficients

The changing (increasing) storage of carbon in wood-based products in use in society is a significant contribution to the assessed climate performance. Long-lived products make a greater contribution than short-lived ones.

The change in storage of carbon in wood-based products in use in society's different sectors is a significant factor for this assessment. If the storage increases, it means that more carbon is kept away from the atmosphere. Conversely, if the product pool is decreasing, there will be net emissions of CO_2 to the atmosphere.

The trend is clearly and steadily positive, as the world market volumes of wood-based products have increased by about 1%/year over the past 60 years (Figure 1) and is expected to continue to increase. This means that the carbon stored in wood-based products also increases, assuming no change in the products' lifetime.

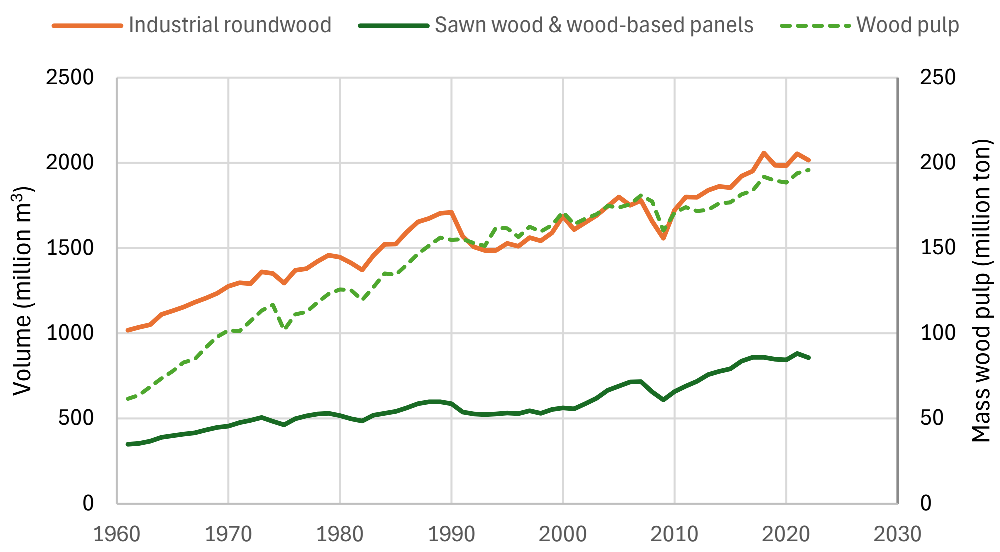

Figure 1. World market development 1960-2022 for the three Tier 1 categories considered in HWP carbon pool development. Conservatively, the market volume has increased by >1%/year since 1960. This means that the HWP carbon pool also has increased. Source: FAOSTAT (FAO, 2024).

Like changes in storage of carbon in the forest, the storage of carbon in wood-based products is part of the official climate reporting by countries, and an integral part of the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019b). The terminology used by IPCC is "Harvested Wood Products" (HWP). This means that basic and widely agreed methodology is available to calculate changes in the HWP carbon pool. This methodology can also be applied to this assessment.

While different variants exist in the IPCC Guidelines, the methodology adopted for this assessment is the "production approach". This is the most common choice among countries that report their national data annually, such as Sweden and all other EU countries (European Environment Agency, 2021; UNFCCC, 2022). The "production approach" means that the producer of wood-based products account for the increase in carbon storage, wherever that product is actually used. This is helpful, as it reduces the risk of double-counting and as production data are typically available with good precision.

Conceptually, the increase of the HWP carbon pool is easily explained as the difference between carbon added to the pool through new products, and the removal of products as they reach end-of-life and are typically incinerated or disposed of in other ways (Figure 2)

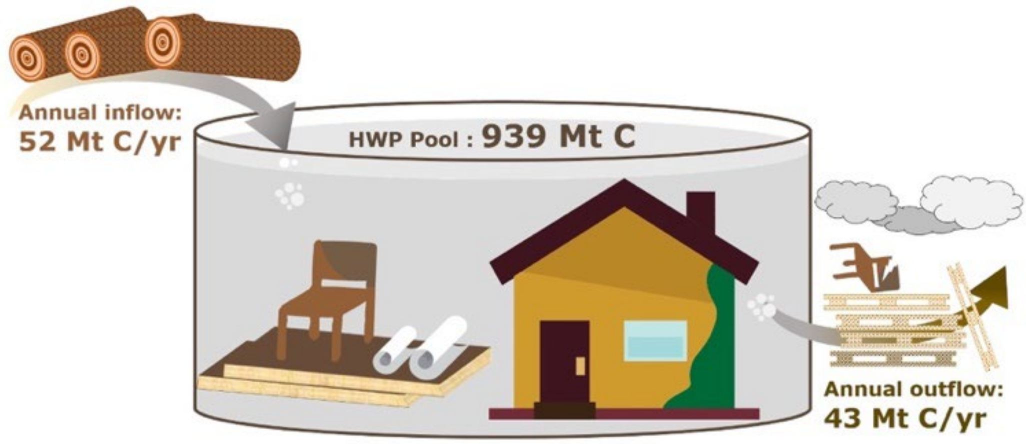

Figure 2. Illustration of the HWP Pool inflow, storage and outflow for the EU in 2018, using the "production approach". The net HWP pool increase was 52-43 = 9 MtC or 33 Mt CO_2e in 2018. (From: JRC, 2021).

In practical terms, however, the assessment is faced with some difficulties.

Calculation of the inflow of carbon from the entity/corporation during the stipulated time period is straightforward. It is simply the carbon content of the volume of delivered products – noting that bioenergy products are excluded, as they are considered to be used in the near term and therefore will not accumulate any stored carbon.

The outflow, however, is practically impossible to measure, as it would require keeping track of every product, through recycling phases, until it finally leaves the product pool. For this reason, the IPCC Guidelines provide a model and basic parameters to make an estimate of the outflow in the time period considered.

The approach builds on assumed half-life of three broad product categories. These assumptions are provided by IPCC as a Tier 1 option and have become a standard (IPCC, 2019b):

- Sawn wood, 35 years
- Wood-based panels, 25 years
- Paper or other fibre-based products, 2 years (another complication here is that recycling of fibre material will extend the life of the material in use, depending on the rate of recycling)

This means that half of the delivered product volume will remain in use after these time periods. The gradual decay of products in the pool can then be estimated – provided that we have data on product volumes that have been delivered over at least the past 100 years. This is needed, as the half-life for solid wood products is long.

A few countries report the detailed pool change for each product category. Sweden is one example, and the annual results of HWP pool change estimates are provided publicly as official statistics (Statistics Sweden, 2023). Many countries, including all EU Member States, report the total change of the HWP pool every year (European Environment Agency, 2021). This means that empirical data is available for estimating the contributions to the HWP carbon pool of additional wood-based products.

These results can also be verified through modeling that applies the notion of a gradually expanding world market for wood-based products, the Tier 1 half-life provided by IPCC, and different levels of recycling rates.

The variable sought for the assessment of HWP carbon pool change is the HWP Coefficient, which expresses the proportional net increase of the HWP carbon pool for a given volume of a product category delivered to the market. With steadily increasing volumes on the world market, the HWP Coefficient is always a number between 0 and 1 (Equation 1).

(1) $$HWP_{coefficient} = \frac{HWP_{inflow} - HWP_{outflow}}{HWP_{inflow}}$$

where:

- $HWP_{coefficient}$ = proportional increase of the HWP pool for a product category (unitless)
- HWP_{inflow} = new quantity of the product category added to the HWP pool (t CO_2e)
- $HWP_{outflow}$ = quantity of the product category exiting the pool due to decay or end-use (t CO_2e)

and the product categories considered, based on IPCC categories, are:

1. Industrial roundwood from the forest (not included in IPCC methodology, but can be established based on proportions used for solid wood products and paper products)
2. Sawn wood
3. Wood-based panels
4. Fibre/paper-based products
5. Wood-based energy

Given that the world market volume for wood-based products has been steadily increasing for many years, and is expected to continue to do so, an HWP Coefficient is always larger than 0. The HWP Coefficient cannot be higher than 1.

Based on empirical data from national reporting and modeling, default HWP coefficients have been established (Table 1, next page).

Table 1. Default HWP coefficients (see also Tables 2 and 3). Note: A forthcoming Technical Report to the ISO standard that is under development will elaborate on methodology and analyses that have led to the coefficients listed below.

Product category	HWP Coefficient	Notes
Sawn wood	0.3	Assumes 35 years half-life
Wood-based panels	0.25	Assumes 25 years half-life
Fibre / Paper	0.04	Assumes 2 years half-life and a recycling rate of 30%
Wood-based energy	0	Wood-based energy is assumed to instantly oxidize
Roundwood under bark	0.1	Assumes 25% of volume resulting in sawn wood products or panels and 25% of volume resulting in fibre/paper product, and the remaining 50% not contributing to the HWP

The default HWP coefficients can be adjusted if the entity/corporation has additional information:

- on half-life and recycling rates (Table 2), or
- roundwood utilization rate for solid wood products and fibre/paper products (Table 3, next page)

Table 2. HWPC model results assuming a market volume increase of 1% per year for different combinations of half-life and recycling rates. IPCC Guidelines for HWP calculations recommend a half-life of 35 years for sawn wood, 25 years for wood-based panels, and 2 years for paper products. These cases appear in Table 1 above and have been marked in yellow, with the assumption of a 30% recycling rate for paper products.

Half life years	Recycling rate %									
	0	10	20	30	40	50	60	70	80	90
2	0.02	0.03	0.03	0.04	0.04	0.05	0.07	0.09	0.14	0.25
5	0.06	0.07	0.08	0.09	0.11	0.13	0.15	0.20	0.27	0.44
10	0.12	0.13	0.15	0.17	0.19	0.22	0.27	0.33	0.43	0.61
15	0.17	0.19	0.21	0.23	0.26	0.30	0.35	0.42	0.53	0.70
20	0.22	0.24	0.26	0.29	0.32	0.37	0.42	0.50	0.61	0.76
25	0.26	0.28	0.31	0.34	0.38	0.42	0.48	0.56	0.66	0.80
30	0.30	0.32	0.35	0.38	0.42	0.47	0.53	0.60	0.70	0.83
35	0.33	0.36	0.39	0.42	0.46	0.51	0.57	0.64	0.73	0.85
40	0.36	0.39	0.42	0.46	0.50	0.54	0.60	0.67	0.76	0.87
45	0.39	0.42	0.45	0.49	0.53	0.58	0.63	0.70	0.78	0.88
50	0.42	0.45	0.48	0.51	0.56	0.60	0.66	0.72	0.80	0.89

Table 3. HWPC for roundwood under scenarios where different fractions of the roundwood are solid wood products and paper products respectively. For solid wood products, the average results for a half-life of 25 and 35 years (Table 2) is used (0.33+0.26)/2 = 0.3. For paper (fibre-based) products, a half-life of 2 years and 30% recycling is used. A common scenario is that 25% of the wood becomes solid wood products and 25% becomes paper products – this scenario is marked in yellow.

% Solid wood products	% fibre-based products (30% recycling assumed in modeling)								
	0	5	10	15	20	25	30	35	40
10	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
15	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
20	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
25	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
30	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
40	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
50	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
60	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18

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