TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Civil Engineering and Architecture

POTENTIAL FOR CO_2 REMOVAL FROM HARVESTED WOOD PRODUCTS THROUGH ALTERNATIVE DECAY FUNCTION AND CASCADING SCENARIOS IN NORWAY

POTENTSIAAL SÜSINIKDIOKSIIDI EEMALDAMISEKS METSARAIE TOODETEST ALTERNATIIVSETE LAGUNEMISFUNKTSIOONIDE JA KASKAADSTSENAARIUMIDE KAUDU NORRA NÄITEL

MASTER THESIS

Student:	Francisco Tienda Resendez
Student code:	214154EABM
Supervisor:	Viktoria Voronova / Senior Lecturer (TalTech)
Co-supervisor:	Roja Modaresi / Senior Researcher (NTI-Norwegian Institute of Wood Technology)

Tallinn 2023

(*On the reverse side of title page*)

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THESIS TASK

Student: Francisco Tiend Resendez, 214154EABM

Study programme: EABM03/18 – Environmental Engineering and Management

Supervisor: Viktoria Voronova, Senior Lecturer (TalTech), +372 6202506

Co-supervisor: Roja Modaresi, Senior Researcher (NTI – Norwegian Institute of Wood Technology), +47 40295791

Thesis topic:

Potential for CO_2 Removal from Harvested Wood Products through Alternative Decay Function and Cascading Scenarios in Norway

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Thesis main objectives:

1. Identify the impact of wood cascading in the estimation of HWP in Norway.
2. Literature review and assessment of the current methodologies for estimating HWP.
3. Improve the 2019 IPCC guidelines for the estimation of HWP.

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Introduction and History of HWP Contribution to GHG Inventories	28/02/23
2.	Assessment of current methodologies for the estimation of HWP Carbon Contribution	13/03/23
3.	Development of an improved methodology for the estimation of HPW Carbon Estimation	18/03/23
4.	Modeling different scenarios of HWP recovering and recycling in Norway	05/04/23
5.	Presentation and discussion of results in CircWOOD work meeting	21/04/23
6.	Conclusion and summary	01/05/23

Language: English **Deadline for submission of thesis:** “.....” ....20....a

Student: Francisco Tienda Resendez .... “......”...................................20....a
/signature/

Supervisor: Viktoria Voronova .... “.......”......................20....a
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Co-supervisor: Roja Modaresi “Oslo, Norway ” May 24th, 2023

Head of study programme: Karin Pachel.................... “.......”.....................20.....a
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CONTENTS

PREFACE

The completion of this thesis represents the culmination of months of dedicated research, exploration, and analysis. It is with great pleasure that I present this work, titled "Potential for CO_2 Removal from Harvested Wood Products through alternative decay function and cascading scenarios in Norway", as a testament to my academic journey and the invaluable guidance and support I have received along the way.

In this research, I develop different scenarios to analyze the possible future development in the wood industry in Norway with a circular approach and their impact on CO_2 removals. Moreover, an improved methodology for estimating these removals is proposed. This project is aligned with the goals of the "CircWOOD/SirkTRE" project intended to boost the circular use of wood in Norway. I develop this research with the co-supervision and support of the Norwegian Institute of Wood Technology (NTI). I must express my profound appreciation to all my colleagues and friends from NTI who make this an amazing experience.

Especially, I would like to express my deepest gratitude to my thesis co-supervisor, Roja Modaresi (Senior Researcher, NTI). Her invaluable guidance, encouragement, and meticulous attention to detail have pushed me to strive for excellence and challenged me to explore new avenues of knowledge. I am indebted to her for her unwavering support throughout this entire research process.

I am also indebted to my supervisor, Viktoria Voronova (Senior Lecturer, TTU) for her insightful feedback and valuable suggestions that have significantly enriched the content and direction of this work.

Furthermore, I extend my appreciation to Gry Alfredsen (Senior Researcher, NIBIO) who generously shared her time, and knowledge, without whom this study would not have been possible. Her contributions have added depth and relevance to the findings presented in this thesis.

I would also like to acknowledge the support of my parents, siblings and friends, whose unwavering encouragement and belief in my abilities have sustained me throughout this challenging process. Their presence in my life has been a constant source of inspiration and motivation.

Francisco Tienda Resendez
May 15nd, 2023

Keywords: HWP, IPCC guidelines, CO_2 sequestration, circularity, National Inventory Report, UNFCCC, master thesis.

ABBREVIATIONS AND SYMBOLS

- **AFOLU**: Agriculture, Forestry and Other Land Use
- **CRF**: Common Reporting Format
- **ESL**: Estimated Service Life
- **FAO**: Food and Agriculture Organization of the United Nations
- **FAOSTAT**: Food and Agriculture Statistics provided by FAO
- **GHG**: Green House Gases
- **HWP**: Harvested Wood Products
- **INDC**: Intended Nationally Determined Contributions
- **IPCC**: Intergovernmental Panel on Climate Change
- **KP**: Kyoto Protocol
- **KPSG**: Revised Supplementary Methods and Good Practice Guidance Arising from the KP
- **LULUCF**: Land Use, Land-Use Change and Forestry
- **NDC**: Nationally Determined Contributions
- **NIR**: National Inventory Report
- **PA**: Paris Agreement
- **PP**: Semifinished wood product commodity class Paper and Paperboard
- **RSL**: Reference Service Life
- **SW**: Semifinished wood product commodity class Sawnwood
- **UNFCCC**: United Nations Framework Convention on Climate Change
- **WBP**: Semifinished wood product commodity class Wood-Based Panels
- **WMO**: World Resources Institute

1. INTRODUCTION

In recent years, climate change has emerged as a major issue for humanity, posing a threat not only to humans but also to the planet and all living beings. To address this crisis, it is crucial to not only reduce greenhouse gas (GHG) emissions but also enhance their removal from the atmosphere [1]. Experts suggest that one of the most effective and economical ways to combat climate change is found in the GHG mitigation potential of forests [2]. Forest is a sink for carbon dioxide in two ways: first, carbon is sequestrated in trees. Second, it can be absorbed by soil and litter. [3]. Consequently, wood products continue to serve as a means of carbon storage which makes them a key factor in mitigating climate change [4]. For this reason, forestry and harvested wood products (HWP) have taken an important role in the global reporting of GHG inventories and the contribution from each country [2].

In order to measure the global situation regarding climate change mitigation, there are international entities, such as the Intergovernmental Panel on Climate Change (IPCC) which is in charge of reporting the global data about GHG emissions. The primary goal of the IPCC is to provide various levels of government with scientific data that can aid in the formulation of climate policies. Additionally, the reports issued by the IPCC play a crucial role in international negotiations concerning climate change. The IPCC is comprised of governments that are affiliated with either the United Nations (UN) or the World Meteorological Organization (WMO). Organisms such as the UN have developed agreements as the United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol and Paris Agreement which establish the pursued goals to globally reduce the emissions of GHG. Under the UNFCCC all the parties must submit biannually their National Inventory Report (NIR) and Common Reporting Formats (CRF) which are documents that carefully described the estimation and total amounts of GHG emitted or removed by different sectors in each country [5].

One of the main sectors in the NIR and CRF is Agriculture, Forestry and Other Land Uses (AFOLU). Almost 25% of the total GHG generated by human activities (10-12 Gt CO_2 eq/yr) is attributable to the AFOLU sector, primarily due to deforestation and agricultural activities such as livestock farming, soil management, and nutrient management. HWP is one category in the AFOLU that has gained high interest for its potential on reducing the annual total CO_2 contribution by countries, particularly those who are big producers or consumers of wood products. In this category, it is estimated how much carbon is in "stock", or in other words, stored in wood products that are in use, but also how much carbon is released to the atmosphere by their decay [6]. The IPCC provides guidelines for the estimation of emissions and removals arising from the HWP pool.

It is necessary to highlight that the current guidelines do not consider the consequences of extending the life service of wood products by recycling practices. For this reason, this research analyzes how the current frameworks shape the use of reclaimed wood and what changes need to be made to encourage beneficial behavior, what are the gaps in the existing guidelines, what improvements have been already proposed by other authors and should be considered for the international guidelines, also how recovered and recycled fractions of "sawnwood", "wood-based panels" and "paper and paperboard" can be quantified in the total net contribution of CO_2.

The awareness of the potential of HWP to decelerate the global warming has led to the creation of projects where the focus is intensifying the usage of wood in different industries and to recover and utilize the reclaimed wood. According to studies, extending the life of wood products is environmentally beneficial as it reduces the global warming potential as more cascading levels are included [7]. Clear proof of this is found in Norway, where there is a national project intended to encourage the circular use of wood by improving innovation and technologies to achieve a higher sustainability status in the country. This project is called "CircWOOD" and is part of the "Green Platform" which is a Norwegian initiative that offers assistance to expedite green transformation in the business sector through research and innovation. Moreover, based on statistics, the wood waste generated in the Nordic countries is higher than in any other country EU/EAA [8]. This is another purpose of the development of "CircWOOD", taking advantage of this renewable resource and upcycling HWP instead of their disposal after their life service.

2. HISTORY OF HARVESTED WOOD PRODUCTS CONTRIBUTION TO GHG INVENTORIES

The awareness of how carbon can be sequestered by forests and stored in wood products has existed for many years. This knowledge combined with the concern about how to reduce the environmental impact due to the generation of different pollutants such as greenhouse gases (GHG) and other anthropogenic activities, has brought on research on how this carbon sequestration and stock could be quantified in order to estimate the environmental impact based on the emissions or removals that the society produce, as it is shown in the timeline of Figure 2.1.

In 1983, Johnson and Sharpe [3] put forth the notion of using merchantable forest volumes to measure carbon storage or depletion. To achieve this, a conversion ratio from merchantable weight to total forest biomass was utilized. Nevertheless, it was also found in this study that for accurate estimation of carbon storage in forested areas, this ratio should consider the size and quality of unmerchantable trees as well. Moreover, it is necessary to mention that at the time further development in methodologies to assess carbon losses in litter and soil after forest harvest was already being suggested [3]. In the same year, another study about how the sequestration potential in wood was highly dependent on the rotation period of harvesting was published [8]. According to Cooper, shortening the rotation of wood harvesting could reduce up to 80% of the maximum lifetime carbon storage [8]. The findings of these studies demonstrated that accurately calculating carbon saved in forest and/or wood products was more complex, and several variables needed to be considered.

This last statement would be later supported by the outcomes from other researchers. In 1990, by utilizing an analytical methodology, Dewar established a relationship between carbon retention, vegetative growth, and rotation period. This research highlighted several significant concepts, such as the crucial role of wood products in the overall carbon pool, the potential efficiency of fast-growing tree species in carbon storage and producing long-lasting products, and the significance of accurately measuring the contribution of wood products to the total carbon pool [9].

In 1992, The United Nations Framework Convention on Climate Change (UNFCCC) enable the signing of the "Earth Summit" convention and entered into force in 1994. The agreement was signed by 181 governments and the European Community which committed to creating and sharing inventories of their greenhouse gas (GHG) emissions and removals, using the formats provided by the convention [10]. The Intergovernmental Panel for Climate Change (IPCC) guidelines for completion of the GHG inventories were accepted in 1994 but were not published until 1995. Later, the "Revised 1996 IPCC

Guidelines for National Greenhouse Gas Inventories" were officially adopted by the UNFCCC [11].

The 1996 IPCC guidelines introduced the first methodological guidance for developing national greenhouse gas (GHG) inventories. The guideline proposed a default approach, which would later be known as the "instantaneous-oxidation" method. Under this approach, it is assumed that all the carbon in wood is oxidized and emitted to the atmosphere when that wood is harvested and removed from the forest, and as consequence, this carbon inflow does not affect the existing pool of wood products. However, the IPCC acknowledged that this assumption could lead to inaccurate estimates of carbon stock changes if the size of the wood-products pool changed [11, 12].

During a meeting held in 1998 by the IPCC where experts discussed and analyzed the methods for estimating and reporting emissions or removals due to carbon stock changes in HWP, three other approaches ("stock-change", "production" and "atmospheric-flow") were introduced [13]. After providing these new approaches, different studies were conducted to compare them. In 2001, an article published by the Norwegian Pollution Control Authority showed how the outcomes could considerably vary depending on the approach adopted and how the lack of databases was an issue for obtaining accurate estimations based on the IPCC guidelines [14]. Similar to Norway, other parties of the UNFCCC including Australia, Canada, Japan, New Zealand, the Russian Federation, Samoa, Sweden, Switzerland, and the USA, submitted their views on the approaches [15].

In this period the concern about HWP Contribution gained momentum, and in 2003 several countries including Argentina, Australia, Canada, Denmark (acting on behalf of the EU and its Member States), Japan, Mexico, New Zealand, Samoa (representing AOSIS10), USA, and Uruguay, submitted their opinions on the potential impact of harvested wood products accounting, outlining various approaches and methodologies. With this information a technical paper on HWP was created, which defined wood products, provided global data on stocks and trade of wood products, and described methodologies for estimating the contribution of HWP to emissions/removals in the "Land Use, Land-Use Change and Forestry" (LULUCF) sectors [16].

This technical paper also led to the creation of the Good Practice Guidance for LULUCF, which was released the same year by the IPCC to assist Parties in creating inventories regarding LULUCF, in accordance with Articles 3.3, 3.4, and 3.7 of the Kyoto Protocol, and later agreements under the Marrakech Accords. This guide was based on the IPCC Guidelines (2000). The guidance included an appendix that presented various accounting approaches that could be used for further development of methodologies regarding HWP contributions [17]. In 2003, the National Inventory Submissions were started by the parties of the UNFCC. Since this year the UNFCC has collected annually the submissions that consist of the national inventory reports (NIR) and common reporting format (CRF) of all parties included in Annex I to the Convention.

Due to the issues raised by parties to the UNFCCC regarding the approaches provided for accounting the carbon emissions/removals of HWP, in 2003, Ford-Robertson made available a document describing a new approach, the "simple-decay approach" [18]. The approach assumes that emissions resulting from wood products are evaluated over time as the products decay. This differs from the "atmospheric-flow" or "stock-change" approaches, which allocate emissions to their point of origin. Instead, the "simple- decay" approach proposes that the producer is responsible for the emissions. This approach is similar to the "production" approach since it estimates emissions at the time they occur, rather than their location. But according to experts, unlike the "production" approach, it concentrates on emissions rather than changes in carbon stocks [12].

In 2006, the new guideline for National Greenhouse Inventories is published by IPCC. In this new version, the "simple-decay" approach is included. It is also described 3 methodologies (Tier 1, Tier 2 and Tier 3) to estimate the HWP contribution based on the data availability and clarification about when the HWP contribution can be reported as zero [19]. Furthermore, that year, Cowie et al. [20] released an article where a new approach was proposed, the "stock-change approach for HWP of domestic origin" (SCAD).

Despite the availability of improved methods for carbon accounting in HWP, the first commitment period of the Kyoto Protocol (2008-2012) relied on the assumption that the amount of carbon leaving the HWP pool each year was equivalent to the amount of carbon entering it, which is known as the "instantaneous-oxidation" approach. This arise the concern of different parties, particularly the ones whose stock of harvested wood products had been increasing in the last years and their projections were likely to increase further. This was the case of Norway, which in 2009 published a report analyzing the different accounting approaches and methods for estimating the annual change of CO_2 emissions/removals due to HWP [21].

Due to the pressure, the accounting rules for harvested wood products (HWP) were revised for the second commitment period of the Kyoto Protocol (2013-2020). This decision was made at the 17th Conference of the Parties (COP17) to the United Nations Framework Convention on Climate Change (UNFCCC) and the 7th Session of the Conference of the Parties (CMP7) to the Kyoto Protocol. The 2013 Revised Supplementary Methods and Good Practice Guidance, resulting from the Kyoto Protocol (2013 KPSG), now stipulate that CO_2 emissions and removals from HWP should be accounted for using a "production" approach.

This updated guide provides more detailed explanations of the "direct inventory-based" and "flux data-based" methods [2, 12].

Before the 2015 global climate talks in Paris, countries submitted their Intended Nationally Determined Contributions (INDCs) to the UNFCCC, which outlined their plans for addressing climate change after 2020, according to the Paris Agreement goals. About 65% of countries incorporated forests into their INDCs, and these countries were responsible for 95% of the world's round wood production. However, many of these countries did not include HWP in their data due to reasons such as the use of the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) framework, which resulted in a lack of information on how they were calculating greenhouse gas emissions and removals from forests, and whether forest harvesting is being considered. As a result, it was unclear what the full extent of their forest coverage was, and how they were accounting for forests in their INDCs [12].

In 2019, the IPCC published a refinement of its 2006 guidelines. In this update some terms such as "instantaneous oxidation" and "reporting zero" are avoided, instead, new terminology was provided, "steady state". If the assumption of a "steady-state HWP pool" is made, it does not mean that carbon losses resulting from biomass being harvested and used for HWP are being overlooked. Instead, these losses are considered as a part of the estimated carbon stock changes for living or dead biomass in forests and other wood-producing categories. Also, this refinement changed the pools assigned to the semi-finished wood products, the IPCC uses 3 commodities according to the FAO statistics: sawnwood, wood-based panels, and paper and paperboard. In addition, it was updated the methodology to calculate the carbon inflows and estimate the carbon stocks regarding the HWP pool [22].

An assessment was conducted in 2019 to analyze the existing approaches used to estimate the carbon emissions and removals associated with HWP. The study identified potential scenarios of "double-counting" or "non-counting" due to different combinations of approaches used by importing and exporting countries. In 2019, Sato and Nojiri concluded that the "instantaneous oxidation" approach is necessary for countries where HWP is a minor category, as at least one-third of the countries in the world are expected to fall into this category. Additionally, the "stock-change" and "atmospheric-flow" approaches cannot be used by countries that do not fully cover the total domestic forest and/or wood harvesting in their nationally determined contributions (NDCs). In this sense, the best solution for a global common approach for accounting for the annual HWP Contribution to the annual carbon emissions/removals would be the combination of the "instantaneous oxidation" approach with approaches using the production system boundary such as "production," "SCAD," and "simple decay" [12].

During 2020, researchers developed a new methodology to enhance estimations of carbon stock for HWP. Zhang et al. linked the global HWP production and consumption by using Eora multiregional input and output tables [23]. Eora is a global supply chain database, that in this research was used to complement the data obtained from the Statistics provided by the Food and Agriculture Organization of the United Nations (FAOSTAT), which is the main database used and suggested by the current guidelines. The authors mentioned that using only FAOSTAT is insufficient for the proper estimation of HWP carbon contribution due to the producing countries for the imported HWP and the end-using countries for the exported HWP are not provided [23].

In 2021, the World Resources Institute developed the Greenhouse Gas Protocol, a standard to regulate the environmental performance of corporations, but it did not include the HWP carbon storage. Holmgren, in 2021, emphasized the need for forest corporations to incorporate the effects of HWP to improve the annual national reports and suggested the use of IPCC guidelines for this purpose [24]. However, it is evident that current approaches, methodologies, and databases must continue upgrading to achieve reliable results at local, national, and global levels.

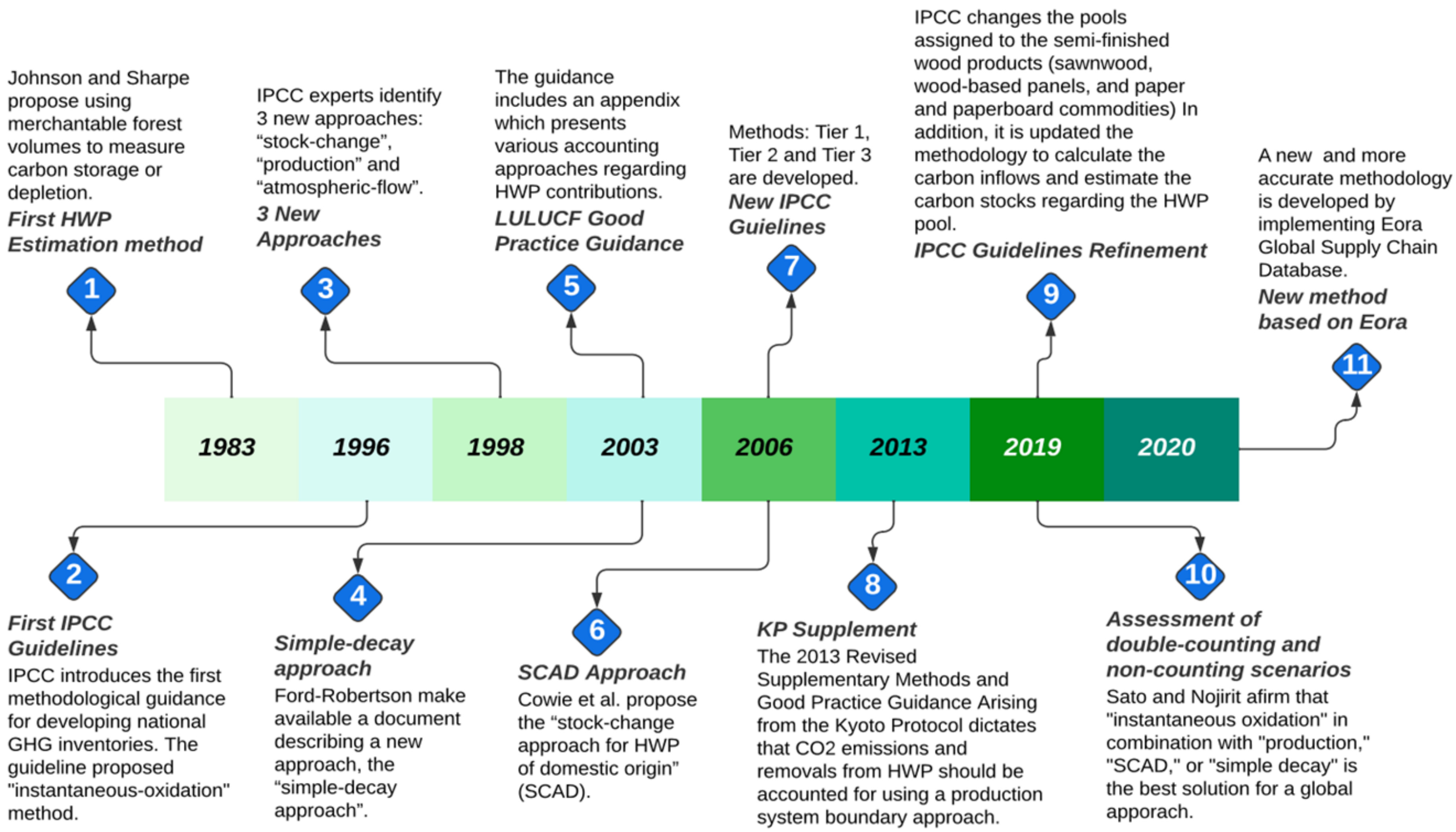

Figure 2.1 Timeline of the methodology development for the HWP Carbon contribution estimation

3. ASSESSMENT OF CURRENT METHODOLOGIES FOR THE ESTIMATION OF HWP CARBON CONTRIBUTION

Based on the history discussed in Chapter 2 about how the HWP Carbon Contribution accounting has been estimated, an assessment with an emphasis on the updated guidelines and methodologies will be developed for this chapter.

As an initial step, it would be appropriate to define some key concepts used for the description of the methods explained in section 3.1, such as, "approach" and "method".

An approach determines WHAT data are included in estimating CO_2 contributions from HWP, according to the system boundary set by the approach. On the other hand, the method specifies the calculations required to apply the selected approach, in other words, it outlines HOW to estimate the carbon contribution to be reported [22].

3.1 Description of existing approaches

In the "2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories", 4 different approaches are defined for estimating CO_2 emissions and removals arising from HWP. These approaches are "stock-change", "production", "atmospheric-flow", and "simple-decay". According to the guidelines, "stock-change" and "atmospheric-flow" approaches defines system boundaries more suitable for HWP consuming or importing countries, while "production" and "simple-decay" are better approaches for producing or exporting countries, this in terms of the benefits regarding carbon storage in HWP reported for the GHG inventories [22].

Additionally, there are two conceptual frameworks involved in the design of these 4 approaches. The first one considers the changes in carbon stocks in the HWP pool year by year and then estimates the emissions and removals of the CO_2 based on these changes. And the other conceptual framework is focused on identifying and tracking CO_2 fluxes between the atmosphere and HWP [22]. The last information is summarized in Table 3.1 to make it more understandable. However, it is important to mention that the concept of "conceptual framework" can lead to further questions and confusion when comparing all the approaches and methods, and this will be detailed discussed in section 3.3.

Although, according to the guidelines none of the approaches is suggested more than others. They are proposed to fit in the different situations of the reporting countries regarding their available data and their consumption and/or production volumes of HWP.

Table 3.1 Complementary similarities and distinctions between the 4 HWP approaches

Approach	Suitable country	Conceptual Framework
Stock change	Consuming	Carbon stock changes
Production	Producing	Carbon stock changes
Atmospheric flow	Consuming	CO_2 fluxes
Simple decay	Producing	CO_2 fluxes

3.1.1 Stock-change approach

The "stock-change" approach is used to estimate the annual change in the carbon stock of products being used, i.e., it accounts for the net carbon contribution due to the HWP used by the "consuming country". The estimated consumption of HWP reflects the yearly additions or reductions to the carbon pool in HWP, which is determined by the amount of carbon lost during forest harvesting that is then transferred to the wood products consumed in the country, which is counted as carbon gain. This calculation is based on data obtained from domestic production, imports, and exports of HWP. Since this approach works within national boundaries, any exported HWP is not included in the system boundary, whereas any imported HWP is considered part of the HWP carbon pool estimate for the given year [12, 22]. The system boundary of the "stock-change" approach is graphically represented in Figure 3.1 which is the scheme used in the updated IPPC guidelines (2019) and found in Annex 12A.

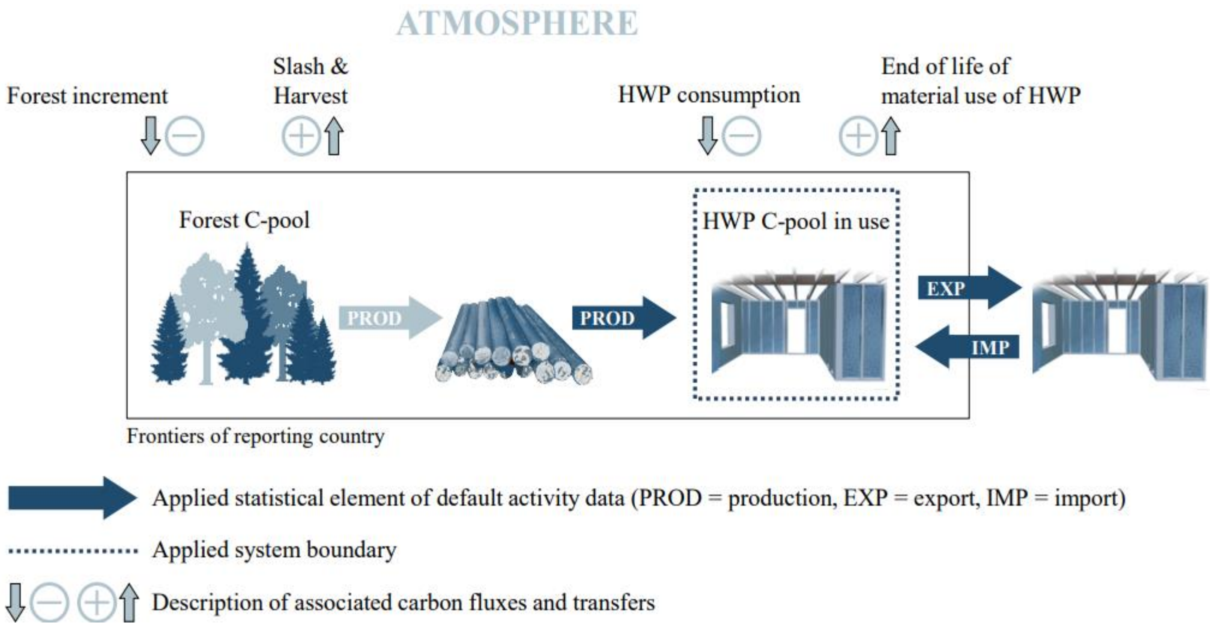

Figure 3.1 Conceptual illustration of the "stock-change" approach, estimating CO_2 emissions and removals associated with the carbon stock in the HWP pool in use based on calculated consumption data of HWP [22, 25]

3.1.2 Production approach

The "production" approach calculates the carbon contribution of the HWP pool based on all the wood products harvested and consumed in the country, including those that are exported and utilized in other countries but does not consider the effect of imported wood. This approach can track the entire lifecycle of wood products from harvesting to disposal. The carbon transferred from forest carbon pools to the HWP pool is counted as a carbon loss in the forest land pool of the producing country and a carbon gain in the HWP pool of the producing country. In simple words, if a country decides to adopt the "production" approach, it is responsible for reporting the carbon stock changes resulting from the harvested wood products even if these products are used abroad [12, 22]. The system boundary of the "production" approach is graphically represented in Figure 3.2 which is the scheme used in the updated IPCC guidelines (2019) and found in Annex 12A [22].

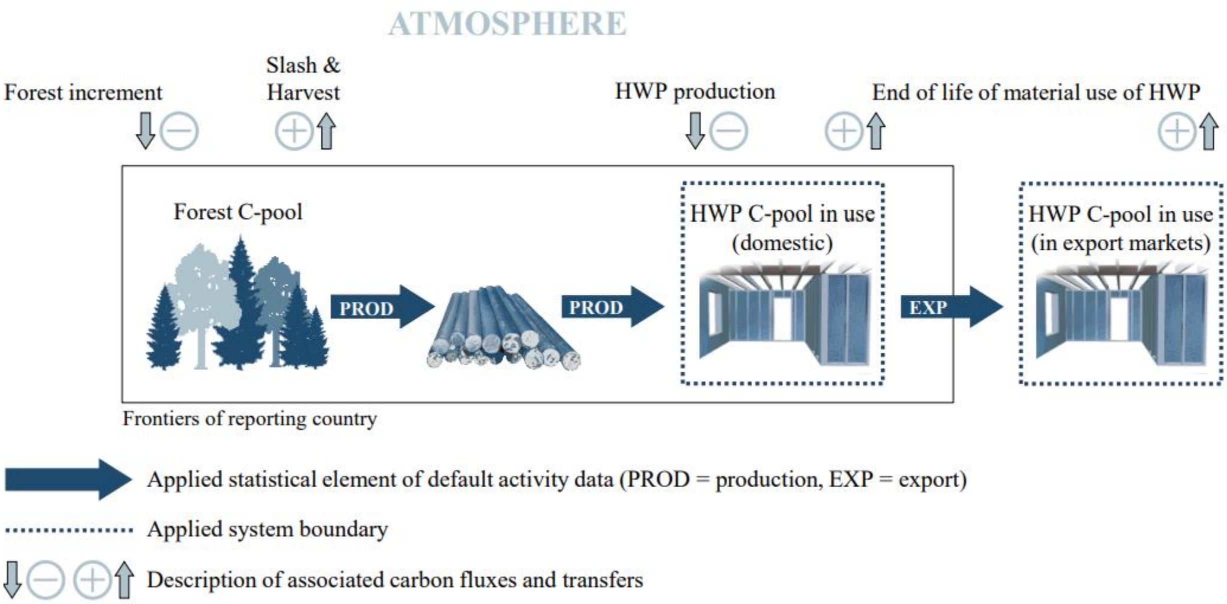

Figure 3.2 Conceptual illustration of the "production" approach, estimating emissions and removals of CO_2 associated with the carbon stock in the HWP pool in use based on data on HWP production originating from domestic harvest [22, 25]

3.1.3 Atmospheric-flow approach

Under the "atmospheric-flow" approach, the focus is on estimating the CO_2 fluxes to and from the atmosphere resulting from the harvested and utilized wood products within national frontiers. When using the "atmospheric-flow" approach, the consuming country is responsible to report the CO_2 emissions and removals due to the HWP, and like the "stock-change" approach, exports are excluded in the quantification but imported woody biomass is considered as carbon gain in the HWP pool [22].

Following the “atmospheric-flow” approach, the carbon removals resulting from the forest are reported by the country where it was grown, while the carbon emissions resulting from the oxidation of harvested wood products are reported by the consuming country. Therefore, when carbon is transferred from forest land pools to the HWP pool, it is not considered a carbon loss in the producing country's forest land pools. Instead, it is accounted for as emissions at the end of the HWP's life in the consuming country. This approach accurately reflects the carbon exchange between land and the atmosphere [12]. The system boundary of the “atmospheric-flow” approach is graphically represented in Figure 3.3 which is the scheme used in the updated IPPC guidelines (2019) and found in Annex 12A [22].

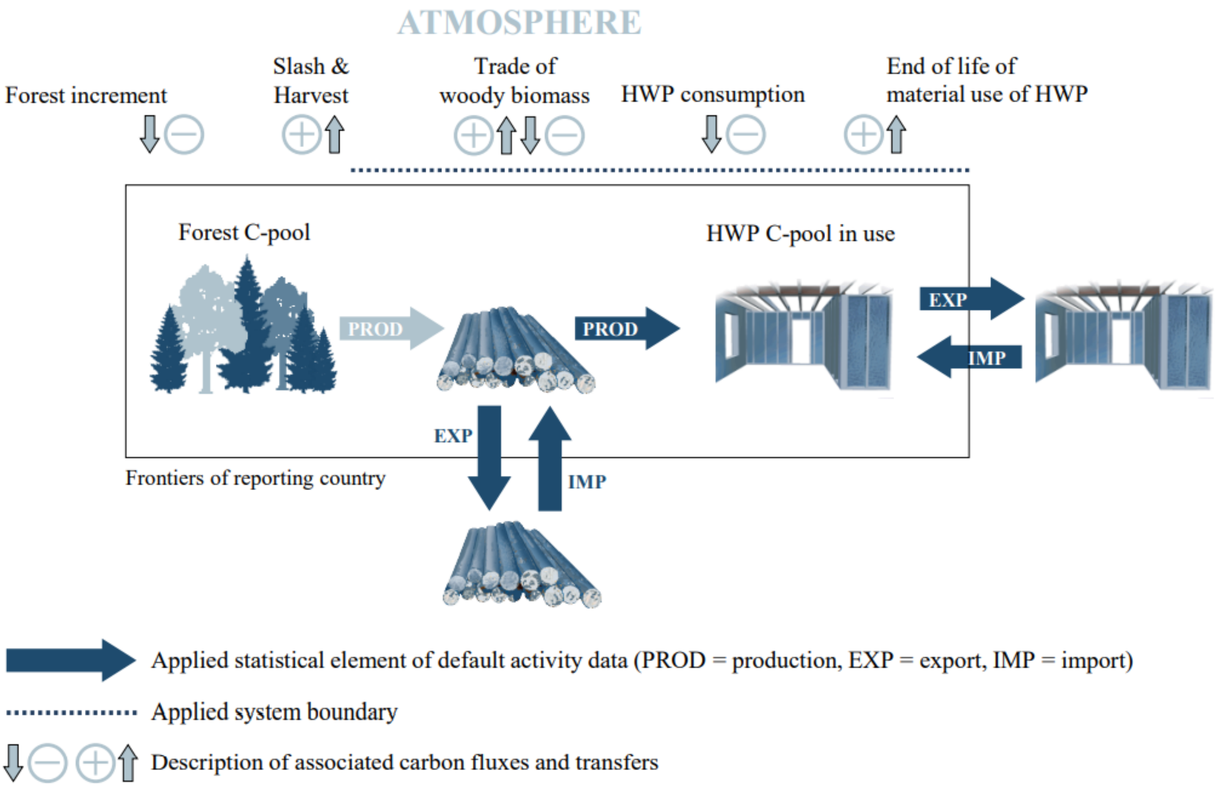

Figure 3.3 Conceptual illustration of the “atmospheric-flow” approach, estimating CO_2 fluxes associated with HWP based on data on the carbon stock in the HWP pool in use and traded woody biomass [22, 25]

3.1.4 Simple-decay approach

As it was mentioned, the “simple-decay” approach is designed for being applied by producing countries, in this sense it keeps a similar system boundary as the “production” approach does. Moreover, the “simple-decay” approach, like the “atmospheric-flow” approach, addresses the carbon fluxes between the atmosphere and HWP, and according to the IPPC guidelines also considers the woody biomass used for energy purposes. This approach estimates the arising carbon contribution resulting from wood production by harvesting forests and other wood-producing areas in a specific country, regardless of where this HWP is used, inside or outside the accounting country [22]. The system boundary of the "simple-decay" approach is graphically represented in Figure 3.4 which is a scheme developed based on the schemes provided by updated IPPC guidelines (2019) for the other approaches [22].

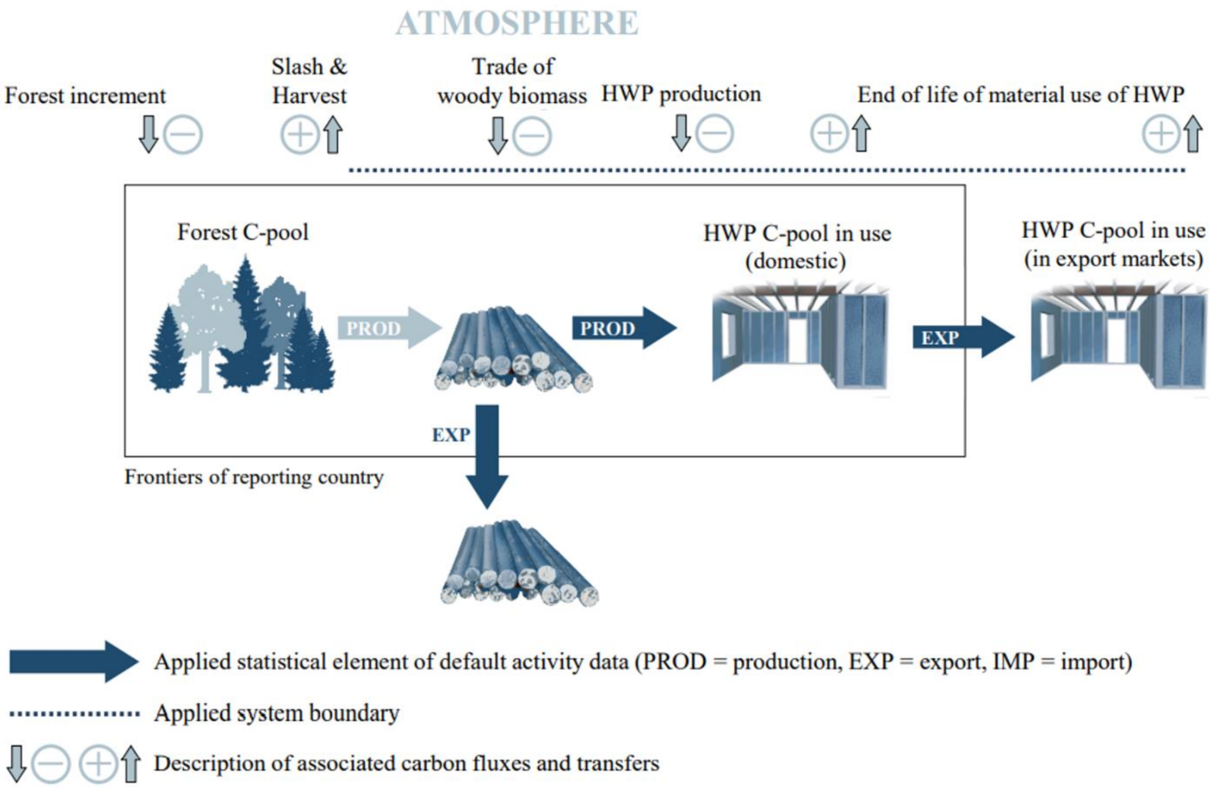

Figure 3.4 Conceptual illustration of the "simple-decay" approach, estimating CO_2 fluxes associated with HWP based on data on the carbon stock in the HWP pool in use and traded woody biomass

3.1.5 Assumption of instantaneous oxidation, reporting zero, and steady-state.

As it was discussed in Chapter 2, the concept of "instantaneous oxidation" has been used since the development of the first methodologies for the quantification of the CO_2 emissions generated by wood harvesting. "Instantaneous oxidation" is an assumption that considers that all harvested wood biomass is oxidized immediately, and based on this, the carbon stored in the HWP is released to the atmosphere and accounted for in the year it was produced. Consequently, the carbon stock in the HWP pool would not undergo any change during that year as the inflow is the same as the outflow, and the HWP contribution would be zero for the corresponding year. However, the IPCC guidelines recommend as a good practice to report the amounts of wood harvested, imported, and exported in the AFOLU section, even if "instantaneous-oxidation" is assumed [19].

“Instantaneous oxidation” and “reporting zero” are usually applied by countries where the HWP is a minor category in the AFOLU section. Besides, these assumptions can and are commonly adopted by countries where the available data regarding HWP are insufficient or unreliable to adopt any of the suggested approaches [12].

In the 2019 refinement of the 2006 IPPC guidelines, these two above mentioned concepts are avoided, and the “steady-state” assumption is suggested instead [22]. “Steady-state” is in simple words an update in the terminology used to conclude that the carbon stock in HWP has not changed in the reporting year. As the assumptions of “instantaneous oxidation” or “steady-state” would bring out the same numerical outcome in the estimation of the HWP carbon contribution, implying the preference for one of these concepts is purposeless.

3.2 Description of Methods

After selecting the more suitable approach for the country and therefore defining the system boundary of WHAT is going to be considered in the calculations for the carbon emissions and removals arising due to the HWP, the next step will be selecting the method and defining the set of calculations to be used. The IPPC provides three different methods: Tier 1, Tier 2, and Tier 3. Where Tier 1, called the “first-order decay” method, is the most basic method based on default factors determined by the IPCC. Tier 2 is a method using country-specific data, it applies the same main equations that Tier 1 but applies the country data to develop more specific parameters, and hence a more accurate estimation. Tier 3 is the more complex option which is the application of country-specific methods.

3.2.1 Available data and method selection

The selection of the method is based on the availability of data on HWP. The relevant statistics can be looked for in publicly available databases such as FAOSTAT or other national databases [26]. For the developed methods, three main categories of wood products are utilized. These 3 commodity classes of semi-finished wood products are sawnwood, wood-based panels, and paper and paperboard. The general methodology does not consider other end uses categories or finished products in order to avoid double counting or losses in the volume through the manufacturing processes. As it is shown in the scheme of the process chain and the resulting wood products (Figure 3.5), considering these 3 commodity classes the major volume of the harvested wood is covered in the estimations [22].

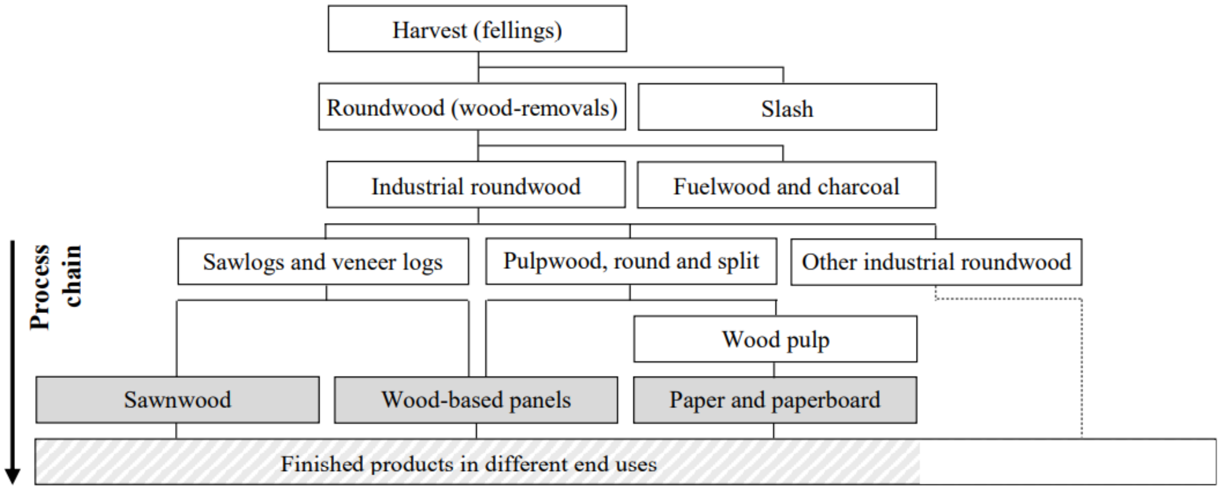

Figure 3.5 Simplified classification of wood products based on FAO forest products definitions [2, 22]

It is important to mention that to avoid double counting, some specific products are intentionally left out from the definitions of the three semi-finished wood product categories. For instance, sleepers, V-jointed sawnwood and laminated veneer lumber (LVL) are not included in the definition of sawnwood, because these products are manufactured through further processing and are considered as finished products [22].

Sawnwood refers to wood that has been created from both domestic and imported roundwood, either by sawing it lengthways or using a profile-chipping process, and that is thicker than 6 mm. This includes various types of wood products such as planks, beams, joists, boards, rafters, scantlings, laths, boxboards, and lumber, which can be unplaned, planed, or end-jointed. However, it does not include sleepers, wooden flooring, or moldings that have been continuously shaped along any of their edges or faces. Additionally, sawnwood produced by re-sawing previously sawn pieces is also excluded from this definition [22].

Wood-based panels category refers to a collection of products including veneer sheets, plywood, particle board, and fiberboard [22].

Paper and paperboard is a combined category that includes graphic papers, sanitary and household papers, packaging materials, and other types of paper and paperboard. However, it does not include manufactured paper products such as boxes, cartons, books, magazines, and other similar items [22].

The datasets of the sawnwood and wood-based panels are reported in cubic meters of solid volume, while the amount of paper and paperboard produced and traded is reported in metric tonnes. Both units permit countries to make the conversion of HWP quantified into units of carbon.

When these 3 commodity classes can be found in an open database as FAOSTAT it is implied that Tier 1 can be used and probably Tier 2. However, for Tier 3 more details can be considered in the calculations according to the country-specific methodology, for example, the "other industrial roundwood" portion of the harvested wood (Fig. 3.5) is discarded and considered as zero in Tier 1 and 2, but it could be accounted in Tier 3 if the developed method allows it [22].

To simplify the decision process of choosing the appropriate method for the reporting country, the IPCC guidelines provide a decision tree diagram (Fig. 3.6). In the diagram one can view that if there is no available data, then an assumption of "steady-state" is adopted. Then, if there is available activity data for the three commodity classes of semi-finished wood products, but no specific statistics and emission factors of the country, only Tier 1 can be implemented. Therefore, if there are specific information and factors for the specific reporting country, Tier 2 should be used. Tier 3 could be applied only when the reporting country has developed its own methodology and has the needed activity data for an accurate estimation of the carbon emissions and removals of the HWP. And that is why the level of complexity and detail vary in the calculations and data collection process, based on the method adopted. It is important to mention, that the guidelines encourage providing, in as much as possible, the most accurate results as can be observed in Figure 3.6 [22]. From the decision tree, it is good to highlight according to the IPCC, the adopted approaches do not influence the method selection, as it does not affect the accuracy of the country estimation, but from a global perspective, the approach selection could impact it, as it is discussed in section 3.3.

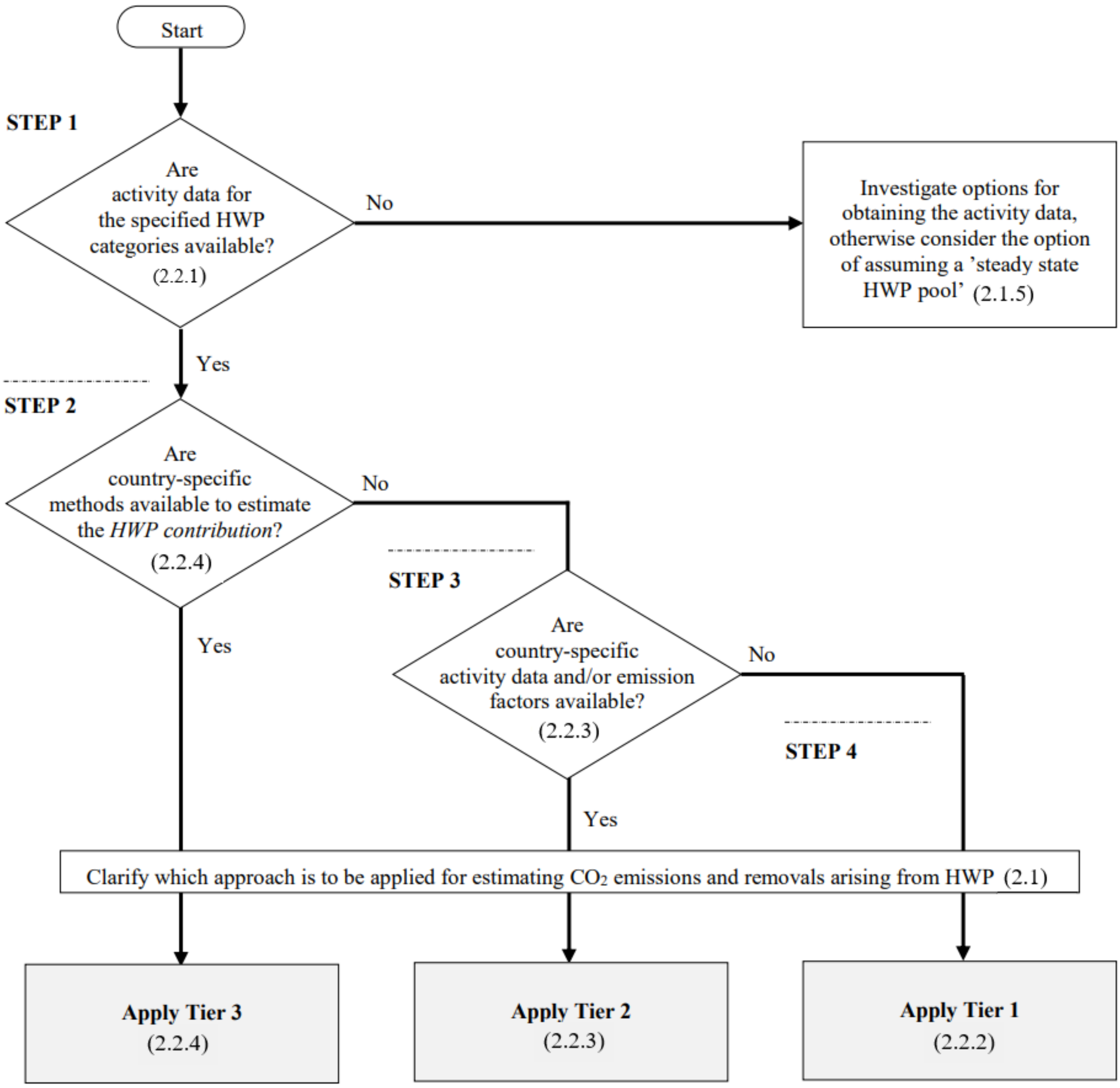

Figure 3.6 Decision tree for choosing the relevant tier method for estimating CO_2 emissions and removals arising from HWP [22].

3.2.2 Tier 1 method using first-order decay function

The total CO_2 emissions and removals arising from the HWP can be estimated once the carbon stock, carbon stock change, and annual inflow are known for each commodity class in the year reported. Some of these variables are calculated differently depending on the adopted approach. For this reason, in the section it is explained step by step the methodology to calculate the total contribution of CO_2 for each approach and according to the 2019 refinement of the 2006 IPPC guidelines [22].

Step 1 Calculation of carbon inflow

The first step is to obtain the annual carbon inflow for specific HWP commodity classes as follows:

For "stock-change" and "atmospheric-flow" approaches:

For the "consuming country" approaches, the carbon inflow is calculated based on Equations (3.1) and (3.2) [2, 22, 25].

$$Inflow_{SCA_l}(i) = HWP_{C_l}(i) \bullet cf_l \quad (3.1)$$

$$HWP_{C_l}(i) = HWP_{P_l}(i) + HWP_{IM_l}(i) - HWP_{EX_l}(i) \quad (3.2)$$

With $HWP_{C_l}(i) = 0, if\ HWP_{C_l}(i) < 0\ or\ HWP_{EX_l}(i) > HWP_{P_l}(i) + HWP_{IM_l}(i)$

where:

$Inflow_{SCA_l}(i)$ = carbon inflow in HWP from the calculated domestic consumption of the respective HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in Mt C/yr.

$HWP_{C_l}(i)$ = calculated domestic consumption of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³

cf_l = carbon conversion factor of the specific semi-finished HWP commodity class $\boldsymbol{l}$. (See Table 12.1 IPCC 2019)

$HWP_{P_l}(i)$ = production of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

$HWP_{IM_l}(i)$ = import of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

$HWP_{EX_l}(i)$ = export of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

For “production” and “simple-decay” approaches:

For the approaches with a producing system boundary, the carbon inflow is calculated based on Equations (3.3) and (3.4) [2, 22, 25].

$$Inflow_{PA_l}(i) = HWP_{DP_l}(i) \bullet cf_l \quad (3.3)$$

$$HWP_{DP_l}(i) = HWP_{P_l}(i) \bullet f_R(i) \quad (3.4)$$

with:

$f_R(i) = f_{IRW}(i)$ for “sawnwood” and “wood-base panels” categories

$f_R(i) = [f_{IRW}(i) \bullet (1-q) \bullet f_{PULP}(i)] + q \bullet f_{RecP}(i)$ for “paper and paper board”

$$f_{IRW}(i) = 0\ if\ f_{IRW}(i) < 0; f_{PULP}(i) = 0\ if\ f_{PULP}(i) < 0;\ f_{RecP}(i) = 0\ if\ f_{RecP}(i) < 0$$

where:

$Inflow_{PA_l}(i)$ = carbon inflow in HWP from the production of the respective HWP commodity class $\boldsymbol{l}$ originating from the domestic harvest in the year $\boldsymbol{i}$, in Mt C/yr.

$HWP_{DP_l}(i)$ = production of the specific semi-finished HWP commodity class $\boldsymbol{l}$ originating from domestic harvest in the year $\boldsymbol{i}$, in m³

cf_l = carbon conversion factor of the specific semi-finished HWP commodity class $\boldsymbol{l}$. (See Table 12.1 IPCC 2019)

$HWP_{P_l}(i)$ = production of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

$f_R(i)$ = share of woody feedstock commodity class R (IRW, PULP or RecP) for the production of the specific semi-finished HWP commodity class originating from domestic harvest in the year $\boldsymbol{i}$, as calculated according to Equation (3.5)

IRW = HWP feedstock commodity class "industrial roundwood".

$PULP$ = HWP feedstock commodity class "wood pulp".

$RecP$ = HWP feedstock commodity class "recovered paper".

Q = recovered paper utilization rate.

According to the system boundary of the "production" and "simple-decay" approaches, it is necessary to exclude the carbon contribution from the imported HWP, for this reason, Equation (3.5) is used to calculate the feedstock factor $f_R(i)$ [2, 22, 25].

$$f_R(i) = \frac{R_P(i) - R_{EX}(i)}{R_P(i) + R_{IM}(i) - R_{EX}(i)} \tag{3.5}$$

with:

$R = IRW$ for feedstock category "industrial roundwood"

$R = PULP$ for feedstock category "wood pulp"

$R = RecP$ for feedstock category "recovered paper"

Step 2 Estimation of carbon stock at initial time

For "stock-change", "production", "atmospheric-flow" and "simple-decay" approaches.

It is necessary to know the current carbon stock and for that the stock in the HWP pool in use at the initial time t_0 must be estimated before. For this, the Tier 1 method assumes a "steady state" for the HWP pool at the starting time t_0 when activity data begins. In this sense, the carbon stock change of the HWP at the initial time t_0 is assumed to be 0 as a proxy. Equation (3.6) is used to estimate the "steady-state" carbon stock $C(t_0)$ for each HWP commodity class l, based on the average $Inflow_l\,(i)$ of the first 5 annual statistical records available, and considering a decay rate based on a first-order decay function [2, 22, 25].

$$C_l(t_0) = \frac{Inflow_{l_{average}}}{k} \tag{3.6}$$

with:

$$Inflow_{l_{average}} = \left(\sum_{i=t_0}^{t_4} Inflow_l\,(i)\right)/5 \quad (3.7)$$

$$k = \ln 2\,/HL \quad (3.8)$$

where:

$C_l(t_0)$	=	the carbon stock in the specific HWP commodity class $\boldsymbol{l}$ at the initial time, in Mt C.
$Inflow_{l_{average}}$	=	the average carbon inflow to the specific HWP commodity class $\boldsymbol{l}$ during the first 5 reported years, in Mt C/yr.
k	=	decay constant of FOD for each HWP commodity class $\boldsymbol{l}$, in yr^{-1}.
$Inflow_l(i)$	=	the carbon inflow to the specific HWP commodity class $\boldsymbol{l}$ during the year $\boldsymbol{i}$, in Mt C/yr.
HL	=	the half-life of the specific HWP commodity in the HWP pool, in years. (See Table 12.3 IPCC 2019)

Step 3 Calculation of carbon stocks and annual changes

For "stock-change", "production", "atmospheric-flow" and "simple-decay" approaches.

Once the carbon inflows of each year and the initial carbon stock are known, it is possible to calculate the carbon stocks in the HWP in use for every year, and consequently the carbon stock changes. For this, a first-order-order decay function is implemented, Equation (3.9), which removes the decayed portion of the carbon stock and a portion of the carbon flowing into the HWP in-use pool. To calculate the change in the carbon stock, equation (3.10) is used [22, 25, 27].

$$C_l(i+1) = e^{-k} \bullet C_l(i) + \left[\frac{(1-e^{-k})}{k}\right] \bullet Inflow_l(i) \quad (3.9)$$

$$\Delta C_l(i) = C_l(i+1) - C_l(i) \quad (3.10)$$

where:

$C_l(i)$ = the carbon stock in the specific HWP commodity class $\boldsymbol{l}$ at the beginning of the year $\boldsymbol{i}$, in Mt C.

k = decay constant of FOD for each HWP commodity class $\boldsymbol{l}$, in yr^{-1}.

$Inflow_l(i)$ = the carbon inflow to the specific HWP commodity class $\boldsymbol{l}$ during the year $\boldsymbol{i}$, in Mt C/yr.

$\Delta C_l(i)$ = the carbon stock change of the specific HWP commodity class $\boldsymbol{l}$ during the year $\boldsymbol{i}$, in Mt C/yr.

It is possible to visualize an example of how to implement steps 2 and 3 in an MS EXCEL spreadsheet in the IPCC 2019 guidelines in Box 12.1 [22].

Step 4 Calculation of total CO_2 contributions

For "stock-change", "production" and "simple-decay" approaches:

Once the carbon stock change for each HWP commodity class is known, the total emissions and removals arising from the HWP in use can be calculated for the specific year. For the "stock-change", "production" and "simple-decay" approaches Equation (3.11) can be used [2, 22, 25, 27].

$$\Delta CO_{2_{TOTAL}}(i) = -44/12 \bullet \sum_{l=1}^{n} \Delta C_l(i) \tag{3.11}$$

where:

$\Delta CO_{2_{TOTAL}}(i)$ = total CO_2 emissions and removals from net changes of the carbon stock in HWP in use during the year $\boldsymbol{i}$, in Mt CO_2.

$\Delta C_l(i)$ = the carbon stock change of the specific HWP commodity class $\boldsymbol{l}$ during the year $\boldsymbol{i}$, in Mt C/yr.

l = index number of the semi-finished HWP commodity class.

n = number of selected HWP commodity classes of the semi-finished HWP commodities of sawnwood, wood-based panels, and paper and paperboard.

For "atmospheric-flow" approach:

The total annual CO_2 contribution due to the HWP pool for the "atmospheric approach", in contrast to the "stock-change" approach, also considers the traded carbon of the HWP serving for wood fuel or feedstock, Equation (3.12) [2, 22, 25].

$$\Delta CO_{2_{AFA}}(i) = -44/12 \bullet \left(\sum_{l=1}^{n} \Delta C_{SCA_l}(i) + \sum_{j=1}^{m} RC_{EX_j}(i) - \sum_{j=1}^{m} RC_{IM_j}(i)\right) \quad (3.12)$$

with:

$$RC_{TRADE_j}(i) = R_{TRADE_j}(i) \bullet cf_j$$

$TRADE = IM$ for imports of the relevant feedstock category $\boldsymbol{j}$

$TRADE = EX$ for exports of the relevant feedstock category $\boldsymbol{j}$

where:

$\Delta CO_{2_{AFA}}(i)$ = emissions and removals of CO_2 following the "atmospheric-flow" approach, including emissions and removals associated with the carbon storage in the HWP pool in use due to the utilization of wood as material in the country (i.e., "stock-change" approach) during the year $\boldsymbol{i}$, in Mt CO_2/yr.

$\Delta C_{SCA_l}(i)$ = carbon stock change in the specific semi-finished HWP commodity class $\boldsymbol{l}$ during the year $\boldsymbol{i}$, calculated from domestic consumption (i.e., "stock-change" approach), in Mt C/yr.

l = index number of the semi-finished HWP commodity class.

n = number of selected commodity classes of the semi-finished HWP commodities of sawnwood, wood-based panels, paper and paperboard.

m = number of included HWP feedstock categories.

$RC_{EX_j}(i)$ = exported carbon in the relevant HWP feedstock commodity class $\boldsymbol{j}$ serving as wood fuel and/or raw material for the manufacture of semi-finished HWP during the year $\boldsymbol{i}$, in Mt C/yr.

$RC_{IM}(i)$ = exported carbon in the relevant HWP feedstock commodity class $\boldsymbol{j}$ serving as wood fuel and/or raw material for the manufacture of semi-finished HWP during the year $\boldsymbol{i}$, in Mt C/yr.

$RC_{TRADE_j}(i)$ = carbon in the relevant traded HWP feedstock commodity class $\boldsymbol{j}$ serving as wood fuel and/or raw material for the manufacturing of semi-finished HWP, in Mt C

cf_j = carbon conversion factor of the specific HWP feedstock commodity class (See Table 12.2 IPCC 2019).

3.2.3 Tier 2 method using country-specific data

The method Tier 2 uses the same set of equations used for Tier 1, but the main change of this method is due to the use of either country-specific activity data and/or country-specific emission factors related to the service life and half-life for the HWP domestically consumed and exported (if a production boundary system is used) what provides more accurate estimations for the specific conditions of the reporting country. Then, in this section, it will be explained in detail what are the differences implemented for Tier 2 in the 4 main steps used in Tier 1.

Step 1 Calculation of carbon inflow

When calculating the carbon $\boldsymbol{Inflow_l}$ for Equations (3.1) and (3.3), if it is possible, it should be used the country-specific activity data obtained from national surveys which provide more detailed and accurate statistics than the reported by FAOSTAT, this data must at least accomplish the same categorization of the commodity classes used in Tier 1 [22].

Particularly for the "production" approach, the IPCC guidelines suggest reporting CO_2 emissions and removals separately for changes in the carbon stock of domestically consumed and exported HWP. To achieve this, it is necessary to calculate the annual carbon inflow to the HWP pool for the relevant commodity class that is domestically consumed using Equation (3.13), especially when country-specific emission factors are used [22].

$$Inflow_{PADC_l}(i) = HWP_{DC_l}(i) \bullet cf_l \tag{3.13}$$

$$HWP_{DC_l}(i) = HWP_{DP_l}(i) - HWP_{EX_l}(i) \bullet f_R(i) \tag{3.14}$$

with: $$HWP_{DC_l}(i) = 0 \; if \; HWP_{EX_l}(i) \bullet f_R(i) > HWP_{DP_l}(i)$$

where:

$Inflow_{PADC_l}(i)$ = carbon inflow in HWP from the domestic production and consumption of the specific semi-finished HWP commodity class originating from domestic harvest in the year $\boldsymbol{i}$, in Mt C/yr.

$HWP_{DC_l}(i)$ = domestically produced and consumed HWP of the specific semi-finished HWP commodity class originating from domestic harvest in the year $\boldsymbol{i}$, in m³.

cf_l = carbon conversion factor of the specific semi-finished HWP commodity class $\boldsymbol{l}$ (See Table 12.1 IPCC 2019).

$HWP_{DP_l}(i)$ = production of the specific semi-finished HWP commodity class $\boldsymbol{l}$ originating from domestic harvest in the year $\boldsymbol{i}$, in m³

$HWP_{EX_l}(i)$ = export of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

$f_R(i)$ = share of woody feedstock commodity class R (IRW, PULP or RecP) for the production of the specific semi-finished HWP commodity class originating from domestic harvest in the year $\boldsymbol{i}$, as calculated according to Equation (3.5)

Steps 2 and 3 Calculation of Carbon Stock and changes

Countries can minimize the uncertainties related to the assumptions underlying the default Tier 1 half-life values of HWP commodities classes for semi-finished wood products (see Table 12.3 in IPCC 2019) by utilizing country-specific half-life values under Tier 2. These specific emission factors can be applied for both the domestic use of HWP commodity classes, and for exported HWP commodity classes in the importing country (depending on the system boundary of the adopted approach) [22]. The IPPC guidelines explain how to develop these half-life factors based on the country's specifications. Equation (3.15) can be used to estimate the country-specific half-lives, however in Table 12.4 of the IPCC 2019 guidelines it is shown an example of the calculation [22].

The country-specific half-life values are obtained based on the national estimated service life (ESL) which is obtained according to the ISO 15686 standard series and adjusted in combination with an obsolescence factor (O). The ISO series obtain this value by considering a reference service life (RSL) which is the expected service life of a product under a reference set of in-use conditions. Therefore, the ESL is obtained considering any differences from the reference in-use conditions [28], for this the RSL is modified by seven factors, such as grade of the component as supplied, installation, work execution, indoor, environment, outdoor environment, usage conditions, and maintenance. A theoretical example with wooden claddings in Norway is included in the 2019 IPCC guidelines (see Box 12.2) [22, 29].

Moreover, obsolescence occurs when a product or facility becomes incapable of meeting evolving needs. It typically arises from unforeseen changes that are not necessarily related to the construction of the facility, such as functional, technological, and economic obsolescence. Assessments of obsolescence should be founded on the knowledge and expertise of the designer and client, and ideally, supported by documented feedback from practical experience [22, 28].

Alternatively, in case the obsolescence factor is not implemented, a decay function can be applied that employs service life data to project the decay profile, which is based on products being removed from use rather than a biological decay pattern. This approach can also estimate the actual time required for products to become obsolete [22].

$$HL_l = ESL_{ADJUSTED_l} \bullet \ln 2 \tag{3.15}$$

$$ESL_{ADJUSTED_l} = \sum_{M=1}^{x} \left(f_{M_l} \bullet ESL_{M_l} \bullet O_{M_l} \right) \tag{3.16}$$

where:

HL_l	=	half-life value for a specific HWP commodity class, in yr.
f_{M_l}	=	market $\boldsymbol{M}$ share of a specific commodity class $\boldsymbol{l}$, in %.
ESL_{M_l}	=	national estimated service life for a specific commodity class $\boldsymbol{l}$ and market $\boldsymbol{M}$ that a HWP product is expected to have under a set of specific in-use conditions, in yr.
O_{M_l}	=	national obsolescence factor for a specific commodity class $\boldsymbol{l}$ and market $\boldsymbol{M}$ estimated based on the ISO 15686 standard series.
x	=	number of included HWP markets such as construction, furniture, packaging, and paper.

When calculating CO_2 emissions and removals resulting from HWP using the "production" approach and using country-specific half-life data for exported HWP, it is recommended to use the half-life data from the importing country, but only if the same commodity classes are considered by the importing countries. If not, the default values provided in Tier 1 must be used [22].

Step 4 Calculation of total CO_2 contributions

For this step, nothing is modified from the methodology described in Tier 1.

3.2.4 Tier 3 using country-specific methods

It is suggested that in order to achieve the same level of precision as Tier 1 and 2, it is important to confirm that the commodity classes for a country's HWP cover equivalent volumes as those based on the international classification system and the system boundary adopted by the country. It is also recommended that countries make HWP commodity classes large enough to include every weighty contribution to the carbon volumes of the HWP pool. These commodity classes can be deemed significant if they represent at least 5% of the total HWP volumes corresponding to the chosen approach [22].

3.2.5 Other proposed methodologies based on the IPCC guidelines

In 2020, Zhang, X. et al proposed an improved methodology for accounting for the carbon emission and removals due to the HWP. In this new methodology, two important modifications to the IPPC methods are suggested. First, the use of the EORA global supply chain database [30] to complement the activity data from FAOSTAT to allocate the volumes of the produced semi-finished wood products to their end-use categories according to the consuming country. And the second change, is the use of a decay function based on a Chi-square distribution, instead of using the first-order decay function proposed by the IPCC guidelines to calculate the carbon stock changes [23].

Since in the research, a global case study for the estimation of the carbon stock is carried out, detailed data regarding importing and exporting HWP is needed. For this reason, FAOSTAT is not sufficient to map globally HWP production and consumption, because the traded quantity is reported but without specifying the producer for the imported wood products and the consuming country for the exports. To solve this lack of data, it is used the multi-region input-output tables from EORA database which allow the linking of the production with the end-uses of the HWP, such as construction, furniture, paper, and other HWP [23].

Based on this process of detailing and enriching the HWP activity data, it would be possible to use Tier 2 in cases where, by using only FAOSTAT data, Tier 1 is the single option, and for cases where the country-specific data is available for the use of Tier 2, by combining the data of Eora database, Tier 3 could be developed [23].

One of the most relevant upgrades to the current guidelines from this method is the inclusion of dynamic decay rates calculated with a decay function based on a Chi-squared distribution, a one-parameter gamma distribution. By this, it can be considered more realistically how quickly carbon is being removed from the stock of the HWP pool and released into the atmosphere [23, 31]. It is important to mention that this contribution and observation was done previously by other authors such as Marland, et. al in 2009. However, other experts have mentioned that the use of this method to estimate the decay rate is depended on the availability of detailed information on the decay rates of wood products that usually do not exist [31, 32].

3.3 Review of the approaches and methods

3.3.1 Comparison and discussion

Based on the provided approaches and methods by the 2019 IPCC guidelines, in this section, an assessment is carried out to find the existing or possible gaps generated using them. A key point to start with is the fact that these guidelines are designed to avoid double counting and non-counting of the HWP carbon contributions, but this can only be achieved if all countries follow the same approach. In this sense, the possibility of double counting and non-counting scenarios exists even if all the countries follow and report according to the updated IPCC guidelines. For instance, if a consuming system boundary is adopted by an importing country that buys HWP from a country that reports its annual HWP carbon contribution based on a producing system boundary, double counting of the traded carbon will occur at a global level. Hence, a global common approach would be the ideal option to avoid these issues.

The idea of providing a common global methodology arises different difficulties especially to define a system boundary that benefits consuming and producing countries in the same way and which would adapt to the availability of data for each country. For this, reason the IPCC guidelines do not mention any preference or suggestion for a specific approach as it is quite complex to only provide one option for the different contexts of each party. Moreover, it is possible to find certain advantages and disadvantages among the suggested approaches.

Comparing "stock-change" and "production" it can be said that it is easier to collect the data needed to carry out an estimation based on the "stock-change" approach. In addition, based on the "stock-change" the country can assess the entire management of wood products inside the national boundaries. Nevertheless, the system boundaries of the national forestland and the domestic consumption of HWP are usually not the same, because the imported wood is added to the HWP carbon pool which can differ from the trade policies of different countries and have further implications. Furthermore, since it is often difficult to obtain wood transportation data on a regional or project level, "stock-change" approach is most commonly applied to national territorial boundaries [12].

On the other hand, the "production" approach can provide an evaluation of the mitigation potential from the AFOLU sector by describing the lifecycle of forest management and the end life of HWP. This approach enables the tracking of the origin of HWP to avoid the accounting of products from deforestation and forest degradation activities [23]. This approach can be adopted to calculate the forestland carbon pool at different geographical levels, including projects and harvest-related activities. However, it should be noted that determining the domestic ratio parameter can be difficult since the reporting country often lacks control over the reported data from the exported HWP carbon stocks, which can result generate uncertainties in the outcomes [12].

Analyzing the "atmospheric-flow" approach, it is impacted by trade and can result in a significant net sink from the land use sector in countries that export large quantities of wood and wood products, similar to the "stock-change" approach. Although this approach can be applied to national territorial boundaries, it is not well-suited for smaller system boundaries as obtaining accurate data on periods and locations of wood incineration at such scale is often challenging. However, it is important to mention that as this approach considers the emissions due to fuel consumption it can provide an accurate representation of how carbon flows between the atmosphere and land. Consequently, it needs more specific data to calculate the total annual contribution of CO_2 as it can be appreciated in the description of the methods. As result, not many countries adopt this approach for their national inventory reports, evidence of this is that none of the parties implement it in the 2018 GHG inventories submitted by the Annex I (UNFCCC) countries for the period from 1990 to 2016 [12].

The "simple-decay" approach, like the "atmospheric-flow", is not commonly adopted compared to the other approaches and the assumption of "instantaneous oxidation". This approach has the same system boundary as the "production" approach, but it focuses on the carbon flow from the forest to HWP as it was already explained [12]. Nevertheless, this approach follows exactly the same methodology as the "production" approach for Tier 1 and Tier 2, so working with the same activity data would provide the same results. This could be confusing, as the conceptual framework is different, and it is not even mentioned in the methods description of the IPCC guidelines. That is why, additional justification for its inclusion in the IPCC guidelines should be provided.

Although, before considering a common global approach, it should be taken into account the limited available activity data for many countries in the world. For example, it is expected that around one-third of the countries in the globe would need to make a "steady-state" or "instantaneous oxidation" assumption for the estimation of their annual HWP carbon contribution, and currently, it is widely used. Thence, even when these assumptions provide inaccurate estimations, it is the unique option for many countries, and it will not change until their national surveys and statistics improve [12].

In the 2006 guidelines, it is mentioned the main uncertainties in the estimation methodology arise due to two main points: first the use of default factors which might be different from the national specific values; and second, the equations provided in the method do not represent the real-world processes of how the carbon pools vary along the harvesting activities and the usage, disposal, and recycling of wood products. Particularly, the decay rate of wood which estimation is essential for the estimation of the carbon outflow and stock, but it is difficult to represent mathematically the actual process. As it was pointed out in other research, considering the half-life values as a constant and using the first-order decay function might not accurately estimate the real carbon stock of HWP, especially when considering long-term products, because the current used decay function considers that the biggest portion of the stock decay in the first years which is not always the same case depending on the wood products [23, 31]. Furthermore, if a country implements wood cascading practices to extend the life service of wood material, this could not be reflected by using the updated guidelines. In the methodology for the "production" approach, only the share of the recovery paper is considered, and the recovered portion does not impact the half-life values or in the calculation of the carbon stock and carbon oxidation rate.

Regarding the other methods proposed in the 3.2.5 section, the implementation of a new methodology to estimate the decay rate in the wood products is a good alternative to model more accurate the carbon stock change in the HWP pool, particularly in the case of "sawnwood" and "wood-based panels" which have a higher life service than the "paper and paperboard" commodity classes. Also, the use of another database to improve the activity data found in FOASTAT can be beneficial to improve the calculations. However, further evaluation of the "EORA global supply chain database" should be done and it is important to say that it is not an open public source, so there is a need to pay to get full access to it, which is a disadvantage to be adopted in the guidelines for the general use of all the involved parties [30].

Comparing the last updated version with the previous one of the IPCC guidelines (2006), one of the main changes has been the historical data considered in the estimation of the carbon emissions and removals arising to the HWP pool. In the 2006 guidelines, all the available data was used, and 1900 was considered the starting year. In contrast, the 2019 version change the starting year to 1990 with the purpose of reducing uncertainties due to the progress in data collection and statistics of the harvesting and production volumes. Over time, the data reported and collected regarding the production of wood products has changed due to improvements in the industry. For example, developments in the facilities used to process and handle the materials have led to make easier quantification and in the same direction, different policies have pushed individual corporates from bigger to lower scales to report their production volumes. For this reason, considering older data can provide unrealistic results in the current carbon stock for the in-use HWP pool [22, 33]. As it was shown in a comparison of the different guidelines version, when the initial year is later, the initial carbon stocks tend to be larger, resulting in lower carbon removals. This is because higher stocks in earlier years lead to higher carbon outflows in later years, resulting in lower net carbon stock increases [34].

In this previously mentioned study, developed by Kayo C. et at., it was found that the 2019 refinement considerably reduces the estimates of global carbon removal by HWP. This is highly attributed to the usage of later data, as explained before, but also to new carbon conversion factors, which are relatively lower, and the exclusion of other industrial roundwood in the commodity classes accounted. And particularly for the "production" approach, the reduction of carbon stock and removals is a consequence of an update in the calculation of the share of woody feedstock, in the 2019 guidelines. In the equation of the share of woody feedstock for the production originating from domestic harvest, different from the 2006 guidelines, it is removed the export feedstock from the production feedstock in the numerator (Equation 3.5) [19, 22, 34].

3.3.2 Suggestions and conclusions

According to the current situation of many countries, "instantaneous-oxidation" or "steady-state" should continue being implemented by those countries where activity data is not available or the HWP carbon contribution does not provide a significant number of emissions or removals in their NIR. However, it should at least encourage the improvement of statistics and data collection through policy instruments.

Regarding the other four approaches, it should be noticed, that "production" and "stock-change" are the ones which based on the needed data collection are more practical and feasible to develop. Since, the "atmospheric-flow" approach requires more specific data which makes it more difficult to implement, and the "simple-decay" presents a high similarity in methodology to the "production" approach. The last two approaches are different only in the theoretical definition, where "production" focuses on the carbon stock data and "simple-decay" focuses on the CO_2 flows as the "atmospheric-flow" does, but the method for both is the same. It is comprehensible, why the "stock-change" and "production" are the most used approaches.

But it must be highlighted that based on the IPCC 2013 KP Supplement, the "production" approach is the one which meets better the suggestions for the second commitment period, where it is said that parties should not account for the importing harvested wood product in the pool [2]. Perhaps, this approach could lead to difficulties at the moment of tracking the usage in the importing countries and their proper emission factors, however, it can represent the life cycle of the HWP from the collection of the raw material until the end life of the product. And as the usage of both "production" and "stock-change" by exporting and importing countries respectively would result in a double counting case, it would be ideal to standardize the use of only one of them [12]. Such as the EU established in 2018 in the regulation 2018/841 on the inclusion of greenhouse gas emissions and removals from LULUCF in the 2030 climate and energy framework [35], where the use of a "production" approach is enforced.

The improvement of 2019 of only using historical data until 1990 is helpful to provide more reliable results about the current situation in the storage of carbon in the pool. Nevertheless, this last version of the IPCC guidelines has not been stipulated as the one which all the parties should follow to develop their reports and usually are established as voluntary guidelines for the inventory reporting [2, 11, 19, 22]. As result, countries can and have developed their reports using different versions, 2006, 2013 or 2019 [12]. Which would provide different outcomes regardless of if the same approach, method, and activity data is used [31]. And this will finally impact the global accounting for the emissions and removals by the HWP. For this reason, the importance and concern on establishing one specific guideline to be used for the reporting of HWP contribution, which provides a global common methodology, or at least the combination of "steady-state" assumption and one approach. It would reduce the uncertainties and remove the possible double and non-counting scenarios.

It would be convenient to develop a new methodology to overlap gaps that the current methods do not cover. A significant gap is caused by the estimation of the decay rate through the first-order decay function, which does not calculate properly the outflow rate for long-term products. In this sense, other decay functions should be incorporated to obtain more realistic results. Like this, it is important to consider the recovering and recycling of "sawnwood" and "wood-based panels", and how they will impact the half-life values for the estimation of the carbon stock changes in the HWP pool.

4. METHODOLOGY UPGRADING FOR HWP CARBON CONTRIBUTION ESTIMATION

To improve the existing methodology, an upgrade of the methods used for Tier 1 and 2 in the 2019 refinement of the IPCC guidelines, will be proposed in this chapter. It is important to mention that these changes in the methods aimto estimate more accurately the decay rate of the HWP, but also, to integrate recovery and recycling practices in the estimations of the total net emissions and removals in the HWP pool.

Like the methodology described in the 2019 guidelines and in sections 3.2.2 and 3.2.3 of this document, the main steps of the proposed methodology are as follows.

1. **Calculation of carbon inflow**
2. Estimation of carbon stock at initial time
3. **Calculation of carbon stocks and annual changes**
4. Calculation of total CO_2 contributions

The upgrades are focused on the first and third steps. The first main step is the obtention of the carbon inflow which, based on the refined guidelines, is calculated with Equation (3.1) for the "stock-change" and "atmospheric-flow" approaches, and with Equations (3.3) and (3.5) for the inflow according to the "production" and "simple-decay approaches". For the calculation of carbon stocks and stock changes in the third step, Equations (3.9) and (3.10) are applied.

4.1 Calculation of Carbon Inflow

With the idea of considering the recovered and recycled volumes from the different wood semi-finished products in the carbon flows and storage in the HWP pool, the recovery portion from the before-considered "decayed" or "obsolete" volumes will be added to the inflow volumes. Then, Equations (3.1) and (3.3) for the different approaches will be replaced by Equations (4.1) and (4.4), respectively.

It can be noticed that in both equations, the main change is the addition of the summary of recovery portions from every semi-finished commodity class which is reintroduced in the inflow of the specific evaluated inflow of the respective commodity class. In other words, from the carbon stock of each HWP commodity class, it will be considered the recovered portions from the decayed quantity and allocated to the specific commodity class where it is going to be reutilized or recycled, for instance, the "sawnwood" category can have a recovered percentage of 50% from the total decayed. Later from this 50%, the re-utilization rate is considered, continuing with the example, perhaps 10% is reintroduced in the same commodity class, other 25% could be used for "wood-based panels", 15% for "paper and paperboard", and the rest of the recovered volume is used in low-value products with a shorter or unknown life service and for this reason, it is considered as part of the outflow. This can be visualized in Figure 4.1.

For "stock-change" and "atmospheric-flow" approaches:

$$Inflow_{SCA_l}(i) = HWP_{C_l}(i) \bullet cf_l + \sum_{l=1}^{n}\left[Q_l(i) \bullet HWP_{DECAY_l}\right] \quad (4.1)$$

$$HWP_{C_l}(i) = HWP_{P_l}(i) + HWP_{IM_l}(i) - HWP_{EX_l}(i) \quad (4.2)$$

$$Q_l(i) = Rec_l(i) \bullet q_l(i) \quad (4.3)$$

where:

$Inflow_{SCA_l}(i)$ = carbon inflow in HWP from the calculated domestic consumption of the respective HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in Mt C/yr.

$HWP_{C_l}(i)$ = calculated domestic consumption of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³

cf_l = carbon conversion factor of the specific semi-finished HWP commodity class $\boldsymbol{l}$. (See Table 12.1 IPCC 2019)

HWP_{DECAY_l} = carbon outflow from the decayed HWP of the respective commodity class $\boldsymbol{l}$ in Mt C/yr. (See Equation 4.7)

$Q_l(i)$ = recycled rate from the decayed HWP and reintroduced to a specific commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$.

$Rec_l(i)$ = recovery rate from the decayed HWP in a specific commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$.

$q_l(i)$ = reutilized rate from the recovered HWP in a specific commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$.

n = number of commodity classes of the semi-finished HWP commodities which have a recovered portion reintroduced in the same or other commodity classes.

$HWP_{P_l}(i)$ = production of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

$HWP_{IM_l}(i)$ = import of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

$HWP_{EX_l}(i)$ = export of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

For "production" and "simple-decay" approaches:

It is important to highlight that in the 2019 IPCC guidelines, the methodology for the "production" and "simple decay" approaches already considers the recovered rate from the "paper and paperboard" category, but not the recovered amounts from the solid wood categories. Hence, the formula for the estimation of the woody feedstock share factor is also modified, but only for the "paper and paperboard" share, with the aim of avoiding double-counting, Equation (4.5).

The Equation (3.5), obtained from the 2019 IPCC Guidelines, to calculate the annual fraction of the domestically produced feedstock $\boldsymbol{f_R(i)}$ is not modified.

$$Inflow_{PA_l}(i) = (HWP_{DP_l}(i) \bullet cf_l) + \sum_{i=1}^{n}\left[Q_l(i) \bullet HWP_{DECAY_l}\right] \quad (4.4)$$

$$HWP_{DP_l}(i) = HWP_{P_l}(i) \bullet f_R(i) \quad (4.5)$$

with:

$f_R(i) = f_{IRW}(i)$ for "sawnwood" and "wood-base panels" categories

$f_R(i) = [f_{IRW}(i) \bullet f_{PULP}(i)]$ for "paper and paper board" category and:

$$f_R(i) = \frac{R_P(i) - R_{EX}(i)}{R_P(i) + R_{IM}(i) - R_{EX}(i)} \quad (3.5)$$

$R = IRW$ for feedstock category "industrial roundwood"

$R = PULP$ for feedstock category "wood pulp"

where:

$Inflow_{PA_l}(i)$ = carbon inflow in HWP from the production of the respective HWP commodity class $\boldsymbol{l}$ originating from the domestic harvest in the year $\boldsymbol{i}$, in Mt C/yr.

$HWP_{DP_l}(i)$ = production of the specific semi-finished HWP commodity class $\boldsymbol{l}$ originating from domestic harvest in the year $\boldsymbol{i}$, in m³

cf_l = carbon conversion factor of the specific semi-finished HWP commodity class $\boldsymbol{l}$. (See Table 12.1 IPCC 2019)

$HWP_{P_l}(i)$ = production of the specific semi-finished HWP commodity class $\boldsymbol{l}$ in the year $\boldsymbol{i}$, in m³.

HWP_{DECAY_l} = carbon outflow from the decayed HWP of the respective commodity class $\boldsymbol{l}$ in Mt C/yr. (See Equation 4.7)

Q_l = recycled rate from the decayed HWP and reintroduced to a specific commodity class $\boldsymbol{l}$ (See Equation 4.3)

n = number of commodity classes of the semi-finished HWP commodities which have a recovered portion reintroduced in the same or other commodity classes.

$f_R(i)$ = share of woody feedstock commodity class R (IRW, PULP) for the production of the specific semi-finished HWP commodity class originating from domestic harvest in the year $\boldsymbol{i}$, as calculated according to Equation (3.5).

IRW = HWP feedstock commodity class "industrial roundwood".

$PULP$ = HWP feedstock commodity class "wood pulp".

4.2 Calculation of carbon stocks and annual changes

Now, the carbon outflow from the HWP pool due to the products decaying will be calculated based on a gamma distribution, Equation (4.6) instead of an exponential distribution as the first order decay function does. As it was already exposed in the discussion of the second chapter, other methods have been already proposed that use a decay function based on the chi-square distribution, with the main purpose of modeling more precisely the inflow and outflow of the HWP to the carbon stock [23, 31, 32, 36].

$$Gamma\ (\tau) = \frac{\tau^{(\alpha-1)}}{\Gamma(\alpha)\beta^{\alpha}} e^{-\tau/\beta} \tag{4.6}$$

where:

τ = Variable gamma-distributed

β = Scale parameter

α = Shape parameter

The gamma distribution is a two parameters free chi-square distribution, $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}$ are the parameters that define the horizontal and vertical scales and shape of the gamma distribution curve, and the variable $\boldsymbol{\tau}$ would be the time since consumption if it is used to evaluate the decay rate of HWP. According to experts, fixing the scale parameter to $\boldsymbol{\beta}$=2 is enough to estimate the dynamic decay rate of the wood products in use [23, 31, 32, 36]. Also, the shape parameter could be simplified in $\boldsymbol{\alpha}= \boldsymbol{k}/2$ where according to Cherubini et al. $\boldsymbol{k}$ is estimated assuming that the time of maximum decay rate is the average lifetime, in other words, $\boldsymbol{k}$ can be considered the estimated service life (ESL) or adjusted ESL (if the obsolescence factor is applied), moreover in the same research, the authors underline a correction based on the addition of 2 units to the $\boldsymbol{k}$ parameter, in order to align it to the peak in the distribution curve [32]. Furthermore, to consider the decay portion from every year, it should be used a cumulative function which integrates the results from every year, to simplify this, instead of considering an integral equation, it will be used a mathematical sum of all the values, as a discrete form of the integral [37]. To compile all the previous considerations, equation (4.7) is proposed.

$$HWP_{l_{DECAY}} = \sum_{i=0}^{t} \left[\frac{t^{\left(\frac{AESL_l+2}{2}-1\right)}}{\Gamma\left(\frac{AESL_l+2}{2}\right) \bullet 2^{\left(\frac{AESL_l+2}{2}\right)}} e^{-t/2} \bullet Inflow_l(i-t) \right] \tag{4.7}$$

where:

HWP_{DECAY_l} = accumulative decayed HWP of the respective commodity class $\boldsymbol{l}$ in Mt C/yr.

t = time since consumption in years.

$AESL$ = adjusted estimated service life of the respective HWP commodity class $\boldsymbol{l}$ in years. (See Table 12.4 of the 2019 IPCC guidelines)

$Inflow_l(i)$ = carbon inflow in the HWP pool of the respective commodity class $\boldsymbol{l}$ in the specific reporting year $\boldsymbol{i}$, in Mt C/yr.

Then, the carbon stock of the reporting year and the stock change can be quantified by using Equation (3.8).

$$C_l(i+1) = C_l(i) + Inflow_l(i) - Outflow_l(i) \tag{4.8}$$

with:

$$Outflow = (1 - Q_{Total_l}) HWP_{l_{DECAY}} \tag{4.9}$$

$$\Delta C_l(i) = C_l(i+1) - C_l(i) \tag{4.10}$$

where:

$C_l(i)$ = the carbon stock in the specific HWP commodity class $\boldsymbol{l}$ at the beginning of the year $\boldsymbol{i}$, in Mt C.

$Inflow_l(i)$ = the carbon inflow to the specific HWP commodity class $\boldsymbol{l}$ during the year $\boldsymbol{i}$, in Mt C/yr.

$Outflow_l(i)$ = the carbon outflow to the specific HWP commodity class $\boldsymbol{l}$ during the year $\boldsymbol{i}$, in Mt C/yr.

HWP_{DECAY_l} = accumulative decayed HWP of the respective commodity class $\boldsymbol{l}$ in Mt C/yr.

Q_{TOTAL_l} = Total recycled rate from the decayed volume of a specific commodity class $\boldsymbol{l}$ (See Figure 4.1)

$\Delta C_l(i)$ = the carbon stock change of the specific HWP commodity class $\boldsymbol{l}$ during the year $\boldsymbol{i}$, in Mt C/yr.

In Figure 4.1 it can be viewed how the proposed inflow and outflow equations (Eq. 4.1, 4.4, 4.7) are used to calculate the annual carbon stock and the carbon stock changes. At the bottom of the table, it is provided the data regarding the carbon which origin is from the recovery of other HWP commodity classes and reintroduced in the evaluated commodity class, in this case, "sawnwood". The same allocation for the recovery portions will be done for each commodity class according to the recovery and recycling practices of the country.

It is important to clarify that the carbon reintroduced to inflow by the recovery of different semi-finished wood product categories should receive special treatment to take into account the corresponding carbon conversion factors. For instance, the carbon from the "sawnwood" and recycled in "wood-based panels" needs to be converted first to m^3 of "sawnwood", and then, be converted again into carbon units by applying a conversion factor for "recovered wood-based panels". And like the IPCC guidelines and other proposed methodologies, if the data about the end-use categories is available for the reporting country the corresponding HWP percentages for the main end-use categories (such as construction, furniture, packing and paper, etc.) should be allocated and treated with their specific emission factor in order to estimate more precisely the carbon conversion factors, service life values, and recovery and decay rate.

	A	B	C	D	E	F	G
1	**SAWNWOOD CARBON STOCK ESTIMATION**						
2		Carbon Conversion Factor		0.229			
3		Adjusted Estimated Service Life		50			
4		((AESL+2)/2)		26			
5							
6	Year	Harvested	Inflow	Decay in the year			
7				2018	2019	2020	2021
8	2018	1000	=(B8*D2)+(D15*D13)+D24+D26	=$C8*((D$7-$A8+1)^($D$4-1))/((GAMMA($D$4)*(2^$D$4))*(EXP(-(D$7-$A8+1)/2)))	Eq. 13	Eq. 13	Eq. 13
9	2019	1010	=(B9*D2)+(E15*E13)+E24+E26	0	Eq. 13	Eq. 13	Eq. 13
10	2020	1020	=(B10*D2)+(F15*F13)+F24+F26	0	0	Eq. 13	Eq. 13
11	2021	1000	=(B11*D2)+(G15*G13)+G24+G26	0	0	0	Eq. 13
12	2022	1050	=(B12*D2)+(H15*H13)+H24+H26	0	0	0	0
13	HWP_{DECAY}			=SUM(D8:D12)	=SUM(E8:E12)	=SUM(F8:F12)	=SUM(G8:G12)
14	REC_{TOTAL}			50%	50%	50%	50%
15	$q_{SAWNWOOD}$			10%	10%	10%	10%
16	$q_{WOOD\ BASE\ PANELS}$			25%	25%	25%	25%
17	$q_{PAPER\ AND\ PAPERBOARD}$			10%	10%	10%	10%
18	Q_{TOTAL}			=D14*SUM(D15:D17)	=E14*SUM(E15:E17)	=F14*SUM(F15:F17)	=G14*SUM(G15:G17)
19	Outflow			=(1-D18)*D13	=(1-E18)*E13	=(1-F18)*F13	=(1-G18)*G13
20	Carbon Stock			=C8-D19	=D20+C9-E19	=E20+C10-F19	=F20+C11-G19
21	Change in Stock			=D20	=E20-D20	=F20-E20	=G20-F20
22							
23				Carbon from wood-based panel recovered for recycling as sawnwood			
24				0	0	0	0
25				Carbon from paper and paperboard recovered for recycling as sawnwood			
26				0	0	0	0

Figure 4.1 Example for implementing Equations (4.1), (4.3), (4.4), (4.7), (4.8), (4.9) and (4.10) in a spreadsheet (e.g., MS EXCEL)

5. MODELLING DIFFERENT SCENARIOS CONSIDERING RECOVERED AND RECYCLING FRACTIONS

With the purpose of implementing the upgraded methodology (See Chapter 4) and evaluating how the carbon dioxide contribution will behave by adopting different recovered and recycling practices in the future, 6 scenarios were modeled for this chapter.

Through the research done, it was found that not only are innovative recycling technologies needed for the circular use of wood, but also the development of sorting and recovering technologies is essential from the sustainability point of view [37]. For this reason, the scenarios proposed are based on 4 key elements in the wood industry and HWP usage: decay rate, recycling consideration, recovering improvement, and recycling improvement. The aim of considering these 4 elements is to gain a better understanding of the contribution of wood recycling and the need for a methodology (to estimate the carbon contribution due to HWP) capable to consider the reutilization of solid wood and paper. Table 5.1 provides an overview of the features of each proposed scenario, how the decay rate is estimated, and if the recovered and recycled fractions are considered.

To provide comparable results, some variables were fixed for all the scenarios, such as the adopted approach, forecast of production, calculation of initial carbon stock, carbon conversion factors, and service life values:

- "Production approach" was selected based on the activity data available in Norway, and as producer country of HWP, it is the most suitable approach in consideration of the discussion developed in section 3.3.
- A forecast for the production of the different semifinished products ("sawnwood", "wood-based panels", and "paper and paperboard") from 2022 to 2100 was estimated by using the historical data from FAOSTAT from 1990 to 2021 [26] and the function "FORCAST.ETS" in MS EXCEL, it is important to mention that for some commodity classes, some data were avoided to obtain a positive increase in the future production volumes. This production data was the same used for all the consequent calculations in each scenario.
- For all the scenarios, the initial carbon stock was calculated as the IPCC guidelines establishes. An average of the first 5 (1990-1994) inflow values and the first order decay function were considered to obtain this initial value of the carbon stock, Equation (3.6).

- The carbon conversion factors and the service life values for the estimation of the emissions and removals arising from the produced and decayed HWP was obtained from the default values provided by the 2019 IPCC guidelines (See Table 12.1 and Table 12.3 of 2019 IPCC) [22].

Table 5.1 Different scenarios proposed. FOD: First-order decay function. GAMMA: Gamma distribution-based decay function. NO: recovering and recycling practices are not considered. -: recovering and recycling practices not considered for solid wood categories. S: consideration of sorted and recovered wood fractions based on existing statistics and technologies. S+: proposing sorted and recovered wood fractions based on an optimistic technological development. R: consideration of recycling wood fractions based on existing statistics and technologies. R+: proposing recycling wood fractions based on an optimistic technological development

Scenario	Decay Function	Recovering (Material)	Recycling
REF IPCC 2019	FOD	-	-
0	GAMMA	-	-
1	GAMMA	S	R
2	GAMMA	S	R+
3	GAMMA	S+	R
4	GAMMA	S+	R+

5.1 IPCC 2019 and Scenario 0

The first scenario considered is based on the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. For this scenario the approach adopted is “production”, and the implemented method is Tier 1. On the other hand, scenario 0 is very similar to the “IPCC 2019” scenario but estimates the decaying rate of HWP using the gamma distribution-based decay function described in Equation (4.7). The first scenario is proposed as a reference of the status regarding the existing methodologies, or at least the last updated guideline proposed by a competent global organization. It is important to mention that the 2019 refinement has not been officially adopted by all the parties and there are many countries which still using the 2006 IPCC guidelines [19] or the 2013 KPSG [2] to develop their NIR and estimations for the HWP category. However, these methodologies were not considered in the proposed scenarios, because there are previous studies assessing the differences between them [12, 34] and their inclusion would differ with the scope and purpose of this study.

According to the 2019 IPCC guideline, recovered paper and its utilization rate are considered for the calculation of the feedstock share and domestic production of the “paper and paperboard” commodity class. The recovered paper amounts were obtained from FAOSTAT like the other production values [26], and because of the lack of official statistics regarding the recycled percentage of paper for paper production, based on different unofficial international databases it was assumed a recycling rate of 70% in the year 2021 and used as a constant for the future years. For 1990, the reutilization rate assumed is 0 and it increase linearly until reaches 70% in 2021. In Table 5.2 it can be viewed how the recovered and recycling rates change over time. The recovered rate is not constant from 2021 to 2100, it varies according to the production forecast of “paper and paperboard” and “recovered paper”, but it coincides with very similar results in those years. For better understanding, it is recommended to consult the complete model file.

Table 5.2 Recovered (material) and recycled rates for “IPCC 2019” and “Scenario 0”

Year	Semi-finished HWP	Recovered (material)	Recycling rate		
			SW	WBP	PP
1990	SW	0	0	0	0
	WBP	0	0	0	0
	PP	**6%**	0	0	0
2021	SW	0	0	0	0
	WBP	0	0	0	0
	PP	**50%**	0	0	**70%**
2100	SW	0	0	0	0
	WBP	0	0	0	0
	PP	**50%**	0	0	**70%**

5.2 Scenario 1

Scenario 1 was proposed with the intention to evaluate the impact of considering recovered and recycled solid wood volumes according to the existing statistics and available technologies in the wood industry. For the “paper and paperboard” commodity classes the material recovering fractions and recycling rates were the same as in the reference scenario (IPCC 2019) and scenario 0.

The recovered percentages for “sawnwood” and “wood-based panels” commodity classes were proposed based on national statistics obtained from Statistics Norway (Statistisk Sentralbyrå) [38]. According to the data, in 2021 the percentage of material recovered from wood waste was 27%. Based on this, for both commodity classes, it was considered 0% of recovered material in 1990, and in 2011 it starts increasing until reach 27% in 2021. Later, it is assumed a linear increase until reaches 50% in the year 2100. This last assumption was based on a study that develop a model for the prediction of timber [39].

Regarding the recycling rates for the “sawnwood” category, the values were proposed based on a study about the potential for cascading of the recovered wood from building deconstruction [40]. In 1990, the recycling fractions were considered 0, and they increase linearly until reach 25%, 21% and 10% in 2021 for the corresponding commodity classes, “sawnwood”, “wood-based panels” and “paper and paperboard” (Table 5.3). These values keep steady for the next years. These recycling rate values represent the percentage of recovered “sawnwood” material that is recycled into products that are part of one of the considered commodity classes.

Based on research about current technologies and wood cascading practices for products categorized in the “wood-based panels” commodity class [37, 40], the recycling rates for this category start at 0% in 1990 and linearly increase until reaches 0%, 21%, 10% for “sawnwood”, “wood-based panels” and “paper and paperboard” correspondingly. These values stay constant until 2100 year.

Table 5.3 Recovered (material) and recycled rates for “Scenario 1”

Year	Semi-finished HWP	Recovered (material)	Recycling rate		
			SW	WBP	PP
1990	SW	0	0	0	0
	WBP	0	0	0	0
	PP	**6%**	0	0	0
2021	SW	**27%**	**25%**	**21%**	**10%**
	WBP	**27%**	**0**	**25%**	**5%**
	PP	**50%**	0	0	**70%**
2100	SW	**50%**	**25%**	**21%**	**10%**
	WBP	**50%**	**0**	**25%**	**5%**
	PP	**50%**	0	0	**70%**

5.3 Scenario 2

The aim of scenario 2 is to estimate the impact on the HWP carbon stock and total CO_2 contribution by the development of innovative alternatives for wood cascading and recycling practices to add value to recovered material at the end of its life service and reintroduce a higher amount to the inflow of HWP pool.

In this sense, an optimistic increase in the recycling rates is assumed for all the commodity classes after 2021, but before it, the recycling rates used are the same used in scenario 1. From 2021 to 2100, it is expected a gradual rising as described in Table 5.4.

Basically, in 2100 from the recovered “sawnwood” fraction, 35% is recycled in the same semi-finish product category, 50% in “wood-based panels” and 10% in “paper and paperboard”. Of the recovered material of “wood-based panels”, 50% is reutilized in the same commodity class, and 15% in the “paper and paperboard” category. And from this last category, 90% of the recovered volumes are reintroduced to the paper production industry.

Regarding the percentages of recovered material for scenario 2, the settings of scenario 1 are implemented without any change (Check section 5.2).

Table 5.4 Recovered (material) and recycled rates for "Scenario 2"

Year	Semi-finished HWP	Recovered (material)	Recycling rate		
			SW	WBP	PP
1990	SW	0	0	0	0
	WBP	0	0	0	0
	PP	**6%**	0	0	0
2021	SW	**27%**	**25%**	**21%**	**10%**
	WBP	**27%**	**0**	**25%**	**5%**
	PP	**50%**	0	0	**70%**
2100	SW	**50%**	**35%**	**50%**	**10%**
	WBP	**50%**	**0**	**50%**	**15%**
	PP	**50%**	0	0	**90%**

5.4 Scenario 3

For this scenario, a similar arrangement is used as the one used in scenario 1 for the recycling rates and recovered material fractions, but after 2021 there is a modification of the recovered material percentages. For scenario 3, a faster improvement of the sorting and recovering technologies is assumed. In this sense, it is considered that the recovered material of solid wood categories will pass from 27% in 2021 to 75% in 2100, and for "paper and paperboard" the change will be from 50% to 90% as shown in Table 5.5.

Table 5.5 Recovered (material) and recycled rates for "Scenario 3"

Year	Semi-finished HWP	Recovered (material)	Recycling rate		
			SW	WBP	PP
1990	SW	0	0	0	0
	WBP	0	0	0	0
	PP	**6%**	0	0	0
2021	SW	**27%**	**25%**	**21%**	**10%**
	WBP	**27%**	**0**	**25%**	**5%**
	PP	**50%**	0	0	**70%**
2100	SW	**75%**	**25%**	**21%**	**10%**
	WBP	**75%**	**0**	**25%**	**5%**
	PP	**90%**	0	0	**70%**

5.5 Scenario 4

Scenario 4 is proposed to analyze the consequences of having an optimistic improvement in sorting and recovering, and in recycling technologies. To represent this situation and obtain comparable results with the other scenarios, a combination of the settings used in scenarios 2 and 3 is needed. In this sense, for accounting the improvement in the recycling practices, the values proposed are the same as those used in scenario 2. But for the recovering volumes, the values used are the ones used in scenario 3. For a better understanding of the assumed values for scenario 4, it is recommended to visualize Table 5.6.

Table 5.6 Recovered (material) and recycled rates for "Scenario 4"

Year	Semi-finished HWP	Recovered (material)	Recycling rate		
			SW	WBP	PP
1990	SW	0	0	0	0
	WBP	0	0	0	0
	PP	**6%**	0	0	0
2021	SW	**27%**	**25%**	**21%**	**10%**
	WBP	**27%**	**0**	**25%**	**5%**
	PP	**50%**	0	0	**70%**
2100	SW	**75%**	**35%**	**50%**	**10%**
	WBP	**75%**	**0**	**50%**	**15%**
	PP	**90%**	0	0	**90%**

5.6 Results and Discussion

In this section, the results for the different proposed scenarios are shown in Figures 5.1 and 5.2. As it was expected, an increase in the HWP carbon stock values is appreciated first because of implementing the gamma distribution-based decay function, and secondly for the inclusion of recovered and recycling material fractions. Likely, in the graph of the total annual net CO_2 contribution due to HWP, a higher removal is expected in the future years if the recovered and recycling practices are considered and improved in the industry.

Analyzing the carbon stock results (Fig. 5.1), it can be mentioned that all the scenarios used the same data and equation to calculate the initial carbon stock value (Eq. 3.6), which for Norway would be 30 Mt in 1990. However, a significant difference in the increasing rate of the values is viewed in the first years of the modeling, particularly in comparison of the reference scenario with the others.

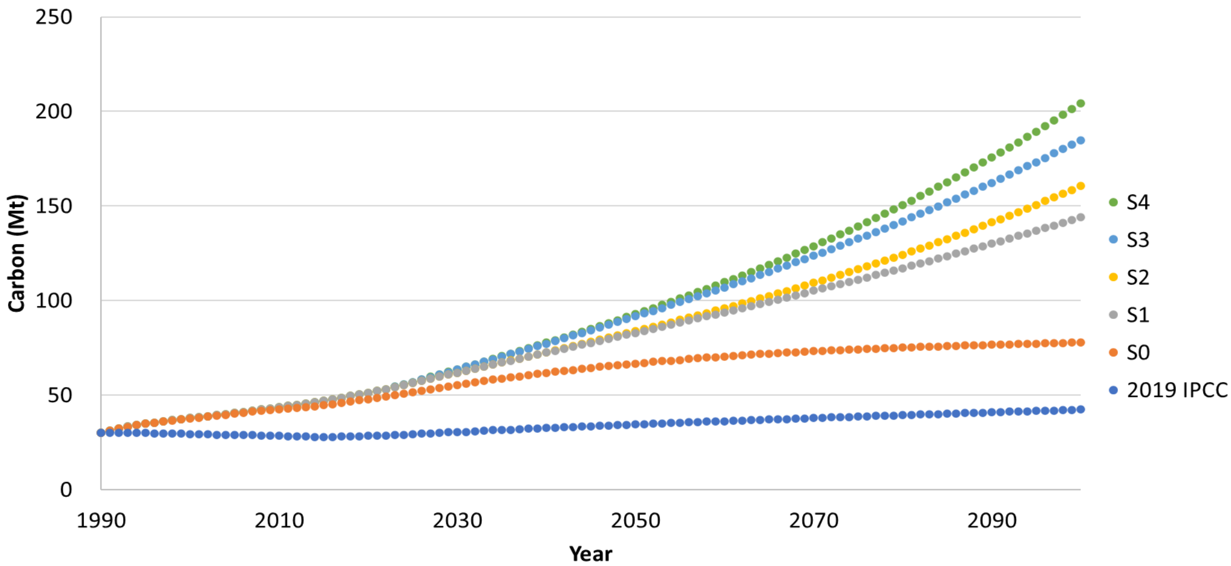

Figure 5.1 Carbon stock of HWP in Norway from 1990 to 2100 for the proposed scenarios

In 2023, the carbon stock in HWP decreases to 28.9 Mt according to the 2019 IPCC. On the other hand, scenario 0 increases to 49.9 Mt, scenarios 1 and 2 reach 54.3 Mt, and scenarios 3 and 4 reach 54.5 Mt in the same year. Based on these results, it is necessary to highlight the important difference between the reference scenario and scenario 0. The use of a more accurate decay rate function can lead to a higher and more reliable estimation of the amounts of CO_2 stored in the wood products produced by the country.

The last statement is also supported by the outcomes of modeling the scenarios over a longer period. In 2100, according to the HWP production forecast, the 2019 IPCC reaches 42.4 Mt in its carbon stock, while scenario 0 increases by almost double, 77.9 Mt. Then, it is also highly notable a impact of including the material recovery and recycling fractions in the calculations. Scenario 1 increases to 144.1 Mt which is nearly twice the carbon stock of scenario 0, and more than triple the 2019 IPCC's results. If improvements in recovery technologies and cascading practices are developed, according to the potential increase proposed, it is possible to reach 204.2 Mt in the HWP carbon stock as shown in scenario 4 in the year 2100.

In the total net CO_2 contribution of the HPW graph, it is observed how the values for the 2019 IPCC and scenario tend to 0 with the passing of the years. This can be explained based on the inflow of HWP in the pool. For both scenarios the inflow amounts are the same every year, the only difference is the outflowing amounts which are dependent on the decay function. By applying the first-order decay function a higher decayed fraction is expected in the first years. Unlikely, with the gamma distribution-based decay function, a higher decay of HWP occurs when they reach their expected life service. However, if the production does not increase significantly in the future years, they will tend to be similar as the outflow rate will reach a balance at a certain point.

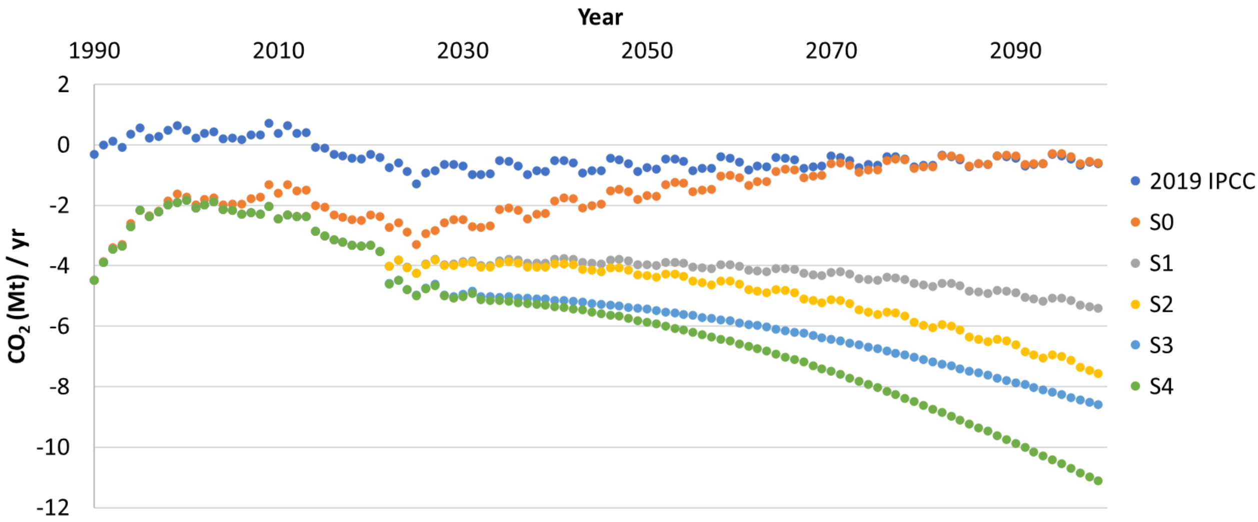

Figure 5.2 Total net CO_2 contribution of HWP in Norway from 1990 to 2100 for the proposed scenarios

The values for the total carbon dioxide contribution due to HWP in scenarios 1, 2, 3, and 4 continue decreasing in the upcoming years, opposite to the reference and scenario 0. This is due to a higher increase in the inflow of HWP. For the last 4 scenarios, a fraction of recovered and recycled material is reintroduced to their inflow every year. That is why the removals are rising each year, and even more if the recovered and recycling percentages are larger.

It is important to emphasize the weighty change in the values from the reference scenario to the other considering the sorting, re-use, and recycling practices. Scenario 2019 IPCC has expected total annual CO_2 contribution of -0.8 Mt in 2023, and -0.6 Mt in 2100. For scenario 0, -2.7 Mt is reached in 2023, and -0.6 Mt in 2100 likely the IPCC. Scenarios 1 and 2 reach -4.0 Mt, and scenarios 3 and 4 achieve a CO_2 contribution of -4.6 Mt in 2023. At this point, an improvement in the potential removals of HWP by implementing material recovery and wood cascading in the industry is already remarkable. Moreover in 2100, based on the proposed features for each scenario, it is expected to be able to remove -5.4, -7.6, -8.6 or -11.1 Mt (analogous to scenarios 1, 2, 3 and 4) of CO_2 from the atmosphere by adopting and developing practices for recovering and recycling wood waste from the different wood products categories. Comparing the reference scenario with the more optimistic scenario (S4) there is a difference of 10.5 CO2 Mt in 2100, which could be removed from the atmosphere and reported by following an optimal development and using the proposed improved methodology.

CONCLUSION

Based on the extensive literature research developed in the first two chapters it was possible to identify several gaps in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Inventories. The possibility of countries adopting different approaches to estimate the annual carbon contribution by HWP can lead to cases of double counting or non-counting of the HWP amounts. For this reason, a common global approach is needed in order to obtain a global estimation of the GHG inventories more accurately.

The "production" approach might be the more suitable option to be adopted, as it provides a more practical methodology, which in contrast to the "stock-change" approach, it is possible to combine with the "instantaneous-oxidation" assumption without any potential double or non-counting scenario. This assumption needs to be available for use in the NIR and CRF, because nearly one-third of all the parties in the globe are estimated to have a lack of statistics regarding forestry management and HWP production [12], and as a consequence, they are not able to adopt any of the approaches and implement the methods provided.

Statistics are an essential factor for the proper development of accurate estimations. That is why other research proposed the use of alternative global databases to improve the tracking of trading wood resources and their end usages inside and outside the country [23]. Implementing more detailed and specific data makes it possible to estimate more accurately the estimated service life of the different wood products considered, hence estimating more precise the carbon stock and the decay of products every year. However, transparency and accessibility of the data are crucial for its application at a global level.

Other critiques regarding the 2019 IPCC must focus on some of the concepts adopted through their historical development, and its intention to reconceptualize others. The assumption of "instantaneous-oxidation" is a concept that literally expresses the overall meaning of it, and it has been already well used in several studies. Avoid the use of the last concept and implement "steady state", which numerically talking it would not impact the results of the calculation, and can simply complicate the reporting following up without a meaningful purpose. Similarly, the "stock-change" and "simple-decay" concepts can lead to further misunderstanding as do not express a clear idea about their definition. In this sense, it would be more meaningful for their update instead of other concepts.

One of the main updates of the 2019 IPCC guidelines is the consideration of only earlier historical data (since 1990), which is beneficial to avoid the uncertainties developed by the improvement of data collection methods through the years. Although the current guidelines are the best among other IPCC versions, it has not been defined by the UNFCCC as the main recommended guide to creating the annual submissions. Instead, in 2023 it was recommended to continue following the 2006 IPCC Guidelines for National Greenhouse Gas Inventories in the 2024 annual submissions. This was concluded in the 20th Meeting of Inventory Lead Reviewers, which corresponds to the 2023 annual meeting requested by the Conference of the Parties (COP) to improve the quality, efficiency, and consistency of the reviews of NIR and CRF [41]. This gap in the time for making changes in the reporting framework is highly impactful from the global perspective as many use the 2006 IPCC, but others are applying the 2013 KPSG or 2019 IPCC which cannot be compared between each other as the methodologies vary, and this lead to inaccurate global results [12].

Talking about the improved methodology to integrate the recovered material and recycling fractions while estimating the decay of the HWP with a gamma distribution-based decay function, it is outstanding and valuable for achieving more accurate estimations of the total CO_2 emissions and removals arising from the HWP pool in Norway. But also, provides an option to report the national efforts on boosting the circular use of wood by the implementation of cascading practices, unlikely the current methodologies which do not consider the recovery or recycling rates.

The new methodology might be used as the method Tier 3 (country-specific method) in Norway; but also, it is possible to use it at a local level by the corporates which are implementing recovered materials as input in their manufacturing process. The methodology can support wood products companies to report their carbon removals by adopting sustainability strategies. And with the development of appropriate legislation, corporates would be able to obtain incentives for improving their green practices.

Moreover, the improved methodology could be used to update the current guidelines to obtain more accurate estimations about the present situation of climate change in the world. At least the implementation of a new decay function is feasible for all the parties which are reporting with any of the main 4 approaches because the provided decay function only needs as input the estimated service life values, which are already used for the first-order decay function. In this sense, no new data is necessary.

If material recovered and recycled fractions from the different wood products commodity classes are intended to be considered in the annual estimations, data on the volumes or rates of wood reutilization should be available. Then, it is crucial, not only to encourage circular use of wood but parallelly also to improve data collection and statistics in this sector.

SUMMARY

Experts suggest that one of the most effective and economical ways to combat climate change is found in the GHG mitigation potential of forests [2]. In this context, the forests are a sink for carbon dioxide in two ways: first, carbon sequestrated in trees. Second, it can be absorbed by soil and litter [3]. Consequently, wood products continue to serve as a means of carbon storage which makes them a key factor in mitigating climate change [4]. For this reason, forestry and harvested wood products (HWP) have taken an important role in the global reporting of GHG inventories and the contribution from each country [2]. In Norway, the awareness of the potential of HWP to decelerate global warming has led to the creation of a national project intended to encourage the circular use of wood by improving innovation and technologies to achieve a higher sustainability status in the country.

This research analyses the potential for CO_2 removals of HWP in Norway, it proposes an improvement to the IPCC guidelines for estimating the annual CO_2 contribution arising from the HWP [22] by the use of a gamma distribution based-decay function to calculate the carbon stock and considering wood material recovery and recycling into the accounted categories in the calculation.

The study compares six different scenarios to assess the impact of adopting the proposed methodology and cascading practices in the wood industry. These scenarios are modeled with a focus on the "production" approach. The REF Scenario follows the 2019 IPCC guidelines step by step, while S0 follows the 2019 IPCC guidelines but uses a different decay function for estimating the outflow of HWP each year. S1 uses the new methodology and considers the current recovery and recycling fractions, while S2 follows the proposed methodology and assumes an optimistic development in recovery technologies. S3 follows the proposed methodology and assumes an optimistic increase in recycling fractions, and S4 combined an optimistic increase in the volumes of recovered material and recycling fractions that are reintroduced into the HWP pool.

Based on the results, it was found that simply implementing a new decay function nearly doubles the carbon stock rise every year after 2021, compared to the reference results from the 2019 IPCC. Additionally, including reclaimed wood in the estimation of carbon stock can lead to results three times higher than the reference scenario. Similarly, based on the change in carbon stock, the potential for CO_2 removal in Norway shows a constant increase if wood material recovery and recycling in long-term products are implemented in the upcoming years.

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APPENDICES

Table A.1 Industrial Roundwood production activity data in Norway from 1990-2021, and forecast for 2022-2100

Norway	Industrial roundwood + (Total)			
FAOSTAT	Production	Imports	Exports	Consumed
year	m3	m3	m3	m3
1990	10,900,000	1,020,935	625,393	10,274,607
1991	10,345,000	1,074,963	706,860	9,638,140
1992	9,200,000	1,070,285	723,150	8,476,850
1993	9,253,000	1,151,143	683,515	8,569,485
1994	8,274,000	2,617,100	435,000	7,839,000
1995	8,575,000	3,712,000	436,000	8,139,000
1996	7,956,000	2,459,000	384,000	7,572,000
1997	8,047,000	2,848,000	467,000	7,580,000
1998	7,670,100	3,494,000	469,000	7,201,100
1999	7,707,000	3,037,000	583,000	7,124,000
2000	7,477,790	3,315,000	514,000	6,963,790
2001	7,884,540	2,772,000	476,000	7,408,540
2002	7,462,889	2,561,000	551,000	6,911,889
2003	6,989,161	2,722,096	397,466	6,591,695
2004	7,353,000	2,865,602	347,649	7,005,351
2005	8,489,959	3,144,536	523,688	7,966,271
2006	7,282,477	2,333,281	740,707	6,541,770
2007	8,211,911	2,538,546	949,431	7,262,480
2008	8,070,781	1,807,560	897,002	7,173,779
2009	6,630,826	932,974	867,903	5,762,923
2010	8,322,430	1,288,074	864,795	7,457,635
2011	8,506,294	1,354,790	938,573	7,567,721
2012	8,787,408	939,750	1,621,854	7,165,554
2013	9,019,476	661,319	2,636,598	6,382,878
2014	9,808,072	446,875	3,288,332	6,519,740
2015	10,158,700	378,028	3,987,100	6,171,600
2016	10,304,000	416,797	3,521,721	6,782,279
2017	10,491,029	513,197	3,540,916	6,950,113
2018	10,835,891	454,820	3,544,001	7,291,890
2019	11,038,700	402,386	3,648,503	7,390,197
2020	10,241,686	336,633	3,559,652	6,682,034
2021	11,451,883	349,368	3,873,402	7,578,481
2022	11,241,273	595,825	5,169,639	6,071,634
2023	11,373,221	716,110	5,271,571	6,101,651
2024	11,505,169	332,862	5,373,503	6,131,667
2025	11,637,117	78,415	5,475,435	6,161,683
2026	11,769,066	325,169	5,577,367	6,191,699
2027	11,901,014	445,454	5,679,299	6,221,715
2028	12,032,962	62,206	5,781,230	6,251,731
2029	12,164,910	0	5,883,162	6,281,748
2030	12,296,858	54,514	5,985,094	6,311,764
2031	12,428,806	174,799	6,087,026	6,341,780
2032	12,560,755	0	6,188,958	6,371,796
2033	12,692,703	0	6,290,890	6,401,812
2034	12,824,651	0	6,392,822	6,431,828
2035	12,956,599	0	6,494,754	6,461,845
2036	13,088,547	0	6,596,686	6,491,861
2037	13,220,495	0	6,698,618	6,521,877
2038	13,352,444	0	6,800,550	6,551,893
2039	13,484,392	0	6,902,482	6,581,909
2040	13,616,340	0	7,004,414	6,611,926
2041	13,748,288	0	7,106,346	6,641,942
2042	13,880,236	0	7,208,278	6,671,958
2043	14,012,184	0	7,310,210	6,701,974
2044	14,144,133	0	7,412,142	6,731,990
2045	14,276,081	0	7,514,074	6,762,006
2046	14,408,029	0	7,616,006	6,792,023
2047	14,539,977	0	7,717,938	6,822,039

2048	14,671,925	0	7,819,870	6,852,055
2049	14,803,873	0	7,921,802	6,882,071
2050	14,935,822	0	8,023,734	6,912,087
2051	15,067,770	0	8,125,666	6,942,103
2052	15,199,718	0	8,227,598	6,972,120
2053	15,331,666	0	8,329,530	7,002,136
2054	15,463,614	0	8,431,462	7,032,152
2055	15,595,562	0	8,533,394	7,062,168
2056	15,727,511	0	8,635,326	7,092,184
2057	15,859,459	0	8,737,258	7,122,200
2058	15,991,407	0	8,839,190	7,152,217
2059	16,123,355	0	8,941,122	7,182,233
2060	16,255,303	0	9,043,054	7,212,249
2061	16,387,251	0	9,144,986	7,242,265
2062	16,519,200	0	9,246,918	7,272,281
2063	16,651,148	0	9,348,850	7,302,297
2064	16,783,096	0	9,450,782	7,332,314
2065	16,915,044	0	9,552,714	7,362,330
2066	17,046,992	0	9,654,646	7,392,346
2067	17,178,940	0	9,756,578	7,422,362
2068	17,310,889	0	9,858,510	7,452,378
2069	17,442,837	0	9,960,442	7,482,394
2070	17,574,785	0	10,062,374	7,512,411
2071	17,706,733	0	10,164,306	7,542,427
2072	17,838,681	0	10,266,238	7,572,443
2073	17,970,629	0	10,368,170	7,602,459
2074	18,102,578	0	10,470,102	7,632,475
2075	18,234,526	0	10,572,034	7,662,491
2076	18,366,474	0	10,673,966	7,692,508
2077	18,498,422	0	10,775,898	7,722,524
2078	18,630,370	0	10,877,830	7,752,540
2079	18,762,318	0	10,979,762	7,782,556
2080	18,894,267	0	11,081,694	7,812,572
2081	19,026,215	0	11,183,626	7,842,589
2082	19,158,163	0	11,285,558	7,872,605
2083	19,290,111	0	11,387,490	7,902,621
2084	19,422,059	0	11,489,422	7,932,637
2085	19,554,007	0	11,591,354	7,962,653
2086	19,685,956	0	11,693,286	7,992,669
2087	19,817,904	0	11,795,218	8,022,686
2088	19,949,852	0	11,897,150	8,052,702
2089	20,081,800	0	11,999,082	8,082,718
2090	20,213,748	0	12,101,014	8,112,734
2091	20,345,696	0	12,202,946	8,142,750
2092	20,477,644	0	12,304,878	8,172,766
2093	20,609,593	0	12,406,810	8,202,783
2094	20,741,541	0	12,508,742	8,232,799
2095	20,873,489	0	12,610,674	8,262,815
2096	21,005,437	0	12,712,606	8,292,831
2097	21,137,385	0	12,814,538	8,322,847
2098	21,269,333	0	12,916,470	8,352,863
2099	21,401,282	0	13,018,402	8,382,880
2100	21,533,230	0	13,120,334	8,412,896

Table A.2 Pulp for paper production activity data in Norway from 1990-2021, and forecast for 2022-2100

Norway	Pulp for paper + (Total)			
FAOSTAT	Production	Imports	Exports	Consumed
year	metric-t	metric-t	metric-t	metric-t
1990	2,045,000	67,200	479,100	1,565,900
1991	1,960,000	56,100	443,200	1,516,800
1992	1,863,400	47,945	455,632	1,407,768
1993	2,024,000	66,985	402,983	1,621,017
1994	2,215,000	92,200	477,400	1,737,600
1995	2,485,000	115,300	459,500	2,025,500
1996	2,270,000	103,300	389,500	1,880,500

1997	2,362,000	136,700	397,000	1,965,000
1998	2,420,600	124,000	392,000	2,028,600
1999	2,354,000	155,301	418,000	1,936,000
2000	2,395,000	156,000	408,000	1,987,000
2001	2,273,000	101,000	499,000	1,774,000
2002	2,174,000	92,000	485,000	1,689,000
2003	2,255,000	97,360	506,439	1,748,561
2004	2,389,000	92,543	520,125	1,868,875
2005	2,324,000	79,929	535,563	1,788,437
2006	2,303,000	58,957	487,552	1,815,448
2007	2,233,000	51,172	492,747	1,740,253
2008	2,099,000	44,068	489,737	1,609,263
2009	1,672,000	58,264	385,619	1,286,381
2010	1,884,000	47,964	441,067	1,442,933
2011	1,605,000	44,357	451,015	1,153,985
2012	1,242,000	38,825	373,353	868,647
2013	1,088,000	50,127	306,736	781,264
2014	763,000	76,484	210,758	552,242
2015	751,000	84,267	181,188	569,812
2016	874,000	87,734	184,919	689,081
2017	902,000	88,917	224,588	677,412
2018	885,000	91,802	243,872	641,128
2019	833,000	64,175	197,288	635,712
2020	983,000	68,611	203,615	779,385
2021	1,054,000	70,799	218,772	835,228
2022	1,071,740	71,569	464,892	606,849
2023	1,089,623	74,812	466,768	622,855
2024	1,107,506	67,719	468,645	638,861
2025	1,125,389	66,847	470,521	654,867
2026	1,143,271	67,617	472,398	670,873
2027	1,161,154	70,860	474,274	686,880
2028	1,179,037	63,768	476,151	702,886
2029	1,196,920	62,895	478,028	718,892
2030	1,214,802	63,665	479,904	734,898
2031	1,232,685	66,908	481,781	750,904
2032	1,250,568	59,816	483,657	766,910
2033	1,268,451	58,944	485,534	782,917
2034	1,286,333	59,714	487,410	798,923
2035	1,304,216	62,956	489,287	814,929
2036	1,322,099	55,864	491,164	830,935
2037	1,339,982	54,992	493,040	846,941
2038	1,357,864	55,762	494,917	862,948
2039	1,375,747	59,005	496,793	878,954
2040	1,393,630	51,912	498,670	894,960
2041	1,411,513	51,040	500,547	910,966
2042	1,429,395	51,810	502,423	926,972
2043	1,447,278	55,053	504,300	942,978
2044	1,465,161	47,961	506,176	958,985
2045	1,483,044	47,088	508,053	974,991
2046	1,500,926	47,858	509,929	990,997
2047	1,518,809	51,101	511,806	1,007,003
2048	1,536,692	44,009	513,683	1,023,009
2049	1,554,575	43,137	515,559	1,039,015
2050	1,572,457	43,906	517,436	1,055,022
2051	1,590,340	47,149	519,312	1,071,028
2052	1,608,223	40,057	521,189	1,087,034
2053	1,626,106	39,185	523,065	1,103,040
2054	1,643,988	39,955	524,942	1,119,046
2055	1,661,871	43,197	526,819	1,135,053
2056	1,679,754	36,105	528,695	1,151,059
2057	1,697,637	35,233	530,572	1,167,065
2058	1,715,519	36,003	532,448	1,183,071
2059	1,733,402	39,246	534,325	1,199,077
2060	1,751,285	32,153	536,202	1,215,083
2061	1,769,168	31,281	538,078	1,231,090
2062	1,787,050	32,051	539,955	1,247,096
2063	1,804,933	35,294	541,831	1,263,102
2064	1,822,816	28,202	543,708	1,279,108

2065	1,840,699	27,329	545,584	1,295,114
2066	1,858,581	28,099	547,461	1,311,120
2067	1,876,464	31,342	549,338	1,327,127
2068	1,894,347	24,250	551,214	1,343,133
2069	1,912,230	23,378	553,091	1,359,139
2070	1,930,112	24,148	554,967	1,375,145
2071	1,947,995	27,390	556,844	1,391,151
2072	1,965,878	20,298	558,721	1,407,157
2073	1,983,761	19,426	560,597	1,423,164
2074	2,001,644	20,196	562,474	1,439,170
2075	2,019,526	23,439	564,350	1,455,176
2076	2,037,409	16,346	566,227	1,471,182
2077	2,055,292	15,474	568,103	1,487,188
2078	2,073,175	16,244	569,980	1,503,195
2079	2,091,057	19,487	571,857	1,519,201
2080	2,108,940	12,395	573,733	1,535,207
2081	2,126,823	11,522	575,610	1,551,213
2082	2,144,706	12,292	577,486	1,567,219
2083	2,162,588	15,535	579,363	1,583,225
2084	2,180,471	8,443	581,239	1,599,232
2085	2,198,354	7,571	583,116	1,615,238
2086	2,216,237	8,340	584,993	1,631,244
2087	2,234,119	11,583	586,869	1,647,250
2088	2,252,002	4,491	588,746	1,663,256
2089	2,269,885	3,619	590,622	1,679,262
2090	2,287,768	4,389	592,499	1,695,269
2091	2,305,650	7,631	594,376	1,711,275
2092	2,323,533	539	596,252	1,727,281
2093	2,341,416	0	598,129	1,743,287
2094	2,359,299	437	600,005	1,759,293
2095	2,377,181	3,680	601,882	1,775,300
2096	2,395,064	0	603,758	1,791,306
2097	2,412,947	0	605,635	1,807,312
2098	2,430,830	0	607,512	1,823,318
2099	2,448,712	0	609,388	1,839,324
2100	2,466,595	0	611,265	1,855,330

Table A.3 Recovered paper production activity data in Norway from 1990-2021, and forecast for 2022-2100

Norway	Rec paper + (Total)			
FAOSTAT	Production	Imports	Exports	Consumed
year	metric-t	metric-t	metric-t	metric-t
1990	102,000	47,700	69,800	32,200
1991	130,000	46,100	81,000	49,000
1992	130,000	46,264	109,869	20,131
1993	178,000	34,609	134,627	43,373
1994	178,000	59,500	149,000	29,000
1995	346,000	71,000	169,000	177,000
1996	367,000	47,000	182,000	185,000
1997	432,000	41,700	216,700	215,300
1998	287,400	53,000	219,000	68,400
1999	293,000	33,000	277,000	16,000
2000	351,000	63,000	248,000	103,000
2001	441,000	76,000	192,000	249,000
2002	456,000	87,000	161,000	295,000
2003	456,000	83,062	152,869	303,131
2004	478,000	63,609	198,724	279,276
2005	441,000	52,495	232,575	208,425
2006	474,000	59,972	261,138	212,862
2007	462,000	74,013	294,853	167,147
2008	469,000	80,330	286,585	182,415
2009	477,000	103,319	285,445	191,555
2010	474,000	148,241	326,329	147,671
2011	427,000	147,558	375,322	51,678
2012	469,000	85,764	380,376	88,624
2013	514,000	68,905	408,200	105,800

2014	607,000	20,866	453,299	153,701
2015	635,000	23,548	484,283	150,717
2016	605,000	25,827	470,034	134,966
2017	602,000	29,757	458,207	143,793
2018	604,000	30,777	465,245	138,755
2019	573,000	24,905	427,386	145,614
2020	533,000	20,260	389,589	143,411
2021	533,000	56,337	413,868	119,132
2022	482,657	100,109	425,709	56,948
2023	485,226	90,689	438,177	47,049
2024	514,339	92,597	450,645	63,694
2025	591,904	91,152	463,113	128,791
2026	604,931	106,271	475,581	129,349
2027	628,206	96,851	488,050	140,156
2028	567,033	98,759	500,518	66,515
2029	569,601	97,314	512,986	56,616
2030	598,715	112,433	525,454	73,261
2031	676,280	103,013	537,922	138,358
2032	689,307	104,920	550,390	138,916
2033	712,582	103,475	562,859	149,723
2034	651,409	118,594	575,327	76,082
2035	653,977	109,175	587,795	66,182
2036	683,091	111,082	600,263	82,828
2037	760,656	109,637	612,731	147,925
2038	773,683	124,756	625,199	148,483
2039	796,958	115,336	637,667	159,290
2040	735,785	117,244	650,136	85,649
2041	738,353	115,799	662,604	75,749
2042	767,466	130,918	675,072	92,395
2043	845,032	121,498	687,540	157,492
2044	858,059	123,406	700,008	158,050
2045	881,334	121,961	712,476	168,857
2046	820,161	137,079	724,945	95,216
2047	822,729	127,660	737,413	85,316
2048	851,842	129,567	749,881	101,962
2049	929,408	128,122	762,349	167,059
2050	942,434	143,241	774,817	167,617
2051	965,710	133,822	787,285	178,424
2052	904,537	135,729	799,753	104,783
2053	907,105	134,284	812,222	94,883
2054	936,218	149,403	824,690	111,528
2055	1,013,784	139,983	837,158	176,626
2056	1,026,810	141,891	849,626	177,184
2057	1,050,086	140,446	862,094	187,991
2058	988,913	155,565	874,562	114,350
2059	991,481	146,145	887,031	104,450
2060	1,020,594	148,053	899,499	121,095
2061	1,098,160	146,608	911,967	186,193
2062	1,111,186	161,726	924,435	186,751
2063	1,134,461	152,307	936,903	197,558
2064	1,073,289	154,214	949,371	123,917
2065	1,075,857	152,769	961,839	114,017
2066	1,104,970	167,888	974,308	130,662
2067	1,182,536	158,469	986,776	195,760
2068	1,195,562	160,376	999,244	196,318
2069	1,218,837	158,931	1,011,712	207,125
2070	1,157,665	174,050	1,024,180	133,484
2071	1,160,233	164,630	1,036,648	123,584
2072	1,189,346	166,538	1,049,117	140,229
2073	1,266,912	165,093	1,061,585	205,327
2074	1,279,938	180,212	1,074,053	205,885
2075	1,303,213	170,792	1,086,521	216,692
2076	1,242,040	172,700	1,098,989	143,051
2077	1,244,609	171,255	1,111,457	133,151
2078	1,273,722	186,373	1,123,925	149,796
2079	1,351,287	176,954	1,136,394	214,894
2080	1,364,314	178,861	1,148,862	215,452
2081	1,387,589	177,416	1,161,330	226,259

2082	1,326,416	192,535	1,173,798	152,618
2083	1,328,985	183,116	1,186,266	142,718
2084	1,358,098	185,023	1,198,734	159,363
2085	1,435,663	183,578	1,211,203	224,461
2086	1,448,690	198,697	1,223,671	225,019
2087	1,471,965	189,277	1,236,139	235,826
2088	1,410,792	191,185	1,248,607	162,185
2089	1,413,361	189,740	1,261,075	152,285
2090	1,442,474	204,859	1,273,543	168,930
2091	1,520,039	195,439	1,286,012	234,028
2092	1,533,066	197,347	1,298,480	234,586
2093	1,556,341	195,902	1,310,948	245,393
2094	1,495,168	211,020	1,323,416	171,752
2095	1,497,736	201,601	1,335,884	161,852
2096	1,526,850	203,508	1,348,352	178,497
2097	1,604,415	202,063	1,360,820	243,595
2098	1,617,442	217,182	1,373,289	244,153
2099	1,640,717	207,763	1,385,757	254,960
2100	1,579,544	209,670	1,398,225	181,319

Table A.4 Sawnwood production activity data in Norway from 1990-2021, and forecast for 2022-2100

Norway	Sawnwood + (Total)			
FAOSTAT	Production	Imports	Exports	Consumed
year	m3	m3	m3	m3
1990	2,412,800	437,500	634,100	1,778,700
1991	2,261,900	422,400	644,200	1,617,700
1992	2,361,900	447,100	810,600	1,551,300
1993	2,315,000	524,600	871,900	1,443,100
1994	2,415,000	777,600	777,900	1,637,100
1995	2,210,000	683,000	713,000	1,497,000
1996	2,420,000	799,000	709,000	1,711,000
1997	2,520,000	1,028,000	704,000	1,816,000
1998	2,524,700	971,000	692,000	1,832,700
1999	2,336,000	839,000	763,000	1,573,000
2000	2,280,000	945,000	656,270	1,623,730
2001	2,253,000	985,000	580,590	1,672,410
2002	2,225,000	931,000	619,000	1,606,000
2003	2,186,000	813,779	558,995	1,627,005
2004	2,230,000	876,653	481,224	1,748,776
2005	2,326,000	1,042,032	442,081	1,883,919
2006	2,389,000	1,035,435	473,004	1,915,996
2007	2,402,000	1,172,610	387,401	2,014,599
2008	2,228,000	935,678	416,341	1,811,659
2009	1,850,000	910,609	457,633	1,392,367
2010	2,118,000	947,956	484,528	1,633,472
2011	2,271,000	1,002,573	467,806	1,803,194
2012	2,289,404	1,063,371	494,052	1,795,352
2013	2,206,000	1,055,392	515,575	1,690,425
2014	2,407,000	1,009,459	516,945	1,890,055
2015	2,444,000	1,019,739	565,522	1,878,478
2016	2,533,000	1,019,635	600,377	1,932,623
2017	2,655,000	1,035,032	653,562	2,001,438
2018	2,675,122	960,515	681,066	1,994,056
2019	2,658,000	994,169	718,688	1,939,312
2020	2,683,000	1,043,240	860,385	1,822,615
2021	2,811,428	1,107,992	703,129	2,108,299
2022	2,819,468	1,110,037	699,253	2,120,216
2023	2,827,509	1,126,215	695,377	2,132,132
2024	2,835,549	1,142,393	691,501	2,144,049
2025	2,843,590	1,158,571	687,625	2,155,965
2026	2,851,630	1,174,749	683,749	2,167,882
2027	2,859,671	1,190,926	679,873	2,179,798
2028	2,867,711	1,207,104	675,997	2,191,715
2029	2,875,752	1,223,282	672,120	2,203,631
2030	2,883,792	1,239,460	668,244	2,215,548
2031	2,891,833	1,255,638	664,368	2,227,465

2032	2,899,873	1,271,816	660,492	2,239,381
2033	2,907,914	1,287,994	656,616	2,251,298
2034	2,915,954	1,304,172	652,740	2,263,214
2035	2,923,995	1,320,350	648,864	2,275,131
2036	2,932,035	1,336,528	644,988	2,287,047
2037	2,940,076	1,352,706	641,112	2,298,964
2038	2,948,116	1,368,883	637,236	2,310,880
2039	2,956,157	1,385,061	633,360	2,322,797
2040	2,964,197	1,401,239	629,484	2,334,713
2041	2,972,238	1,417,417	625,608	2,346,630
2042	2,980,278	1,433,595	621,732	2,358,547
2043	2,988,319	1,449,773	617,855	2,370,463
2044	2,996,359	1,465,951	613,979	2,382,380
2045	3,004,400	1,482,129	610,103	2,394,296
2046	3,012,440	1,498,307	606,227	2,406,213
2047	3,020,481	1,514,485	602,351	2,418,129
2048	3,028,521	1,530,662	598,475	2,430,046
2049	3,036,561	1,546,840	594,599	2,441,962
2050	3,044,602	1,563,018	590,723	2,453,879
2051	3,052,642	1,579,196	586,847	2,465,796
2052	3,060,683	1,595,374	582,971	2,477,712
2053	3,068,723	1,611,552	579,095	2,489,629
2054	3,076,764	1,627,730	575,219	2,501,545
2055	3,084,804	1,643,908	571,343	2,513,462
2056	3,092,845	1,660,086	567,467	2,525,378
2057	3,100,885	1,676,264	563,591	2,537,295
2058	3,108,926	1,692,441	559,714	2,549,211
2059	3,116,966	1,708,619	555,838	2,561,128
2060	3,125,007	1,724,797	551,962	2,573,044
2061	3,133,047	1,740,975	548,086	2,584,961
2062	3,141,088	1,757,153	544,210	2,596,878
2063	3,149,128	1,773,331	540,334	2,608,794
2064	3,157,169	1,789,509	536,458	2,620,711
2065	3,165,209	1,805,687	532,582	2,632,627
2066	3,173,250	1,821,865	528,706	2,644,544
2067	3,181,290	1,838,043	524,830	2,656,460
2068	3,189,331	1,854,220	520,954	2,668,377
2069	3,197,371	1,870,398	517,078	2,680,293
2070	3,205,412	1,886,576	513,202	2,692,210
2071	3,213,452	1,902,754	509,326	2,704,127
2072	3,221,493	1,918,932	505,450	2,716,043
2073	3,229,533	1,935,110	501,573	2,727,960
2074	3,237,574	1,951,288	497,697	2,739,876
2075	3,245,614	1,967,466	493,821	2,751,793
2076	3,253,655	1,983,644	489,945	2,763,709
2077	3,261,695	1,999,822	486,069	2,775,626
2078	3,269,735	2,015,999	482,193	2,787,542
2079	3,277,776	2,032,177	478,317	2,799,459
2080	3,285,816	2,048,355	474,441	2,811,375
2081	3,293,857	2,064,533	470,565	2,823,292
2082	3,301,897	2,080,711	466,689	2,835,209
2083	3,309,938	2,096,889	462,813	2,847,125
2084	3,317,978	2,113,067	458,937	2,859,042
2085	3,326,019	2,129,245	455,061	2,870,958
2086	3,334,059	2,145,423	451,185	2,882,875
2087	3,342,100	2,161,601	447,308	2,894,791
2088	3,350,140	2,177,778	443,432	2,906,708
2089	3,358,181	2,193,956	439,556	2,918,624
2090	3,366,221	2,210,134	435,680	2,930,541
2091	3,374,262	2,226,312	431,804	2,942,458
2092	3,382,302	2,242,490	427,928	2,954,374
2093	3,390,343	2,258,668	424,052	2,966,291
2094	3,398,383	2,274,846	420,176	2,978,207
2095	3,406,424	2,291,024	416,300	2,990,124
2096	3,414,464	2,307,202	412,424	3,002,040
2097	3,422,505	2,323,380	408,548	3,013,957
2098	3,430,545	2,339,557	404,672	3,025,873
2099	3,438,586	2,355,735	400,796	3,037,790

2100	3,446,626	2,371,913	396,920	3,049,706

Table A.5 Wood-based panels production activity data in Norway from 1990-2021, and forecast for 2022-2100

Norway	Wood-based panels + (Total)			
FAOSTAT	Production	Imports	Exports	Consumed
year	m3	m3	m3	m3
1990	658,000	129,300	170,200	487,800
1991	573,000	114,600	158,200	414,800
1992	559,000	115,438	158,848	400,152
1993	501,000	119,172	226,963	274,037
1994	570,000	138,000	201,600	368,400
1995	560,000	143,000	226,000	334,000
1996	544,000	157,000	233,000	311,000
1997	531,000	207,700	257,300	273,700
1998	576,600	160,000	269,070	307,530
1999	511,000	170,650	286,050	224,950
2000	535,000	209,861	340,773	194,227
2001	528,000	175,980	289,690	238,310
2002	476,140	190,631	251,020	225,120
2003	461,000	205,586	252,160	208,840
2004	589,000	236,692	265,938	323,062
2005	583,000	258,829	253,473	329,527
2006	620,000	253,074	192,147	427,853
2007	585,000	350,562	243,844	341,156
2008	498,237	333,984	216,313	281,924
2009	486,467	303,763	186,754	299,713
2010	566,504	357,355	242,398	324,106
2011	520,028	363,216	249,073	270,955
2012	484,400	325,388	212,140	272,260
2013	380,820	407,703	185,696	195,124
2014	438,000	408,767	208,951	229,049
2015	447,000	400,488	205,419	241,581
2016	436,000	293,051	106,276	329,724
2017	448,000	433,742	162,236	285,764
2018	458,000	564,036	269,724	188,276
2019	424,000	482,505	198,207	225,793
2020	458,000	472,521	267,154	190,846
2021	498,947	538,561	378,811	120,136
2022	585,899	444,885	309,035	276,864
2023	586,957	456,798	309,751	277,206
2024	588,015	466,886	310,467	277,548
2025	589,073	478,800	311,183	277,890
2026	590,131	488,888	311,899	278,232
2027	591,189	500,802	312,615	278,574
2028	592,246	510,890	313,331	278,916
2029	593,304	522,803	314,047	279,258
2030	594,362	532,891	314,763	279,600
2031	595,420	544,805	315,479	279,942
2032	596,478	554,893	316,195	280,283
2033	597,536	566,807	316,911	280,625
2034	598,594	576,895	317,627	280,967
2035	599,652	588,808	318,343	281,309
2036	600,710	598,896	319,059	281,651
2037	601,768	610,810	319,775	281,993
2038	602,826	620,898	320,491	282,335
2039	603,884	632,812	321,207	282,677
2040	604,942	642,900	321,923	283,019
2041	606,000	654,813	322,639	283,361
2042	607,058	664,901	323,355	283,703
2043	608,116	676,815	324,071	284,045
2044	609,173	686,903	324,787	284,387
2045	610,231	698,817	325,503	284,729
2046	611,289	708,905	326,219	285,071
2047	612,347	720,818	326,935	285,413
2048	613,405	730,906	327,651	285,755

2049	614,463	742,820	328,367	286,097
2050	615,521	752,908	329,083	286,439
2051	616,579	764,822	329,799	286,780
2052	617,637	774,910	330,515	287,122
2053	618,695	786,823	331,231	287,464
2054	619,753	796,911	331,947	287,806
2055	620,811	808,825	332,662	288,148
2056	621,869	818,913	333,378	288,490
2057	622,927	830,827	334,094	288,832
2058	623,985	840,915	334,810	289,174
2059	625,042	852,828	335,526	289,516
2060	626,100	862,916	336,242	289,858
2061	627,158	874,830	336,958	290,200
2062	628,216	884,918	337,674	290,542
2063	629,274	896,832	338,390	290,884
2064	630,332	906,920	339,106	291,226
2065	631,390	918,833	339,822	291,568
2066	632,448	928,921	340,538	291,910
2067	633,506	940,835	341,254	292,252
2068	634,564	950,923	341,970	292,594
2069	635,622	962,837	342,686	292,936
2070	636,680	972,925	343,402	293,277
2071	637,738	984,838	344,118	293,619
2072	638,796	994,926	344,834	293,961
2073	639,854	1,006,840	345,550	294,303
2074	640,912	1,016,928	346,266	294,645
2075	641,969	1,028,842	346,982	294,987
2076	643,027	1,038,930	347,698	295,329
2077	644,085	1,050,843	348,414	295,671
2078	645,143	1,060,931	349,130	296,013
2079	646,201	1,072,845	349,846	296,355
2080	647,259	1,082,933	350,562	296,697
2081	648,317	1,094,847	351,278	297,039
2082	649,375	1,104,935	351,994	297,381
2083	650,433	1,116,848	352,710	297,723
2084	651,491	1,126,936	353,426	298,065
2085	652,549	1,138,850	354,142	298,407
2086	653,607	1,148,938	354,858	298,749
2087	654,665	1,160,852	355,574	299,091
2088	655,723	1,170,940	356,290	299,433
2089	656,781	1,182,853	357,006	299,774
2090	657,839	1,192,941	357,722	300,116
2091	658,896	1,204,855	358,438	300,458
2092	659,954	1,214,943	359,154	300,800
2093	661,012	1,226,857	359,870	301,142
2094	662,070	1,236,945	360,586	301,484
2095	663,128	1,248,858	361,302	301,826
2096	664,186	1,258,946	362,018	302,168
2097	665,244	1,270,860	362,734	302,510
2098	666,302	1,280,948	363,450	302,852
2099	667,360	1,292,862	364,166	303,194
2100	668,418	1,302,950	364,882	303,536

Table A.6 Paper and paperboard production activity data in Norway from 1990-2021, and forecast for 2022-2100

Norway	Paper and paperboard + (Total)			
FAOSTAT	Production	Imports	Exports	Consumed
year	m3	m3	m3	m3
1990	1,819,000	268,200	1,476,300	342,700
1991	1,784,000	290,100	1,464,000	320,000
1992	1,683,000	306,950	1,363,411	319,589
1993	1,958,000	326,898	1,596,602	361,398
1994	2,148,000	358,100	1,768,200	379,800
1995	2,261,000	506,000	1,961,000	300,000
1996	2,096,000	519,000	1,832,000	264,000
1997	2,129,000	475,900	1,936,600	192,400

1998	2,260,200	470,000	1,994,583	265,617
1999	2,241,000	493,000	2,003,000	238,000
2000	2,300,000	466,000	1,981,415	318,585
2001	2,220,000	434,000	2,041,000	179,000
2002	2,114,000	450,000	1,865,000	249,000
2003	2,186,000	467,462	1,871,052	314,948
2004	2,294,000	450,100	2,003,599	290,401
2005	2,223,000	475,739	1,911,090	311,910
2006	2,109,000	490,740	1,821,218	287,782
2007	2,010,000	516,362	1,714,179	295,821
2008	1,900,000	484,480	1,643,062	256,938
2009	1,577,000	431,814	1,296,122	280,878
2010	1,695,000	404,505	1,454,761	240,239
2011	1,496,000	432,752	1,334,813	161,187
2012	1,209,000	441,431	1,083,010	125,990
2013	1,079,000	439,850	984,056	94,944
2014	1,023,000	476,719	978,212	44,788
2015	979,000	397,364	943,493	35,507
2016	1,099,000	377,828	1,064,013	34,987
2017	1,097,000	364,016	994,988	102,012
2018	1,134,000	390,215	1,060,974	73,026
2019	1,155,000	326,027	903,092	251,908
2020	933,000	301,880	847,339	85,661
2021	1,010,000	298,402	921,239	88,761
2022	2,091,942	297,841	1,846,012	245,931
2023	2,105,653	297,281	1,951,404	154,249
2024	2,119,363	296,720	1,875,004	244,358
2025	2,133,073	296,159	1,980,396	152,677
2026	2,146,783	295,599	1,903,997	242,786
2027	2,160,493	295,038	2,009,389	151,104
2028	2,174,204	294,477	1,932,990	241,213
2029	2,187,914	293,917	2,038,382	149,532
2030	2,201,624	293,356	1,961,983	239,641
2031	2,215,334	292,795	2,067,375	147,959
2032	2,229,044	292,235	1,990,976	238,069
2033	2,242,754	291,674	2,096,368	146,387
2034	2,256,465	291,113	2,019,968	236,496
2035	2,270,175	290,552	2,125,360	144,814
2036	2,283,885	289,992	2,048,961	234,924
2037	2,297,595	289,431	2,154,353	143,242
2038	2,311,305	288,870	2,077,954	233,351
2039	2,325,015	288,310	2,183,346	141,669
2040	2,338,726	287,749	2,106,947	231,779
2041	2,352,436	287,188	2,212,339	140,097
2042	2,366,146	286,628	2,135,940	230,206
2043	2,379,856	286,067	2,241,332	138,525
2044	2,393,566	285,506	2,164,933	228,634
2045	2,407,276	284,946	2,270,324	136,952
2046	2,420,987	284,385	2,193,925	227,061
2047	2,434,697	283,824	2,299,317	135,380
2048	2,448,407	283,264	2,222,918	225,489
2049	2,462,117	282,703	2,328,310	133,807
2050	2,475,827	282,142	2,251,911	223,916
2051	2,489,538	281,582	2,357,303	132,235
2052	2,503,248	281,021	2,280,904	222,344
2053	2,516,958	280,460	2,386,296	130,662
2054	2,530,668	279,900	2,309,897	220,772
2055	2,544,378	279,339	2,415,288	129,090
2056	2,558,088	278,778	2,338,889	219,199
2057	2,571,799	278,217	2,444,281	127,517
2058	2,585,509	277,657	2,367,882	217,627
2059	2,599,219	277,096	2,473,274	125,945
2060	2,612,929	276,535	2,396,875	216,054
2061	2,626,639	275,975	2,502,267	124,372
2062	2,640,349	275,414	2,425,868	214,482
2063	2,654,060	274,853	2,531,260	122,800
2064	2,667,770	274,293	2,454,861	212,909
2065	2,681,480	273,732	2,560,252	121,228

2066	2,695,190	273,171	2,483,853	211,337
2067	2,708,900	272,611	2,589,245	119,655
2068	2,722,611	272,050	2,512,846	209,764
2069	2,736,321	271,489	2,618,238	118,083
2070	2,750,031	270,929	2,541,839	208,192
2071	2,763,741	270,368	2,647,231	116,510
2072	2,777,451	269,807	2,570,832	206,619
2073	2,791,161	269,247	2,676,224	114,938
2074	2,804,872	268,686	2,599,825	205,047
2075	2,818,582	268,125	2,705,217	113,365
2076	2,832,292	267,565	2,628,817	203,475
2077	2,846,002	267,004	2,734,209	111,793
2078	2,859,712	266,443	2,657,810	201,902
2079	2,873,422	265,883	2,763,202	110,220
2080	2,887,133	265,322	2,686,803	200,330
2081	2,900,843	264,761	2,792,195	108,648
2082	2,914,553	264,200	2,715,796	198,757
2083	2,928,263	263,640	2,821,188	107,075
2084	2,941,973	263,079	2,744,789	197,185
2085	2,955,684	262,518	2,850,181	105,503
2086	2,969,394	261,958	2,773,781	195,612
2087	2,983,104	261,397	2,879,173	103,931
2088	2,996,814	260,836	2,802,774	194,040
2089	3,010,524	260,276	2,908,166	102,358
2090	3,024,234	259,715	2,831,767	192,467
2091	3,037,945	259,154	2,937,159	100,786
2092	3,051,655	258,594	2,860,760	190,895
2093	3,065,365	258,033	2,966,152	99,213
2094	3,079,075	257,472	2,889,753	189,322
2095	3,092,785	256,912	2,995,145	97,641
2096	3,106,495	256,351	2,918,745	187,750
2097	3,120,206	255,790	3,024,137	96,068
2098	3,133,916	255,230	2,947,738	186,178
2099	3,147,626	254,669	3,053,130	94,496
2100	3,161,336	254,108	2,976,731	184,605

Table A.7 Scenario 1 recovered and recycling fractions

year	Sawnwood				Wood-based panels				Paper and paperboard			
	REC	Recycling			REC	Recycling			REC	Recycling		
		q_{SW}	q_{WB}	q_{PP}		q_{SW}	q_{WB}	q_{PP}		q_{SW}	q_{WB}	q_{PP}
1990	0%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	0%
1991	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	0%	3%
1992	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	5%
1993	0%	0%	0%	0%	0%	0%	0%	0%	9%	0%	0%	7%
1994	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	9%
1995	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	12%
1996	0%	0%	0%	0%	0%	0%	0%	0%	18%	0%	0%	14%
1997	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	16%
1998	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	18%
1999	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	21%
2000	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	23%
2001	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	25%
2002	0%	0%	0%	0%	0%	0%	0%	0%	22%	0%	0%	27%
2003	0%	0%	0%	0%	0%	0%	0%	0%	21%	0%	0%	30%
2004	0%	0%	0%	0%	0%	0%	0%	0%	21%	0%	0%	32%
2005	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	34%
2006	0%	0%	0%	0%	0%	0%	0%	0%	22%	0%	0%	36%
2007	0%	0%	0%	0%	0%	0%	0%	0%	23%	0%	0%	39%
2008	0%	0%	0%	0%	0%	0%	0%	0%	25%	0%	0%	41%
2009	0%	0%	0%	0%	0%	0%	0%	0%	30%	0%	0%	43%
2010	0%	0%	0%	0%	0%	0%	0%	0%	28%	0%	0%	45%
2011	1%	0%	0%	0%	1%	0%	0%	0%	29%	0%	0%	48%
2012	3%	2%	1%	0%	3%	0%	2%	1%	39%	0%	0%	50%
2013	5%	4%	1%	0%	5%	0%	4%	1%	48%	0%	0%	52%
2014	6%	6%	4%	1%	6%	0%	6%	1%	59%	0%	0%	54%
2015	8%	8%	6%	2%	8%	0%	8%	2%	65%	0%	0%	57%

2016	8%	10%	8%	3%	8%	0%	10%	2%	55%	0%	0%	59%
2017	7%	12%	10%	4%	7%	0%	12%	3%	55%	0%	0%	61%
2018	7%	14%	12%	5%	7%	0%	14%	3%	53%	0%	0%	63%
2019	6%	16%	14%	6%	6%	0%	16%	3%	50%	0%	0%	66%
2020	11%	18%	16%	7%	11%	0%	18%	4%	57%	0%	0%	68%
2021	27%	20%	18%	8%	27%	0%	20%	4%	53%	0%	0%	70%
2022	27%	22%	20%	9%	27%	0%	22%	4%	23%	0%	0%	70%
2023	28%	25%	21%	10%	28%	0%	25%	5%	23%	0%	0%	70%
2024	28%	25%	21%	10%	28%	0%	25%	5%	24%	0%	0%	70%
2025	28%	25%	21%	10%	28%	0%	25%	5%	28%	0%	0%	70%
2026	29%	25%	21%	10%	29%	0%	25%	5%	28%	0%	0%	70%
2027	29%	25%	21%	10%	29%	0%	25%	5%	29%	0%	0%	70%
2028	29%	25%	21%	10%	29%	0%	25%	5%	26%	0%	0%	70%
2029	29%	25%	21%	10%	29%	0%	25%	5%	26%	0%	0%	70%
2030	30%	25%	21%	10%	30%	0%	25%	5%	27%	0%	0%	70%
2031	30%	25%	21%	10%	30%	0%	25%	5%	31%	0%	0%	70%
2032	30%	25%	21%	10%	30%	0%	25%	5%	31%	0%	0%	70%
2033	31%	25%	21%	10%	31%	0%	25%	5%	32%	0%	0%	70%
2034	31%	25%	21%	10%	31%	0%	25%	5%	29%	0%	0%	70%
2035	31%	25%	21%	10%	31%	0%	25%	5%	29%	0%	0%	70%
2036	31%	25%	21%	10%	31%	0%	25%	5%	30%	0%	0%	70%
2037	32%	25%	21%	10%	32%	0%	25%	5%	33%	0%	0%	70%
2038	32%	25%	21%	10%	32%	0%	25%	5%	33%	0%	0%	70%
2039	32%	25%	21%	10%	32%	0%	25%	5%	34%	0%	0%	70%
2040	33%	25%	21%	10%	33%	0%	25%	5%	31%	0%	0%	70%
2041	33%	25%	21%	10%	33%	0%	25%	5%	31%	0%	0%	70%
2042	33%	25%	21%	10%	33%	0%	25%	5%	32%	0%	0%	70%
2043	34%	25%	21%	10%	34%	0%	25%	5%	36%	0%	0%	70%
2044	34%	25%	21%	10%	34%	0%	25%	5%	36%	0%	0%	70%
2045	34%	25%	21%	10%	34%	0%	25%	5%	37%	0%	0%	70%
2046	34%	25%	21%	10%	34%	0%	25%	5%	34%	0%	0%	70%
2047	35%	25%	21%	10%	35%	0%	25%	5%	34%	0%	0%	70%
2048	35%	25%	21%	10%	35%	0%	25%	5%	35%	0%	0%	70%
2049	35%	25%	21%	10%	35%	0%	25%	5%	38%	0%	0%	70%
2050	36%	25%	21%	10%	36%	0%	25%	5%	38%	0%	0%	70%
2051	36%	25%	21%	10%	36%	0%	25%	5%	39%	0%	0%	70%
2052	36%	25%	21%	10%	36%	0%	25%	5%	36%	0%	0%	70%
2053	36%	25%	21%	10%	36%	0%	25%	5%	36%	0%	0%	70%
2054	37%	25%	21%	10%	37%	0%	25%	5%	37%	0%	0%	70%
2055	37%	25%	21%	10%	37%	0%	25%	5%	40%	0%	0%	70%
2056	37%	25%	21%	10%	37%	0%	25%	5%	40%	0%	0%	70%
2057	38%	25%	21%	10%	38%	0%	25%	5%	41%	0%	0%	70%
2058	38%	25%	21%	10%	38%	0%	25%	5%	38%	0%	0%	70%
2059	38%	25%	21%	10%	38%	0%	25%	5%	38%	0%	0%	70%
2060	38%	25%	21%	10%	38%	0%	25%	5%	39%	0%	0%	70%
2061	39%	25%	21%	10%	39%	0%	25%	5%	42%	0%	0%	70%
2062	39%	25%	21%	10%	39%	0%	25%	5%	42%	0%	0%	70%
2063	39%	25%	21%	10%	39%	0%	25%	5%	43%	0%	0%	70%
2064	40%	25%	21%	10%	40%	0%	25%	5%	40%	0%	0%	70%
2065	40%	25%	21%	10%	40%	0%	25%	5%	40%	0%	0%	70%
2066	40%	25%	21%	10%	40%	0%	25%	5%	41%	0%	0%	70%
2067	40%	25%	21%	10%	40%	0%	25%	5%	44%	0%	0%	70%
2068	41%	25%	21%	10%	41%	0%	25%	5%	44%	0%	0%	70%
2069	41%	25%	21%	10%	41%	0%	25%	5%	45%	0%	0%	70%
2070	41%	25%	21%	10%	41%	0%	25%	5%	42%	0%	0%	70%
2071	42%	25%	21%	10%	42%	0%	25%	5%	42%	0%	0%	70%
2072	42%	25%	21%	10%	42%	0%	25%	5%	43%	0%	0%	70%
2073	42%	25%	21%	10%	42%	0%	25%	5%	45%	0%	0%	70%
2074	43%	25%	21%	10%	43%	0%	25%	5%	46%	0%	0%	70%
2075	43%	25%	21%	10%	43%	0%	25%	5%	46%	0%	0%	70%
2076	43%	25%	21%	10%	43%	0%	25%	5%	44%	0%	0%	70%
2077	43%	25%	21%	10%	43%	0%	25%	5%	44%	0%	0%	70%
2078	44%	25%	21%	10%	44%	0%	25%	5%	45%	0%	0%	70%
2079	44%	25%	21%	10%	44%	0%	25%	5%	47%	0%	0%	70%
2080	44%	25%	21%	10%	44%	0%	25%	5%	47%	0%	0%	70%
2081	45%	25%	21%	10%	45%	0%	25%	5%	48%	0%	0%	70%
2082	45%	25%	21%	10%	45%	0%	25%	5%	46%	0%	0%	70%
2083	45%	25%	21%	10%	45%	0%	25%	5%	45%	0%	0%	70%

2084	45%	25%	21%	10%	45%	0%	25%	5%	46%	0%	0%	70%
2085	46%	25%	21%	10%	46%	0%	25%	5%	49%	0%	0%	70%
2086	46%	25%	21%	10%	46%	0%	25%	5%	49%	0%	0%	70%
2087	46%	25%	21%	10%	46%	0%	25%	5%	49%	0%	0%	70%
2088	47%	25%	21%	10%	47%	0%	25%	5%	47%	0%	0%	70%
2089	47%	25%	21%	10%	47%	0%	25%	5%	47%	0%	0%	70%
2090	47%	25%	21%	10%	47%	0%	25%	5%	48%	0%	0%	70%
2091	47%	25%	21%	10%	47%	0%	25%	5%	50%	0%	0%	70%
2092	48%	25%	21%	10%	48%	0%	25%	5%	50%	0%	0%	70%
2093	48%	25%	21%	10%	48%	0%	25%	5%	51%	0%	0%	70%
2094	48%	25%	21%	10%	48%	0%	25%	5%	49%	0%	0%	70%
2095	49%	25%	21%	10%	49%	0%	25%	5%	48%	0%	0%	70%
2096	49%	25%	21%	10%	49%	0%	25%	5%	49%	0%	0%	70%
2097	49%	25%	21%	10%	49%	0%	25%	5%	51%	0%	0%	70%
2098	50%	25%	21%	10%	50%	0%	25%	5%	52%	0%	0%	70%
2099	50%	25%	21%	10%	50%	0%	25%	5%	52%	0%	0%	70%
2100	50%	25%	21%	10%	50%	0%	25%	5%	50%	0%	0%	70%

Table A.8 Scenario 2 recovered and recycling fractions

year	Sawnwood				Wood-based panels				Paper and paperboard			
	REC	Recycling			REC	Recycling			REC	Recycling		
		q_{SW}	q_{WB}	q_{PP}		q_{SW}	q_{WB}	q_{PP}		q_{SW}	q_{WB}	q_{PP}
1990	0%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	0%
1991	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	0%	3%
1992	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	5%
1993	0%	0%	0%	0%	0%	0%	0%	0%	9%	0%	0%	7%
1994	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	9%
1995	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	12%
1996	0%	0%	0%	0%	0%	0%	0%	0%	18%	0%	0%	14%
1997	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	16%
1998	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	18%
1999	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	21%
2000	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	23%
2001	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	25%
2002	0%	0%	0%	0%	0%	0%	0%	0%	22%	0%	0%	27%
2003	0%	0%	0%	0%	0%	0%	0%	0%	21%	0%	0%	30%
2004	0%	0%	0%	0%	0%	0%	0%	0%	21%	0%	0%	32%
2005	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	34%
2006	0%	0%	0%	0%	0%	0%	0%	0%	22%	0%	0%	36%
2007	0%	0%	0%	0%	0%	0%	0%	0%	23%	0%	0%	39%
2008	0%	0%	0%	0%	0%	0%	0%	0%	25%	0%	0%	41%
2009	0%	0%	0%	0%	0%	0%	0%	0%	30%	0%	0%	43%
2010	0%	0%	0%	0%	0%	0%	0%	0%	28%	0%	0%	45%
2011	1%	0%	0%	0%	1%	0%	0%	0%	29%	0%	0%	48%
2012	3%	2%	1%	0%	3%	0%	2%	1%	39%	0%	0%	50%
2013	5%	4%	1%	0%	5%	0%	4%	1%	48%	0%	0%	52%
2014	6%	6%	4%	1%	6%	0%	6%	1%	59%	0%	0%	54%
2015	8%	8%	6%	2%	8%	0%	8%	2%	65%	0%	0%	57%
2016	8%	10%	8%	3%	8%	0%	10%	2%	55%	0%	0%	59%
2017	7%	12%	10%	4%	7%	0%	12%	3%	55%	0%	0%	61%
2018	7%	14%	12%	5%	7%	0%	14%	3%	53%	0%	0%	63%
2019	6%	16%	14%	6%	6%	0%	16%	3%	50%	0%	0%	66%
2020	11%	18%	16%	7%	11%	0%	18%	4%	57%	0%	0%	68%
2021	27%	20%	18%	8%	27%	0%	20%	4%	53%	0%	0%	70%
2022	27%	22%	20%	9%	27%	0%	22%	4%	23%	0%	0%	70%
2023	28%	25%	21%	10%	28%	0%	25%	5%	23%	0%	0%	71%
2024	28%	25%	21%	10%	28%	0%	25%	5%	24%	0%	0%	71%
2025	28%	25%	22%	10%	28%	0%	26%	5%	28%	0%	0%	71%
2026	29%	25%	22%	10%	29%	0%	26%	5%	28%	0%	0%	71%
2027	29%	26%	23%	10%	29%	0%	26%	6%	29%	0%	0%	72%
2028	29%	26%	23%	10%	29%	0%	27%	6%	26%	0%	0%	72%
2029	29%	26%	23%	10%	29%	0%	27%	6%	26%	0%	0%	72%
2030	30%	26%	24%	10%	30%	0%	27%	6%	27%	0%	0%	72%
2031	30%	26%	24%	10%	30%	0%	28%	6%	31%	0%	0%	73%
2032	30%	26%	24%	10%	30%	0%	28%	6%	31%	0%	0%	73%
2033	31%	26%	25%	10%	31%	0%	28%	6%	32%	0%	0%	73%

2034	31%	26%	25%	10%	31%	0%	29%	6%	29%	0%	0%	73%
2035	31%	27%	26%	10%	31%	0%	29%	7%	29%	0%	0%	74%
2036	31%	27%	26%	10%	31%	0%	29%	7%	30%	0%	0%	74%
2037	32%	27%	26%	10%	32%	0%	30%	7%	33%	0%	0%	74%
2038	32%	27%	27%	10%	32%	0%	30%	7%	33%	0%	0%	74%
2039	32%	27%	27%	10%	32%	0%	30%	7%	34%	0%	0%	75%
2040	33%	27%	27%	10%	33%	0%	31%	7%	31%	0%	0%	75%
2041	33%	27%	28%	10%	33%	0%	31%	7%	31%	0%	0%	75%
2042	33%	27%	28%	10%	33%	0%	31%	7%	32%	0%	0%	75%
2043	34%	28%	29%	10%	34%	0%	32%	8%	36%	0%	0%	76%
2044	34%	28%	29%	10%	34%	0%	32%	8%	36%	0%	0%	76%
2045	34%	28%	29%	10%	34%	0%	32%	8%	37%	0%	0%	76%
2046	34%	28%	30%	10%	34%	0%	32%	8%	34%	0%	0%	76%
2047	35%	28%	30%	10%	35%	0%	33%	8%	34%	0%	0%	77%
2048	35%	28%	30%	10%	35%	0%	33%	8%	35%	0%	0%	77%
2049	35%	28%	31%	10%	35%	0%	33%	8%	38%	0%	0%	77%
2050	36%	29%	31%	10%	36%	0%	34%	9%	38%	0%	0%	77%
2051	36%	29%	32%	10%	36%	0%	34%	9%	39%	0%	0%	78%
2052	36%	29%	32%	10%	36%	0%	34%	9%	36%	0%	0%	78%
2053	36%	29%	32%	10%	36%	0%	35%	9%	36%	0%	0%	78%
2054	37%	29%	33%	10%	37%	0%	35%	9%	37%	0%	0%	78%
2055	37%	29%	33%	10%	37%	0%	35%	9%	40%	0%	0%	79%
2056	37%	29%	33%	10%	37%	0%	36%	9%	40%	0%	0%	79%
2057	38%	29%	34%	10%	38%	0%	36%	9%	41%	0%	0%	79%
2058	38%	30%	34%	10%	38%	0%	36%	10%	38%	0%	0%	79%
2059	38%	30%	35%	10%	38%	0%	37%	10%	38%	0%	0%	80%
2060	38%	30%	35%	10%	38%	0%	37%	10%	39%	0%	0%	80%
2061	39%	30%	35%	10%	39%	0%	37%	10%	42%	0%	0%	80%
2062	39%	30%	36%	10%	39%	0%	38%	10%	42%	0%	0%	80%
2063	39%	30%	36%	10%	39%	0%	38%	10%	43%	0%	0%	81%
2064	40%	30%	36%	10%	40%	0%	38%	10%	40%	0%	0%	81%
2065	40%	30%	37%	10%	40%	0%	39%	10%	40%	0%	0%	81%
2066	40%	31%	37%	10%	40%	0%	39%	11%	41%	0%	0%	81%
2067	40%	31%	38%	10%	40%	0%	39%	11%	44%	0%	0%	82%
2068	41%	31%	38%	10%	41%	0%	40%	11%	44%	0%	0%	82%
2069	41%	31%	38%	10%	41%	0%	40%	11%	45%	0%	0%	82%
2070	41%	31%	39%	10%	41%	0%	40%	11%	42%	0%	0%	82%
2071	42%	31%	39%	10%	42%	0%	41%	11%	42%	0%	0%	83%
2072	42%	31%	39%	10%	42%	0%	41%	11%	43%	0%	0%	83%
2073	42%	32%	40%	10%	42%	0%	41%	12%	45%	0%	0%	83%
2074	43%	32%	40%	10%	43%	0%	42%	12%	46%	0%	0%	83%
2075	43%	32%	41%	10%	43%	0%	42%	12%	46%	0%	0%	84%
2076	43%	32%	41%	10%	43%	0%	42%	12%	44%	0%	0%	84%
2077	43%	32%	41%	10%	43%	0%	43%	12%	44%	0%	0%	84%
2078	44%	32%	42%	10%	44%	0%	43%	12%	45%	0%	0%	84%
2079	44%	32%	42%	10%	44%	0%	43%	12%	47%	0%	0%	85%
2080	44%	32%	42%	10%	44%	0%	44%	12%	47%	0%	0%	85%
2081	45%	33%	43%	10%	45%	0%	44%	13%	48%	0%	0%	85%
2082	45%	33%	43%	10%	45%	0%	44%	13%	46%	0%	0%	85%
2083	45%	33%	44%	10%	45%	0%	44%	13%	45%	0%	0%	86%
2084	45%	33%	44%	10%	45%	0%	45%	13%	46%	0%	0%	86%
2085	46%	33%	44%	10%	46%	0%	45%	13%	49%	0%	0%	86%
2086	46%	33%	45%	10%	46%	0%	45%	13%	49%	0%	0%	86%
2087	46%	33%	45%	10%	46%	0%	46%	13%	49%	0%	0%	87%
2088	47%	33%	45%	10%	47%	0%	46%	13%	47%	0%	0%	87%
2089	47%	34%	46%	10%	47%	0%	46%	14%	47%	0%	0%	87%
2090	47%	34%	46%	10%	47%	0%	47%	14%	48%	0%	0%	87%
2091	47%	34%	47%	10%	47%	0%	47%	14%	50%	0%	0%	88%
2092	48%	34%	47%	10%	48%	0%	47%	14%	50%	0%	0%	88%
2093	48%	34%	47%	10%	48%	0%	48%	14%	51%	0%	0%	88%
2094	48%	34%	48%	10%	48%	0%	48%	14%	49%	0%	0%	88%
2095	49%	34%	48%	10%	49%	0%	48%	14%	48%	0%	0%	89%
2096	49%	34%	48%	10%	49%	0%	49%	14%	49%	0%	0%	89%
2097	49%	35%	49%	10%	49%	0%	49%	15%	51%	0%	0%	89%
2098	50%	35%	49%	10%	50%	0%	49%	15%	52%	0%	0%	89%
2099	50%	35%	50%	10%	50%	0%	50%	15%	52%	0%	0%	90%
2100	50%	35%	50%	10%	50%	0%	50%	15%	50%	0%	0%	90%

Table A.9 Scenario 3 recovered and recycling fractions

year	Sawnwood				Wood-based panels				Paper and paperboard			
	REC	Recycling			REC	Recycling			REC	Recycling		
		q_{SW}	q_{WB}	q_{PP}		q_{SW}	q_{WB}	q_{PP}		q_{SW}	q_{WB}	q_{PP}
1990	0%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	0%
1991	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	0%	3%
1992	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	5%
1993	0%	0%	0%	0%	0%	0%	0%	0%	9%	0%	0%	7%
1994	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	9%
1995	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	12%
1996	0%	0%	0%	0%	0%	0%	0%	0%	18%	0%	0%	14%
1997	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	16%
1998	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	18%
1999	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	21%
2000	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	23%
2001	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	25%
2002	0%	0%	0%	0%	0%	0%	0%	0%	22%	0%	0%	27%
2003	0%	0%	0%	0%	0%	0%	0%	0%	21%	0%	0%	30%
2004	0%	0%	0%	0%	0%	0%	0%	0%	21%	0%	0%	32%
2005	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	34%
2006	0%	0%	0%	0%	0%	0%	0%	0%	22%	0%	0%	36%
2007	0%	0%	0%	0%	0%	0%	0%	0%	23%	0%	0%	39%
2008	0%	0%	0%	0%	0%	0%	0%	0%	25%	0%	0%	41%
2009	0%	0%	0%	0%	0%	0%	0%	0%	30%	0%	0%	43%
2010	0%	0%	0%	0%	0%	0%	0%	0%	28%	0%	0%	45%
2011	1%	0%	0%	0%	1%	0%	0%	0%	29%	0%	0%	48%
2012	3%	2%	1%	0%	3%	0%	2%	1%	39%	0%	0%	50%
2013	5%	4%	1%	0%	5%	0%	4%	1%	48%	0%	0%	52%
2014	6%	6%	4%	1%	6%	0%	6%	1%	59%	0%	0%	54%
2015	8%	8%	6%	2%	8%	0%	8%	2%	65%	0%	0%	57%
2016	8%	10%	8%	3%	8%	0%	10%	2%	55%	0%	0%	59%
2017	7%	12%	10%	4%	7%	0%	12%	3%	55%	0%	0%	61%
2018	7%	14%	12%	5%	7%	0%	14%	3%	53%	0%	0%	63%
2019	6%	16%	14%	6%	6%	0%	16%	3%	50%	0%	0%	66%
2020	11%	18%	16%	7%	11%	0%	18%	4%	57%	0%	0%	68%
2021	27%	20%	18%	8%	27%	0%	20%	4%	53%	0%	0%	70%
2022	28%	22%	20%	9%	28%	0%	22%	4%	53%	0%	0%	70%
2023	28%	25%	21%	10%	28%	0%	25%	5%	54%	0%	0%	70%
2024	29%	25%	21%	10%	29%	0%	25%	5%	54%	0%	0%	70%
2025	30%	25%	21%	10%	30%	0%	25%	5%	55%	0%	0%	70%
2026	30%	25%	21%	10%	30%	0%	25%	5%	55%	0%	0%	70%
2027	31%	25%	21%	10%	31%	0%	25%	5%	56%	0%	0%	70%
2028	31%	25%	21%	10%	31%	0%	25%	5%	56%	0%	0%	70%
2029	32%	25%	21%	10%	32%	0%	25%	5%	57%	0%	0%	70%
2030	33%	25%	21%	10%	33%	0%	25%	5%	57%	0%	0%	70%
2031	33%	25%	21%	10%	33%	0%	25%	5%	58%	0%	0%	70%
2032	34%	25%	21%	10%	34%	0%	25%	5%	58%	0%	0%	70%
2033	34%	25%	21%	10%	34%	0%	25%	5%	59%	0%	0%	70%
2034	35%	25%	21%	10%	35%	0%	25%	5%	59%	0%	0%	70%
2035	36%	25%	21%	10%	36%	0%	25%	5%	60%	0%	0%	70%
2036	36%	25%	21%	10%	36%	0%	25%	5%	60%	0%	0%	70%
2037	37%	25%	21%	10%	37%	0%	25%	5%	60%	0%	0%	70%
2038	37%	25%	21%	10%	37%	0%	25%	5%	61%	0%	0%	70%
2039	38%	25%	21%	10%	38%	0%	25%	5%	61%	0%	0%	70%
2040	39%	25%	21%	10%	39%	0%	25%	5%	62%	0%	0%	70%
2041	39%	25%	21%	10%	39%	0%	25%	5%	62%	0%	0%	70%
2042	40%	25%	21%	10%	40%	0%	25%	5%	63%	0%	0%	70%
2043	40%	25%	21%	10%	40%	0%	25%	5%	63%	0%	0%	70%
2044	41%	25%	21%	10%	41%	0%	25%	5%	64%	0%	0%	70%
2045	42%	25%	21%	10%	42%	0%	25%	5%	64%	0%	0%	70%
2046	42%	25%	21%	10%	42%	0%	25%	5%	65%	0%	0%	70%
2047	43%	25%	21%	10%	43%	0%	25%	5%	65%	0%	0%	70%
2048	43%	25%	21%	10%	43%	0%	25%	5%	66%	0%	0%	70%
2049	44%	25%	21%	10%	44%	0%	25%	5%	66%	0%	0%	70%
2050	45%	25%	21%	10%	45%	0%	25%	5%	67%	0%	0%	70%

2051	45%	25%	21%	10%	45%	0%	25%	5%	67%	0%	0%	70%
2052	46%	25%	21%	10%	46%	0%	25%	5%	68%	0%	0%	70%
2053	47%	25%	21%	10%	47%	0%	25%	5%	68%	0%	0%	70%
2054	47%	25%	21%	10%	47%	0%	25%	5%	69%	0%	0%	70%
2055	48%	25%	21%	10%	48%	0%	25%	5%	69%	0%	0%	70%
2056	48%	25%	21%	10%	48%	0%	25%	5%	70%	0%	0%	70%
2057	49%	25%	21%	10%	49%	0%	25%	5%	70%	0%	0%	70%
2058	50%	25%	21%	10%	50%	0%	25%	5%	71%	0%	0%	70%
2059	50%	25%	21%	10%	50%	0%	25%	5%	71%	0%	0%	70%
2060	51%	25%	21%	10%	51%	0%	25%	5%	72%	0%	0%	70%
2061	51%	25%	21%	10%	51%	0%	25%	5%	72%	0%	0%	70%
2062	52%	25%	21%	10%	52%	0%	25%	5%	72%	0%	0%	70%
2063	53%	25%	21%	10%	53%	0%	25%	5%	73%	0%	0%	70%
2064	53%	25%	21%	10%	53%	0%	25%	5%	73%	0%	0%	70%
2065	54%	25%	21%	10%	54%	0%	25%	5%	74%	0%	0%	70%
2066	54%	25%	21%	10%	54%	0%	25%	5%	74%	0%	0%	70%
2067	55%	25%	21%	10%	55%	0%	25%	5%	75%	0%	0%	70%
2068	56%	25%	21%	10%	56%	0%	25%	5%	75%	0%	0%	70%
2069	56%	25%	21%	10%	56%	0%	25%	5%	76%	0%	0%	70%
2070	57%	25%	21%	10%	57%	0%	25%	5%	76%	0%	0%	70%
2071	57%	25%	21%	10%	57%	0%	25%	5%	77%	0%	0%	70%
2072	58%	25%	21%	10%	58%	0%	25%	5%	77%	0%	0%	70%
2073	59%	25%	21%	10%	59%	0%	25%	5%	78%	0%	0%	70%
2074	59%	25%	21%	10%	59%	0%	25%	5%	78%	0%	0%	70%
2075	60%	25%	21%	10%	60%	0%	25%	5%	79%	0%	0%	70%
2076	60%	25%	21%	10%	60%	0%	25%	5%	79%	0%	0%	70%
2077	61%	25%	21%	10%	61%	0%	25%	5%	80%	0%	0%	70%
2078	62%	25%	21%	10%	62%	0%	25%	5%	80%	0%	0%	70%
2079	62%	25%	21%	10%	62%	0%	25%	5%	81%	0%	0%	70%
2080	63%	25%	21%	10%	63%	0%	25%	5%	81%	0%	0%	70%
2081	64%	25%	21%	10%	64%	0%	25%	5%	82%	0%	0%	70%
2082	64%	25%	21%	10%	64%	0%	25%	5%	82%	0%	0%	70%
2083	65%	25%	21%	10%	65%	0%	25%	5%	83%	0%	0%	70%
2084	65%	25%	21%	10%	65%	0%	25%	5%	83%	0%	0%	70%
2085	66%	25%	21%	10%	66%	0%	25%	5%	84%	0%	0%	70%
2086	67%	25%	21%	10%	67%	0%	25%	5%	84%	0%	0%	70%
2087	67%	25%	21%	10%	67%	0%	25%	5%	85%	0%	0%	70%
2088	68%	25%	21%	10%	68%	0%	25%	5%	85%	0%	0%	70%
2089	68%	25%	21%	10%	68%	0%	25%	5%	85%	0%	0%	70%
2090	69%	25%	21%	10%	69%	0%	25%	5%	86%	0%	0%	70%
2091	70%	25%	21%	10%	70%	0%	25%	5%	86%	0%	0%	70%
2092	70%	25%	21%	10%	70%	0%	25%	5%	87%	0%	0%	70%
2093	71%	25%	21%	10%	71%	0%	25%	5%	87%	0%	0%	70%
2094	71%	25%	21%	10%	71%	0%	25%	5%	88%	0%	0%	70%
2095	72%	25%	21%	10%	72%	0%	25%	5%	88%	0%	0%	70%
2096	73%	25%	21%	10%	73%	0%	25%	5%	89%	0%	0%	70%
2097	73%	25%	21%	10%	73%	0%	25%	5%	89%	0%	0%	70%
2098	74%	25%	21%	10%	74%	0%	25%	5%	90%	0%	0%	70%
2099	74%	25%	21%	10%	74%	0%	25%	5%	90%	0%	0%	70%
2100	75%	25%	21%	10%	75%	0%	25%	5%	91%	0%	0%	70%

Table A.10 Scenario 4 recovered and recycling fractions

year	Sawnwood				Wood-based panels				Paper and paperboard			
	REC	Recycling			REC	Recycling			REC	Recycling		
		q_{SW}	q_{WB}	q_{PP}		q_{SW}	q_{WB}	q_{PP}		q_{SW}	q_{WB}	q_{PP}
1990	0%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	0%
1991	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	0%	3%
1992	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	5%
1993	0%	0%	0%	0%	0%	0%	0%	0%	9%	0%	0%	7%
1994	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	9%
1995	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	12%
1996	0%	0%	0%	0%	0%	0%	0%	0%	18%	0%	0%	14%
1997	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	16%
1998	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	18%
1999	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	21%
2000	0%	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%	23%

2001	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	25%
2002	0%	0%	0%	0%	0%	0%	0%	0%	22%	0%	0%	27%
2003	0%	0%	0%	0%	0%	0%	0%	0%	21%	0%	0%	30%
2004	0%	0%	0%	0%	0%	0%	0%	0%	21%	0%	0%	32%
2005	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	34%
2006	0%	0%	0%	0%	0%	0%	0%	0%	22%	0%	0%	36%
2007	0%	0%	0%	0%	0%	0%	0%	0%	23%	0%	0%	39%
2008	0%	0%	0%	0%	0%	0%	0%	0%	25%	0%	0%	41%
2009	0%	0%	0%	0%	0%	0%	0%	0%	30%	0%	0%	43%
2010	0%	0%	0%	0%	0%	0%	0%	0%	28%	0%	0%	45%
2011	1%	0%	0%	0%	1%	0%	0%	0%	29%	0%	0%	48%
2012	3%	2%	1%	0%	3%	0%	2%	1%	39%	0%	0%	50%
2013	5%	4%	1%	0%	5%	0%	4%	1%	48%	0%	0%	52%
2014	6%	6%	4%	1%	6%	0%	6%	1%	59%	0%	0%	54%
2015	8%	8%	6%	2%	8%	0%	8%	2%	65%	0%	0%	57%
2016	8%	10%	8%	3%	8%	0%	10%	2%	55%	0%	0%	59%
2017	7%	12%	10%	4%	7%	0%	12%	3%	55%	0%	0%	61%
2018	7%	14%	12%	5%	7%	0%	14%	3%	53%	0%	0%	63%
2019	6%	16%	14%	6%	6%	0%	16%	3%	50%	0%	0%	66%
2020	11%	18%	16%	7%	11%	0%	18%	4%	57%	0%	0%	68%
2021	27%	20%	18%	8%	27%	0%	20%	4%	53%	0%	0%	70%
2022	28%	22%	20%	9%	28%	0%	22%	4%	53%	0%	0%	70%
2023	28%	25%	21%	10%	28%	0%	25%	5%	54%	0%	0%	71%
2024	29%	25%	21%	10%	29%	0%	25%	5%	54%	0%	0%	71%
2025	30%	25%	22%	10%	30%	0%	26%	5%	55%	0%	0%	71%
2026	30%	25%	22%	10%	30%	0%	26%	5%	55%	0%	0%	71%
2027	31%	26%	23%	10%	31%	0%	26%	6%	56%	0%	0%	72%
2028	31%	26%	23%	10%	31%	0%	27%	6%	56%	0%	0%	72%
2029	32%	26%	23%	10%	32%	0%	27%	6%	57%	0%	0%	72%
2030	33%	26%	24%	10%	33%	0%	27%	6%	57%	0%	0%	72%
2031	33%	26%	24%	10%	33%	0%	28%	6%	58%	0%	0%	73%
2032	34%	26%	24%	10%	34%	0%	28%	6%	58%	0%	0%	73%
2033	34%	26%	25%	10%	34%	0%	28%	6%	59%	0%	0%	73%
2034	35%	26%	25%	10%	35%	0%	29%	6%	59%	0%	0%	73%
2035	36%	27%	26%	10%	36%	0%	29%	7%	60%	0%	0%	74%
2036	36%	27%	26%	10%	36%	0%	29%	7%	60%	0%	0%	74%
2037	37%	27%	26%	10%	37%	0%	30%	7%	60%	0%	0%	74%
2038	37%	27%	27%	10%	37%	0%	30%	7%	61%	0%	0%	74%
2039	38%	27%	27%	10%	38%	0%	30%	7%	61%	0%	0%	75%
2040	39%	27%	27%	10%	39%	0%	31%	7%	62%	0%	0%	75%
2041	39%	27%	28%	10%	39%	0%	31%	7%	62%	0%	0%	75%
2042	40%	27%	28%	10%	40%	0%	31%	7%	63%	0%	0%	75%
2043	40%	28%	29%	10%	40%	0%	32%	8%	63%	0%	0%	76%
2044	41%	28%	29%	10%	41%	0%	32%	8%	64%	0%	0%	76%
2045	42%	28%	29%	10%	42%	0%	32%	8%	64%	0%	0%	76%
2046	42%	28%	30%	10%	42%	0%	32%	8%	65%	0%	0%	76%
2047	43%	28%	30%	10%	43%	0%	33%	8%	65%	0%	0%	77%
2048	43%	28%	30%	10%	43%	0%	33%	8%	66%	0%	0%	77%
2049	44%	28%	31%	10%	44%	0%	33%	8%	66%	0%	0%	77%
2050	45%	29%	31%	10%	45%	0%	34%	9%	67%	0%	0%	77%
2051	45%	29%	32%	10%	45%	0%	34%	9%	67%	0%	0%	78%
2052	46%	29%	32%	10%	46%	0%	34%	9%	68%	0%	0%	78%
2053	47%	29%	32%	10%	47%	0%	35%	9%	68%	0%	0%	78%
2054	47%	29%	33%	10%	47%	0%	35%	9%	69%	0%	0%	78%
2055	48%	29%	33%	10%	48%	0%	35%	9%	69%	0%	0%	79%
2056	48%	29%	33%	10%	48%	0%	36%	9%	70%	0%	0%	79%
2057	49%	29%	34%	10%	49%	0%	36%	9%	70%	0%	0%	79%
2058	50%	30%	34%	10%	50%	0%	36%	10%	71%	0%	0%	79%
2059	50%	30%	35%	10%	50%	0%	37%	10%	71%	0%	0%	80%
2060	51%	30%	35%	10%	51%	0%	37%	10%	72%	0%	0%	80%
2061	51%	30%	35%	10%	51%	0%	37%	10%	72%	0%	0%	80%
2062	52%	30%	36%	10%	52%	0%	38%	10%	72%	0%	0%	80%
2063	53%	30%	36%	10%	53%	0%	38%	10%	73%	0%	0%	81%
2064	53%	30%	36%	10%	53%	0%	38%	10%	73%	0%	0%	81%
2065	54%	30%	37%	10%	54%	0%	39%	10%	74%	0%	0%	81%
2066	54%	31%	37%	10%	54%	0%	39%	11%	74%	0%	0%	81%
2067	55%	31%	38%	10%	55%	0%	39%	11%	75%	0%	0%	82%
2068	56%	31%	38%	10%	56%	0%	40%	11%	75%	0%	0%	82%

2069	56%	31%	38%	10%	56%	0%	40%	11%	76%	0%	0%	82%
2070	57%	31%	39%	10%	57%	0%	40%	11%	76%	0%	0%	82%
2071	57%	31%	39%	10%	57%	0%	41%	11%	77%	0%	0%	83%
2072	58%	31%	39%	10%	58%	0%	41%	11%	77%	0%	0%	83%
2073	59%	32%	40%	10%	59%	0%	41%	12%	78%	0%	0%	83%
2074	59%	32%	40%	10%	59%	0%	42%	12%	78%	0%	0%	83%
2075	60%	32%	41%	10%	60%	0%	42%	12%	79%	0%	0%	84%
2076	60%	32%	41%	10%	60%	0%	42%	12%	79%	0%	0%	84%
2077	61%	32%	41%	10%	61%	0%	43%	12%	80%	0%	0%	84%
2078	62%	32%	42%	10%	62%	0%	43%	12%	80%	0%	0%	84%
2079	62%	32%	42%	10%	62%	0%	43%	12%	81%	0%	0%	85%
2080	63%	32%	42%	10%	63%	0%	44%	12%	81%	0%	0%	85%
2081	64%	33%	43%	10%	64%	0%	44%	13%	82%	0%	0%	85%
2082	64%	33%	43%	10%	64%	0%	44%	13%	82%	0%	0%	85%
2083	65%	33%	44%	10%	65%	0%	44%	13%	83%	0%	0%	86%
2084	65%	33%	44%	10%	65%	0%	45%	13%	83%	0%	0%	86%
2085	66%	33%	44%	10%	66%	0%	45%	13%	84%	0%	0%	86%
2086	67%	33%	45%	10%	67%	0%	45%	13%	84%	0%	0%	86%
2087	67%	33%	45%	10%	67%	0%	46%	13%	85%	0%	0%	87%
2088	68%	33%	45%	10%	68%	0%	46%	13%	85%	0%	0%	87%
2089	68%	34%	46%	10%	68%	0%	46%	14%	85%	0%	0%	87%
2090	69%	34%	46%	10%	69%	0%	47%	14%	86%	0%	0%	87%
2091	70%	34%	47%	10%	70%	0%	47%	14%	86%	0%	0%	88%
2092	70%	34%	47%	10%	70%	0%	47%	14%	87%	0%	0%	88%
2093	71%	34%	47%	10%	71%	0%	48%	14%	87%	0%	0%	88%
2094	71%	34%	48%	10%	71%	0%	48%	14%	88%	0%	0%	88%
2095	72%	34%	48%	10%	72%	0%	48%	14%	88%	0%	0%	89%
2096	73%	34%	48%	10%	73%	0%	49%	14%	89%	0%	0%	89%
2097	73%	35%	49%	10%	73%	0%	49%	15%	89%	0%	0%	89%
2098	74%	35%	49%	10%	74%	0%	49%	15%	90%	0%	0%	89%
2099	74%	35%	50%	10%	74%	0%	50%	15%	90%	0%	0%	90%
2100	75%	35%	50%	10%	75%	0%	50%	15%	91%	0%	0%	90%

Table A.11 Scenario IPCC 2019 results: Carbon Stock and CO_2 Contribution 1990-2100

Year	IPCC 2019 Carbon Stock (Mg C)			Total Carbon Stock (MT)	CO_2 Stock Change (MT)
	Sawnwood	Wood Based Panels	Paper and paperboard		
1990	23,538,445	4,811,027	1,690,678	30.0	-0.3
1991	23,574,518	4,838,261	1,713,029	30.1	0.0
1992	23,573,653	4,842,725	1,711,064	30.1	0.1
1993	23,586,904	4,841,980	1,666,833	30.1	-0.1
1994	23,587,136	4,826,753	1,706,385	30.1	0.4
1995	23,535,142	4,808,139	1,680,545	30.0	0.6
1996	23,417,784	4,778,695	1,673,009	29.9	0.2
1997	23,372,789	4,756,967	1,679,946	29.8	0.3
1998	23,329,810	4,729,290	1,677,468	29.7	0.5
1999	23,257,775	4,702,966	1,644,420	29.6	0.6
2000	23,173,070	4,669,414	1,588,928	29.4	0.5
2001	23,068,912	4,637,890	1,593,541	29.3	0.2
2002	22,988,307	4,613,006	1,639,478	29.2	0.4
2003	22,905,638	4,579,034	1,651,559	29.1	0.4
2004	22,807,275	4,540,380	1,669,986	29.0	0.2
2005	22,718,892	4,527,124	1,719,742	29.0	0.2
2006	22,651,536	4,514,227	1,741,472	28.9	0.2
2007	22,606,638	4,512,030	1,739,095	28.9	0.3
2008	22,566,915	4,503,653	1,694,959	28.8	0.3
2009	22,527,911	4,486,082	1,659,375	28.7	0.7
2010	22,447,186	4,474,489	1,558,493	28.5	0.4
2011	22,416,529	4,480,294	1,476,719	28.4	0.6
2012	22,413,709	4,474,798	1,313,586	28.2	0.4
2013	22,433,119	4,466,048	1,196,268	28.1	0.4
2014	22,446,464	4,435,472	1,100,592	28.0	-0.1
2015	22,517,074	4,422,933	1,063,137	28.0	-0.1
2016	22,597,713	4,413,734	1,021,848	28.0	-0.3
2017	22,695,684	4,402,017	1,022,936	28.1	-0.4
2018	22,811,253	4,392,327	1,019,075	28.2	-0.5

2019	22,934,902	4,386,594	1,024,034	28.3	-0.5
2020	23,056,736	4,373,324	1,046,817	28.5	-0.3
2021	23,183,792	4,369,417	1,006,775	28.6	-0.4
2022	23,338,563	4,376,474	955,585	28.7	-0.8
2023	23,463,084	4,398,351	1,015,674	28.9	-0.6
2024	23,576,776	4,417,444	1,047,076	29.0	-0.9
2025	23,724,297	4,444,619	1,115,497	29.3	-1.3
2026	23,895,752	4,477,401	1,261,031	29.6	-0.9
2027	24,041,507	4,503,719	1,342,133	29.9	-0.9
2028	24,175,167	4,526,930	1,419,632	30.1	-0.7
2029	24,344,946	4,558,719	1,396,797	30.3	-0.7
2030	24,519,626	4,591,467	1,368,334	30.5	-0.7
2031	24,687,104	4,622,250	1,362,485	30.7	-1.0
2032	24,841,132	4,649,586	1,447,120	30.9	-1.0
2033	25,011,551	4,680,691	1,515,610	31.2	-1.0
2034	25,180,451	4,711,227	1,578,653	31.5	-0.5
2035	25,347,862	4,741,208	1,523,116	31.6	-0.6
2036	25,513,814	4,770,650	1,478,891	31.8	-0.7
2037	25,678,335	4,799,568	1,477,929	32.0	-1.0
2038	25,841,453	4,827,976	1,557,519	32.2	-0.9
2039	26,003,195	4,855,887	1,600,604	32.5	-0.9
2040	26,163,589	4,883,316	1,652,963	32.7	-0.5
2041	26,322,661	4,910,276	1,610,592	32.8	-0.5
2042	26,480,436	4,936,779	1,569,296	33.0	-0.6
2043	26,636,941	4,962,838	1,552,513	33.2	-0.9
2044	26,792,200	4,988,465	1,624,621	33.4	-0.9
2045	26,946,238	5,013,672	1,678,791	33.6	-0.8
2046	27,099,078	5,038,470	1,730,987	33.9	-0.4
2047	27,250,744	5,062,871	1,676,606	34.0	-0.5
2048	27,401,260	5,086,885	1,635,014	34.1	-0.6
2049	27,550,647	5,110,524	1,632,072	34.3	-0.9
2050	27,698,928	5,133,796	1,703,588	34.5	-0.8
2051	27,846,124	5,156,713	1,742,075	34.7	-0.8
2052	27,992,257	5,179,284	1,790,040	35.0	-0.5
2053	28,137,347	5,201,519	1,751,054	35.1	-0.5
2054	28,281,416	5,223,426	1,714,016	35.2	-0.5
2055	28,424,483	5,245,015	1,698,114	35.4	-0.8
2056	28,566,567	5,266,294	1,764,746	35.6	-0.8
2057	28,707,688	5,287,271	1,814,969	35.8	-0.8
2058	28,847,865	5,307,956	1,863,829	36.0	-0.4
2059	28,987,117	5,328,356	1,813,605	36.1	-0.4
2060	29,125,461	5,348,479	1,776,109	36.3	-0.6
2061	29,262,915	5,368,332	1,773,468	36.4	-0.8
2062	29,399,497	5,387,923	1,840,281	36.6	-0.7
2063	29,535,224	5,407,259	1,876,305	36.8	-0.7
2064	29,670,113	5,426,347	1,921,643	37.0	-0.4
2065	29,804,180	5,445,194	1,885,665	37.1	-0.4
2066	29,937,441	5,463,806	1,852,050	37.3	-0.5
2067	30,069,912	5,482,189	1,837,177	37.4	-0.8
2068	30,201,608	5,500,351	1,899,915	37.6	-0.7
2069	30,332,545	5,518,297	1,947,338	37.8	-0.7
2070	30,462,738	5,536,032	1,993,785	38.0	-0.4
2071	30,592,200	5,553,563	1,946,871	38.1	-0.4
2072	30,720,948	5,570,896	1,912,504	38.2	-0.5
2073	30,848,993	5,588,035	1,910,210	38.3	-0.8
2074	30,976,351	5,604,987	1,973,491	38.6	-0.7
2075	31,103,035	5,621,755	2,007,706	38.7	-0.7
2076	31,229,058	5,638,346	2,051,058	38.9	-0.4
2077	31,354,433	5,654,763	2,017,462	39.0	-0.4
2078	31,479,172	5,671,013	1,986,481	39.1	-0.5
2079	31,603,288	5,687,098	1,972,505	39.3	-0.7
2080	31,726,794	5,703,025	2,032,251	39.5	-0.7
2081	31,849,701	5,718,796	2,077,528	39.6	-0.7
2082	31,972,021	5,734,417	2,122,105	39.8	-0.3
2083	32,093,765	5,749,892	2,077,848	39.9	-0.4
2084	32,214,946	5,765,224	2,045,929	40.0	-0.5
2085	32,335,573	5,780,418	2,043,962	40.2	-0.7
2086	32,455,658	5,795,476	2,104,480	40.4	-0.6

2087	32,575,211	5,810,404	2,137,301	40.5	-0.6
2088	32,694,243	5,825,204	2,179,089	40.7	-0.4
2089	32,812,765	5,839,880	2,147,419	40.8	-0.4
2090	32,930,785	5,854,435	2,118,527	40.9	-0.4
2091	33,048,314	5,868,874	2,105,326	41.0	-0.7
2092	33,165,361	5,883,197	2,162,697	41.2	-0.6
2093	33,281,937	5,897,410	2,206,272	41.4	-0.6
2094	33,398,049	5,911,515	2,249,296	41.6	-0.3
2095	33,513,708	5,925,515	2,207,235	41.6	-0.4
2096	33,628,922	5,939,413	2,177,296	41.7	-0.5
2097	33,743,700	5,953,211	2,175,055	41.9	-0.7
2098	33,858,051	5,966,913	2,232,799	42.1	-0.6
2099	33,971,982	5,980,521	2,264,257	42.2	-0.6
2100	34,085,502	5,994,037	2,305,145	42.4	

Table A.12 Scenario 0 results: Carbon Stock and CO_2 Contribution 1990-2100

Year	Scenario 0 Carbon Stock (Mg C)			Total Carbon Stock (MT)	CO_2 Stock Change (MT)
	Sawnwood	Wood Based Panels	Paper and paperboard		
1990	23,538,445	4,811,027	1,690,678	30.0	-4.5
1991	24,041,036	4,972,031	2,249,605	31.3	-3.9
1992	24,507,037	5,110,701	2,701,193	32.3	-3.4
1993	24,987,277	5,244,215	3,013,574	33.2	-3.3
1994	25,454,632	5,363,024	3,324,892	34.1	-2.6
1995	25,869,246	5,477,977	3,503,234	34.9	-2.2
1996	26,216,817	5,581,433	3,640,827	35.4	-2.3
1997	26,635,145	5,691,896	3,751,760	36.1	-2.2
1998	27,054,619	5,795,724	3,823,613	36.7	-1.9
1999	27,443,896	5,900,158	3,839,977	37.2	-1.6
2000	27,818,952	5,996,532	3,811,772	37.6	-1.7
2001	28,172,683	6,094,031	3,831,686	38.1	-2.0
2002	28,548,139	6,197,386	3,894,324	38.6	-1.8
2003	28,919,914	6,290,829	3,924,602	39.1	-1.7
2004	29,274,201	6,378,566	3,958,483	39.6	-2.0
2005	29,636,621	6,490,947	4,024,712	40.2	-2.0
2006	30,018,525	6,603,259	4,064,039	40.7	-2.0
2007	30,421,776	6,725,942	4,074,848	41.2	-1.8
2008	30,829,362	6,842,095	4,035,387	41.7	-1.7
2009	31,236,886	6,948,373	3,996,064	42.2	-1.3
2010	31,601,497	7,059,741	3,882,432	42.5	-1.6
2011	32,015,063	7,187,728	3,777,991	43.0	-1.3
2012	32,456,112	7,303,448	3,582,305	43.3	-1.5
2013	32,919,513	7,414,425	3,422,698	43.8	-1.5
2014	33,377,099	7,501,365	3,285,991	44.2	-2.0
2015	33,892,656	7,603,670	3,215,508	44.7	-2.1
2016	34,419,533	7,706,500	3,151,507	45.3	-2.3
2017	34,965,189	7,803,558	3,138,683	45.9	-2.4
2018	35,530,069	7,898,942	3,129,515	46.6	-2.5
2019	36,104,683	7,994,247	3,133,905	47.2	-2.5
2020	36,678,898	8,077,555	3,160,716	47.9	-2.3
2021	37,259,399	8,165,475	3,123,723	48.5	-2.4
2022	37,868,525	8,259,641	3,067,484	49.2	-2.7
2023	38,447,701	8,364,090	3,125,520	49.9	-2.6
2024	39,015,248	8,461,287	3,165,520	50.6	-2.9
2025	39,615,259	8,562,151	3,248,579	51.4	-3.3
2026	40,237,517	8,664,442	3,421,786	52.3	-2.9
2027	40,831,388	8,756,191	3,540,264	53.1	-2.8
2028	41,409,057	8,840,786	3,653,408	53.9	-2.6
2029	42,017,882	8,930,193	3,656,379	54.6	-2.5
2030	42,625,940	9,017,166	3,637,364	55.3	-2.5
2031	43,220,001	9,099,027	3,633,012	56.0	-2.7
2032	43,792,550	9,174,489	3,724,542	56.7	-2.7
2033	44,372,462	9,251,055	3,811,200	57.4	-2.7
2034	44,941,073	9,324,706	3,896,853	58.2	-2.2
2035	45,497,599	9,395,713	3,856,259	58.7	-2.1
2036	46,041,393	9,464,335	3,811,441	59.3	-2.2

2037	46,571,955	9,530,819	3,805,775	59.9	-2.4
2038	47,088,939	9,595,393	3,889,525	60.6	-2.3
2039	47,592,154	9,658,266	3,947,299	61.2	-2.3
2040	48,081,556	9,719,621	4,017,377	61.8	-1.9
2041	48,557,239	9,779,618	3,987,592	62.3	-1.8
2042	49,019,418	9,838,386	3,946,358	62.8	-1.8
2043	49,468,407	9,896,024	3,924,633	63.3	-2.1
2044	49,904,603	9,952,598	3,998,830	63.9	-2.0
2045	50,328,456	10,008,143	4,066,854	64.4	-2.0
2046	50,740,449	10,062,660	4,137,614	64.9	-1.5
2047	51,141,076	10,116,122	4,095,504	65.4	-1.5
2048	51,530,823	10,168,475	4,052,691	65.8	-1.6
2049	51,910,147	10,219,644	4,045,275	66.2	-1.8
2050	52,279,465	10,269,537	4,120,621	66.7	-1.7
2051	52,639,146	10,318,050	4,172,732	67.1	-1.7
2052	52,989,500	10,365,078	4,237,260	67.6	-1.3
2053	53,330,778	10,410,513	4,210,281	68.0	-1.2
2054	53,663,174	10,454,259	4,173,893	68.3	-1.3
2055	53,986,825	10,496,228	4,154,093	68.6	-1.6
2056	54,301,822	10,536,351	4,223,224	69.1	-1.5
2057	54,608,216	10,574,577	4,286,801	69.5	-1.5
2058	54,906,025	10,610,875	4,353,401	69.9	-1.0
2059	55,195,248	10,645,238	4,315,116	70.2	-1.0
2060	55,475,873	10,677,679	4,277,104	70.4	-1.1
2061	55,747,883	10,708,232	4,270,969	70.7	-1.3
2062	56,011,273	10,736,950	4,341,938	71.1	-1.2
2063	56,266,048	10,763,903	4,391,197	71.4	-1.2
2064	56,512,238	10,789,174	4,452,520	71.8	-0.9
2065	56,749,895	10,812,858	4,428,311	72.0	-0.8
2066	56,979,103	10,835,058	4,395,913	72.2	-0.8
2067	57,199,976	10,855,882	4,378,016	72.4	-1.1
2068	57,412,660	10,875,442	4,443,647	72.7	-1.0
2069	57,617,336	10,893,850	4,504,123	73.0	-1.0
2070	57,814,213	10,911,215	4,567,756	73.3	-0.6
2071	58,003,532	10,927,645	4,532,594	73.5	-0.6
2072	58,185,556	10,943,240	4,498,309	73.6	-0.7
2073	58,360,576	10,958,097	4,493,322	73.8	-0.9
2074	58,528,901	10,972,305	4,561,069	74.1	-0.8
2075	58,690,856	10,985,947	4,608,281	74.3	-0.8
2076	58,846,778	10,999,097	4,667,234	74.5	-0.5
2077	58,997,014	11,011,824	4,645,283	74.7	-0.5
2078	59,141,915	11,024,187	4,616,015	74.8	-0.5
2079	59,281,833	11,036,241	4,599,747	74.9	-0.8
2080	59,417,118	11,048,033	4,662,753	75.1	-0.7
2081	59,548,117	11,059,604	4,720,904	75.3	-0.7
2082	59,675,167	11,070,989	4,782,291	75.5	-0.4
2083	59,798,595	11,082,220	4,749,699	75.6	-0.4
2084	59,918,716	11,093,322	4,718,388	75.7	-0.5
2085	60,035,833	11,104,319	4,714,410	75.9	-0.7
2086	60,150,230	11,115,228	4,779,689	76.0	-0.6
2087	60,262,178	11,126,066	4,825,374	76.2	-0.7
2088	60,371,929	11,136,846	4,882,511	76.4	-0.4
2089	60,479,718	11,147,580	4,862,441	76.5	-0.3
2090	60,585,763	11,158,275	4,835,705	76.6	-0.4
2091	60,690,264	11,168,939	4,820,841	76.7	-0.6
2092	60,793,403	11,179,579	4,881,815	76.9	-0.6
2093	60,895,347	11,190,200	4,938,173	77.0	-0.6
2094	60,996,246	11,200,804	4,997,748	77.2	-0.3
2095	61,096,236	11,211,397	4,967,322	77.3	-0.3
2096	61,195,437	11,221,980	4,938,460	77.4	-0.4
2097	61,293,956	11,232,555	4,934,758	77.5	-0.6
2098	61,391,890	11,243,124	4,997,421	77.6	-0.6
2099	61,489,322	11,253,689	5,041,532	77.8	-0.6
2100	61,586,325	11,264,250	5,097,534	77.9	

Table A.13 Scenario 1 results: Carbon Stock and CO_2 Contribution 1990-2100

Year	Scenario 1 Carbon Stock (Mg C)			Total Carbon Stock (MT)	CO_2 Stock Change (MT)
	Sawnwood	Wood Based Panels	Paper and paperboard		
1990	23,538,445	4,811,027	1,733,474	30.1	-4.5
1991	24,041,036	4,972,031	2,292,401	31.3	-3.9
1992	24,507,037	5,110,701	2,750,035	32.4	-3.5
1993	24,987,277	5,244,215	3,078,880	33.3	-3.3
1994	25,454,632	5,363,024	3,404,849	34.2	-2.7
1995	25,869,246	5,477,977	3,610,309	35.0	-2.2
1996	26,216,817	5,581,433	3,747,869	35.5	-2.4
1997	26,635,145	5,691,896	3,865,290	36.2	-2.2
1998	27,054,619	5,795,724	3,945,533	36.8	-2.0
1999	27,443,896	5,900,158	3,995,518	37.3	-1.9
2000	27,818,952	5,996,532	4,047,059	37.9	-1.8
2001	28,172,683	6,094,031	4,097,206	38.4	-2.1
2002	28,548,139	6,197,386	4,189,813	38.9	-2.0
2003	28,919,914	6,290,829	4,262,876	39.5	-1.9
2004	29,274,201	6,378,566	4,337,516	40.0	-2.1
2005	29,636,621	6,490,947	4,446,494	40.6	-2.2
2006	30,018,525	6,603,259	4,542,946	41.2	-2.3
2007	30,421,776	6,725,942	4,644,691	41.8	-2.2
2008	30,829,362	6,842,095	4,731,532	42.4	-2.3
2009	31,236,886	6,948,373	4,844,601	43.0	-2.0
2010	31,601,497	7,059,741	4,927,640	43.6	-2.4
2011	32,015,063	7,187,728	5,051,043	44.3	-2.3
2012	32,456,112	7,303,448	5,124,935	44.9	-2.4
2013	32,919,513	7,414,431	5,197,647	45.5	-2.4
2014	33,377,100	7,501,395	5,301,861	46.2	-2.9
2015	33,892,660	7,603,763	5,461,239	47.0	-3.0
2016	34,419,546	7,706,741	5,656,327	47.8	-3.1
2017	34,965,222	7,804,044	5,867,602	48.6	-3.2
2018	35,530,135	7,899,733	6,088,247	49.5	-3.3
2019	36,104,813	7,995,509	6,326,325	50.4	-3.3
2020	36,679,128	8,079,403	6,580,914	51.3	-3.3
2021	37,259,911	8,168,677	6,814,241	52.2	-3.5
2022	37,870,167	8,267,276	7,065,330	53.2	-4.0
2023	38,451,099	8,377,427	7,466,989	54.3	-3.8
2024	39,021,324	8,482,155	7,832,711	55.3	-4.1
2025	39,624,937	8,591,680	8,224,932	56.4	-4.2
2026	40,251,943	8,703,840	8,644,188	57.6	-3.9
2027	40,851,959	8,806,738	9,016,056	58.7	-3.8
2028	41,437,442	8,903,835	9,363,729	59.7	-4.0
2029	42,056,041	9,007,171	9,721,947	60.8	-3.9
2030	42,676,133	9,109,564	10,076,207	61.9	-3.9
2031	43,284,800	9,208,402	10,425,157	62.9	-3.8
2032	43,874,830	9,302,460	10,784,948	64.0	-4.0
2033	44,475,398	9,399,297	11,173,889	65.0	-4.0
2034	45,068,120	9,494,944	11,570,716	66.1	-3.8
2035	45,652,471	9,589,714	11,935,179	67.2	-3.8
2036	46,228,032	9,683,903	12,295,915	68.2	-3.8
2037	46,794,499	9,777,781	12,675,917	69.2	-3.9
2038	47,351,686	9,871,593	13,093,442	70.3	-3.9
2039	47,899,525	9,965,557	13,516,457	71.4	-3.9
2040	48,438,057	10,059,855	13,948,330	72.4	-3.8
2041	48,967,425	10,154,638	14,357,151	73.5	-3.8
2042	49,487,860	10,250,023	14,768,446	74.5	-3.8
2043	49,999,664	10,346,092	15,193,969	75.5	-3.9
2044	50,503,197	10,442,891	15,655,886	76.6	-3.9
2045	50,998,854	10,540,438	16,131,329	77.7	-3.9
2046	51,487,053	10,638,716	16,619,867	78.7	-3.8
2047	51,968,214	10,737,686	17,078,095	79.8	-3.8
2048	52,442,749	10,837,287	17,535,799	80.8	-3.8
2049	52,911,046	10,937,441	18,014,899	81.9	-4.0
2050	53,373,462	11,038,058	18,534,303	82.9	-4.0
2051	53,830,313	11,139,047	19,060,400	84.0	-4.0
2052	54,281,874	11,240,316	19,596,503	85.1	-3.9

2053	54,728,376	11,341,779	20,108,556	86.2	-3.9
2054	55,170,007	11,443,363	20,623,343	87.2	-3.9
2055	55,606,913	11,545,007	21,152,953	88.3	-4.0
2056	56,039,210	11,646,669	21,720,151	89.4	-4.1
2057	56,466,980	11,748,327	22,300,574	90.5	-4.1
2058	56,890,286	11,849,976	22,894,332	91.6	-4.0
2059	57,309,178	11,951,632	23,457,223	92.7	-4.0
2060	57,723,694	12,053,330	24,019,850	93.8	-4.0
2061	58,133,874	12,155,119	24,603,794	94.9	-4.2
2062	58,539,763	12,257,064	25,228,841	96.0	-4.2
2063	58,941,413	12,359,240	25,860,837	97.2	-4.2
2064	59,338,895	12,461,733	26,503,296	98.3	-4.1
2065	59,732,293	12,564,632	27,120,839	99.4	-4.1
2066	60,121,713	12,668,030	27,741,206	100.5	-4.1
2067	60,507,279	12,772,022	28,376,793	101.7	-4.3
2068	60,889,140	12,876,698	29,050,843	102.8	-4.3
2069	61,267,462	12,982,146	29,737,909	104.0	-4.3
2070	61,642,431	13,088,450	30,438,500	105.2	-4.2
2071	62,014,253	13,195,685	31,107,809	106.3	-4.2
2072	62,383,149	13,303,920	31,777,009	107.5	-4.3
2073	62,749,351	13,413,215	32,467,381	108.6	-4.4
2074	63,113,105	13,523,624	33,199,341	109.8	-4.4
2075	63,474,664	13,635,189	33,938,299	111.0	-4.5
2076	63,834,289	13,747,948	34,687,895	112.3	-4.4
2077	64,192,240	13,861,928	35,411,707	113.5	-4.4
2078	64,548,781	13,977,152	36,138,186	114.7	-4.5
2079	64,904,175	14,093,635	36,879,948	115.9	-4.6
2080	65,258,678	14,211,386	37,660,596	117.1	-4.6
2081	65,612,542	14,330,409	38,453,839	118.4	-4.7
2082	65,966,013	14,450,706	39,260,501	119.7	-4.6
2083	66,319,326	14,572,272	40,035,315	120.9	-4.6
2084	66,672,708	14,695,102	40,809,909	122.2	-4.7
2085	67,026,371	14,819,186	41,605,335	123.5	-4.8
2086	67,380,521	14,944,517	42,442,526	124.8	-4.9
2087	67,735,346	15,071,081	43,286,574	126.1	-4.9
2088	68,091,026	15,198,868	44,141,243	127.4	-4.8
2089	68,447,725	15,327,866	44,969,305	128.7	-4.8
2090	68,805,597	15,458,063	45,799,799	130.1	-4.9
2091	69,164,782	15,589,446	46,645,541	131.4	-5.1
2092	69,525,408	15,722,006	47,530,444	132.8	-5.1
2093	69,887,593	15,855,731	48,427,566	134.2	-5.2
2094	70,251,442	15,990,612	49,337,784	135.6	-5.1
2095	70,617,051	16,126,641	50,215,937	137.0	-5.1
2096	70,984,508	16,263,810	51,093,804	138.3	-5.1
2097	71,353,888	16,402,112	51,990,038	139.7	-5.3
2098	71,725,262	16,541,541	52,927,755	141.2	-5.4
2099	72,098,690	16,682,092	53,872,914	142.7	-5.4
2100	72,474,228	16,823,762	54,830,948	144.1	

Table A.14 Scenario 2 results: Carbon Stock and CO_2 Contribution 1990-2100

Year	Scenario 2 Carbon Stock (Mg C)			Total Carbon Stock (MT)	CO_2 Stock Change (MT)
	Sawnwood	Wood Based Panels	Paper and paperboard		
1990	23,538,445	4,811,027	1,733,474	30.1	-4.5
1991	24,041,036	4,972,031	2,292,401	31.3	-3.9
1992	24,507,037	5,110,701	2,750,035	32.4	-3.5
1993	24,987,277	5,244,215	3,078,880	33.3	-3.3
1994	25,454,632	5,363,024	3,404,849	34.2	-2.7
1995	25,869,246	5,477,977	3,610,309	35.0	-2.2
1996	26,216,817	5,581,433	3,747,869	35.5	-2.4
1997	26,635,145	5,691,896	3,865,290	36.2	-2.2
1998	27,054,619	5,795,724	3,945,533	36.8	-2.0
1999	27,443,896	5,900,158	3,995,518	37.3	-1.9
2000	27,818,952	5,996,532	4,047,059	37.9	-1.8
2001	28,172,683	6,094,031	4,097,206	38.4	-2.1
2002	28,548,139	6,197,386	4,189,813	38.9	-2.0

2003	28,919,914	6,290,829	4,262,876	39.5	-1.9
2004	29,274,201	6,378,566	4,337,516	40.0	-2.1
2005	29,636,621	6,490,947	4,446,494	40.6	-2.2
2006	30,018,525	6,603,259	4,542,946	41.2	-2.3
2007	30,421,776	6,725,942	4,644,691	41.8	-2.2
2008	30,829,362	6,842,095	4,731,532	42.4	-2.3
2009	31,236,886	6,948,373	4,844,601	43.0	-2.0
2010	31,601,497	7,059,741	4,927,640	43.6	-2.4
2011	32,015,063	7,187,728	5,051,043	44.3	-2.3
2012	32,456,112	7,303,448	5,124,935	44.9	-2.4
2013	32,919,513	7,414,431	5,197,647	45.5	-2.4
2014	33,377,100	7,501,395	5,301,861	46.2	-2.9
2015	33,892,660	7,603,763	5,461,239	47.0	-3.0
2016	34,419,546	7,706,741	5,656,327	47.8	-3.1
2017	34,965,222	7,804,044	5,867,602	48.6	-3.2
2018	35,530,135	7,899,733	6,088,247	49.5	-3.3
2019	36,104,813	7,995,509	6,326,325	50.4	-3.3
2020	36,679,128	8,079,403	6,580,914	51.3	-3.3
2021	37,259,911	8,168,677	6,814,241	52.2	-3.5
2022	37,870,167	8,267,276	7,065,330	53.2	-4.0
2023	38,451,099	8,377,427	7,467,432	54.3	-3.8
2024	39,021,324	8,482,155	7,834,136	55.3	-4.1
2025	39,624,965	8,591,807	8,228,119	56.4	-4.3
2026	40,252,045	8,704,257	8,650,375	57.6	-4.0
2027	40,852,207	8,807,650	9,026,410	58.7	-3.8
2028	41,437,935	8,905,493	9,379,591	59.7	-4.0
2029	42,056,917	9,009,871	9,743,918	60.8	-4.0
2030	42,677,577	9,113,658	10,105,488	61.9	-3.9
2031	43,287,046	9,214,297	10,463,356	63.0	-3.9
2032	43,878,175	9,310,624	10,834,558	64.0	-4.0
2033	44,480,203	9,410,260	11,236,533	65.1	-4.1
2034	45,074,818	9,509,299	11,648,285	66.2	-3.9
2035	45,661,572	9,608,124	12,027,779	67.3	-3.9
2036	46,240,126	9,707,095	12,404,941	68.4	-3.9
2037	46,810,258	9,806,553	12,803,465	69.4	-4.0
2038	47,371,864	9,906,809	13,243,072	70.5	-4.0
2039	47,924,959	10,008,145	13,690,093	71.6	-4.1
2040	48,469,663	10,110,809	14,148,254	72.7	-3.9
2041	49,006,197	10,215,014	14,582,896	73.8	-3.9
2042	49,534,865	10,320,935	15,021,586	74.9	-4.0
2043	50,056,040	10,428,712	15,477,083	76.0	-4.1
2044	50,570,147	10,538,448	15,973,555	77.1	-4.1
2045	51,077,644	10,650,213	16,485,780	78.2	-4.2
2046	51,579,007	10,764,046	17,013,833	79.4	-4.1
2047	52,074,713	10,879,961	17,510,601	80.5	-4.1
2048	52,565,226	10,997,950	18,008,619	81.6	-4.1
2049	53,050,988	11,117,992	18,531,126	82.7	-4.3
2050	53,532,409	11,240,058	19,099,617	83.9	-4.3
2051	54,009,860	11,364,115	19,677,390	85.1	-4.4
2052	54,483,672	11,490,135	20,268,354	86.2	-4.3
2053	54,954,134	11,618,101	20,833,799	87.4	-4.3
2054	55,421,495	11,748,007	21,404,015	88.6	-4.3
2055	55,885,969	11,879,867	21,992,707	89.8	-4.5
2056	56,347,738	12,013,713	22,625,755	91.0	-4.6
2057	56,806,958	12,149,598	23,274,976	92.2	-4.6
2058	57,263,767	12,287,596	23,941,231	93.5	-4.5
2059	57,718,293	12,427,800	24,574,672	94.7	-4.5
2060	58,170,656	12,570,321	25,210,107	96.0	-4.6
2061	58,620,978	12,715,286	25,871,053	97.2	-4.8
2062	59,069,384	12,862,833	26,581,010	98.5	-4.8
2063	59,516,011	13,013,110	27,301,240	99.8	-4.9
2064	59,961,010	13,166,270	28,036,079	101.2	-4.8
2065	60,404,545	13,322,469	28,743,534	102.5	-4.8
2066	60,846,798	13,481,861	29,456,329	103.8	-4.9
2067	61,287,971	13,644,598	30,189,091	105.1	-5.1
2068	61,728,278	13,810,826	30,969,293	106.5	-5.2
2069	62,167,955	13,980,682	31,766,164	107.9	-5.2
2070	62,607,249	14,154,295	32,581,205	109.3	-5.1

2071	63,046,422	14,331,781	33,361,979	110.7	-5.1
2072	63,485,746	14,513,249	34,145,340	112.1	-5.3
2073	63,925,504	14,698,792	34,955,130	113.6	-5.5
2074	64,365,982	14,888,494	35,816,619	115.1	-5.5
2075	64,807,472	15,082,426	36,689,115	116.6	-5.6
2076	65,250,267	15,280,651	37,577,310	118.1	-5.5
2077	65,694,659	15,483,220	38,436,177	119.6	-5.6
2078	66,140,936	15,690,174	39,300,659	121.1	-5.7
2079	66,589,383	15,901,548	40,186,229	122.7	-5.9
2080	67,040,277	16,117,369	41,121,854	124.3	-6.0
2081	67,493,886	16,337,656	42,074,402	125.9	-6.1
2082	67,950,471	16,562,427	43,045,936	127.6	-6.0
2083	68,410,281	16,791,691	43,981,559	129.2	-6.0
2084	68,873,553	17,025,459	44,920,079	130.8	-6.1
2085	69,340,514	17,263,736	45,885,746	132.5	-6.4
2086	69,811,378	17,506,527	46,905,507	134.2	-6.4
2087	70,286,347	17,753,836	47,936,820	136.0	-6.5
2088	70,765,611	18,005,668	48,984,735	137.8	-6.4
2089	71,249,347	18,262,029	50,001,417	139.5	-6.5
2090	71,737,721	18,522,923	51,023,919	141.3	-6.6
2091	72,230,888	18,788,358	52,068,547	143.1	-6.8
2092	72,728,993	19,058,345	53,165,730	145.0	-6.9
2093	73,232,170	19,332,893	54,280,147	146.8	-7.0
2094	73,740,544	19,612,016	55,414,167	148.8	-6.9
2095	74,254,232	19,895,731	56,510,977	150.7	-7.0
2096	74,773,342	20,184,054	57,611,054	152.6	-7.1
2097	75,297,976	20,477,006	58,736,855	154.5	-7.4
2098	75,828,228	20,774,609	59,918,637	156.5	-7.5
2099	76,364,188	21,076,889	61,113,176	158.6	-7.6
2100	76,905,940	21,383,871	62,327,471	160.6	

Table A.15 Scenario 3 results: Carbon Stock and CO_2 Contribution 1990-2100

Year	Scenario 3 Carbon Stock (Mg C)			Total Carbon Stock (MT)	CO_2 Stock Change (MT)
	Sawnwood	Wood Based Panels	Paper and paperboard		
1990	23,538,445	4,811,027	1,733,474	30.1	-4.5
1991	24,041,036	4,972,031	2,292,401	31.3	-3.9
1992	24,507,037	5,110,701	2,750,035	32.4	-3.5
1993	24,987,277	5,244,215	3,078,880	33.3	-3.3
1994	25,454,632	5,363,024	3,404,849	34.2	-2.7
1995	25,869,246	5,477,977	3,610,309	35.0	-2.2
1996	26,216,817	5,581,433	3,747,869	35.5	-2.4
1997	26,635,145	5,691,896	3,865,290	36.2	-2.2
1998	27,054,619	5,795,724	3,945,533	36.8	-2.0
1999	27,443,896	5,900,158	3,995,518	37.3	-1.9
2000	27,818,952	5,996,532	4,047,059	37.9	-1.8
2001	28,172,683	6,094,031	4,097,206	38.4	-2.1
2002	28,548,139	6,197,386	4,189,813	38.9	-2.0
2003	28,919,914	6,290,829	4,262,876	39.5	-1.9
2004	29,274,201	6,378,566	4,337,516	40.0	-2.1
2005	29,636,621	6,490,947	4,446,494	40.6	-2.2
2006	30,018,525	6,603,259	4,542,946	41.2	-2.3
2007	30,421,776	6,725,942	4,644,691	41.8	-2.2
2008	30,829,362	6,842,095	4,731,532	42.4	-2.3
2009	31,236,886	6,948,373	4,844,601	43.0	-2.0
2010	31,601,497	7,059,741	4,927,640	43.6	-2.4
2011	32,015,063	7,187,728	5,051,043	44.3	-2.3
2012	32,456,112	7,303,448	5,124,935	44.9	-2.4
2013	32,919,513	7,414,431	5,197,647	45.5	-2.4
2014	33,377,100	7,501,395	5,301,861	46.2	-2.9
2015	33,892,660	7,603,763	5,461,239	47.0	-3.0
2016	34,419,546	7,706,741	5,656,327	47.8	-3.1
2017	34,965,222	7,804,044	5,867,602	48.6	-3.2
2018	35,530,135	7,899,733	6,088,247	49.5	-3.3
2019	36,104,813	7,995,509	6,326,325	50.4	-3.3
2020	36,679,128	8,079,403	6,580,914	51.3	-3.3

2021	37,259,911	8,168,677	6,814,241	52.2	-3.5
2022	37,870,167	8,267,276	7,065,330	53.2	-4.6
2023	38,451,120	8,377,493	7,627,452	54.5	-4.5
2024	39,021,405	8,482,393	8,174,059	55.7	-4.8
2025	39,625,140	8,592,211	8,763,887	57.0	-5.0
2026	40,252,358	8,704,812	9,380,991	58.3	-4.7
2027	40,852,715	8,808,327	9,968,890	59.6	-4.6
2028	41,438,711	8,906,246	10,543,163	60.9	-5.0
2029	42,058,051	9,010,638	11,171,490	62.2	-5.0
2030	42,679,177	9,114,356	11,813,379	63.6	-5.0
2031	43,289,241	9,214,817	12,454,246	65.0	-4.8
2032	43,881,112	9,310,833	13,085,590	66.3	-5.0
2033	44,484,049	9,409,995	13,753,524	67.6	-5.0
2034	45,079,759	9,508,368	14,431,505	69.0	-5.0
2035	45,667,809	9,606,298	15,118,512	70.4	-5.0
2036	46,247,877	9,704,113	15,812,809	71.8	-5.1
2037	46,819,750	9,802,117	16,524,357	73.1	-5.1
2038	47,383,337	9,900,583	17,247,625	74.5	-5.1
2039	47,938,653	9,999,756	17,981,371	75.9	-5.1
2040	48,485,824	10,099,847	18,723,660	77.3	-5.1
2041	49,025,067	10,201,029	19,483,926	78.7	-5.2
2042	49,556,681	10,303,441	20,256,653	80.1	-5.2
2043	50,081,032	10,407,186	21,040,502	81.5	-5.2
2044	50,598,533	10,512,329	21,833,483	82.9	-5.2
2045	51,109,628	10,618,906	22,644,671	84.4	-5.3
2046	51,614,777	10,726,918	23,468,673	85.8	-5.3
2047	52,114,440	10,836,343	24,304,151	87.3	-5.3
2048	52,609,063	10,947,138	25,149,137	88.7	-5.4
2049	53,099,068	11,059,242	26,012,443	90.2	-5.4
2050	53,584,844	11,172,588	26,888,834	91.6	-5.4
2051	54,066,742	11,287,103	27,777,012	93.1	-5.5
2052	54,545,071	11,402,718	28,675,057	94.6	-5.5
2053	55,020,098	11,519,370	29,591,569	96.1	-5.6
2054	55,492,053	11,637,010	30,521,473	97.7	-5.6
2055	55,961,125	11,755,602	31,463,517	99.2	-5.6
2056	56,427,475	11,875,130	32,415,836	100.7	-5.7
2057	56,891,235	11,995,596	33,386,837	102.3	-5.7
2058	57,352,521	12,117,022	34,371,589	103.8	-5.8
2059	57,811,433	12,239,448	35,368,882	105.4	-5.8
2060	58,268,067	12,362,932	36,376,888	107.0	-5.9
2061	58,722,517	12,487,545	37,403,833	108.6	-5.9
2062	59,174,881	12,613,373	38,444,906	110.2	-6.0
2063	59,625,267	12,740,509	39,498,923	111.9	-6.0
2064	60,073,792	12,869,055	40,564,082	113.5	-6.1
2065	60,520,591	12,999,116	41,648,428	115.2	-6.1
2066	60,965,811	13,130,795	42,747,253	116.8	-6.2
2067	61,409,618	13,264,196	43,859,386	118.5	-6.2
2068	61,852,194	13,399,419	44,983,043	120.2	-6.3
2069	62,293,736	13,536,557	46,126,097	122.0	-6.4
2070	62,734,455	13,675,696	47,283,929	123.7	-6.4
2071	63,174,575	13,816,913	48,455,379	125.4	-6.5
2072	63,614,330	13,960,276	49,638,674	127.2	-6.6
2073	64,053,964	14,105,845	50,841,529	129.0	-6.6
2074	64,493,725	14,253,668	52,059,410	130.8	-6.7
2075	64,933,867	14,403,785	53,291,167	132.6	-6.7
2076	65,374,644	14,556,226	54,535,043	134.5	-6.8
2077	65,816,311	14,711,015	55,798,607	136.3	-6.9
2078	66,259,118	14,868,166	57,077,409	138.2	-7.0
2079	66,703,313	15,027,686	58,370,313	140.1	-7.0
2080	67,149,137	15,189,576	59,675,579	142.0	-7.1
2081	67,596,821	15,353,834	61,000,649	144.0	-7.2
2082	68,046,591	15,520,452	62,341,152	145.9	-7.2
2083	68,498,661	15,689,417	63,695,974	147.9	-7.3
2084	68,953,235	15,860,716	65,063,392	149.9	-7.4
2085	69,410,504	16,034,333	66,450,736	151.9	-7.5
2086	69,870,651	16,210,250	67,853,714	153.9	-7.5
2087	70,333,843	16,388,449	69,271,232	156.0	-7.6
2088	70,800,239	16,568,912	70,701,592	158.1	-7.7

2089	71,269,984	16,751,621	72,152,018	160.2	-7.8
2090	71,743,213	16,936,559	73,618,297	162.3	-7.9
2091	72,220,048	17,123,708	75,099,358	164.4	-7.9
2092	72,700,604	17,313,054	76,593,523	166.6	-8.0
2093	73,184,983	17,504,583	78,107,923	168.8	-8.1
2094	73,673,280	17,698,281	79,638,188	171.0	-8.2
2095	74,165,579	17,894,138	81,183,719	173.2	-8.3
2096	74,661,958	18,092,143	82,742,640	175.5	-8.4
2097	75,162,488	18,292,290	84,319,654	177.8	-8.4
2098	75,667,232	18,494,570	85,912,358	180.1	-8.5
2099	76,176,247	18,698,979	87,520,813	182.4	-8.6
2100	76,689,585	18,905,513	89,145,072	184.7	

Table A.16 Scenario 4 results: Carbon Stock and CO_2 Contribution 1990-2100

Year	Scenario 4 Carbon Stock (Mg C)			Total Carbon Stock (MT)	CO_2 Stock Change (MT)
	Sawnwood	Wood Based Panels	Paper and paperboard		
1990	23,538,445	4,811,027	1,733,474	30.1	-4.5
1991	24,041,036	4,972,031	2,292,401	31.3	-3.9
1992	24,507,037	5,110,701	2,750,035	32.4	-3.5
1993	24,987,277	5,244,215	3,078,880	33.3	-3.3
1994	25,454,632	5,363,024	3,404,849	34.2	-2.7
1995	25,869,246	5,477,977	3,610,309	35.0	-2.2
1996	26,216,817	5,581,433	3,747,869	35.5	-2.4
1997	26,635,145	5,691,896	3,865,290	36.2	-2.2
1998	27,054,619	5,795,724	3,945,533	36.8	-2.0
1999	27,443,896	5,900,158	3,995,518	37.3	-1.9
2000	27,818,952	5,996,532	4,047,059	37.9	-1.8
2001	28,172,683	6,094,031	4,097,206	38.4	-2.1
2002	28,548,139	6,197,386	4,189,813	38.9	-2.0
2003	28,919,914	6,290,829	4,262,876	39.5	-1.9
2004	29,274,201	6,378,566	4,337,516	40.0	-2.1
2005	29,636,621	6,490,947	4,446,494	40.6	-2.2
2006	30,018,525	6,603,259	4,542,946	41.2	-2.3
2007	30,421,776	6,725,942	4,644,691	41.8	-2.2
2008	30,829,362	6,842,095	4,731,532	42.4	-2.3
2009	31,236,886	6,948,373	4,844,601	43.0	-2.0
2010	31,601,497	7,059,741	4,927,640	43.6	-2.4
2011	32,015,063	7,187,728	5,051,043	44.3	-2.3
2012	32,456,112	7,303,448	5,124,935	44.9	-2.4
2013	32,919,513	7,414,431	5,197,647	45.5	-2.4
2014	33,377,100	7,501,395	5,301,861	46.2	-2.9
2015	33,892,660	7,603,763	5,461,239	47.0	-3.0
2016	34,419,546	7,706,741	5,656,327	47.8	-3.1
2017	34,965,222	7,804,044	5,867,602	48.6	-3.2
2018	35,530,135	7,899,733	6,088,247	49.5	-3.3
2019	36,104,813	7,995,509	6,326,325	50.4	-3.3
2020	36,679,128	8,079,403	6,580,914	51.3	-3.3
2021	37,259,911	8,168,677	6,814,241	52.2	-3.5
2022	37,870,167	8,267,276	7,065,330	53.2	-4.6
2023	38,451,120	8,377,493	7,628,476	54.5	-4.5
2024	39,021,405	8,482,393	8,177,371	55.7	-4.8
2025	39,625,169	8,592,211	8,771,104	57.0	-5.0
2026	40,252,465	8,704,812	9,394,071	58.4	-4.8
2027	40,852,975	8,808,327	9,990,043	59.7	-4.7
2028	41,439,232	8,906,246	10,574,742	60.9	-5.0
2029	42,058,986	9,010,638	11,216,019	62.3	-5.1
2030	42,680,727	9,114,356	11,873,545	63.7	-5.0
2031	43,291,671	9,214,817	12,532,840	65.0	-4.9
2032	43,884,755	9,310,833	13,185,428	66.4	-5.1
2033	44,489,319	9,409,995	13,877,508	67.8	-5.1
2034	45,087,157	9,508,368	14,582,632	69.2	-5.2
2035	45,677,930	9,606,298	15,299,853	70.6	-5.2
2036	46,261,415	9,704,113	16,027,484	72.0	-5.2
2037	46,837,506	9,802,117	16,775,558	73.4	-5.2
2038	47,406,215	9,900,583	17,538,620	74.8	-5.3

2039	47,967,668	9,999,756	18,315,494	76.3	-5.3
2040	48,522,096	10,099,847	19,104,295	77.7	-5.4
2041	49,069,823	10,201,029	19,914,539	79.2	-5.4
2042	49,611,251	10,303,441	20,740,806	80.7	-5.4
2043	50,146,845	10,407,186	21,581,838	82.1	-5.5
2044	50,677,113	10,512,329	22,435,702	83.6	-5.5
2045	51,202,594	10,618,906	23,311,577	85.1	-5.6
2046	51,723,835	10,726,918	24,204,176	86.7	-5.6
2047	52,241,383	10,836,343	25,112,254	88.2	-5.7
2048	52,755,769	10,947,138	26,033,904	89.7	-5.7
2049	53,267,500	11,059,242	26,978,055	91.3	-5.8
2050	53,777,051	11,172,588	27,939,589	92.9	-5.9
2051	54,284,858	11,287,103	28,917,307	94.5	-5.9
2052	54,791,323	11,402,718	29,909,355	96.1	-6.0
2053	55,296,806	11,519,370	30,924,455	97.7	-6.1
2054	55,801,634	11,637,010	31,957,660	99.4	-6.1
2055	56,306,103	11,755,602	33,007,821	101.1	-6.2
2056	56,810,481	11,875,130	34,073,137	102.8	-6.3
2057	57,315,017	11,995,596	35,162,146	104.5	-6.4
2058	57,819,945	12,117,022	36,270,048	106.2	-6.4
2059	58,325,491	12,239,448	37,395,739	108.0	-6.5
2060	58,831,877	12,362,932	38,537,452	109.7	-6.6
2061	59,339,329	12,487,545	39,703,545	111.5	-6.7
2062	59,848,078	12,613,373	40,889,346	113.4	-6.8
2063	60,358,363	12,740,509	42,093,774	115.2	-6.8
2064	60,870,437	12,869,055	43,315,084	117.1	-6.9
2065	61,384,563	12,999,116	44,561,457	118.9	-7.0
2066	61,901,020	13,130,795	45,828,326	120.9	-7.1
2067	62,420,096	13,264,196	47,114,626	122.8	-7.2
2068	62,942,096	13,399,419	48,418,621	124.8	-7.3
2069	63,467,330	13,536,557	49,748,327	126.8	-7.4
2070	63,996,121	13,675,696	51,099,268	128.8	-7.5
2071	64,528,795	13,816,913	52,470,393	130.8	-7.6
2072	65,065,687	13,960,276	53,859,974	132.9	-7.7
2073	65,607,128	14,105,845	55,275,873	135.0	-7.8
2074	66,153,453	14,253,668	56,713,706	137.1	-7.9
2075	66,704,994	14,403,785	58,172,432	139.3	-8.0
2076	67,262,077	14,556,226	59,650,337	141.5	-8.1
2077	67,825,022	14,711,015	61,155,146	143.7	-8.3
2078	68,394,141	14,868,166	62,682,561	145.9	-8.4
2079	68,969,739	15,027,686	64,231,563	148.2	-8.5
2080	69,552,107	15,189,576	65,800,452	150.5	-8.6
2081	70,141,526	15,353,834	67,396,829	152.9	-8.7
2082	70,738,265	15,520,452	69,016,489	155.3	-8.9
2083	71,342,582	15,689,417	70,658,431	157.7	-9.0
2084	71,954,719	15,860,716	72,320,975	160.1	-9.1
2085	72,574,909	16,034,333	74,011,616	162.6	-9.2
2086	73,203,372	16,210,250	75,726,234	165.1	-9.4
2087	73,840,313	16,388,449	77,463,854	167.7	-9.5
2088	74,485,930	16,568,912	79,222,817	170.3	-9.6
2089	75,140,406	16,751,621	81,010,519	172.9	-9.8
2090	75,803,917	16,936,559	82,822,925	175.6	-9.9
2091	76,476,629	17,123,708	84,659,087	178.3	-10.0
2092	77,158,697	17,313,054	86,517,365	181.0	-10.2
2093	77,850,271	17,504,583	88,405,068	183.8	-10.3
2094	78,551,492	17,698,281	90,318,004	186.6	-10.4
2095	79,262,497	17,894,138	92,255,704	189.4	-10.6
2096	79,983,415	18,092,143	94,216,328	192.3	-10.7
2097	80,714,371	18,292,290	96,204,700	195.2	-10.8
2098	81,455,486	18,494,570	98,218,545	198.2	-11.0
2099	82,206,878	18,698,979	100,258,043	201.2	-11.1
2100	82,968,661	18,905,513	102,323,358	204.2	