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‘Climate benefits of material substitution by forest biomass and harvested wood products: Perspective 2030’

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Thünen Report 42

Bibliografische Information:
Die Deutsche Nationalbibliothek verzeichnet diese Publikationen in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet unter www.dnb.de abrufbar.

Bibliographic information:
The Deutsche Nationalbibliothek (German National Library) lists this publication in the German National Bibliography; detailed bibliographic data is available on the Internet at www.dnb.de

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Zitationsvorschlag – *Suggested source citation:*
Rüter S, Werner F, Forsell N, Prins C, Vial E, Levet A-L (2016) ClimWood2030, Climate benefits of material substitution by forest biomass and harvested wood products: Perspective 2030 - Final Report. Braunschweig: Johann Heinrich von Thünen-Institut, 142 p, Thünen Rep 42, DOI:10.3220/REP1468328990000

THÜNEN

Thünen Report 42

Herausgeber/Redaktionsanschrift – *Editor/address*

Johann Heinrich von Thünen-Institut
Bundesallee 50
38116 Braunschweig
Germany

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www.thuenen.de

ISSN 2196-2324
ISBN 978-3-86576-160-6
DOI:10.3220/REP1468328990000
urn:nbn:de:gbv:253-201607-dn056927-3

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Thünen Report 42

Hamburg, im April 2016

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Disclaimer

Abstract

The ClimWood2030 study, commissioned by DG CLIMA of the European Commission, quantifies the five ways in which the EU forest sector contributes to climate change mitigation: carbon sequestration and storage in EU forests, carbon storage in harvested wood products in the EU, substitution of wood products for functionally equivalent materials and substitution of wood for other sources of energy, and displacement of emissions from forests outside the EU. It also explores through scenario analysis, based on a series of interlocking models (GLOBIOM, G4M and WoodCarbonMonitor), along with detailed analysis of Forest Based Functional Units, based on life cycle assessment (LCA), the consequences for GHG balances of policy choices at present under consideration. The focus is on the EU-28, but GHG balances for other parts of the world are also considered, notably to assess consequences of EU policy choices for other regions. The five scenarios are (I) The *ClimWood2030 reference scenario*, (II) *Increase carbon stock in existing EU forests*, (III) *Cascade use – increase recovery of solid wood products*, (IV) *Cascade use – prevent first use of biomass for energy* and (V) *Strongly increase material wood use*. The study presents detailed scenario results for key parameters, the policy instruments linked to the scenarios, and main conclusions.

Keywords: forest-based sector, climate change, greenhouse gas balance, harvested wood products, substitution, scenario analysis, policy instruments

Contents

Glossary and acronyms

Biogenic carbon pools: Carbon pools of the forest based sector according to IPCC, comprising for forests the above-ground biomass, below-ground biomass, litter, dead wood, and soil organic carbon as well as the carbon pool in HWP.

Biomass: Material of biological origin (plants or animal matter, excluding material embedded in geological formations and transformed to fossil fuels or peat).

BNB: Bewertungssystem *Nachhaltiges Bauen* für Bundesgebäude des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Assessment System for Sustainable Building of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety for federal buildings

BREEAM: Building Research Establishment Environmental Assessment Methodology, published by the British Building Research Establishment (BRE)

CCS: Carbon capture and storage

CO_2: Carbon dioxide

COP: Conference of the Parties. Member countries of the United Nations Framework Convention on Climate Change (UNFCCC)

DGNB: Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Council)

Direct mitigation impacts related to the use of forest biomass: Net GHG balance (emissions minus removals) in the physical pools of forest carbon (including HWP), resulting from the growth, decay and oxidation of biomass in supply forests and along the full lifecycle of HWP.

Energy substitution: a detailed description of the energy substitution effect is provided in chapter 2.2.3.4.

EPD: Environmental product declaration

EU: European Union

FAO: Food and Agriculture Organization of the United Nations

FB, forest biomass (for the purpose of this study): Any raw or transformed woody biomass grown in forests (timber, bark, branches, stumps, wastes, wood products and industrial by-products).

FBFU: Forest-based functional unit (see definition in chapter 2.2.3.1)

FCBA: Institut technologique FCBA (Forêt Cellulose Bois-construction Ameublement)

FLEGT: Forest Law Enforcement, Governance and Trade

GHG: Greenhouse Gases, whose quantity is usually expressed in t CO_2e (stands for "Tonnes of CO_2-equivalent").

GWP: Global warming potential

HQE: Association pour la Haute Qualité Environnementale

HWP: The carbon pool in Harvested Wood Products as part of LULUCF comprises the semi-finished wood product commodities sawnwood, wood-based panels and paper and paperboard[1].

IA: Impact Assessment

IIASA: International Institute for Applied Systems Analysis

Indirect mitigation impacts related to the use of forest biomass: Net GHG balance (emissions minus removals) due to other sources and sinks of GHG being modified as a result of the use of forest biomass (such as emissions due to the harvest, transport and processing of biomass or emissions avoided through the substitution of other input materials), excluding *direct mitigation impacts related to the use of forest biomass*.

INDRW: Industrial Roundwood (FAO definition)

ISO: International Standards Organisation

KP: Kyoto Protocol

LCA: Life cycle assessment

LCI: Life cycle inventory (as part of LCA)

LEED: Leadership in Energy & Environmental Design

LULUCF: Land Use, Land Use Change and Forestry

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[1] Cf. IPCC (2014)

Material substitution: a detailed description of the material substitution effect is provided in chapter 2.2.3.3.

MS: Member State (of EU-28)

Mt: Megatons

n. a.: not available

NFPs: National Forest Programs of EU Member States

NREAPs: National Renewable Energy Action Plans of EU Member States

Potential displacement factor: (absolute and relative) measure of the efficiency with which the increased use of forest biomass in the production of a given type of functional units would reduce net GHG emissions, over the full life cycle of the functional units under consideration. E.g.: "Building a timber house instead of an equivalent, non-timber house would save X (% of) t CO_2e over the lifecycle of the houses."

Recycling rate: According to Article 3(17) of the Waste Framework Directive (2008/98/EC) recycling means 'any recovery operation by which waste materials are reprocesses into products, materials or substances whether for the original or other purposes. It includes reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels of for backfilling operations.' The recycling rate refers to the share of waste material that is used for material recovery, i.e. is not landfilled and not used for energy recovery or used for any other end-of-life treatment (except material recycling).

REDD+: Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

RoW: Rest of the world (i.e. here: outside EU-28). Forest emissions and removals for the RoW include three main sources of emissions/removals: Afforestation - the category includes emissions and removals related to afforestation and accounts for changes in biomass, soil, and dead organic matter; Deforestation - the category includes emissions and removals related to deforestation with respect to changes in biomass, soil, and dead organic matter; Forest Management - the category includes emissions and removals related to change in the above and below ground forest carbon stocks in managed forests. The change in the forest carbon stock mainly relates to changes in the thinning intensity and choice of forest rotation length. It should be kept in mind that these three mentioned categories make up for the main forest related emissions and removals but do not take into account all land use and land use change emissions and removals. Furthermore, the categories does not consider the forest carbon sink of protected forest areas as well as areas set aside from management.

SFM: Sustainable forest management

SRC: Short rotation coppices, usually used for the production of woody biomass for bioenergy

Substitution: Any use of biomass that replaces the use of non-biomass inputs to produce a similar functional unit.

SWDS: Solid waste disposal sites

UNFCCC: United Nations Framework Convention on Climate Change

Executive Summary

Background and objectives

The EU forest based sector contributes to climate change mitigation in five rather different ways:

i) carbon sequestration and storage in EU forests
ii) carbon storage in EU harvested wood products
iii) substitution of wood for other sources of energy
iv) substitution of wood products for functionally equivalent materials and
v) GHG impacts associated with EU-extra trade, increasing or decreasing the pressure on forests of E'U trade partners (i.e. EU forest footprint)

Each of these pathways has different characteristics, and there could be trade-offs between them. It has so far proved difficult to quantify their contribution to greenhouse gas (GHG) balances in a comparable way at EU level, and therefore to assess these possible trade-offs.

The ClimWood2030 study carries out this quantification, and explores, through scenario analysis, the consequences for GHG balances of policy choices at present under consideration. It aims to provide relevant information for evidence based policy making in this area.

The scenario analysis is based on a series of interlocking models (GLOBIOM, G4M and Wood-CarbonMonitor), along with detailed analysis of Forest Based Functional Units, based on life cycle assessment (LCA). It examines the impact of policy choices on GHG balances for all parts of the forest based sector[2].

The study addresses GHG balances and carbon flows associated with forests, and with the production, trade, use and disposal of wood products. The focus is on the EU-28, but GHG balances for other parts of the world are also considered, notably to assess consequences of EU policy choices for other regions. The full analysis by means of scenarios covers the period from 2000 to 2030.

It should be stressed that the scenarios must only be considered as thought experiments and not as assessing the impacts of actual or intended EU policies. They are meant to outline the magnitude of potential changes in the EU's forest based sector and to test the impact on overall GHG balances of specific policy changes and wood-related market developments. None of the scenarios – not even the reference scenario – is more likely to occur than any other. In all probability

[2] The sum of FBFU modelled to estimate indirect material substitution effects within the context of this study amount to approximately 30 % of the total EU wood market in 2010 and cover between 17% and 43% in 2030 (see chapter 2.2.3.1)

the future will consist of a mixture of the scenarios – along with some unexpected elements. Furthermore, the scenarios focus on GHG balances: the acceptability, feasibility, as well as full social, environmental and economic impacts of such policies could not be fully assessed in this study.

Scenarios

Five scenarios have been defined:

I ***ClimWood2030 reference*** scenario: based on the official EU Reference scenario, and assuming achievement of official EU energy and climate targets for 2020, with continued business-as-usual trend until 2030;

II ***Increase forest carbon stock in existing EU forests***: exploring the consequences of a decision to focus policy on increasing the carbon stock in EU-28 forest, notably by reducing domestic harvest rates;

III ***Cascade use – increase recovery of solid wood products***: exploring the consequences of decisions to encourage cascade use by improving the recovery of solid wood products, for material and energy purposes;

IV ***Cascade use – prevent first use of biomass for energy***: exploring the consequences of decisions to encourage cascade use by ensuring that wood of sufficient quality and dimensions harvested in EU-28 forests is first used as raw material, and only subsequently as a source of energy;

V ***Strongly increase material wood use***: exploring the consequences of success in increasing wood consumption in its major markets, especially the construction sector, by innovation, investment and promotion.

The scenario results are presented below, in tables and figures.

Table ES-1: Annual average EU-28 GHG impact of scenarios as compared to the *ClimWood2030 reference* scenario [in Mt CO_2e yr^{-1}].

Scenario			Snapshots		
			#01 (2000-2010)	#02 (2011-2020)	#03 (2021-2030)
ClimWood2030 reference scenario (I)			absolute values		
	Emissions/removals[3]	EU forests	-242.90	-188.03	-134.02
		EU HWP	-33.89	-11.69	-16.71
	Emissions/removals[3]	Non-EU forests	1377.46	2357.71	2096.79
	Substitution potential[4]	Energy use	-14.95	-186.44	-222.19
		Material use	-2.91	-31.68	-34.17
	Total EU-28 only		**-294.65**	**-417.84**	**-407.08**
Increase C stock in existing EU forests (II)			*relative to ClimWood2030 reference scenario*		
	Emissions/removal	EU forests	–	*-77.23*	*-205.60*
		EU HWP	–	*+9.03*	*+14.48*
	Emissions/removals	Non-EU forests	–	*+13.51*	*+40.12*
	Substitution potential	Energy use	–	*+11.05*	*+33.34*
		Material use	–	*+5.31*	*+10.78*
	Total EU-28 only		**–**	**-51.84**	**-147.00**
Cascading – increased recovery of solid wood products (III)			*relative to ClimWood2030 reference scenario*		
	Emissions/removals	Forests	–	*-0.02*	*+0.02*
		HWP	–	*-0.05*	*-0.03*
	Emissions/removals	Non-EU forests	–	*+0.23*	*-1.39*
	Substitution potential	Energy use	–	*-3.92*	*-11.39*
		Material use	–	*-0.05*	*-0.44*
	Total EU-28 only		**–**	**-4.03**	**-11.83**
Cascading – prevent first use of biomass for energy (VI)			*relative to ClimWood2030 reference scenario*		
	Emissions/removals	Forests	–	*+9.00*	*+30.38*
		HWP	–	*-10.71*	*-22.84*
	Emissions/removals	Non-EU forests	–	*+2.23*	*-37.30*
	Substitution potential	Energy use	–	*+7.61*	*+19.91*
		Material use	–	*-7.18*	*-18.47*
	Total EU-28 only		**–**	**-1.28**	**+8.98**
Strongly increase material wood use (V)			*relative to ClimWood2030 reference scenario*		
	Emissions/removals	Forests	–	*+9.38*	*+18.26*
		HWP	–	*-6.63*	*-14.09*
	Emissions/removals	Non-EU forests	–	*+2.02*	*+5.35*
	Substitution potential	Energy use	–	*-2.03*	*-5.20*
		Material use	–	*-4.60*	*-10.01*
	Total EU-28 only		**–**	**-3.89**	**-11.04**

Note: Readers are referred to the full study for the exact definitions of the terms used, as well as methodological features which should be taken into account. In particular, the data for non-EU forests concern the forest pool only, not the HWP pool and not the substitution effects, which could not be analysed.

[3] Positive value = GHG net source, negative value = GHG net sink

[4] Positive value = additional GHG emissions through substitution, negative value = GHG savings through substitution

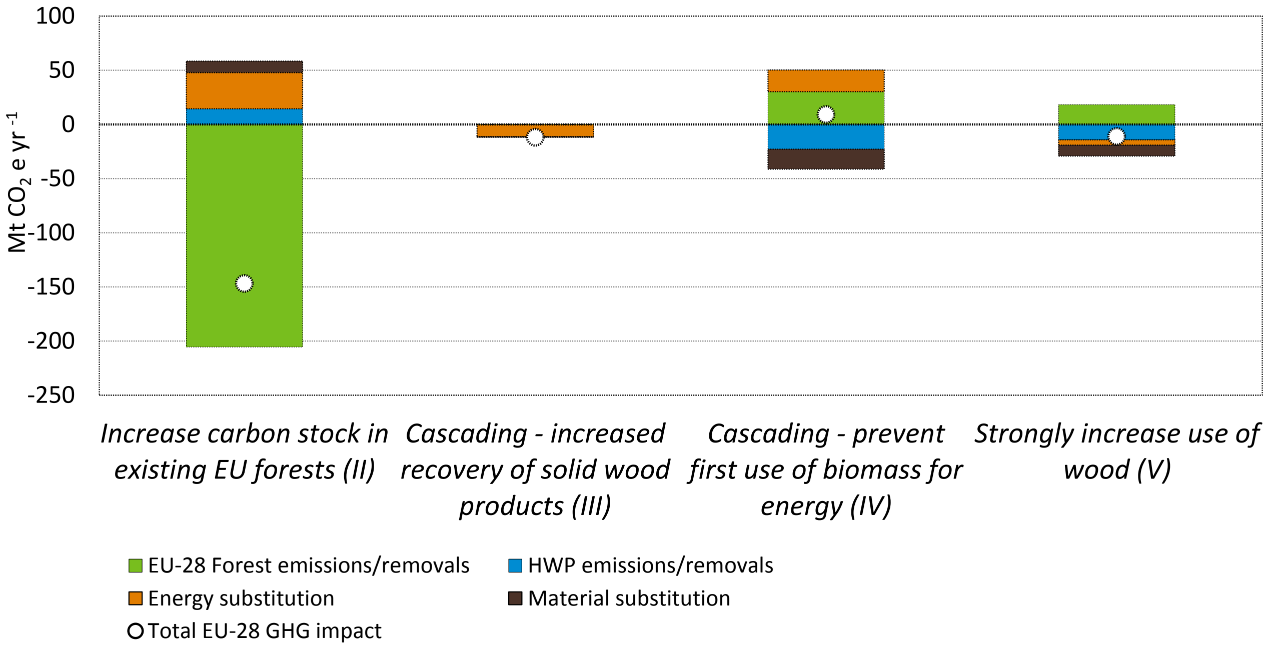

Figure ES-1: Annual average impact of scenarios for EU-28 parameters on GHG balances as compared to the *ClimWood2030 reference* scenario, period 2021-2030, detailed per contributor [in Mt CO_2e yr^{-1}].

Table ES-1: Annual average impact of scenarios on EU and non-EU forest emissions/removals as compared to the *ClimWood2030 reference* scenario [in Mt CO_2e yr^{-1}]

Scenario	Snapshots		
	#01 (2000-2010)	**#02 (2011-2020)**	**#03 (2021-2030)**
ClimWood2030 reference scenario (I)	absolute values		
EU Forests	-242.90	-188.03	-134.02
Non-EU Forests	1377.46	2357.71	2096.79
Increase C stock in existing EU forests (II)	*relative to ClimWood2030 reference scenario*		
EU Forests	–	*-77.23*	*-205.60*
Non-EU Forests	–	*13.51*	*40.12*
Cascading - increased recovery of solid wood products (III)	*relative to ClimWood2030 reference scenario*		
EU Forests	–	*-0.02*	*0.02*
Non-EU Forests	–	*0.23*	*-1.39*
Cascading - prevent first use of biomass for energy (IV)	*relative to ClimWood2030 reference scenario*		
EU Forests	–	*9.00*	*30.38*
Non-EU Forests	–	*2.23*	*-37.30*
Strongly increase use of wood (V)	*relative to ClimWood2030 reference scenario*		
EU Forests	–	*9.38*	*18.26*
Non-EU Forests	–	*2.02*	*5.35*

Main conclusions

A holistic approach to quantify carbon pools and flows throughout the forest based sector, as well as substitution effects, along the lines pioneered by ClimWood2030, is necessary to understand the overall effects for the GHG balance of policy choices in the forest based sector.

(1) The ClimWood2030 approach is new and should be widely reviewed and discussed.

(2) Material use of HWP leads to lower GHG emissions over the whole life cycle than the use of functionally equivalent alternatives (1.5 to 3.5 t CO_2 saved per ton of HWP). Reciprocally, if HWP were replaced by other materials, associated fossil GHG emissions would be considerably higher.

(3) ClimWood2030 has constructed five scenarios, a *ClimWood2030 reference* scenario (I) and four policy scenarios: *Increase carbon stock in existing EU forests* (II*), Cascade use – increase recovery of solid wood products* (III), *Cascade use – prevent first use of biomass for energy* (IV) and *Strongly increase material wood use* (V). These are thought experiments, not forecasts of likely outcomes or policy recommendations.

(4) The *ClimWood2030 reference scenario* assumes that the EU and Member States achieve their policy goals in the field of bioenergy for 2020, and that the share of renewable energy rises to 24 % in 2030. In this scenario, energy substitution by wood biomass saves an additional 36 Mt CO_2e yr^{-1} on average for the period 2021-2030 (compared to current levels), as the 2020 bioenergy targets are met and then exceeded. This material is supplied by increased harvests from EU-28 forests to supply the biomass energy called for by the policy targets. Total harvests increase by 21 % between periods 2000-2010 and 2021-2030. Harvest for energy use by nearly 50 %, leading to a steep decline in the EU forest sink: the net removals from EU forests decrease by 45 % in period 2000-2010 to 2021-2030. However, EU forests remain a sink (10 % increase of carbon pool over 30 years). In the base period, energy wood harvest is about 60 % of industrial wood harvest, but in the last decade, this proportion rises to 87 %. The average price observed in the GLOBIOM model for harvested stem wood increases by 16 % between 2010 and 2030. EU-28 net imports of industrial roundwood and wood pulp more than double, and in 2030, net imports reach about 10 % of domestic harvests. Development of HWP markets remains stagnant in this scenario. The policy imperative to produce more wood for energy through intensified silviculture and increased harvests might cause tension with the need to conserve soils and biodiversity, because of harvest techniques (larger machines), or removal of previously unused biomass (stumps, branches).

(5) Scenario II *Increase carbon stock in existing EU forests* shows the best overall GHG impact of all scenarios up to 2030. However, under this scenario, emissions from forest outside the EU increase, wood prices double over 20 years, and employment and livelihoods in forestry are reduced. ClimWood2030 only analyses in quantitative terms the period to 2030. If a longer period had been considered, net carbon removals by EU forests would decline quickly thereafter as saturation is reached, and the substitution factors (which are cumulative

and spread over time) or the lack thereof, would become more important. Saturated forests may even release carbon as they lose vitality and become more vulnerable to damage and more frequent climate extremes. Eventually, substitution potential will become the only way of maintaining a system-wide sink in the forest-based sector of the EU-28. Over the seventy year period 2031-2100, the cumulative effect of differences among scenarios is highly significant. This indicates clearly that policy choices adopted for a time frame up to 2030 have implications much beyond 2030

(6) In all the scenarios, very large amounts of wood are used for energy purposes (e.g. in 2030 477 Mm^3 of wood[5] outside wood industries in the *ClimWood2030 reference* scenario). In effect these assumptions (achieving the bioenergy targets without substitution between renewable energies and without expansion of SRC) bring about a "wood shortage" and high wood prices, which make it difficult to combine the policy choices of the various policy scenarios. For instance, a "win-win" scenario could be conceived whereby wood consumption rises as in scenario V, and there is more cascade use, through improved wood recovery (scenario III) and priority to material use (scenario IV). However, given the high and inflexible demand for wood-based energy resulting from the high-level policy choices, and the resulting high wood prices, combined with the requirements of sustainable wood supply, these choices lead to rather marginal differences between the scenarios.

(7) All the scenarios are very dependent on the underlying assumptions about how renewable energy targets are achieved: If solar and wind energy grow faster than projected by the EU Impact Assessment or if short rotation coppice and/or perennial energy crops and/or non-wood biomass develop rapidly, there would be much less pressure to mobilise large volumes of wood for energy from EU and global forests. The lower demand for energy wood would create more opportunities to develop cascade use and HWP climate benefits.

(8) In some scenarios, notably scenario II *Increase carbon stock in existing EU forests*, GHG emissions from non-EU forests are higher than in the reference scenario, but in others, notably Scenario IV *Cascade use – prevent first use of biomass for energy*, it is lower. Extra-EU trade can therefore increase or decrease the pressure on forests of EU trade partners (i.e. the EU forest footprint). In the *Increase carbon stock in existing EU forests* scenario, the emissions/removals from non-EU forests increase by roughly 40 Mt CO_2e in the period 2021-2030 as compared to the *ClimWood2030 reference scenario*. The increase in emissions/removals from non-EU forests is however fully balanced by the increase of the EU forest carbon stock. In the *Cascade use – prevent first use of biomass for energy* scenario, the emissions/removals from non-EU forests decreased by roughly 37 Mt CO_2e in the period in period 2021-2030 as compared to the *ClimWood2030 reference scenario*. It should however be kept in mind that the impacts on emissions/removals from non-EU forests of

[5] This converts into 1.14E+11 oil equivalent, assuming an average wood density of 500 kg/m^3, a heating value of wood of 20 MJ/kg dry wood and 41.868 MJ/oil equivalent

changes in EU are quite small as compared to the change over time in deforestation/afforestation emission in non-EU countries.

(9) Strongly increasing the use of wood, notably in construction (scenario V) can reduce GHG emissions by alternative materials, compared to the *ClimWood2030 reference* scenario, by 11 Mt CO_2e yr^{-1} on average.

(10) An optimum combination of the forest protection, cascade and substitution approaches outlined in scenarios II-V, coupled with further progress in energy efficiency and renewable energies (beyond the EU Reference Scenario) and probably with an increase in the area of short rotation coppice, might yield additional GHG savings in the 2020-2030 period, and would continue to do so for decades, with sustainable development co-benefits.

(11) The most relevant policy instruments considered to achieve the scenario outcomes include:

(a) Wood mobilisation measures (except scenario II);
(b) Economic incentives to store carbon in living forest biomass, possibly by carbon incentives, or reducing existing incentives for wood production (scenario II only);
(c) Measures to increase recovery of post-consumer wood, including full implementation of the Landfill Directive, improving markets and logistics for post-consumer wood, and regulating disposal of wood-containing waste;
(d) Maintenance of construction activity at a high level;
(e) Performance based construction standards, neutral with regards to the type of material used, so as not to hinder the use of wood products in construction;
(f) Public/private investment in increased R&D for innovative and carbon efficient uses for wood products and for wood promotion as part of an overall climate change mitigation strategy.

(12) The ClimWood2030 scenarios would also influence other aspects of sustainable forest management, including employment, livelihoods and biodiversity, although these parameters have not been explicitly computed in the scenarios. However, in all scenarios, wood supply is on a sustainable basis and there is no reduction in the area of forest protected to conserve biodiversity.

(13) ClimWood2030 quantifies the importance of the EU-28 forest based sector relative to other GHG flows. Around 2010, the EU-28 forest had net reported GHG removals of about -240 Mt CO_2e from the atmosphere every year, which can be compared to emissions in 2012 of 878 Mt CO_2e by European industry, and 502 Mt CO_2e by transport and storage, or 3700 Mt CO_2e from global net forest conversion (net emissions/removals from forest conversion, i.e. mostly tropical deforestation). Thus already today, the forest of the EU-28 is making a significant contribution to improving the European GHG balance.

(14) In addition, the carbon pool in EU-28 forest products is increasing by nearly 35 Mt CO_2e every year. The carbon pool in HWP is about 15 % of the carbon pool in forests. The size of the HWP carbon pool depends not only on how many products are produced, imported and

consumed, but on their length of life in service. Extending HWP life could also bring climate benefits.

Synthèse

Contexte et objectifs

La filière forêt bois de l'Union européenne contribue à l'atténuation du changement climatique selon cinq voies différentes:

i) L'absorption et le stockage du dioxyde de carbone de l'air par les forêts de l'UE ;
ii) le stockage du carbone dans les produits bois[6] dans l'UE ;
iii) la substitution « énergie », c'est-à-dire l'utilisation de combustible bois à la place de combustibles fossiles dans l'UE;
iv) la substitution « matériau », soit l'utilisation de produits bois dans l'UE à la place d'autres matériaux sur la base d'une équivalence fonctionnelle;
v) l'impact des échanges extra-européens, qui augmentent ou réduisent la pression sur les forêts des partenaires commerciaux de l'UE, et par conséquent l'empreinte carbone globale des forêts de l'UE.

Ces cinq voies présentent des profils différents et peuvent interagir, de façon positive ou négative. Jusqu'ici, une difficulté importante de ce type d'évaluation était de mesurer ces contributions de façon comparable au niveau de l'UE et de quantifier les interactions possibles.

L'étude ClimWood2030 a pour objectif la quantification des effets d'absorption, stockage et substitution et évalue, par l'analyse de différents scénarios, les conséquences pour les bilans de gaz à effet de serre (GES) des choix politiques actuellement envisagés. L'étude vise à fournir des informations importantes pour l'élaboration de politiques pour la filière forêt bois s'appuyant sur des éléments factuels.

L'analyse des scénarios est basée sur une combinaison de modèles (GLOBIOM, G4M et WoodCarbonMonitor) auxquels s'ajoute une évaluation détaillée des différentes unités fonctionnelles de la filière forêt bois basée sur l'analyse de cycle de vie (ACV)[7]. Ainsi, les choix politiques sont évalués sur la base des bilans de GES de toutes les composantes de la filière forêt bois.

L'étude porte sur les bilans de GES et les flux de carbone associés à la forêt mais aussi à la production, à l'import-export, à l'utilisation et à la fin de vie des produits bois. L'étude est centrée

[6] Le GIEC désigne ces produits par le terme « Produit Ligneux Récoltés » (PLR) en traduction de «harvested wood products» (HWP). Pour faciliter la lecture du document, le terme de Produit Bois est employé ici.

[7] Les unités fonctionnelles de la filière forêt bois analysées afin d'évaluer la substitution matériau indirecte dans le contexte de l'étude totalisent environ 30 % du marché total des produits bois dans l'Union européenne en 2010 et entre 17 % et 43 % en 2030 (voir section 3.2.3.1)

sur l'UE-28, mais les bilans de GES sont également considérés pour d'autres régions du monde notamment pour évaluer les conséquences des choix de politique de l'UE en dehors de ses frontières. L'horizon temporel des scénarios étudiés couvre la période 2000-2030.

Il faut souligner que les scénarios étudiés doivent être considérés comme des expériences virtuelles et non comme une évaluation des impacts des politiques de l'UE actuelles ou en préparation. Ils ont pour but d'estimer l'ampleur des changements potentiels au sein de la filière forêt bois et d'évaluer l'impact sur les bilans globaux de GES de changements politiques spécifiques et des évolutions de marché des produits bois. Aucun des scénarios – même le scénario de référence – ne peut être considéré comme le scénario le plus plausible. Plus probablement, l'avenir se composera d'un mélange de ces scénarios – avec quelques éléments inattendus. En outre, les scénarios se concentrent sur les bilans de GES: l'acceptabilité, la faisabilité, ainsi que les impacts sociaux, environnementaux et économiques de telles politiques n'ont pas pu être entièrement évalués dans cette étude.

Scénarios

Cinq scénarios ont été définis:

I ***Le scénario de référence ClimWood2030***: il est basé sur le scénario de référence de l'UE en considérant que les objectifs de l'UE pour 2020 en matière d'énergie et de climat sont atteints et en faisant l'hypothèse d'un scénario «business as usual» jusqu'en 2030;

II ***Augmenter les stocks de carbone dans les forêts de l'UE***: il permet d'estimer les conséquences d'une décision politique éventuelle visant à augmenter les stocks de carbone dans les forêts existantes de l'UE-28, notamment en réduisant le taux de récolte domestique;

III ***Utilisation en cascade – augmenter la valorisation des produits bois en fin de vie***: il permet d'estimer les conséquences de décisions politiques éventuelles visant à encourager l'utilisation en cascade des produits bois par la valorisation des déchets bois (recyclage et valorisation énergétique);

IV ***Utilisation en cascade – empêcher l'utilisation directe de biomasse en énergie***: il permet d'estimer les conséquences de décisions politiques éventuelles encourageant l'utilisation en cascade du bois en donnant la priorité à l'utilisation matière du bois. La gestion sylvicole est menée de manière à obtenir du bois de dimension et de qualité suffisante pour que le bois récolté dans les forêts de l'UE-28 soit d'abord employé en tant que matière première, et seulement ensuite comme source d'énergie;

V ***Augmenter fortement l'utilisation du matériau bois***: il permet d'estimer les conséquences d'une augmentation de la consommation de produits bois sur ses marchés importants, particulièrement le secteur de la construction, par l'innovation, l'investissement et la promotion du bois.

Les résultats des scénarios sont présentés dans les tableaux et figures ci-dessous.

Tableau ES-1: Différence des bilans GES annuels moyens de l'UE-28 des différents scénarios par rapport au scénario de référence ClimWood2030 [en Mt CO_2e an^{-1}].

Scénario		Snapshots		
		#01 (2000-2010)	#02 (2011-2020)	#03 (2021-2030)
Scénario de référence ClimWood2030 (I)		valeurs absolues		
Emissions/absorption[8]	Forêts UE	-242,90	-188,03	-134,02
	Produits bois UE	-33,89	-11,69	-16,71
Emissions/ absorption	Forêts hors UE	1377,46	2357,71	2096,79
Impact potentiel de la substitution[9]	Utilisation énergétique	-14,95	-186,44	-222,19
	Utilisation matériau	-2,91	-31,68	-34,17
Total (uniquement UE-28)		**-294,65**	**-417,84**	**-407,08**
Augmenter les stocks de carbone dans les forêts de l'UE (II)		*par rapport au scenario de référence ClimWood2030*		
Emissions/ absorption	Forêts UE	–	*-77,23*	*-205,60*
	Produits bois UE	–	*+9,03*	*+14,48*
Emissions/ absorption	Forêts hors UE	–	*+13,51*	*+40,12*
Impact potentiel de la substitution	Utilisation énergétique	–	*+11,05*	*+33,34*
	Utilisation matériau	–	*+5,31*	*+10,78*
Total (uniquement UE-28)		**–**	**-51,84**	**-147,00**
Utilisation en cascade – augmenter la valorisation des produits bois en fin de vie (III)		*par rapport au scenario de référence ClimWood2030*		
Emissions/ absorption	Forêts UE	–	*-0,02*	*+0,02*
	Produits bois UE	–	*-0,05*	*-0,03*
Emissions/ absorption	Forêts hors UE	–	*+0,23*	*-1,39*
Impact potentiel de la substitution	Utilisation énergétique	–	*-3,92*	*-11,39*
	Utilisation matériau	–	*-0,05*	*-0,44*
Total (uniquement UE-28)		**–**	**-4,03**	**-11,83**
Utilisation en cascade – empêcher l'utilisation directe de biomasse en énergie (IV)		*par rapport au scenario de référence ClimWood2030*		
Emissions/ absorption	Forêts UE	–	*+9,00*	*+30,38*
	Produits bois UE	–	*-10,71*	*-22,84*
Emissions/ absorption	Forêts hors UE	–	*+2,23*	*-37,30*
Impact potentiel de la substitution	Utilisation énergétique	–	*+7,61*	*+19,91*
	Utilisation matériau	–	*-7,18*	*-18,47*
Total (uniquement UE-28)		**–**	**-1,28**	**+8,98**
Augmenter fortement l'utilisation du matériau bois (V)		*par rapport au scenario de référence ClimWood2030*		
Emissions/ absorption	Forêts UE	–	*+9,38*	*+18,26*
	Produits bois UE	–	*-6,63*	*-14,09*
Emissions/ absorption	Forêts hors UE	–	*+2,02*	*+5,35*
Impact potentiel de la substitution	Utilisation énergétique	–	*-2,03*	*-5,20*
	Utilisation matériau	–	*-4,60*	*-10,01*
Total (uniquement UE-28)		**–**	**-3,89**	**-11,04**

Note: Le lecteur doit se référer au rapport complet de l'étude pour les définitions précises des termes utilisés et pour les choix méthodologiques considérés. En particulier, les bilans GES hors Europe concernent les réservoirs de carbone des forêts extra européennes mais n'incluent pas les réservoirs de carbone dans les produits bois récoltés ni les effets de substitution ayant lieu hors de l'Europe.

[8] Valeur positive = source nette de GES, valeur négative = puits net de GES

[9] Valeur positive = émissions additionnelles de GES liées à l'effet de substitution, valeur négative = émissions de GES évitées par l'effet de substitution

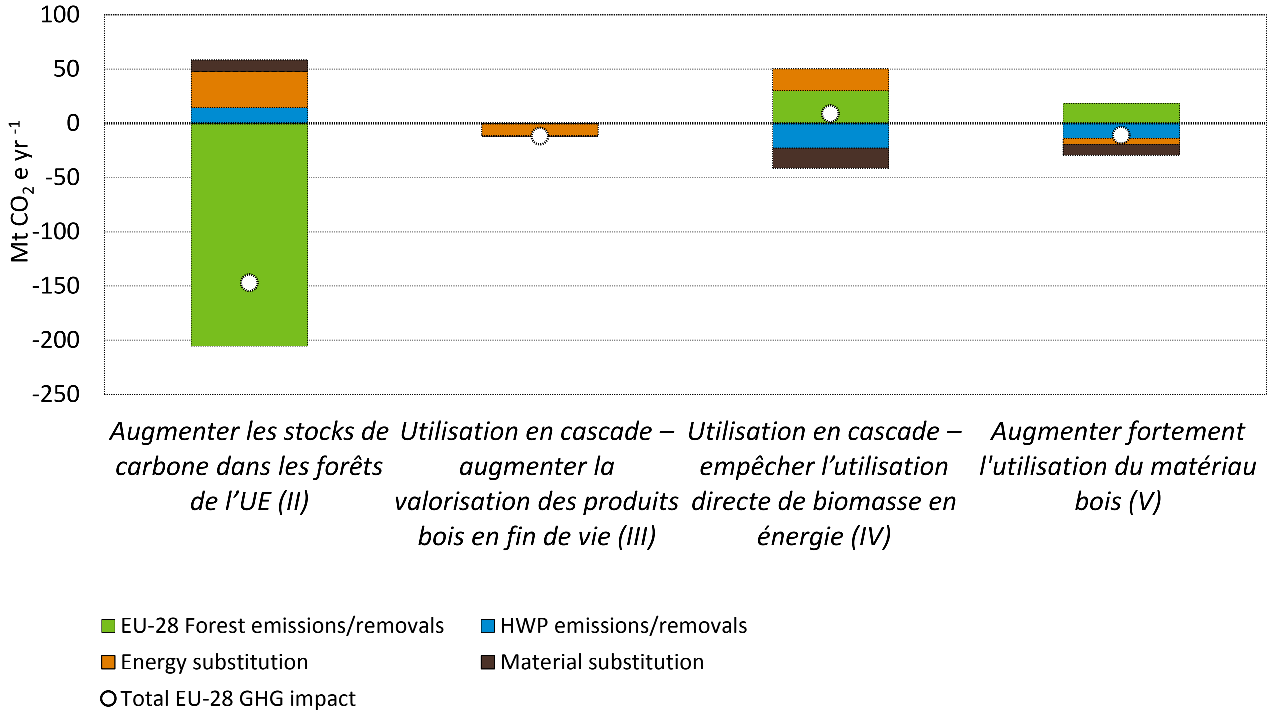

Figure ES-1: Différence des bilans GES annuels moyens de l'UE- 28 des différents scénarios par rapport au *scénario de référence ClimWood2030*, pour la période 2021-2030, détaillé par contributeur [en Mt CO_2e an^{-1}].

Tableau ES-2: Différence des bilans GES annuels moyens des différents scénarios des forêts UE et hors UE par rapport au *scénario de référence ClimWood2030* [en Mt CO_2e an^{-1}]

Scénario	**Snapshots**		
	#01 (2000-2010)	**#02 (2011-2020)**	**#03 (2021-2030)**
Scénario de référence ClimWood2030 (I)	valeurs absolues		
Forêts UE	-242,90	-188,03	-134,02
Forêts hors UE	1377,46	2357,71	2096,79
Augmenter les stocks de carbone dans les forêts de l'UE (II) *par rapport au scenario de référence ClimWood2030*			
Forêts UE	–	*-77,23*	*-205,60*
Forêts hors UE	–	*13,51*	*40,12*
Utilisation en cascade – augmenter la valorisation des produits bois en fin de vie (III) *par rapport au scenario de référence*			
Forêts UE	–	*-0,02*	*0,02*
Forêts hors UE	–	*0,23*	*-1,39*
Utilisation en cascade – empêcher l'utilisation directe de biomasse en énergie (VI) *par rapport au scenario de référence*			
Forêts UE	–	*9,00*	*30,38*
Forêts hors UE	–	*2,23*	*-37,30*
Augmenter fortement l'utilisation du matériau bois (V) *par rapport au scenario de référence ClimWood2030*			
Forêts UE	–	*9,38*	*18,26*
Forêts hors UE	–	*2,02*	*5,35*

Conclusions principales

Une approche globale pour évaluer les stocks et les flux de carbone dans l'ensemble de la filière forêt bois, ainsi que les effets de substitution telle qu'initiée dans l'étude ClimWood2030, est nécessaire pour comprendre les effets globaux des choix politiques sur les bilans GES dans la filière forêt bois.

(1) L'approche présentée dans ClimWood2030 est nouvelle et devrait être largement passée en revue et discutée.

(2) L'utilisation matériau des produits bois entraîne une baisse des émissions de GES sur l'ensemble du cycle de vie par comparaison à des produits alternatifs fonctionnellement équivalents (économie de 1.5-3.5 t CO_2 par tonne de produis bois). Si l'on remplaçait les produits bois par d'autres matériaux, les émissions de GES seraient d'autant plus élevées.

(3) L'étude ClimWood2030 présente cinq scénarios, un *scénario de référence ClimWood2030* (I) et quatre scénarios illustrant des choix politiques: *Augmenter les stocks de carbone dans les forêts de l'UE* (II), *Utilisation en cascade – augmenter la valorisation des produits bois en fin de vie* (III), *Utilisation en cascade – empêcher l'utilisation directe de biomasse en énergie* (IV) et *Augmenter fortement l'utilisation du matériau bois* (V). Ces scénarios correspondent à des expériences virtuelles et ne sont pas des prévisions ni des recommandations en matière de politique.

(4) Le *scénario de référence Climwood2030*, suppose que l'Union et les Etats Membres atteignent leurs objectifs en matière de bioénergie pour 2020, et que la part des énergies renouvelables atteigne 24 % en 2030. Dans ce scénario, la substitution des énergies fossiles par la biomasse ligneuse économise en moyenne 36 Mt CO_2 an^{-1} supplémentaires pour la période 2021-2030 (comparé aux niveaux actuels), quand les objectifs 2020 pour la bioénergie sont atteints et dépassés. Ce bois provient de récoltes supplémentaires dans les forêts de l'UE afin de fournir l'énergie issue de la biomasse prévue par les objectifs politiques. La récolte totale augmente de 21 % entre les périodes 2000-2010 et 2021-2030. La récolte du bois énergie augmente de près de 50 %, d'où une réduction du puits GES des forêts de l'UE. L'absorption nette des forêts de l'UE diminue de 45 % entre 2000-2010 et 2021-2030. Néanmoins, les forêts de l'UE restent un puits pour les GES: le réservoir de carbone augmente de 10 % en 30 ans. Dans la période de base, la récolte de bois énergie représente 60 % de la récolte du bois industrie, mais dans la dernière période, cette proportion atteint 87 %. Selon le modèle GLOBIOM, le prix moyen du bois rond récolté augmente de 16 % entre 2010 et 2030. Les importations nettes de bois d'industrie et de la pâte à papier par l'UE-28 sont plus que doublées d'ici 2030, et représentent à cet horizon 10 % de la récolte domestique. Dans ce scénario, les marchés des produits bois restent au même niveau. L'objectif politique prioritaire de produire plus de bois énergie par une sylviculture intensifiée et des récoltes plus importantes pourraient entrer en conflit avec la nécessité de conserver les sols et la biodiversité. Les causes de cette tension pourraient être liées aux techniques de récolte (équipements plus lourds) ou à la récolte de biomasse qui auparavant restait en forêt (souches, branches).

(5) Le scénario *Augmenter les stocks de carbone dans les forêts de l'UE* (II) présente le meilleur bilan GES parmi tous les scénarios sur la période étudiée. Cependant, dans ce scénario, les émissions liées à la forêt en dehors de l'UE augmentent, les prix du bois doublent sur 20 ans, et l'emploi et les revenus liés à la filière forêt bois européenne diminuent. Les scénarios de l'étude ClimWood2030 ne portent que sur la période 2010 à 2030. Si une période plus longue avait été considérée, l'absorption de carbone par les forêts diminuerait rapidement par le phénomène de saturation alors que les gains ou les pertes liées à la substitution continueraient d'augmenter du fait de leur caractère cumulatif et de leur répartition dans le temps. Des forêts «saturée» (du point de vue carbone) peuvent même émettre du carbone car elles perdent de la vitalité et deviennent plus vulnérables aux dommages et aux événements climatiques extrêmes. Sur le long terme, le potentiel de substitution sera la seule possibilité de maintenir le puits carbone de la filière bois de l'UE-28 dans son ensemble. Sur la période de 70 ans 2031-2100, l'effet cumulé des différences entre scénarios est très important. Ceci indique clairement que les choix politiques pour la période qui finit en 2030 auront des conséquences bien après cette année.

(6) Dans tous les scénarios, des volumes très importants de bois sont utilisés pour l'énergie (p.ex. en 2030, 477 Mm^3 de bois[10] sont utilisés pour l'énergie, en dehors des industries du bois, dans le *scénario de référence ClimWood2030*). En effet, ces hypothèses de départ des scénarios (objectifs atteints pour la bioénergie, sans substitution entre énergies renouvelables et sans expansion des taillis à rotation courte) conduisent à une «pénurie de bois» et des prix élevés du bois. Il est donc difficile de combiner les choix politiques sur lesquels sont basés les différents scénarios. Par exemple, on pourrait concevoir un scénario gagnant-gagnant, dans lequel la consommation du bois est en hausse comme dans le scénario V, où il y a plus d'utilisation en cascade par la valorisation des produits bois en fin de vie (III), et en accordant la priorité aux utilisations matériau (IV). Cependant, la demande forte et non flexible pour le bois énergie, qui résulte des choix politiques de haut niveau, combinée aux exigences de l'approvisionnement durable en bois se traduit par des différences marginales entre les scénarios.

(7) Tous les scénarios sont très dépendants des hypothèses sous-jacentes liées aux moyens pour atteindre les objectifs de l'Europe en matière de consommation d'énergie renouvelable. Si les énergies solaire et éolienne se développent plus rapidement que projeté dans l'Analyse d'impact du cadre pour le climat et l'énergie à l'horizon 2030[11] ou si les taillis à courte rotation et/ou les cultures énergétiques (ligneuses ou non) se développent rapidement, une pression moins forte serait exercée pour mobiliser de grands volumes de bois énergie dans les forêts existantes. Une demande moindre en bois énergie permettrait de

[10] L'équivalent de 1.14 E+11 tep, si l'on calcule sur la base d'une densité moyenne du bois de 500kg/m^3, une valeur énergétique de bois de 20 MJ/kg de bois sec et 41.868 MJ/tep

[11] European Commission. Impact Assessment: Accompanying the Communication; A policy framework for climate and energy in the period from 2020 up to 2030. (2014).

mieux développer l'utilisation en cascade et d'améliorer la pénétration des produits bois sur les différents marchés.

(8) Dans certains scénarios, notamment le scénario II *Augmenter les stocks de carbone dans les forêts de l'UE*, les émissions de GES des forêts hors de l'Union Européenne sont plus élevées que dans le scénario de référence, mais dans d'autres scénarios, notamment le Scénario IV *Utilisation en cascade – empêcher l'utilisation directe de biomasse en énergie*, les émissions des forêts extra européennes sont inférieures au scénario de référence. Les échanges extra-européens peuvent augmenter ou réduire la pression sur les forêts des partenaires commerciaux de l'UE, et par conséquent influencer l'empreinte carbone des forêts de l'UE. Dans le scénario II *Augmenter les stocks de carbone dans les forêts de l'UE*, les émissions/absorptions de GES des forêts hors de l'Union Européenne augmentent de 40 Mt CO_2e dans la période 2021-2030 par rapport au *Scénario de Référence ClimWood2030*. Cette augmentation des émissions est entièrement compensée par l'augmentation du puits carbone des forêts européennes. Dans le Scénario IV *Utilisation en cascade – empêcher l'utilisation directe de biomasse en énergie*, les émissions des forêts extra européennes diminuent de 37 Mt CO_2e dans la période 2021-2030 par rapport au scénario de Référence ClimWood2030. Néanmoins, il faut souligner que les impacts sur les émissions/absorptions des forêts extra-européennes des changements en Europe sont relativement mineurs comparés aux changement sur la période des émissions dues à la déforestation extra-européenne.

(9) Une forte augmentation de l'utilisation du bois en remplacement d'autres matériaux, notamment dans la construction (Scénario V) peut réduire les émissions de GES de 11 Mt CO_2e par rapport au scénario de référence.

(10) Une combinaison optimum des approches de protection des forêts, de cascade et de substitution décrites dans les scénarios II à V, couplées avec des améliorations de l'efficacité énergétique et une augmentation de l'offre des autres énergies renouvelables (au-delà du scénario de référence de l'UE) ainsi qu'une augmentation des surfaces dédiées aux taillis à courte rotation pourraient créer des réductions d'émissions de GES additionnelles durant la période 2020-2030. Ces réductions pourraient se prolonger après 2030 avec des bénéfices additionnels en matière de développement durable.

(11) Les instruments politiques les plus pertinents qui sous-tendent les différents scénarios pourraient comprendre:

(a) Des mesures pour faciliter la mobilisation du bois en forêt (excepté pour le scénario II);
(b) Des incitations économiques pour stocker le carbone en forêt, principalement par des crédits carbone, ou des réductions des incitations existantes en faveur de la récolte de bois (scénario II seulement);
(c) Des mesures pour augmenter la valorisation des déchets bois y compris par la mise en application stricte de la directive sur la mise en décharge, l'amélioration du fonction-

nement du marché des déchets de bois, une meilleure gestion de la logistique liée à ces déchets et un meilleur contrôle de leur élimination;

(d) Des mesures pour maintenir un haut niveau d'activité dans la construction;

(e) Des normes de construction basées sur les performances à atteindre, qui soient neutres par rapport au matériau utilisé, afin de ne pas créer de barrières injustifiées à l'utilisation des produits bois dans la construction;

(f) Un investissement public/privé dans la R&D accru pour des usages innovants et efficaces du point de vue de l'effet de serre pour les produits bois ainsi que dans la promotion du matériau bois en tant qu'élément d'une stratégie globale d'atténuation du changement climatique.

(12) Les scénarios construits pour ClimWood2030 influenceraient également d'autres aspects de la gestion durable des forêts, y compris l'emploi, les revenus issus de la forêt et la biodiversité, bien que ces paramètres n'aient pas été explicitement calculés dans les scénarios. Cependant, dans tous les scénarios, l'offre de bois en Europe satisfait aux conditions de la gestion durable et il n'y a aucune diminution des aires protégées pour conserver la biodiversité.

(13) ClimWood2030 estime l'importance des flux de GES de la filière forêt bois de l'UE-28, en les comparants aux flux des autres secteurs. Vers 2010, la forêt de l'UE avait une absorption nette annuelle estimée des GES de -240 Mt CO_2e, ce qui peut être comparé aux émissions de GES de 878 Mt CO_2e produites par l'industrie européenne et de 502 Mt CO_2e par le transport et la logistique, ou 3700 Mt CO_2e résultant de la conversion des forêts au niveau global (émissions nettes de la conversion des forêts, surtout la déforestation tropicale). Il en résulte que déjà aujourd'hui, la forêt de l'UE contribue de façon significative à l'amélioration du bilan GES de l'Union européenne.

(14) De plus, le réservoir carbone des produits bois de l'UE-28 augmente de près de 35 Mt CO_2e chaque année. Le réservoir carbone des produits bois représente approximativement 15 % du réservoir carbone des forêts. La taille du réservoir carbone résultant des produits bois dépend non seulement de la quantité de produits fabriqués, importés et consommés, mais également de leur durée de vie en service. Prolonger cette vie en service peut aussi apporter des améliorations au bilan de gaz à effet de serre.

1 Introduction

The European Union (EU) is committed at the highest level to climate change mitigation. At the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 (COP21), alongside governments from all over the world, EU members recognised the need to "hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 °C", that "sustainable lifestyles and sustainable patterns of consumption and production [...] play an important role in addressing climate change" and aimed to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (UNFCCC 2015).

The EU has made quantified commitments. In particular, the 2030 climate and energy framework, adopted by EU leaders in October 2014, sets three key targets for the year 2030:

- At least 40 % cuts in greenhouse gas emissions (from 1990 levels)
- At least 27 % share for renewable energy
- At least 27 % improvement in energy efficiency

In this context, one challenge is to find the best combination of policies for the forest management and wood use sector, where there are significant gains to be made by sequestration and storage of carbon in forest and harvested wood products (HWP), by strengthening the circular economy and by substituting materials and energy with higher emissions over the whole life cycle. There are clear trade-offs between these approaches, but it has not yet been possible to compare and combine them in a quantitative way. For the EU, it is also necessary to consider interactions with the rest of the world: it is not climate effective to reduce EU emissions by transferring them to parts of the world, where they may or may not be accounted. This study is a first attempt at such a quantified approach, based on scenario analysis, life cycle assessment (LCA) and detailed market analysis.

The EU has identified[12] the land use and the food sector, alongside the housing and mobility sectors, as key domains for effective restructuring and climate change mitigation. Research, innovation, and investments into the bio economy are considered cornerstones in the transition to a low-carbon economy. The resource efficiency roadmap also refers to the land use sector by encouraging the use of bioenergy and the substitution of carbon intensive materials in chemistry, construction, etc. by bio-products.

[12] See Commission documents 'Roadmap to a Resource Efficient Europe' and 'Roadmap for moving to a competitive low carbon economy in 2050'

Currently, activities in the EU land use land change and forestry (LULUCF) sector are reported but not included in EU GHG emission reduction targets[13], despite their direct impact on effects on the atmospheric CO_2 concentration.

A major challenge remains that policies and strategies impacting on land use, biomass production, trade and use are not integrated in view of optimizing their overall GHG emission mitigation effect. Furthermore, the overall mitigation effect resulting from individual policy interventions including the feedback mechanisms they trigger across sectors and economic actors is not appropriately quantified and understood.

This study aims to provide insight into the implications of different forest management and wood use choices in the EU-28 (and abroad) for their potential, overall contribution to mitigate climate change: in EU forests, in non-EU forests, in wood-based products and in substituting more emissive materials and sources of energy.

1.1 Background

Direct effects on biogenic carbon balances of forests and HWP are internationally recognized, e.g. in the context of annual GHG inventories that are prepared by countries. The use of wood products, however, can also involve indirect effects which remain challenging to quantify: The use of wood can avoid the use of alternative materials which generate more emissions ("GHG effects related to material substitution") and can replace the direct use of fossil fuels for energy purposes ("GHG effects related to direct substitution of fossil fuels").

Although the fact that wood products potentially substitute products made from other materials is accepted and associated mitigation effects have been described (e.g. by Sathre and O'Connor 2010, Gustavsson *et al.* 2006, Werner *et al.* 2006 and Werner and Richter 2007), there is no general agreement on the magnitude of the overall effect, whether on a product level or on country or EU levels.

So far, only very few studies provide a complete overview of the different GHG effects of the forest based sector, which includes the impact of biogenic carbon storage on emissions and removals as well as potential substitution effects (e.g. Taverna *et al.* 2007). For the EU, no such information is available.

This study addresses several methodological challenges to quantify the overall GHG balance of EU forest based sector including potential substitution effects. These include:

- definition of the alternative products to be substituted by wood products;

[13] Noting potential LULUCF debits would have to be compensated from ESD sectors

- timing of effects (and the geographical location) of emissions for the production of wood products and their alternatives;
- service life of different wood products;
- shifts in market shares of different wood products impacting not only the storage time but also the time when post-consumer wood will be available e.g. for an energetic use, etc.
- distinction between EU internal and EU external effects associated with trade of woody biomass

1.2 Goal and scope of the study

The main objective of the study is thus to provide reliable data and analysis on the overall climate change mitigation potential associated with the use of forest biomass in the EU to substitute products composed of other raw materials, and on the potential increase of the carbon stock in EU harvested wood products (HWP) and forests. In the light of the challenges described above, the study tries thus for the first time to compile all relevant GHG effects on the level of EU and its 28 member states.

For this purpose, the consortium has carried out a model-based assessment as a scenario analysis of relevant policies and measures that might have an impact on the total demand for wood, the sourcing of wood and the resulting wood flows within and outside the EU. Derived from this, a comprehensive analysis of these scenarios and their impacts on the following key elements of national GHG balances has been made:

- Changes in forest carbon pools inside and outside EU;
- Changes in the HWP carbon pool;
- Effects of material substitution by using more/less wood within EU;
- Effects of substitution of fossil fuels due to an increased/diminished use of forest biomass, residual wood from industry and post- consumer wood within EU.

As a result, the study provides **annual estimates of net climate effects related to the implementation of relevant policies and measures up to 2030**, taking into account socio-economic drivers, in a scenario analysis consistent with existing scenarios of the European Commission. Where relevant, the analysis was extrapolated in order to also assess the potential impact of selected scenarios beyond the given timeframe of this study.

It should be stressed that the scenarios for the sake to this analysis should be considered as thought experiments and not as assessing the impacts of actual policies. They are only meant to outline the magnitude of potential changes in EUs forest based sector and to test the impact on overall GHG balances caused by policy changes and wood-related market developments within the next 15 years.

The study has furthermore identified and analysed policy instruments, which may influence climate change mitigation through the use of solid biomass, assessing their effectiveness and efficiency. The analysis makes it possible to present recommendations for the project as a whole for policy action to achieve suggested goals. These recommendations will describe best practice, and include general recommendations for EU policy makers (Commission and EU Member States) as regards the use of solid biomass for climate mitigation purposes in the EU by 2020 and 2030. However, the acceptability, feasibility, as well as full social, environmental and economic impacts of such policies could not be fully assessed in this study.

2 Background to the scenarios: concepts, methodology, assumptions and policy instruments

The study team has built a comprehensive system of consistent datasets, models and assumptions, all of which are carefully defined and applied objectively. To understand the study outputs and conclusions, it is necessary to fully take into account these inputs that are summarised in this chapter.

2.1 Methodological background

The following sections describe the methodological background of how changes in biogenic carbon pools in forests and in HWP as well as how substitution effects related to an increased/decreased use of wood are quantified.

2.1.1 Estimating emissions and removals from biogenic carbon pools

To estimate the contribution of the forest based sector to CO_2 emissions and removals, the change of magnitude of defined biogenic carbon pools has to be monitored over time. In the case that these pools increase over time, they act as a net sink, whereas they constitute a net source of emissions in the case that they emit more carbon than they accumulate.

The **forest carbon pool** consists of the carbon contained in living and dead forest biomass and soils. Carbon stored in tree biomass is allocated to different tree compartments. Depending on species and age most carbon is stored in stems. Living biomass comprises also branches, leaves or needles and roots. Further, carbon in dead biomass (dead wood, litter) is also accounted for as biomass carbon.

In order to estimate emissions and removals from changes of the forest carbon pool, different methods exist. For national GHG inventories, the IPCC Good Practice Guidance proposes two methods: the *gain-loss* method which sums all gains (growth) and losses (harvests, fires, etc.) of biomass over a certain period of time, and the *stock-difference* method which compares biomass estimates in a given area at two points in time (IPCC 2003). The implementation at the national scale is not strictly defined and countries are free to use a mix of the two abovementioned methods. The choice of the method depends on national data availability and on the monitoring systems in place. The basic underlying data may come from forest inventories or from other forestry data, such as harvest statistics. The stock-difference method relies essentially on inventories, while the gain-loss method may use information from both, in some cases combined with modelling (cf. Groen *et al.* 2013).

According to the estimates collected and published in Böttcher et. al (2012), the combined Forest Management sink within the EU28 countries is estimated in the range of -350 Mt CO_2 in 2010. The reason for the difference between the estimates in this study and those reported by countries relate to the data being used, the methodological approach, and the pools and subcategories covered. In particular approaches used for estimating emissions and removals of subcategories such as afforestation and deforestation emissions might deviate. It is important to note that the data used in this study are not necessarily applied by the countries in their individual reporting to UNFCCC. Differences may relate to estimates of increment, forest area (in particular the treatment of protected forest areas), biomass expansion factors, and share of harvest losses. In particular the forest harvest levels are an important source of information that may deviate between the average published FAOSTAT numbers and the estimates used by the countries in their own reporting.

As for forest carbon pools, two main methods are available to estimate the magnitude of the national **HWP carbon pool**: *inventory* methods and *flux data* methods. The latter correspond to the *gain-loss* methods where the release of carbon from the pool is estimated by means of information on the carbon flux into the pool and the average retention time of that carbon. In the context of accounting as part of LULUCF the HWP pool is estimated on the basis of information on semi-finished wood product commodities sawnwood, wood-based panels and paper and paperboard (cf. IPCC 2006 and IPCC 2014). The reason for this lies in the availability of data for those categories. They can be derived from national and international statistics like FAOSTAT or UN Comtrade. Applicable information on finished products or uses are hardly available as national sources include data on finished goods only on the basis of production value or per piece (e.g. for furniture). Further information on a specific HWP carbon pool, e.g. wooden houses, which would allow its tracking overtime by means of an inventory method, is not available either. Consequently, most studies on the carbon impact of HWP use flux data methods (e.g. Thompson, Matthews 1989; Winjum *et al.* 1993; IPCC 2006). In this context, it is important to note, that the calculated fluxes from the pool do not necessarily represent carbon fluxes to the atmosphere, but solely the release of carbon from the pool under consideration (e.g. the HWP carbon pool in use).

Discussing the impact of HWP contribution to emissions and removals from its pool changes, it is furthermore essential to differentiate between the terms “method” and “approach”. Where the method, as discussed above, refers to the calculation framework that is used for estimating emissions and removals from changes of the carbon pool, the term approach refers to the system boundary that defines which emissions and removals are to be included in this calculation. The first concept thus defines WHAT is being estimated and reported whereas the later describes HOW the values are derived (cf. Cowie *et al.* 2006).

As summarized by IPCC (2014), “various approaches have been proposed to estimate and report the HWP contribution. They differ in the reference to the atmosphere and the treatment of HWP trade, due to different interpretations of some key terms relevant for the reporting framework.” Winjum *et al.* (1998) identify the stock-change, the production and the atmospheric flow approaches. At COP17 in 2011, UNFCCC Parties could agree on a further production-based approach, which links the origin of the wood to the forests. It has been defined for the purpose of accounting emissions and removals from the HWP pool under the Kyoto-Protocol (KP) (UNFCCC

2012; IPCC 2014). To estimate the storage effect of the material use of wood within a country, estimates have to cover all wood that ends up in this pool within the national boundaries. The calculation of the flux into the carbon pool is thus to be based on the annual consumption values for wood products (i.e. calculated from production plus imports minus exports). This corresponds to the consumption-based *stock-change approach.* In contrast, the *production approach* or the approach as agreed upon for KP accounting calculates the carbon flux into the pool on the basis of carbon domestically produced HWP only. It thus implicitly also includes exports and does not allow to estimate the emissions and removals associated with the HWP pool within the system boundaries of a defined country.

2.1.2 Estimating the GHG impact of products and fuels

The production of semi-finished wood products (i.e. sawnwood, wood-based panels and paper) causes GHG emissions due to the use of thermal and electric energy for the production processes or related to the production of glues and other ancillary materials used in their manufacturing. Semi-finished wood products are further processed to finished wood products destined for the use in different markets, e.g. in the building or packaging sector or for furniture. Finished products are traded just like the semi-finished HWP, and the emissions caused during their manufacturing add up in the GHG balance of the respective producer country. Also during disposal of products, GHG are emitted, e.g. related to transportation, energy consumption during sorting and recycling operations as well as direct emissions from the combustion or decay of the material.

For an integrated quantification of the GHG emissions profile – or the carbon footprint of products, all GHG emissions from the following life cycle stages are to be considered: production (i.e. with raw material extraction, transport, energy generation, production of ancillary materials), use and disposal (i.e. transport, waste treatment processes, disposal processes), as well as potential effects associated with the recycling or energy recovery at the end-of-life. In analogy, GHG emissions profiles of fuels comprise their extraction, processing, transportation and finally their combustion.[14]

A GHG emissions profile is quantified in terms of CO_2-equivalents. This means that all GHG emissions are weighted on the basis of their warming potential as compared to CO_2 and are added up for the different life cycle stages under consideration. GHG emissions associated with products are commonly quantified based on life cycle assessment (LCA), a standardized method to quantify environmental impacts including the direct GHG emissions associated with the manufacturing or the entire life cycle of products and goods.[15] When consumption patterns change, substitution effects can occur. They result from an increased or decreased use of specified goods or fuels with a different GHG profile to meet the same demand for functions and services.

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[14] For fossil fuels, these “upstream” emissions can add up to 15 - 20% of the cumulated GHG emissions from the production and use.

[15] based on ISO standards 14040 and ISO 14044 (cf. ISO 2006a; Ibid. b)

Various international scientific studies suggest that usually the manufacturing of wooden products is associated with lower GHG emissions than their functionally equivalent alternative products (cf. Gustavsson *et al.* 2006; Werner, Richter 2007; Albrecht *et al.* 2008; Sathre, O'Connor 2010). This is why the consideration of potential substitution effects associated with the use wood products is imperative when assessing the GHG implications of different forest management and wood use scenarios.

The fact that GHG emissions are lower than for alternatives – if the wood is sourced from sustainably managed sources – is due to the facts that a) energy consumption tends to be lower for the production of wood products than the production of alternative products, and b) part of the energy needed to produce wood-based products[16] is generated from industrial residual wood along the production chain or directly from forest biomass. Therefore, the "material substitution" from the use of wood is based on (eventually) a lower input of primary energy and on the use of "carbon-neutral" wood fuels instead of fossil fuels.

However, not only do the production processes differ in GHG intensity for wood-based products and their substitutes but also their end-of-life. While wood can be landfilled, recycled as a material or used for energy recovery including the respective substitution potentials, other materials have their own specific end-of-life options and associated substitution potentials.

As mentioned above, wood can also be used as a source of energy. Energy substitution occurs when (sustainably produced) wood is burnt instead of a fossil fuel. The substitution effect is calculated as the difference in cumulated (fossil) GHG emissions of the production chain including the transport, processing and combustion of the fuel needed for the production of an equivalent amount of heat or electricity.

2.2 The ClimWood2030 framework

Shifting GHG balances as well as impacts across several sectors in- and outside the EU have been brought together for analysis by combining a number of separate models which are described in this chapter.

The ClimWood2030 modelling framework is a combination of several models functioning at different scales and covers all the relevant aspects related to the use of forests biomass with regard to its impact on GHG emissions and removals and its contribution to the mitigation of climate change. The models GLOBIOM, G4M and WoodCarbonMonitor have already been applied in a modelling framework within the EUCLIMIT project as well as in the construction of EU forest management reference level (FMRL) projections for DG CLIMA, producing various baseline and reference scenarios based on PRIMES projections of bioenergy production. The Functional Units

[16] Roughly 75% of process energy for wood products manufacturing comes from wood residues (CEI-Bois (2014) Tackle climate change: build with wood. Brussels: Confederation of European wood working industries (CEI-Bois).

model has already been applied in comparable studies on country level, e.g. for Switzerland or Sweden (Taverna *et al.* 2007; Lundmark *et al.* 2014).

Within this study, the models have been used as tools in a scenario analysis in which the impact of concrete assumptions on wood use on total net GHG emissions has been assessed. They allow tracking the shifting of effects between different carbon pools and substitution effects as well as the shifting of carbon storage effects into/out of EU. The modelling framework made it thus possible for the consortium to cover most of the direct and indirect mitigation effects related to use of forest biomass with regard to its impact on GHG emissions and removals and its contribution to the mitigation of climate change:

- **GLOBIOM** is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to provide policy analysis on global issues concerning land use competition between the major land-based production sectors (Havlík et al. 2014). The GLOBIOM model addresses the sourcing and use of forest biomass on the EU level both as a material and fuel, including all wood flows leaving EU-and non-EU forests;
- **G4M** is a geographically explicit agent-based model that assesses afforestation-deforestation-forest management decisions and estimates their impact on biomass and carbon stocks (Gusti 2010).
- The **WoodCarbonMonitor** is a spreadsheet model implementing flux data methods as described by IPCC (IPCC 2006 and IPCC 2014) to estimate delayed emission effects through the material use of wood (cf. Section 2.1.1). It also aggregates available GHG-information of the forest based sector to user-specific snapshots (Rüter 2016)
- The **Model on Functional Units** is a spreadsheet model that combines the wood flows related to an increased and decreased wood of defined wood uses (e.g. wooden wall system) and links them to potential displacement factors resulting from material substitution (cf. Section 2.2.3.3). The model has been specifically developed for the ClimWood2030 model framework and its interfaces. The structure and the modelling approach have been applied in comparable projects on national level (Werner *et al.* 2007, Lundmark *et al.* 2014).

As the project ClimWood2030 assesses the implications of different policy options, the study is interested in the potential consequences of political decision over a time period of up to and beyond 20 years. Given the political targets and challenges of climate change mitigation, the study assumes that the policy options to be assessed imply large-scale structural changes of the economy, for instance related to energy generation technologies, production and transport technologies, etc. This situates the study into a “consequential” assessment context. The consequential modelling context within ClimWood2030 is addressed as follows:

- consequential modelling of changes in wood supply and consumption based on an economic partial equilibrium model (GLOBIOM);
- assessment of resulting displacement factors in a consequential way in LCA (system expansion), selecting marginal technologies where possible or a conservative value where marginal technologies cannot be identified or where LCA data on marginal technologies is not available;

- assessment of the substitution effect as a result of changes in wood consumption (and not as an effect of the use of wood in general).

Within the modelling framework, the market development of wood consumption in defined wood uses is either defined based on the level of semi-finished products by GLOBIOM and then further refined to the consumption of wood in end-uses by market projections ("top-down"), or pre-defined on the level of final wood consumption in end-uses and then used as input to the calculations in GLOBIOM ("bottom-up") (cf. Section 2.2.2 and Annex 1). An overview of the interfaces and information flow within the modelling framework is shown in Figure 2-1.

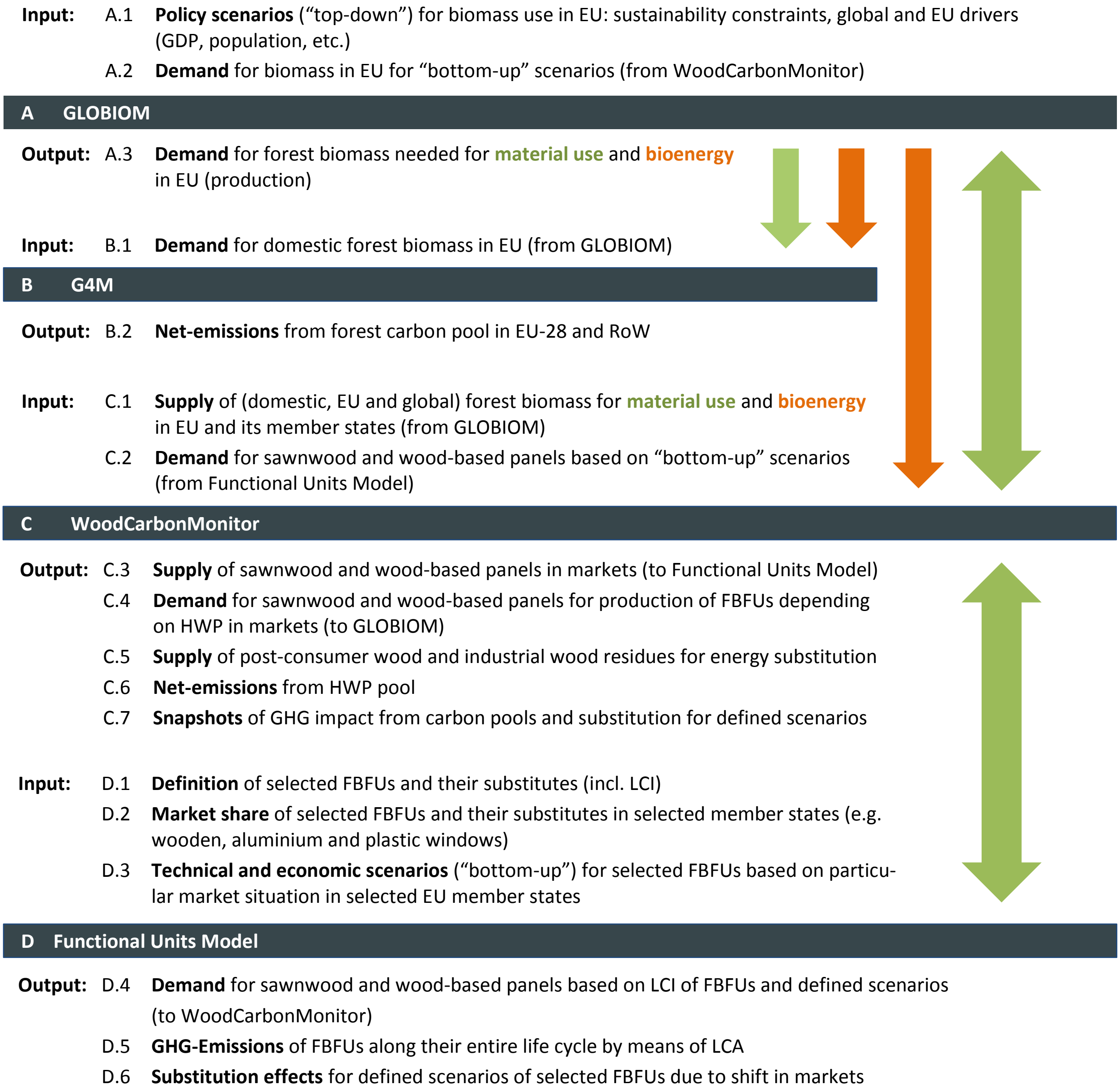

Figure 2-1: Information flow within the ClimWood2030 model framework along the forest wood chain

2.2.1 Applied system boundaries

The spatial system boundary of the ClimWood2030 modelling framework and its coverage of GHG effects are illustrated in Table 2-1.

Table 2-1: Overview of effects addressed in the ClimWood2030 modelling framework

	Inside EU28	Outside EU28	No geographical differentiation
Emissions and removals from **forest carbon pool** change (FM/AR/D)	X	X	
Emissions and removals from **HWP pool**	X	–	
Potential **material substitution** effects from changes of wood consumption in EU28	–	–	X
Potential **energy substitution** effects from changes in consumption of wood fuels within EU28	–	–	X
Substitution effects from changes in wood consumption outside EU-28	–	–	–
GHG emissions from changes in transport due to changes in trade patterns of HWP, (finished products) products made of wood and other materials	–	–	–

The temporal system boundary of the ClimWood2030 modelling framework comprises the years 2010 to 2030. Where relevant and feasible, the analysis was extrapolated, although the full picture with all elements cannot be calculated for after 2030. Substitution effects beyond 2030 that are related to the end-of-life and cascade use of wood products that have been produced between 2010 and 2030 have been estimated up to 2100. These effects need to be considered when collection, recycling and energy recovery rates change between scenarios that can lead to shifts of substitution effects over time.

Since this study intends to estimate the implications on the GHG budget associated with the use of biomass within EU, it is necessary to apply the *stock-change approach* for estimating emissions and removals from the HWP pool (cf. 2.1.1.2). In consequence, the calculations of the annual carbon fluxes into the HWP in use pool are based on the consumption data. This results in an adequate estimate of net emissions from the HWP pool change within the boundaries of the EU member states.

2.2.2 Scenario development

The starting point for the study is the EU 2030 climate and energy framework, framed within the context of EU targets for renewable energy for 2030 and 2050. In this context, to maximise comparability with other EU studies, a reference scenario had to be specified as close as possible to that of the 'EU Reference Scenario[17]' used in the 2014 EU Impact Assessment[18] (hereafter referred

[17] European Commission. EU Energy, transport and GHG emissions trends to 2050. Reference scenario 2013. (2013).

to as the “2014 IA report”). The *ClimWood2030 reference* scenario depicts a development trajectory wherein current policies remain unchanged, no new policies come into play, and no major changes from past trends occur. Targets set in EU Member States National Renewable Energy Action Plans are assumed to be met. In addition to the reference scenario, a number of policy scenarios were produced to outline the climate impacts of radically contrasted policy choices and analyse their implications. Each policy scenario is built around a clear storyline and focuses on a single issue. To allow a clear identification of the consequences and trade-offs related to the policy developments analysed, change in assumptions in a policy scenario only affects a part of the modelling framework being used. With this construction, differences in outcomes between the *ClimWood2030 reference* scenario and a policy scenario can be directly attributed to the issue that the policy scenario is reflecting.

Five scenarios have been defined, which are presented in detail in chapter 3:

I ClimWood2030 reference scenario
II Increase forest carbon stock in EU forests
III Cascade use – increase recovery of solid wood products
IV Cascade use – prevent first use of biomass for energy
V Strongly increase material wood use

Once again, It should be stressed that:

The scenarios developed for this analysis should be considered as thought experiments and not as assessing the impacts of actual policies. They are only meant to outline the magnitude of potential changes in EUs forest based sector and to estimate the impact on overall GHG balances caused by policy changes and wood-related market developments within the next 15 years.

The acceptability, feasibility, as well as full social, environmental and economic impacts of such policies have not been fully assessed.

None of the scenarios – not even the reference scenario – is more likely to occur than any other. In all probability the future will consist of a mixture of the scenarios - along with some unexpected elements. The scenarios present projections for each of the parameters presented in Section 3.1 for EU-28 as a whole, although the calculations are by country, or, in some cases, use a spatial reference framework. The projections are for 10-year periods: the base period (2000-2010) and the ten year periods finishing in 2020 and 2030.

For each scenario the team has identified “policy instruments linked to the scenario”, which are the policy instruments which could be necessary to achieve the goals set out in the scenario story-

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[18] European Commission. Impact Assessment: Accompanying the Communication; A policy framework for climate and energy in the period from 2020 up to 2030. (2014).

line. They are in no way policy recommendations by the ClimWood2030 team, rather an exploration of what could be implied for policy instruments in the circumstances of the scenario under consideration.

Beyond the scenario development on this overarching level, scenarios had to be developed regarding the changes in end-uses of wood, i.e. related to the material substitution effects. These "bottom-up" scenarios were developed based on a market analysis of the current and projected end-use of, for which specific displacement factors were derived for the purpose of this study. Further details on this market analysis can be found in Annex 1.

2.2.3 Material and energy substitution estimates

First of all, it has to be emphasised that in the ClimWood2030 modelling framework the substitution potential of using wood can only be assessed as a combination of the material and energy substitution potential jointly with the effects on forest carbon pools. Due to the dual nature of wood as a material and as a fuel, a clear distinction has to be made, between the effect of "material substitution" and "energy substitution" to avoid double-counting.

This means for the general modelling framework of the project ClimWood2030 that:

- The wood used as energy for the production of wood products is not accounted for under energy substitution (but is the fundamental basis for the material substitution potential, as described above);
- The industrial residual wood leaving the sector of wood industries (i.e., where industrial residual wood is not used internally for the production of other wood-products and where it is thus not accounted for under material substitution) is considered wood for energy use, and the substitution potential accounted for under "energetic substitution";
- Wood used for maintenance has been quantified as part of production and their end-of-life as part of the end-of-life of the entire wood products (cf. FBFU in chapter 2.2.3.1);

  Post-consumer wood is landfilled, recycled and used for energy recovery according to current statistics (JRC 2010b). In the case of material recycling, we assume that the use of chips from forestry at equivalent moisture content is substituted; in the case of energy recovery, the replacement of the current fossil fuel mix used for heat production has been assumed (cf. chapter 2.2.3.4). No substitution potential has been attributed to post-consumer wood disposed of in landfills. Table 2-2 provides an overview of assumptions that have been made regarding the end-of-life destiny of solid wood products for the different scenarios.

Table 2-2: Assumptions on the end-of-life destiny of wood products, excluding fibreboards. (Nemry *et al.* 2008; Mantau *et al.* 2010; own assumptions). Unit: Share of volume of wood products reaching the end of life, %

	2010	2030 all scenarios, except:	Cascading 2030 – increased recovery of solid wood products
landfill	32 %	20 %	1 %
energy recovery	58 %	69 %	85 %
material recycling	10 %	11 %	14 %

- To illustrate the shifting of timing in the increased cascading of wood in particleboard, the recycling & energy recovery and substitution potential is expressed separately for wood that is being recycled as a material after the first life cycle, assuming the same ratio of end-of-life options as described in Alwast et al. (2009).

2.2.3.1 Definition of Forest-Based Functional Units

Substitution effects and thus the displacement factors can only be determined for functionally equivalent products. In the context of LCA, this basis for comparison is named ‘functional unit’. As ClimWood2030 is interested in functional units of wood products, the study refers to a ‘forest-based functional unit’ (FBFU) as the basis for comparison to quantify material substitution potentials.

It is not possible to carry out this detailed analysis for all the many uses for wood products. This section describes how the forest-based functional units included in this study have been selected and their potential alternatives been defined.

The FBFUs considered in ClimWood2030 were selected based on (expected) market shares, the existence of substituting non-wooden products, comparably long service lives, the availability of LCI information, etc. Projections on wood market shares development derive from estimated current market shares which may contain uncertainty. Nevertheless, we consider them as the best consensus based on literature review and expert knowledge. Beyond that, their consumption in EU-28 should be affected by the policy choices assessed in this project. The sum of FBFU modelled within the context of this study amount to approximately 30 % of the total EU wood market in 2010 and cover between 17% and 43% in 2030, depending on the scenario assumption on the change in wood consumed as a material.

Where relevant, FBFUs have been designed to be functionally equivalent during the use phase, e.g. regarding their energy saving performance. In the case of construction elements, 3 different climate zones were distinguished and the construction elements designed to meet the specific energy related requirements defined for this climate zone. In the case of pallets, the specific logistics and transport distances and means were considered as part of the displacement factor for “production”. The same holds for maintenance activities such as re-painting of wooden windows or claddings.

Table 2-3: Selected FBFUs and their substitutes included in the ClimWood2030 project, by sector.

Sector	Forest-based functional unit	Substitutes
Construction: core and shell[19]	Exterior walls: wood frame, cross-laminated timber, log wall (for 3 climate zones, as commonly used)	Exterior walls: brick masonry, reinforced concrete, brick cavity walls, sand-lime brick masonry, breeze concrete, aerated concrete blocks (for 3 climate zones, as commonly used)
	Interior walls (load-bearing): wood frame construction, wood construction (for 3 climate zones, as commonly used)	Interior walls (load-bearing): brick masonry, reinforced concrete, sand-lime brick masonry, breeze concrete masonry (for 3 climate zones, as commonly used)
	Interior walls (non-load-bearing): wood frame construction with different claddings (2 designs)	Interior walls (non-load bearing): plaster board (2 designs)
	Storey ceilings without thermal requirements: laminated veneer lumber, wood joist ceiling	Storey ceilings: reinforced concrete
	Storey ceilings with thermal requirements: wooden beam construction, solid timber element, wood element (for 3 climate zones, as commonly used)	Storey ceilings: reinforced concrete, several designs (for 3 climate zones, as commonly used)
Construction: secondary structure, interior works	Insulation material: wood fibre board	Insulation material: rock wool, glass wool, Polystyrene (XPS, EPS), PUR/PIR
	Windows: wood, wood/Al	Windows: PVC, aluminium
	Claddings (exterior): sawn timber hardwood, pressure vessel treated softwood, painted softwood	Claddings (exterior): fibre cement, cement, stone, aluminium, zinc, steel, HPL
	Flooring: laminate	Flooring: resilient flooring, PVC
	Flooring: parquet (solid, multi-layer)	Flooring: ceramic tiles, artificial stone
Packaging	Pallets (wooden)	Pallets (plastic)
Furniture	Office furniture: wooden filing racks/shelves	Office furniture: filing racks/shelves from steel)
Chemistry	Lignin as adhesive	Phenol for adhesives
Textiles	Viscose	Fibres from oil derivates (PET, recycled PET, polyamides)

Where applicable, FBFUs and their alternatives are compared based on the same service life; replacements of materials or products shorter estimated service life are considered *pro rata temporis* to meet the assumed service life.

Table 2-3 contains the list of selected forest-based functional units (FBFUs) that were identified to be relevant in the context of material substitution potentials in ClimWood2030.

The derivation of the resulting displacement factors "per kg wood" is described in the following section.

[19] Due to limitations of LCA data availability on the building level, the substitution potentials in core and shell have been calculated at the level of construction elements. Due to the current and expected market shares of wood in construction, we concentrate our considerations on residential buildings, notably single and multi-family houses, including multi-storey houses. We are confident, however, that the order of magnitude of the displacement factors derived for wood in construction are also reasonably applicable to these types of buildings.

2.2.3.2 Displacement factors

As an intermediate result of this study, displacement factors were derived for all FBFUs defined in chapter 2.2.3.1 as well as for the relevant flows of wood used for energy purposes outside wood industries (cf. chapter 2.2.3).

A "displacement factor" in this study measures the extent to which a wood product or fuel generates less (or, occasionally, more) GHG over its whole life cycle than a functionally equivalent material or fuel. It is measured in kg CO_2e per kg of wood product (or kg CO_2e per MJ wood fuel input for energy uses). A negative value for the displacement factor indicates that the use of a wood product generates fewer greenhouses gases than another material. Each displacement factor is specific to a particular functional unit.

All displacement factors derived are calculated based on LCA in line with ISO 14044 (cf. Section 2.1.2). More specifically, as far as possible and applicable, the methodological settings of EN 15804 have been followed in the quantification of the GHG profiles. This holds particularly for the system boundary setting, co-product allocation and for the end-of-life modelling as well as possible benefits and burdens beyond the product system.

For the **use of wood as material**, displacement factors have been derived for three stages of the FBFU's life cycle (cf. Section 2.1.2):

- If not described otherwise, „**production**" encompasses raw material extraction, energy generation, transport, etc. related to the production of the wood product and its alternative plus, in the case of construction products, their transport to the construction site.
- The "**end-of-life**" encompasses the transport of the materials of the wood product and its alternatives to a waste processing site, any recycling, recovery and disposal activities (as applicable) as well as potential benefits from substituting primary material or fossil fuels (quantified for net flows only, in accordance with EN 15804).
- Given the short assessment period (up to 2030) as compared to service lives of wood products which may be as long as 80 years, also potential substitution effects that will occur after 2030 have been included in the assessment. This assumed **cascading effect** is covered up to 2100. This allows us also to depict shifts in the timing of energy recovery for scenarios where – as a result of different policies – we increase the share of material recycling of post-consumer wood (instead of landfilling or energy recovery) into particle board. This leads to a delay of the effect of energy recovery for the average service life of particle board (after the next material use) as compared to the reference case (but to an additional substitution potential due to recycling for the end-of-life of the "first" wood product).

For the production phase, an increase in energy efficiency by 20 % up to 2030 has been assumed.[20] Effects related to biogenic carbon in wood have not been included in the emission and displacement factors, as the emissions from burning wood are already covered by the estimates on emissions and removals from biogenic carbon pools in the WoodCarbonMonitor (cf. Figure 2-1).

It may be assumed that an increase in the share of post-consumer wood input into particleboard results in a lower demand for heat (because of dryer material input). However, as a large share of the heat for particleboard production is generated from biomass, the savings of GHG emissions from fossil fuels attributable to increased use of post-consumer material have been ignored, as a conservative assumption.

The policy options considered in ClimWood2030 do not only affect the production and disposal of FBFUs; they can also affect the amount of post-consumer wood from FBFUs that has been recycled into particleboard (as currently the only standard option for wood recycling) as a second life cycle of this commodity. For the net changes in these flows of post-consumer wood, the same assumptions have been applied as for post-consumer wood from the FBFUs defined to quantify material substitution effects (see below).

It should be noted that within the modelling framework, the effects on forest carbon pools – and thus the linkage of the sourcing of timber to the production of HWP – are calculated in GLOBIOM and G4M.

Concerning the **use of wood as solid biofuel**, the general modelling framework of ClimWood2030 distinguishes:

- energy wood from forests that is used in non-industrial installations;
- energy wood from forestry that is used in industrial installations outside wood industries;
- industrial residual wood that is used as a fuel (in the form of chips and pellets) outside the wood industries;
- post-consumer wood used for energy outside wood industries from wood products that have been produced before 2010.

As the amounts of these wood flows differ between the different scenarios, specific displacement factors for each of these wood flows have been developed. To avoid double counting with the displacement factors for material substitution, following fractions of wood are always subtracted:

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[20] Reflecting an assumed increase in energy efficiency in industries by 1% over 20 years. According to a communication by the European Commission, energy intensity in EU industry decreased by almost 19% between 2001 and 2011 (source: ec.europe.eu/energy/en/topics/energy-efficiency, accessed on 2.11.2015). This value, however, is related to economic turn-over and not to physical production, i.e. this value included also effects related to de-industrialisation. It may further on be assumed that these savings represent the „low hanging fruits"; a further increase in energy efficiency might come at proportionally higher cost.

- the share of the respective amounts of wood that are used for the production of the wood products, i.e. the amounts that are used within wood industry either as a material or as a fuel;
- the amount of wood of post-consumer wood that is associated with the production of wood products that have been produced after 2010, for which all substitution effects over the whole cascade have been integrated in the material substitution factors.

2.2.3.3 ClimWood2030 material substitution

Table 2-4 contains the displacement factors for the scenarios under consideration which are relevant for material substitution. The three columns reflect the displacement that has been defined for the three life cycle stages (2.2.3.2). They are the same in all the scenarios, with one exception, the 'Cascading – increase recovery of solid wood products' scenario as there is a significant difference for the displacement factors in this scenario due to changes in the end-of-life parameters, resulting from the scenario assumptions.

It should be borne in mind that the values in Table 2-4 refer to 1 kg of wood product as consumed between 2010 and 2030; thus the value for the end-of-life scenario reflects the effect of the GHG implication of the end-of-life scenario for this kg of wood product – including landfilling, recycling and energy-recovery – as compared to the GHG implications of the equivalent amount of competing materials/products. In analogy, the cascading effect covers the GHG implications of the end-of-life scenario of the amount of the original wood product that was recycled in its first end-of-life; the values in Table 4-4 again refer to 1 kg of wood product as consumed between 2010 and 2030, i.e. the first wood product (and not to 1 kg of wood that is cascaded)[21].

For all FBFUs and competing products, several alternatives were considered. The figures in Annex A.2.2 illustrate the range of displacement factors, first for the production, end-of-life, the total of production + end-of-life and the cascading effect for the construction elements included in the core & shell, and for all FBFUs as integrated in the calculations.

It can be concluded that despite the wide range of the displacement factors for certain FBFUs, the use of wood products leads to GHG savings over the total life cycle as compared to the use of the alternative products under consideration. However, the timing of the GHG savings as the sum of the displacement factor for production and end-of-life is different for each FBFU. In the case of alternative products such as windows or claddings made from metals (steel, aluminium), the initial savings from using wood are high; however, due to the high recycling potential for metals, these savings are partly compensated during the end-of-life phase. For other FBFUs, such as wood used in core & shell, for claddings, laminates, office furniture, pallets, textiles or polyol produc-

[21] This is due to the structure of the FBFU-model, which is set up as a cohort model with the initial input of wood products as the reference flow for the modelling. Alternatively an explicit material flow model could have been set up, where GHG impacts would have been expressed per kg of the effective flow.

tion, both the production as well as the disposal of the wood product leads to over-all GHG savings (see Table 2-4).

The value for the cascading effect is rather small; this is due to the fact that according to European statistics, roughly 14 % of post-consumer wood[22] is currently recycled and available for a subsequent end-of-life scenario (comprising landfill, recycling and energy recovery). This means that the cascading effect quantifies the effect of a very minor part of 1 kg of wood, originally being consumed as part of the FBFU. In addition, some FBFU such as wood fibre insulation board cannot be recycled.

Table 2-4: Displacement factors for the scenarios under consideration and specifically for the *Cascading – increase recovery of solid wood products* scenario, per kg HWP in FBFU.

	Production		End-of-life		Additional cascading effects	
	2010	2030	2010	2030	2010	2030
	kg CO_2-eq./ kg HWP	kg CO_2-eq./ kg HWP	kg CO_2-eq./ kg HWP	kg CO_2-eq./ kg HWP	kg CO_2-eq./ kg HWP	kg CO_2-eq./ kg HWP
GENERAL VALUES						
Core & shell	-1.58	-1.26	-1.11	-1.11	-0.137	-0.137
Insulation	0.398	0.318	-1.17	-1.17	0	0
Windows	-5.53	-4.42	2.21	2.21	-0.133	-0.133
Claddings	-0.902	-0.722	-0.431	-0.431	-0.172	-0.172
Laminates	-1.52	-1.22	-1.19	-1.19	0	0
Parquet	0.0164	0.0131	-0.924	-0.924	-0.133	-0.133
Pallets	-0.442	-0.354	-0.861	-0.861	0.149	0.149
Office furniture	-0.728	-0.582	-0.66	-0.66	-0.123	-0.123
Polyol	-0.770	-0.616	-1.24	-1.24	-0.149	-0.149
Textile	-4.53	-3.62	-0.345	-0.345	-0.0689	-0.0689
VALUES SCENARIO CASCADING – INCREASE RECOVERY OF SOLID WOOD PRODUCTS						
Core & shell	-1.58	-1.26	-1.37	-1.37	-0.156	-0.156
Insulation	0.398	0.318	-1.44	-1.44	0	0
Windows	-5.53	-4.42	1.98	1.98	-0.165	-0.165
Claddings	-0.902	-0.722	-0.715	-0.715	-0.214	-0.214
Laminates	-1.52	-1.22	-1.47	-1.47	0	0
Parquet	0.0164	0.0131	-1.14	-1.14	-0.165	-0.165
Pallets	-0.442	-0.354	-0.861	-0.861	0.149	0.149
Office furniture	-0.728	-0.582	-0.923	-0.923	-0.154	-0.154
Polyol	-0.770	-0.616	-1.53	-1.53	-0.228	-0.228
Textile	-4.53	-3.62	-0.387	-0.387	-0.0773	-0.0773

[22] Indufor (2013): Study on the wood raw material supply and demand for the EU wood-processing industries, final report. Indufor, Helsinki, 140 p. Please note that the percentage is considering post-consumer wood used in wood industries – i.e. particle board industries exclusively. Other sources include other products such as mulch or animal bedding as recycled wood; we expect these products not to be produced from post-consumer wood but from industrial residual wood and suspect higher number of wood "recycling" of wood to be due to unclear terms and definitions in national statistics.

How do these values compare to existing studies? Sathre and O'Connor (2010) made a meta-analysis of existing studies on material substitution effects from the use of wood. They derived an average displacement factor of 2.1 kg CO_2/kg CO_2 in the wood product. Figure 2-2 illustrates how the values derived in this study compare to this value from literature.

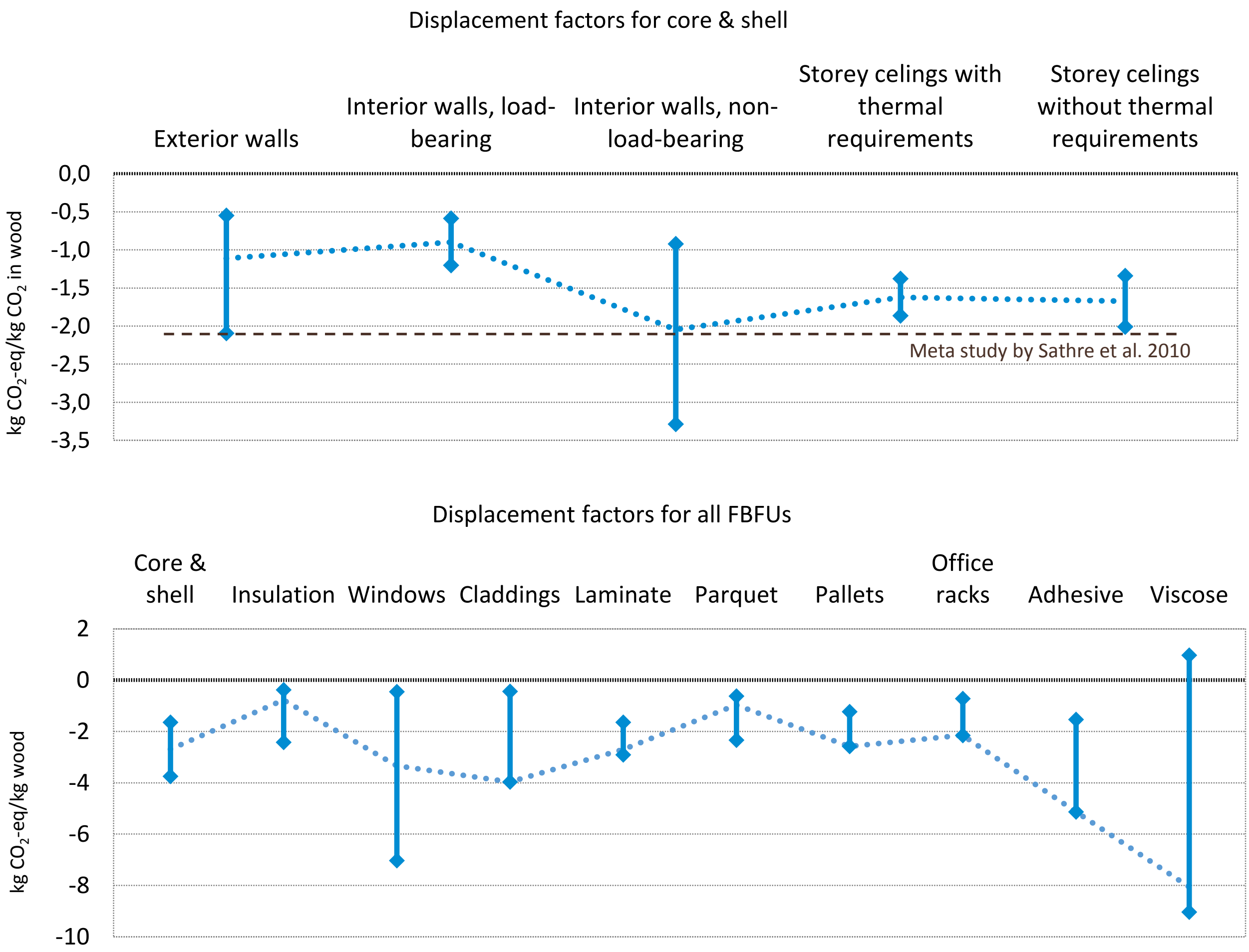

Figure 2-2: Range of displacement factors (general values) for the sum of production and end-of-life (total life cycle), per kg CO_2 in wood product in FBFU as compared to Sathre and O'Connor (2010) (Werner *et. al* 2015). Dotted line: value used in calculations (determined as average or weighted average, depending on the availability of market information).

The displacement factors derived in this study tend to be lower (more conservative) than the value proposed by Sathre and O'Connor (2010). This is mainly due to the fact that many studies they covered include the substitution potential of residual wood generated during the production of the wood product – usually energy recovery and replacement of fossil fuels – as part of the displacement factor for material use. The approach used by Sathre and O'Connor is thus not fully consistent with the modelling framework of ClimWood2030.

In the ClimWood2030 modelling framework, this residual wood is partly used for the production of other wood-based products – the effect being covered in the material substitution of these other wood products – and only partly used for energy recovery outside the wood sector – which is covered under energy substitution. Beyond that, this study also covers products that have not been covered in the meta-analysis by Sathre and O'Connor (2010).Taking into consideration these methodological differences in the quantification of the displacement factors, the range of displacement factors applied in this study confirms the findings of international scientific research, i.e. using one ton of wood instead of one ton of alternative materials saves one to two tons of CO_2 on average, and up to four tons in the case of wood based textiles, over a full life cycle. This conclusion is also important in the light of the fact that the displacement factors have been derived on a case specific basis, e.g. in the context of construction elements. We conclude that the displacement factors applied in this study allow us to reasonably quantify the order of magnitude of the substitution potential of wood used as a material.

2.2.3.4 ClimWood2030 energy substitution

Table 2-5 summarises how the displacement factors in kg CO_2e per MJ wood fuel input have been derived for the different types of wood fuels. We assume that the resulting heat replaces the estimated average fossil fuel mix for heat production in EU-28 (roughly 55 % natural gas, 30 % hard coal, 9 % brown coal and 6 % oil except for domestic use of wood for which we assume substitution of natural gas), which reflects the potential contribution to a substantial reduction of the consumption of fossil fuels as one key target of European policies. Furthermore, we assume that the generated electricity is replacing the current European grid mix "ENTSO"[23].

Boiler efficiencies for the pellet boiler and the chipped wood boilers are taken from ecoinvent 2.2; the efficiencies of the other boilers have been derived from Eur'ObservER (2015) and CEPWEP (2010).

Note also that the use of forest biomass for energy purposes in private households is not covered explicitly in FAO statistics. This use is considered not to be affected by the policy choices underlying the different scenarios, i.e. it is assumed that the use of forest biomass in private households is the same in all scenarios. Therefore, this effect can be disregarded when comparing the different scenarios.

[23] i.e. the electricity mix provided by the European Network of Transmission System Operators for electricity, represented in the ecoinvent dataset „electricity, medium voltage, production ENTSO, at grid".

Table 2-5: Emission factors and potential displacement factors for the different wood flows within the general modelling framework of ClimWood2030 that are used for energy outside wood industries.

	Pellets, mixed, burned in furnace 50kW	Wood chips, from forest, hardwood, burned in furnace 1000kW	Wood chips, from forest, softwood, burned in furnace 1000kW	Wood chips, from industry, hardwood, burned in furnace 1000kW	Wood chips, from industry, softwood, burned in furnace 1000kW	Wood chips, post-consumer wood, burned in furnace 1000kW	Heat, softwood logs, at furnace 30kW	Heat, hardwood logs, at furnace 30kW
Emission factors for wood fuels								
kg CO_2 e./MJ fuel input[24]	0.0111	0.00332	0.00392	0.00257	0.00272	0.00183	0.00517	0.00595
Characteristics of energy generation								
Overall efficiency	85 %	82 %	82 %	82 %	82 %	82 %	68 %	68 %
of which heat	100 %	88 %	88 %	88 %	88 %	88 %	100 %	100 %
of which electricity	0 %	12 %	12 %	12 %	12 %	12 %	0 %	0 %
Energy produced per MJ fuel input								
MJ heat output	0.8475	0.7216	0.7216	0.7216	0.7216	0.7216	0.6993	0.6803
kWh electricity output	0	0.027	0.027	0.027	0.027	0.027	0.000	0.000
Emission factors for substitutes								
kg CO_2 e./MJ heat output fossil fuel mix	0.0973	0.0973	0.0973	0.0973	0.0973	0.0973	0.0690	0.0690
kg CO_2 e./kWh electricity output ENTSO	0.491	0.491	0.491	0.491	0.491	0.491	0	0
Displacement factors per MJ wood fuel input								
kg CO_2 e./MJ fuel input		-0.0803	-0.0797	-0.0810	-0.0809		-0.0431	-0.0410
kg CO_2 e./MJ fuel input	**-0.0713**	**-0.0799**		**-0.0809**		**-0.0684**	**-0.0421**	

Note: We assume a share of 72 % of softwood in energy wood from forestry and 72 % of softwood in industrial residual wood.

2.2.3.5 Concluding remarks on displacement factors and substitution potentials

The ClimWood2030 study is intended to consider scenarios on the future use of wood and wood-products as well associated GHG emissions and substitution potentials to 2030 and beyond. Within this timeframe, we may expect:

- changes in product design, e.g. due to higher insulation requirements for exterior walls, both for wood products and their alternatives;
- technological development in the production of wood products, their alternatives as well as in the production of ancillary materials and semi-finished products used in production;
- changes in energy supply technologies, e.g. related to an increased share of renewable energies, a shift to electricity driven processes (instead of combustion processes) for instance in transportation, implementation of GHG efficient technologies such as carbon capture and storage in the context of fossil fuel combustion, etc.

[24] Based on datasets from the updated ecoinvent 2.2.

This has fundamental implications for the determination of future GHG emission profiles:

- available LCI/LCA data describe current technologies, for both production and energy generation; under current LCA practice and available software it is virtually impossible to calculate time-dependent forecasting emission profiles, which would incorporate the expected change in technologies,
- current product design is known, but future product design, particularly in the building sector, largely depends on future political goal settings, e.g. in the future development of the European Energy Performance Directive.

The ClimWood2030 scenarios are based on a) current product design and b) current production technologies; however, it is safe to assume that the production technologies for both wood-based products and their alternatives will become more GHG-efficient and that thus the material displacement factor per FBFU may decrease over time. Within the modelling framework this is implemented as a general “carbon-efficiency”-factor of -20 % on the displacement factors for the production of FBFUs.

We do not assume such a factor for energy substitution as the replacement of fossil fuels and reduction of GHG emissions are likely to remain a primary policy goal up to 2030.

This study does not attempt a guess on the feasibility, coverage and GHG effect of carbon capture and storage (CCS) technologies as regards the emission profile of fossil fuel combustion. Broadly speaking about material substitution effects, two mechanisms can occur, for a given level of demand:

- an increasing use of wooden products and/or fuels leads to a reduced use of alternative products;
- a decreasing use of wooden products and/or fuels leads to an increased use of alternative products and thus to a substitution of wooden products or fuels.

This holds true if the geographical area of consumption/use considered in a study is identical to the geographical area of total (potential) production. In the context of the ClimWood2030 project, the area of consumption/use is defined as EU-28, whereas the potential area of production for both wooden products/fuels and their alternatives in theory can be global. This brings economic mechanisms into play, e.g. that:

- A decrease in wood consumption in EU-28 could lead to or could be a consequence of:
  - an increased export of wood products, which would lead to an increased use of alternative products in EU-28 but to a decreased use of alternative products outside EU-28 – basically cancelling out the two substitution potentials inside and outside EU-28 (except for effects related to differences in production and disposal technologies and transport).
  - a decreased import of wood products, which would lead to an increased use of wood products outside EU-20 but to a decreased use of wood products inside EU-28 – again

cancelling out the two substitution potentials inside and outside EU-28 (except for effects related to differences in production and disposal technologies and transport).

Analogous considerations can be made for a scenario with an increase in wood consumption within the EU-28.

While these effects can (partly) be addressed for roundwood and semi-finished products like sawn timber and wood- based boards in the partial equilibrium model GLOBIOM, changes in imports/exports of finished products, i.e. the FBFUs as such, could not be addressed in the modelling framework. Consequently, we have to assume that the EU/non-EU trade balance remains unchanged for all FBFUs. For the time being this is considered a minor implication as for the major share of wood flows covered by the FBFU, i.e. wood used in core and shell, it is safe to assume that the large majority of finished wood construction is produced from semi-finished products (which are covered in GLOBIOM) and used within EU-28. This, however, is not necessarily true for other FBFUs such as furniture or laminates.

Shifting of production into or out of EU-28 in line with the scenario considerations has direct consequences for the quantification of the GHG emission profiles of wood products and their alternatives, not only related to transport but also related to production technologies, electricity mixes, waste treatment technologies in place, etc. Such scenario-dependent geographically explicit emission factors for wood products and their alternatives were impossible to generate due to the lack of respective LCI/LCA data.

Some publications have argued that substitution potentials might not be 1:1 but that substitution would only be partial (York 2012, Bird 2013). It is reasoned that an additional supply of (wood) products/energy would lower the price of all functionally equivalent products and/or energy and thus – according to micro-economic reasoning – would increase the overall demand (previously deemed pre-defined). While in theory, such effects are conceivable, particularly in the energy market, we have not come across any literature that investigates such effects for construction products and other products covered in this study in a scientifically sound way that would allow us to include this effect in a structured and well-founded way. Therefore, we base our work on the assumption that it is not the availability and pricing of wooden products that determine the level of construction and the consumption of other FBFUs (*how much*?) in EU-28, it rather determines *how* it is built. We also emphasis that substitution „effects“ always have to be considered to be “potentials” meaning that substitution not necessarily eventuates in any case.

2.3 Quick overview of potential policy instruments and strategies[25]

The ClimWood2030 study is for the use of policy makers, so that they can take decisions based on objective evidence of the potential consequences for the climate of their actions and choices. For that reason, the quantitative analysis of the outlook, based on models and FBFUs, is linked to the policy instruments which the decision makers have at their disposal. One of the many challenges of the study is to link the outputs of the scenarios with the specific instruments which policy makers may wish to implement. This section provides a brief overview of the types of policy instrument available to policy makers in the area covered by Climwood2030, the main characteristics of these instruments and which relevant policy instruments are in place at the EU level.

The issues are complex and at the intersection of many areas: economics, ecosystems, climate, forest management, construction, industry, trade, and others. The same policy instrument may contribute to several different policy goals, and policy goals may be achieved through several policy instruments. This situation makes it difficult to establish simple cause-effect relationships, linking for instance a policy instrument with a given feature of a scenario.

Furthermore, policy instruments may operate at many different levels (local, national, EU, pan-European or global), but this study focuses on the national and EU levels. In this study, "national" level policies also include the subnational level in those countries – such as Belgium, Germany, Italy, Spain or the UK – where forest policy is devolved, in whole or in part, to the subnational level.

In this study, the policy instruments and strategies have been classified into three groups:

- *Regulation*, such as laws, directives and administrative orders. Regulation may be either "hard" – legally enforceable directly – or "soft", which may be defined as sets of rules which are not legally binding, but may have great influence.
- *Financial/economic*, which includes subsidies and incentives to encourage desired actions and discourage those which are not desired. Actions of public actors, such as state forest organisations, have been put in this category, as the state may in some cases bear the costs of actions which benefit society as a whole.
- *Informational*, which includes extension services, consensus forming through dialogue (e.g. national forest programmes, or other national or regional strategies or plans), advice to market actors (such as forest owners), communication/PR, coordination of actions, agreement on voluntary targets, etc.

There would obviously be differences between these categories in terms of speed of implementation, cost, need for political consensus, legal acceptability etc.

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[25] This section summarises the deliverables of WP 4.1 of the project which contain significantly more detailed information and discussion.

2.3.1 Types of policy instruments and strategies which might have an influence on the use of solid biomass for climate change mitigation

Table 2-6 lists relevant types of policy instruments and strategies, under the three categories defined above, by policy area, starting from policy instruments closely linked to the forest sector, and then moving to others focused on different, often broader, fields which influence the forest sector. It shows clearly the wide range of policy instruments which might influence the area under consideration.

Table 2-6: Types of policy instruments and strategies at national or EU level which influence the use of solid biomass for climate change mitigation.

	Regulation	Financial/economic	Informational
Forest management	Forest law Certification	Support for defined forest operations and measures Afforestation programmes	National forest programmes Wood mobilisation strategies
Forest-based industry		Charges for disposal of residues and used products in landfill Support for innovative products and processes Guaranteed wood supply from public forests	National and regional industrial strategies
Trade	Conditions for access to markets Generalised Scheme of Preferences (GSP)	Voluntary Partnership Agreements under FLEGT[26]	
Energy efficiency	Mandatory standards for energy efficiency Green building codes	Support for efficiency measures	Consumer information
Renewable energies	Mandatory targets Technical standards	Support for renewable energy production and consumption incl. feed-in tariffs Investment by publicly owned utilities etc.	National Renewable Energy Action Programmes
Climate change mitigation[27]	Targets under international binding agreements	Carbon taxes Carbon markets Support for fire management and prevention, and pest/disease control	National GHG inventories
Climate change adaptation			National forest programmes
Building and construction	Mandatory building standards Green building codes		
Fiscal policy		Carbon taxes Special fiscal measures in the field of forest management[28]	

[26] VPAs have regulatory, economic and informational dimensions, so could be included under all three headings.

[27] Only includes general climate change mitigation measures, and not those associated with specific sectors such as energy efficiency or renewable energy, which are listed separately.

	Regulation	Financial/economic	Informational
Environment	Conservation of biodiversity Air and water quality standards	Support for environmental projects	
Sustainable production and consumption	Mandatory performance standards “Green public procurement” Hygiene regulations	Support for reuse and recycling	Consumer information and promotion of sustainable raw materials
Agriculture and rural development	Regulations on agriculture	Agricultural support schemes and policies	Strategies for long term rural development
Regional Development		Economic support to regional development	
Research		Support for research on topics related to optimal biomass use	

2.3.2 Existing EU level policy instruments and strategies in this domain

There are many existing EU policy instruments which will influence the use of solid biomass for climate change mitigation, directly or indirectly. They include 14 binding regulations in the areas of trade, energy, climate change, building and construction and environment, and 11 instruments which are considered “informational”, such as strategies and guidelines. In addition, there are four major funding systems which are based on legally binding regulations, but which allow considerable leeway to funding agencies to decide which activities should receive financial support. All four funding systems allow for actions in the area covered by ClimWood2030, each according to its own terms of reference and rules.

Relevant EU policy instruments in place or under discussion include:

- EU Forest Strategy (2013);
- Communication on innovative and sustainable forest-based industries in the EU (2008);
- EU Timber Regulation (EUTR) (2010) (2013);
- FLEGT Regulations (2005, 2008), and tentative EU Action Plan on Deforestation/REDD+;
- Directive on the energy performance of buildings (recast) (2010);
- Energy efficiency directive (2012);
- Energy Roadmap 2050 (2011);
- Renewable Energies Directive (RED) (2009);
- Proposed revision to Directives on fuel quality and renewable energies (2012)(at present nearing the end of the approval process);

[28] To address specific features of the sector, such as long time scale and irregular income. Examples are complete exclusion of forest management from the tax system, taxation of physical forest increment, not revenue from sales, exclusion of forest estates from inheritance tax etc.

- Proposed Directive on medium combustion plants (2013);
- Decision on LULUCF accounting rules (2013);
- EU Emission Trading Scheme (ETS) Directive and revision (2003, 2009);
- EU strategy on adaptation to climate change (2013);
- 2030 Climate and energy policy framework;
- Regulation laying down harmonised conditions for the marketing of construction products (CPR) (2011);
- Directive on the energy performance of buildings (recast) (2010);
- Habitats Directive (1992, and revisions);
- LIFE+ Regulation (2007, 2013);
- Biodiversity Strategy (2011);
- Action Plan on Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) (2008);
- Communication on Green Public Procurement (GPP) (2008);
- Innovating for Sustainable Growth: A Bioeconomy for Europe. Strategy and Action Plan (2012);
- Regulation on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) (2013);
- Strategic Guidelines in rural development (2006);
- Regulation on the European Regional Development Fund (ERDF) (2013);
- Regulation on the Cohesion Fund (2013);
- Horizon 2020 - the Framework Programme for Research and Innovation (2013);
- Forest-based Sector Technology Platform (FTP).

Taken together, these instruments represent a rich but complex regulatory environment, built up over decades, with a number of different policy objectives, including sustainable forest management and a competitive forest based industry, as well as energy efficiency and security, climate change mitigation, safe construction, a single market in the EU, conservation of biodiversity, sustainable production and consumption, sound agriculture and rural development, regional development and many others.

2.3.3 Policy instruments and strategies to achieve specific objectives

Which policy instruments in the field covered by ClimWood2030 might be used to achieve specific objectives? A short list of policy instruments and strategies to achieve particular objectives is set out below.

The policy instruments are of three types:

- Measures which could stimulate the use of solid biomass for climate change mitigation;
- Regulations whose provisions influence, positively or negatively, the use of solid biomass for climate change mitigation;
- Funding instruments which should allow for funding of measures to stimulate the use of solid biomass for climate change mitigation.

Measures to stimulate the use of solid biomass for climate change mitigation

The following policy actions appear to be the most important tools which could stimulate the use of solid biomass for climate change mitigation:

- Support for protection of forests against fire and insects;
- Wood mobilisation strategies and relevant instruments;
- Afforestation programmes, including conversion of agricultural land for SRC and perennials;
- Restricting access to EU markets for wood from unsustainable/illegal sources;
- Promoting transparency and good governance of the forest sector in developing countries;
- Support for renewable energies;
- Raising costs of landfill and/or closing landfills;
- Supporting innovation and research;
- Promoting energy efficiency, especially in buildings, on a full life cycle basis;
- Carbon taxes.

Regulations whose provisions influence, positively or negatively, the use of solid biomass for climate change mitigation

A number of existing policy instruments lay down the “rules of the game” for actors in a number of different fields. The way in which these rules are formulated and implemented may encourage, discourage or even exclude measures which stimulate the use of solid biomass for climate change mitigation. Among these measures are:

- Green building codes (e.g. BREEAM, LEED, HQE, DGNB, BNB): may promote or exclude the use of certain products depending on their environmental performance (e.g. primary energy consumption);
- Green public procurement (GPP): defines what products are considered sustainable and how this may be determined (e.g. certification systems);
- LULUCF accounting rules, reference levels and flexibilities across countries and sectors, if any;
- Carbon cap & trade systems (such as EU ETS, ETS and/or voluntary carbon trading systems): determine whether carbon sequestration projects qualify for carbon credits;

- Sustainability criteria for biofuels and biomass: the outcome of the discussion in progress will determine what intensity of forest management is acceptable for products put on the EU market, and thereby which non-EU suppliers may compete with EU suppliers;
- Proposed Directive on medium combustion plants: will influence the cost of generating electricity from wood (or other fuels).

Funding instruments for measures to stimulate the use of solid biomass for climate change mitigation

Potential EU funding is concentrated in a few EU measures and at the national level. Nevertheless, adequate funding is essential for effective stimulus measures. There are four EU funded programmes potentially relevant to the use of solid biomass to mitigate climate change, all revised in 2013 to cover the period 2014-2020 (it may be assumed that equivalent systems will be put in place for the period after 2020 although their rules and funding could change a lot). All may be used to support actions relevant to ClimWood2030:

- LIFE + to implement EU Environment Action Plan and climate objectives: over 200 projects already funded by LIFE+ concern forest habitats;
- European Agricultural Fund for Rural Development (EAFRD), in the context of the Common Agricultural Policy. The Regulation specifically mentions “fostering carbon conservation and sequestration in agriculture and forestry”;
- European Regional Development fund (ERDF). Its objectives include, among many other things, supporting the shift towards a low-carbon economy in all sectors;
- Horizon 2020 for research and innovation: Among the topics identified are improved forest management models, the low carbon resource-efficient economy, waste use, and monitoring and mitigation of forestry GHG emissions.

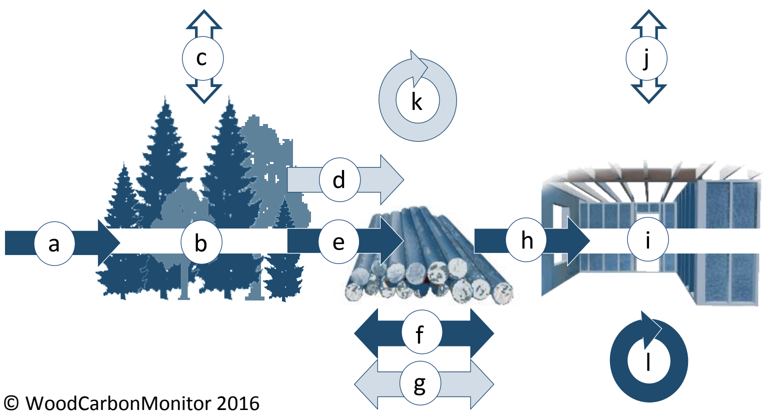
3 ClimWood2030 scenarios

This chapter presents the ClimWood2030 scenarios constructed according to the methods described in the previous chapter. ***It is important to note that these are illustrative scenarios, not predictions.*** They analyse the consequences over time of possible policy choices, assuming a given model structure, and certain, deliberately contrasted, assumptions.

3.1 Description of elements depicted in the scenario results

The outputs of the ClimWood2030 model system, for the base period and the projections, are presented in a standardised format as “snapshots”. As ClimWood2030 brings together quantitative analysis of sectors which are normally analysed separately, each sector using its own specific concepts and terminology, the structure of these snapshots and the concepts and definitions underlying them are presented below in detail.

The figure below is a simplified representation of the main parameters being analysed, and shows the system boundaries. The definitions used by the study are set out below.



a gross annual increment
b forest carbon pool
c forest emissions/removals
d harvest for energy use
e harvest for material use
f extra-EU net-trade of HWP and their feedstock
g extra-EU net-trade of energy wood
h HWP pool inflow (i.e. consumption)
i HWP carbon pool
j HWP emissions/removals
k energy substitution effect
l material substitution effect

> ***Please note that absolute and relative values as presented in subsequent chapters as regards the illustrated flows and pools, as well as emissions/removals and potential substitution effects should not be compared without careful consideration of the definitions below.***

There are four main types of parameter: carbon flows, carbon pools, emissions/removals of GHG to or from the atmosphere, and potential substitution effects. Each of these has specific characteristics, and is measured in a specific way.

Carbon pools and ***carbon flows*** along the forest wood chain are measured in million tons of carbon (Mt C). Please note that the latter do not add up to the displayed pool levels or their changes.

Emissions/removals (i.e. net flows from and to the atmosphere) as well as ***potential substitution effects*** are measured in million tons of CO_2 equivalent (Mt CO_2e).

The **overall GHG impact** of each scenario aggregates emission/removal effects, in Mt CO_2e, from four parameters: changes of the forest and HWP pools (parameters c and j) and the potential substitution effects associated with the use of woody material for energy and material purposes (parameters k and l). For further details on the methodological background, see Chapter2.

3.1.1 Carbon flows along the forest wood chain

All flows of carbon along the forest wood chain that are included in the snapshots are presented in Mt C. They are included for supplementary informational purposes only and do not add up to the total GHG impact of the scenarios.

"**Gross annual increment**" (**parameter a**) includes increment of standing stem biomass (> average 4 cm diameter) measured in Mt C. The parameter does not include a biomass expansion factor and as such is not comparable with changes of total above ground biomass estimates. Changes in soil carbon are not included, although they are for other parameters (notably c1, c2 and c3).

"**Harvest for energy use**" (**parameter d)** includes all harvested biomass which is used for energy generation measured in Mt C. It is calculated by aggregating data from two sources of information.

- The difference between total roundwood and industrial roundwood, both in the base year and the projection, defined as fuelwood according to the FAO classification.
- Any additional roundwood harvest of sufficient quality to be used for subsequent processing to sawnwood and wood-based panels *that is directly used for large-scale energy purposes*. In accordance with the previous 2014 Impact Assessment (2014 IA), the EU 28 bioenergy demand is defined according to the estimates as of PRIMES for the 2014 IA report. The bioenergy demand for each PRIMES biomass feedstock category is within the model framework constrained such that the consumption of each feedstock is equal or higher to that as estimated by PRIMES (forestry, crops, agricultural residues, waste, other etc.).

"**Harvest for material use**" (**parameter e**) comprises harvest of industrial roundwood (cf. FAO definition) which is used in subsequent processing to sawnwood, wood-based panels and pulp and paperboard measured in Mt C. According to the FAO definition industrial roundwood comprises sawlogs and veneer logs; pulpwood, round and split; and other industrial roundwood. Note that the parameter does not include the industrial roundwood (INDRW+) that is potentially harvested for large-scale energy production. The latter amount is included in parameter d.

"**Extra-EU net trade of HWP and their feedstock**" (**parameter f**) comprises two figures:

- Parameter f1 ("**net trade of feedstock**"), measured in Mt C, covers all carbon in raw materials for the subsequent manufacture of HWP (i.e. sawnwood, wood-based panels, paper and paperboard) that is traded by EU-28 with the rest of the world (RoW). This includes roundwood of the same quality as industrial roundwood and wood pulp. Note that parameter f1 potentially includes imported industrial roundwood (INDRW) that might be directly used for large-scale energy production as it is not possible to distinguish this in trade flow, though it can be distinguished in EU domestic harvest (parameters d and e).

- Parameter f2 ("**net trade of HWP**"), measured in Mt C, covers the net trade (exports minus imports) of aggregated semi-finished wood product categories (sawnwood, wood-based panels and paper and paperboard) that are traded by EU-28 with the RoW.

"**Extra-EU net trade of energy wood** "(**parameter g**), measured in Mt C, covers all carbon in wood used for energy purposes and is calculated from the EU countries' external trade balance difference from projected roundwood and industrial roundwood trade. This parameter is consistent with the definition of fuelwood provided by the FAO classification.

"**HWP pool inflow**" (**parameter h**) (i.e. inflow of carbon into the HWP pool), measured in Mt C, is estimated from the calculated consumption of semi-finished products according to the stock-change approach for HWP (cf. IPCC 2006 and IPCC 2014) in order to consistently link the amounts used within the EU-28 member states with the market data used on the level of functional units (i.e. wooden buildings, etc.).

3.1.2 Biogenic carbon pools of the forest wood sector within EU

The estimation of the carbon pools forms the basis for estimating biogenic carbon emissions and removals in the land use sector (cf. Section 2.1.1).

"**Forest carbon pool**" (**parameter b**), measured in Mt C, comprises the carbon stock in forests planted before 1990 and carbon in afforestation efforts after 1990. The pool covers above and below ground biomass (dead wood, litter and soil carbon are not included) and tracks the age structure development of the forest (Gusti 2010).

"**HWP carbon pool**" (**parameter i**), measured in Mt C, includes the carbon in all semi-finished wood products that have been consumed within the EU (calculated using the stock-change approach).

3.1.3 Emissions/removals of biogenic carbon in the forest wood sector

CO_2 emissions and their removals in sinks, in the land-use sector are estimated on the basis of carbon pool changes. Net removals (i.e. sinks) are represented with a negative indicator; net emissions (i.e. sources) are illustrated by positive values.

The parameter "**forest emissions/removals**" (**parameter c**) covers net emissions/removals of CO_2 from the forest pool. In the snapshot it is reported with three subcategories:

- **Parameter c1** ("**Afforestation**"), measured in Mt CO_2 yr^{-1}, covers emissions/removals from forests planted after the year 1990, including above ground biomass, below ground biomass, soil, and dead organic matter in forests. The principal element of "Afforestation" is forest growth, which is explicitly modelled with the aid of age and forest species specific forest growth curves.
- **Parameter c2** ("**Forest management**"), measured in Mt CO_2 yr^{-1}, covers emissions/removals related to change in the carbon stock of above and below ground biomass in forests due to changes in forest management. Forest management includes the change in the forest biomass stocks related to intensification of forest management (notably increased harvests) or decreasing harvest of wood. Forest included under parameter c1 (i.e. those established after 1990) are not included. The principal elements of "forest management" are increment and harvest, both parameters which are explicitly modelled (see Section 3.1.1).
- **Parameter c3** ("**Deforestation**"), measured in Mt CO_2 yr^{-1}, covers emissions/removals from above ground biomass, below ground biomass, soil, and dead organic matter in deforested forests (i.e. where there is a permanent change in land use). The main element of "Deforestation" emissions/removals is that of the current carbon stock and the spatially explicit location of deforestation, both of which are explicitly covered by the applied model framework.

A further parameter (**c'**) ("**Emissions/removals from outside EU forests**"), measured in Mt CO_2 yr^{-1}, covers all emissions/removals of carbon from the forests in RoW (i.e. outside EU-28), including emissions/removals from afforestation, forest management and deforestation (cf. parameters c1-c3). This parameter is developed by the model and incorporates a number of assumptions about consequences of harvest levels in different countries (silviculture, land use change etc.). For this reason, a direct comparison between changes in emissions/removals in the rest of the world and EU-28 is not possible.

"**HWP emissions/removals**" (**parameter j**), measured in Mt CO_2 yr^{-1}, covers the net emissions and removals from the HWP pool, and it is estimated on the basis of changes in the HWP carbon pool (parameter i), applying Equation 2.8.5 as included in the IPCC 2014 KP Supplement on the basis of the data of parameter h.

3.1.4 Substitution effects

"**Energy substitution**" (**parameter k**), measured in Mt CO_2 yr^{-1}, occurs when wood is burnt instead of fossil fuel. It includes the following fuels[29]:

- woody forest biomass,
- industrial residual wood in the form of chips or pellets, and

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[29] For a detailed description of the determination of the displacement factors used for the quantification of energy substitution, please refer to Section 2.2.3.2. Section 3.8 provides a sensitivity analysis of the implications of selecting natural gas instead of the assumed fossil fuel mix for heat generation.

- post-consumer wood that is not related to FBFUs but has entered the HWP pool before 2010; this type of fuel is included because changes in recycling rates or in the rates of wood used for energy recovery as a result of changes in policies will not only affect wood flows that enter the system after 2010 but also the recovery of wood flows that have entered the system before 2010. Energy generated from paper and paperboard has not been included).

For detailed description of the energy substitution effect, refer to Section 2.2.3.4.

“**Material substitution**” (**parameter j**), measured in Mt CO_2, comprises three different substitution effects which are related to an increased/decreased consumption of FBFUs as compared to the ClimWood2030 reference scenario[30]:

- the effect of *producing* one FBFU instead of functionally equivalent alternatives from other materials shows up in the snapshot, in which timeframe the FBFUs are produced. I.e. the snapshots from 2010 to 2030 cover all substitution effects related to the production of FBFUs in this period (as compared to the reference scenario),
- the effect of *disposing/recycling/using* the FBFU including possible substitution effects as compared to the disposing/recycling/using of the alternatives including possible substitution effects shows up in the snapshot, in which timeframe the FBFUs reach the end-of-life. This implies for FBFUs with a short service life (<20 years as the difference between 2010 and 2030) that some substitution effects related to the end-of-life – for the FBFUs that have been produced in the early years of the studied time period – are included in the snapshots, whereas the substitution effects of FBFUs with a short service life that have been produced in the later years as well as all substitution effect related to the end-of-life of FBFU with long service lives (> 20 years) are displayed as an effect beyond 2030 (as compared to the reference scenario),
- the effect of *disposing/recycling/using the amount of recycled wood* of the FBFU after the second life cycle and the possible substitution of forest biomass and fossil energy in a third product life cycle are displayed as an effect beyond 2030 (as compared to the reference scenario) because the service lives of all FBFUs plus the assumed service life of the recycled product are longer than the 20 years between 2010 and 2030.

For detailed description of the material substitution effect, refer to Section 2.2.3.3.

[30] For a detailed description of the determination of the displacement factors used for the quantification of material substitution, please refer to Section 2.2.3.2 and Table 2-4 for the displacement factors used. Chapter 3.8 provides a sensitivity analysis of the implications of selecting natural gas instead of the assumed fossil fuel mix for heat generation in the end-of-life of the materials included in the ClimWood2030 modelling framework.

3.2 ClimWood2030 reference scenario (I)

3.2.1 Storyline and assumptions

The reference point of the assessment is a baseline scenario that is designed to be as comparable as possible to the EU Reference Scenario (European Commission 2013) used in the 2014 IA report (European Commission 2014). For this purpose, the reference scenario that has been chosen for the ClimWood2030 study depicts the same developments and is based on the same underlying assumptions concerning socio-economic growth and policy targets for EU-28.

The *ClimWood2030 reference* scenario is based on the latest statistics from EUROSTAT and FAO-STAT, combined with GDP and population developments, as well as regulatory and economic/financial policy instruments in place as of today. Furthermore, it is assumed that policy targets, which have already been set (e.g. for GHG emission reduction, bioenergy consumption or energy efficiency), do not have to be met, if market drivers are not sufficiently strong. As such, this *ClimWood2030 reference* scenario explores the consequences of current trends.

For improved consistency and comparability, the *ClimWood2030 reference* scenario also considers the same range of policy commitments, currently implemented policies, legislations and targets that have been announced by countries and adopted by late spring 2012. It does take the 2020/2030 climate and energy package by the Commission into account, as far as these were finalised when work on the EU Reference scenario had been completed. Key EU policies that are considered include the EU ETS Directive (2009/29/EC), the Renewable Energy Directive (2009/28/EC), Energy Efficiency Directive (2001/27/EU), and GHG Effort Sharing decision (No 406/2009/EC). From 2012 onwards, no changes in policies are assumed and no new policies are considered. This implies that only already agreed policies in the context of the 2020 package are taken into consideration. Regulatory policy instruments are maintained unchanged over time and no new targets or strategies are assumed to come into play. As estimated for the EU Reference Scenario, the renewable energy share (RES) in the EU-28 would account for a 24.4 % share of gross final energy consumption by 2030, and 28.7 % in 2050. Biomass plays an important role in this trend and demand for biomass increases significantly between 2010 and 2020, after which demand increases at a slow pace until 2050.

Furthermore, the EU Reference scenario assumes limited global climate action, where non-EU regions provide a restricted amount of actions for reducing greenhouse gas (GHG) emissions. All Copenhagen and Cancun pledges are assumed to be followed, but no significant additional policy actions from non-EU regions are assumed to be put forward thereafter (e.g. as a result of Paris 2015 COP21 outcome).

The *ClimWood2030 reference* scenario differs from the EU Reference Scenario in one important way: energy supply from short rotation coppice (SRC) and perennial crops stay at the level of 2010. This assumption is in line with recent developments which suggest a stabilization of land use for short rotation coppices in EU, and leads to higher demand for wood from forests for energy purposes than foreseen in the EU Reference Scenario. There are also differences with respect to wood industries and assumed bioenergy demand, which impact the assessment of aspects such as forest harvest projections, overall land use development, price development, and trade. Also, the production and use of biomass feedstock between alternative purposes can be affected, particularly for resources that are highly market driven. Further differences between this study and that of the 2014 IA report are detailed below.

Table 3-1: Model assumptions for *ClimWood2030 reference* scenario

ClimWood2030 reference **scenario model assumptions**
GDP and population projections according to the EU Reference Scenario of the 2014 EU Impact Assessment study (2014 IA) for climate and energy policies.
Historic HWP consumption up to 2010 (average of 2008-2012) were derived from FAOSTAT. Projected HWP consumption (2015, 2020, 2025 and 2030) represents model outcomes.
PRIMES estimated biomass demand for energy purposes is strictly enforced for EU. No substitution is allowed by the model between feedstock categories. For instance, an increasing use of forest biomass does not reduce the consumption of agricultural biomass.
Total bioenergy demand for EU develops over time according to the EU Reference Scenario of the 2014 IA. The 2020 climate and energy package by the Commission has been taken into account and fulfilled, but not the EU proposed climate and energy targets for 2030. This is in line with the assumption as of the EU Reference scenario in the 2014 IA.
The availability of recycled wood material for HWP and energy production is provided by the WoodCarbonMonitor model. The applied default assumption on end-of-life scenarios for HWP is a collection rate[31] of 68 % (cf. Mantau et al. 2010) in the base year, which increases to 80 % by 2030 and a recycling rate of 10 %, which increases to 11 % by 2030 (cf. Section 2.2.3). This is additional information as to the development in the EU Reference Scenario for the 2014 IA.
Trade of woody commodities (feedstocks, and semi-finished products) between EU Member States and Rest of the World (RoW) is endogenously estimated by the GLOBIOM model. Trade of harvesting residues, wood pulp, and recovered material is not accounted for.
Energy supply from perennials and short rotation coppice (SRC) stay fixed at their 2010 estimates and do not increase or decrease over time - This is not in line with the development in the EU Reference Scenario for the 2014 IA. This assumption is in line with recent developments which suggest a stabilization of land use for short rotation coppices in EU.
Intensification of forest management (both in terms of increasing forest harvest in a stand and in terms of putting more stand under an management strategy for production of timber) is allowed by the model within all non-protected forest in EU and globally. Only sustainable harvest levels are allowed and harvest is never allowed to exceed that of the increment.
Projections 2030 for FBFUs are based on linear projections according to a business-as-usual market development of future use of wood. These projections are scaled to meet the projected change in consumption of HWP in GLOBIOM.

3.2.2 Scenario results

The *ClimWood2030 reference* scenario assumes that the EU and Member States achieve their policy goals in the field of bioenergy for 2020, and that the share of renewable energy rises to 24 % in 2030.

In this scenario, energy substitution by wood biomass increases strongly (from 186 Mt $CO_2e\ yr^{-1}$ in period 2011-2020 to 222 Mt $CO_2e\ yr^{-1}$ on average for the period 2021-2030), as the 2020 bioenergy targets are met and then exceeded. This material is supplied by increased harvests from EU-28 forests to supply the biomass energy called for by the policy targets. Total harvests increase by 21 % between period 2000-2010 and period 2021-2030 and harvest for energy use by nearly

[31] Share of waste not landfilled, i.e. sent the recycling, energy recovery or waste to energy plants.

50 %, leading to a steep decline in the EU forest sink: the emissions/removals from EU forests decrease from 243 Mt CO_2e yr^{-1} in period 2000-2010 to 134 Mt CO_2e yr^{-1} in period 2021-2030. This decrease is influenced essentially by the increment/harvest balance in managed forests. However, as harvest levels are below the increment, the EU forests remain a sink (10 % increase of carbon pool over 30 years).

As a result of more active forest management, the "**gross annual increment**" (parameter a) of the EU-28 forests increases by about 6 % between periods 2000-2010 and 2021-2030.

The "**forest carbon pool**" (parameter b) shows a steady increase over the whole period of 10 %, as the EU-28 forests continue to remove more carbon from the atmosphere than they emit to it.

Throughout the 20 year period, in the *ClimWood2030 reference* scenario the EU-28 "**forest emissions/removals**" (parameter c) remains a significant carbon sink. However in the decade ending in 2030, the net removals of carbon are 45 % less than in the base period. This is the result of opposite trends for the components of this parameter: carbon removals due to afforestation/reforestation nearly triple, while carbon emissions from deforestation fall sharply over the period. However the "forest management" sink – the largest of the three components in period 2000-2010 – at period 2021-2030 is only a quarter of what it was at the beginning, chiefly because of the rise in energy wood harvests.

Over the twenty years, the "**harvest for material use**" (parameter e) rises slightly, while the "harvest for energy use" (parameter d) increases by about 50 %, because of the need to satisfy the scenario assumptions about bioenergy. In the base period, energy wood harvest is about 60 % of industrial wood harvest, but in the last decade, this proportion rises to 87 %. The average price observed in the GLOBIOM model for harvested stem wood increases by 16% between 2010 and 2030.

"**Extra-EU net trade of HWP and their feedstock**" (parameter f): Over the period, the EU-28 net imports of industrial roundwood and wood pulp more than double, and at the end, net imports are about 10 % of domestic harvests. On the other hand, the observed trade surplus in HWP in period 2000-2010 becomes negligible by period 2021-2030.

The data representing the "**extra-EU net trade of wood for energy**" (parameter g) indicate a small net export of energy wood from EU-28, which may be a statistical artefact, due to the known shortcomings of data for energy wood. The projections show a slight increase in this apparent surplus.

Table 3-2: Detailed results for the *ClimWood2030 reference* scenario

Sphere	FORESTS									NET TRADE			HWP			SUBSTITUTION*		SCENARIO OVERALL GHG IMPACT
Description	ANNUAL INCREMENT	CARBON POOL	EMISSIONS/REMOVALS (E/R)					HARVEST		INDRW & WOOD PULP	FUEL WOOD	HWP	CARBON INFLOW	CARBON POOL	E/R	energy	material	
			EU				NON-EU											
			AR	FM	D	Total	Total	energy	material	material	energy	material						
Unit	*Mt C*		*Mt CO_2e/year*					*Mt C*							*Mt CO_2/year*			*Mt CO2/year*
Parameter	a	b	c1	c2	c3	**c**	c'	d	e	f1	g	f2	h	i	**j**	**k**	**l**	**c+j+k+l**
								ABSOLUTE VALUES										
	ClimWood2030 Reference Scenario																	
#01 (2000-2010)	214	9 584	-34,8	- 261	53,3	- 243	1 377	45,1	75,5	-3,34	0,592	3,79	71,6	1 468	-33,9	-14,95**	-2,91**	-294,65
#02 (2011-2020)	222	10 140	-69,2	- 155	36,2	- 188	2 358	57,3	74,9	-5,29	0,883	2,47	67,9	1 530	-11,7	- 186	-31,7	-417,8
#03 (2021-2030)	226	10 515	-93,3	-62,0	21,3	- 134	2 097	67,8	77,7	-8,76	1,01	-0,0943	71,3	1 568	-16,7	- 222	-34,2	-407,1
#04 (post-2030)																- 32	-03,1	-35,0

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value for the reference scenario is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference.

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

The “**HWP pool inflow**” (parameter h), i.e. the consumption of semi-finished products, falls in the first decade by about 5 %, and then recovers to about its level in the base period 2000-2010.

The “**HWP carbon pool**” (parameter i) grows steadily over the period, being about 7 % higher in the period 2021-2030 than at the beginning of the assessment. The “HWP emissions/removals” (parameter j) corresponds thus to net removal of carbon. This, however, falls by nearly two thirds between the 2011-2030 period and the base period, recovering slightly in the last period, when it is about half of the base period. This trend is due to the essentially stagnant development of HWP markets in this scenario.

There is a steep increase in “**energy substitution**” (parameter k) potential, as the volume of wood used for energy rises in accordance with the policy targets. The “**material substitution**” (parameter l) potential stays at roughly the same level over the twenty years in the reference scenario. Since both potential substitution effects have been calculated only since the base years that have been used in this study (i.e. 2008-2012), the value for the first period is almost zero and not comparable with the later periods.

3.2.3 Potential policy instruments

All policy instruments in place in 2012 are assumed to be maintained, notably the so-called “rules of the game”, such as forest legislation, free trade agreements, pricing systems for energy and materials, building codes, safety and health legislation. All the EU level policy instruments at present in place are maintained unchanged, including the EU Timber Regulation and the FLEGT Regulations, the Construction Products Regulation, the Habitats Directive, the Landfill Directive, and the Communication on Green Public Procurement. Sufficient funding would be available, notably through LIFE+, the Cohesion Fund, the Regional Development Fund, Horizon 2020 and the Regulation on Support for Rural Development. Likewise the *ClimWood2030 reference* scenario does not appear to be in contradiction with the future outlined in the EU Forest Strategy, the Communication on innovative and sustainable forest-based industries in the EU, the EU Strategy on adaptation to climate change, the Action Plan on Sustainable Consumption and Production and Sustainable Industrial Policy and Innovation for Sustainable Growth: a Bioeconomy for Europe Strategy and Action Plan. The increased dependence on wood imports suggests EU footprint could increase the pressure on global forest ecosystems, except if socio-environmental safeguards (such as FLEGT and REDD+) ensure that this increased wood production is decoupled from illegality, abuse, deforestation and degradation in source countries.

In the *ClimWood2030 reference* scenario, the main policy drivers for change (i.e. excluding exogenous drivers such as economic and demographic growth, or technical change) are the binding national targets for bioenergy in 2020 contained in the Renewable Energies Directive, MS National Renewable Energy Action Plans (NREAPs) and the Effort Sharing Decision. In this scenario, the model gives priority to achieving these objectives, overriding other parts of the model structure.

As the scenario demonstrates, achieving these targets would involve major changes in the wood forest sector, notably much higher wood harvests than at present. This would imply strong political will and resource mobilisation for wood mobilisation, with investments in infrastructure, changes to wood markets, possibly subsidies/fiscal incentives to raise harvests, investment in training and equipment etc. National forest programmes would need to be modified, and afforestation programmes put in place. Intensification of forest management and the higher temperatures associated with climate change would both imply an increased support for protection of forests against e.g. fire and insects.

The policy imperative to produce more wood for energy through intensified silviculture and increased harvests might cause tension with the need to conserve soils and biodiversity. Under the scenario, safeguards prevent commercial wood production in protected areas, and in high biodiversity areas. Nevertheless, increased tensions might arise in production areas, related to harvest techniques (larger machines), or removal of previously unused biomass (stumps, branches). At the policy level, these tensions would have to be resolved through consensus formation, and to a certain extent through technical progress, perhaps encouraged by publicly supported innovation and research. Thus under the selected *ClimWood2030 reference* scenario, some forest sector policy instruments, notably national forest programmes, might have to be adapted.

3.3 Increase carbon stock in existing EU forests (II)

3.3.1 Storyline and assumptions

This scenario describes a future where the focus inside the EU-28 is on increasing the forest carbon stocks: this limits, but does not stop, the supply of wood for wood using industries. However, it is assumed that the total demand for goods and services (i.e. including also non-wood products) in different sectors (e.g. building, packaging) remains the same as in the *ClimWood2030 reference* scenario, leading to market adjustment through prices and trade flows at the global scale.

This scenario explores the consequences of focusing climate change mitigation efforts in the forest sector on increasing the carbon stock in forests, chiefly by limiting harvests. A longer period than chosen for the ClimWood2030 analysis would have a notable impact on the results due to the limits of the sequestration capacity of forests which would give greater relative importance to substitution effects. This effect has been evaluated in a Swiss study for a time period up to 2100, which showed that when forests could no longer sequester large amounts of carbon, as they reached a state of equilibrium, the importance of substitution of non-renewable materials and energy by renewable wood-based materials and energy increased (Taverna *et al.* 2007).

Table 3-3: Assumptions in the *Increase forest carbon stock in existing EU forests* scenario (II) as compared to the assumptions of the *ClimWood2030 reference* scenario

<table>
<tr><th>ClimWood2030 reference scenario</th><th>Increase forest carbon stock in existing EU forests</th></tr>
<tr><td>GDP and population projections according to the EU Reference Scenario of the 2014 EU Impact Assessment study (2014 IA) for climate and energy policies.</td><td rowspan="7">Same assumptions</td></tr>
<tr><td>Historic HWP consumption up to 2010 (average of 2008-2012) were derived from FAOSTAT. Projected HWP consumption (2015, 2020, 2025 and 2030) represents model outcomes.</td></tr>
<tr><td>PRIMES estimated biomass demand for energy purposes is strictly enforced for EU. No substitution is allowed for between feedstock categories, i.e. an increasing use of forest biomass does not reduce the consumption of agricultural biomass.</td></tr>
<tr><td>Total bioenergy demand for EU develops over time according to EU Reference Scenario of the 2014 IA. The 2020 climate and energy package by the Commission has been taken into account and fulfilled, but not the EU proposed climate and energy targets for 2030. This is in line with the assumption as of the EU Reference Scenario in the 2014 IA.</td></tr>
<tr><td>The availability of recycled wood material for HWP and energy production is provided by the WoodCarbonMonitor model. The applied default assumption on end-of-life scenarios for HWP is a collection rate of 68 % in the base year, which increases to 80 % by 2030 and a recycling rate of 10 %, which increases to 11 %. This is additional information as to the development in the EU Reference Scenario for the 2014 IA. (cf. Section 2.2.2)</td></tr>
<tr><td>The bioenergy 2030 package (and its impact on bioenergy demand) is for this scenario not taken into account.</td></tr>
<tr><td>Data on perennial crops and short rotation coppice (SRC) stay fixed at their 2010 estimates and do not increase nor increase over time - This is not in line with the development in the reference scenario for the 2014 IA.</td></tr>
<tr><td>Intensification of forest management (both in terms of increasing forest harvest in a stand and in terms of putting more stand under an management strategy for production of timber) is allowed within all non-protected forest in EU and globally. Only sustainable harvest levels are allowed and harvest is never allowed to exceed that of the increment.</td><td>Intensification in forest management is constrained in the model to the 2010 level. No additional forest land is allowed to be used for the production of wood for markets, and the allowed forest harvest level is reduced over time to build up the forest carbon stock, to 105 Mt C in 2030, compared to 120 Mt C in 2010 and 145 Mt C in 2030 in the reference scenario. It is further assumed that the production of wood within high biodiversity areas is globally constrained (mapping according to UNEP WCMC). No additional assumptions are made concerning drivers or policies for afforestation or deforestation.
Only sustainable harvest levels are allowed and harvest is never allowed to exceed increment.</td></tr>
<tr><td>Projections 2030 for FBFUs are based on linear projections according to a business-as-usual market development of future use of wood. These projections are scaled to meet the projected change in consumption of HWP in GLOBIOM.</td><td>Same assumptions</td></tr>
</table>

3.3.2 Scenario results

In this scenario, wood harvests from EU-28 forests are significantly lower than in the reference scenario, both for material and energy uses. There is also significant afforestation activity while deforestation is at half the level of the *ClimWood2030 reference* scenario. As a result, the net removals of carbon by EU-28 forests in 2030 are more than triple those of the *ClimWood2030 reference* scenario. However, positive developments for carbon flows in EU forests are partly counterbalanced by developments further downstream and outside Europe: the sink effect of the HWP pool shrinks to nearly nothing and the substitution effects for both material and energy fall significantly. Net imports of industrial roundwood more than triple and imports of HWP and fuel wood increase respectively by 100 % and 200 %. There is displacement of carbon removals from EU-28 forests to forests elsewhere in the world, to the extent of an annual average of 40 Mt CO_2e yr^{-1} during the 2021-2030 period. The overall GHG impact in this scenario of the EU-28 forest sector in the short term (up to 2030) is 36 % better than in the reference scenario, indeed the highest of all scenarios. However, it should be noted that the increased loss of forest carbon outsides EU-28 might accompany negative substitution effects outside EU-28 which are not covered in the ClimWood23030 study (see Section 2.2.1). Also, the price of stem wood doubles as compared to prices observed in the reference scenario in 2030 due to reduced availability of wood from EU-28 forests.

Based on the age class development and an increase of afforested areas, the "**gross annual increment**" (**parameter a**) increases.

In line with the scenario assumptions on decreased harvest rates, there is a clear and large build-up of the **"forest carbon pool**" (**parameter b**), especially during the period 2021-2030.

Unlike the *ClimWood2030 reference* scenario (where forest carbon removals decrease over time), in this scenario, the sink effect of the "**forest emissions/removals**" (**parameter c**) within EU-28 increases significantly, rising from -242 Mt CO_2e yr^{-1} in the base period to -340 Mt CO_2e yr^{-1} on average in the period 2021- 2030, an increase of about 40 %. This is directly related to changes in the management of forests and the reduced harvest rate (cf. parameter d). In addition, an increase in afforested areas and a decrease in deforested areas are observed by 2030, attributable to wood prices, which have risen because of increased wood scarcity. This outcome is driven by economics playing a role for land-use change, i.e. the model framework assumes that increasing the value of forest commodities in comparison to value of agricultural commodities, leads to lower deforestation and higher afforestation.

In the *Increase forest C stock in existing EU forests* scenario, total net forest emissions of the rest of the world (RoW) (**parameter c'**) are roughly 3 % higher than in the *ClimWood2030 reference* scenario. This is directly related to increasing harvest in RoW, driven by a increasing export from RoW to EU-28 from the base to the last period, necessitated by lower harvest levels in EU-28 forests. However, the increase in the EU-28 sink (relative to the reference) remains significantly larger than the observed increase in net emissions from forests in other parts of the world (cf. Table 3-4).

The total harvest from EU forests decreases significantly over the 3 periods under study. By 2030, the **"harvest for material use" (parameter e)** is about half of that in the *ClimWood2030 reference* scenario and the "**harvest for energy use**" (**parameter d)** about 5 % lower. Under the scenario, the total harvest in 2021-2030 is more than 20 % less than in the period 2000-2010. This is driven by the scenario assumptions, which include a protection of high biodiversity areas and a decrease of allowable harvest rates.

Table 3-4: Detailed results for *Increase C stock in existing EU forests* scenario (II)

Sphere	FORESTS									NET TRADE			HWP		SUBSTITUTION*			SCENARIO OVERALL GHG IMPACT
Description	ANNUAL INCREMENT	CARBON POOL	EMISSIONS/REMOVALS (E/R) EU				NON-EU	HARVEST		INDRW & WOOD PULP	FUEL WOOD	HWP	CARBON INFLOW	CARBON POOL	E/R	energy	material	
			AR	FM	D	Total	Total	energy	material	material	energy	material						
Unit	*Mt C*		*Mt CO_2e/year*					*Mt C*							*Mt CO_2/year*			*Mt CO2/year*
Parameter	a	b	c1	c2	c3	**c**	c'	d	e	f1	g	f2	h	i	**j**	**k**	**l**	**c+j+k+l**
ABSOLUTE VALUES																		
ClimWood2030 Reference Scenario																		
#01 (2000-2010)	214	9 584	-34,8	- 261	53,3	- 243	1 377	45,1	75,5	-3,34	0,592	3,79	71,6	1 468	-33,9	-14,95**	-2,91**	-294,65
#02 (2011-2020)	222	10 140	-69,2	- 155	36,2	- 188	2 358	57,3	74,9	-5,29	0,883	2,47	67,9	1 530	-11,7	- 186	-31,7	-417,8
#03 (2021-2030)	226	10 515	-93,3	-62,0	21,3	- 134	2 097	67,8	77,7	-8,76	1,01	-0,0943	71,3	1 568	-16,7	- 222	-34,2	-407,1
#04 (post-2030)																- 32	-03,1	-35,0
VALUES RELATIVE TO REFERENCE SCENARIO																		
Increase C stock in existing EU forests (II)																		
#02 (2011-2020)	→ *0,95*	→ *73,32*	→ *-5,33*	↓ **-66,50**	↘ *-5,41*	↓ **-77,23**	→ *13,5*	→ *-3,19*	↘ *-11,85*	↓ *-5,53*	↓ *-0,58*	↓ *-0,90*	→ *-3,45*	→ *-7,19*	↑ *9,03*	→ *11,05*	↗ *5,31*	↘ **-51,84**
#03 (2021-2030)	→ *6,17*	→ *391,03*	↘ *-19,53*	↓ **-175,28**	↓ *-10,79*	↓ **-205,60**	→ *40,1*	↘ *-2,19*	↓ *-33,62*	↓ *-16,92*	↓ *-2,32*	↓ *-2,05*	↘ *-7,86*	→ *-42,60*	↑ *14,48*	↗ *33,34*	↑ *10,78*	↓ **-147,00**
#04 (post-2030)																→ *1,08*	↑ *1,73*	→ *2,82*

Legend:

- ↑ Scenario II superior to Reference scenario by more than 25%
- ↗ Scenario II superior to Reference scenario by more than 25% but less than 10%
- → Variation between Scenario II and Reference scenario between 10% and -10%
- ↘ Scenario II inferior to Reference scenario by more than -10% but less than -25%
- ↓ Scenario II inferior to Reference scenario by more than -25%

- **51** Difference between Scenario II and Reference scenario greater than 50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *10* Difference between Scenario II and Reference scenario beween 10 and 50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *09* Difference between Scenario II and Reference scenario beween -10 and +10 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *-10* Difference between Scenario II and Reference scenario beween -10 and -50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- **-51** Difference between Scenario II and Reference scenario greater than -50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value for the reference scenario is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference.

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

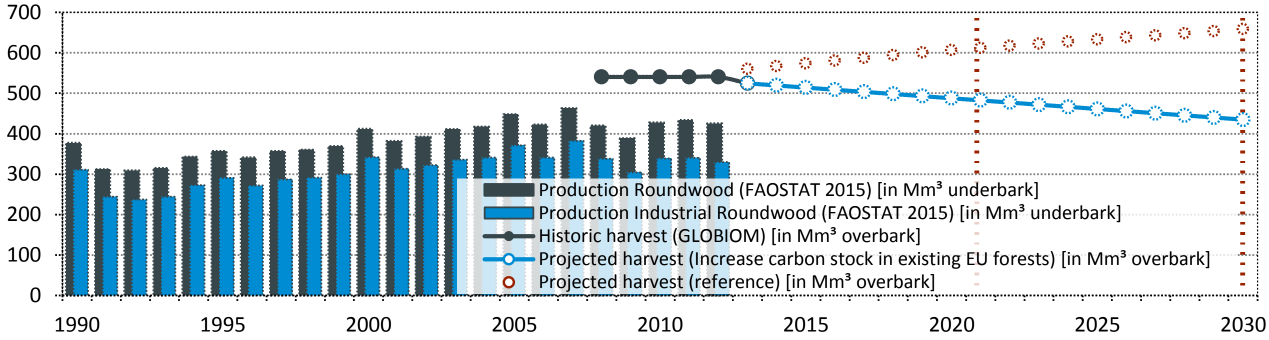

Figure 3-1: Projected annual harvest for scenario II and *ClimWood2030 reference* scenario I

The **average price** observed in the GLOBIOM model for harvested wood correspond to 180 % of the price observed in the *ClimWood2030 reference* scenario in 2030 attributable to reduced availability of wood from EU-28 forests. Over the period 2010-2030, the scenario II leads to an increase of 111 % in wood prices.

"**Extra-EU net trade of HWP and their feedstock**" (**parameter f1 and f2**): The trade deficit that can already be observed in the *ClimWood2030 reference* scenario increases over time and more than triples by 2030. In this scenario, the EU's demand for wood for material purposes is increasingly satisfied from other parts of the world.

For "**extra-EU net trade of wood for energy**" (**parameter g**), the EU-28 becomes a net importer of about 2.5 Mt C for the same reasons as described for the trade of industrial roundwood, although to a lesser degree.

The "**HWP carbon pool inflow**" (**parameter h**) which corresponds to the HWP consumption is about 10 % lower than in the *ClimWood2030 reference* scenario, and lower than the base period (the only scenario where this is the case). This development is driven by higher HWP prices, attributable to reduced availability of wood from EU-28 forests. This reduced availability is only partially compensated by increased imports of roundwood to EU (cf. parameters f1 and f2 and **Figure 3-2**). Furthermore, an increasingly higher level of imports of HWP commodities can be observed for this scenario.

Triggered by the decreased consumption especially of sawnwood and paper and paperboard within this scenario (cf. parameter h), the "**HWP carbon pool**" (**parameter i**) decreases over time as well, thus causing lower net carbon removals ("**HWP emissions/removals**", **parameter j**) than in the *ClimWood2030 reference* scenario, bringing the HWP pool in EU-28 to negligible levels.

The reduced consumption of bioenergy from woody biomass leads to a lower potential of "**energy substitution**" (**parameter k**) and increased GHG emissions from fossil fuels as compared to the reference case. The change in the energy substitution level is directly linked to the change in consumption of fuel wood, not to the large scale bioenergy demand.

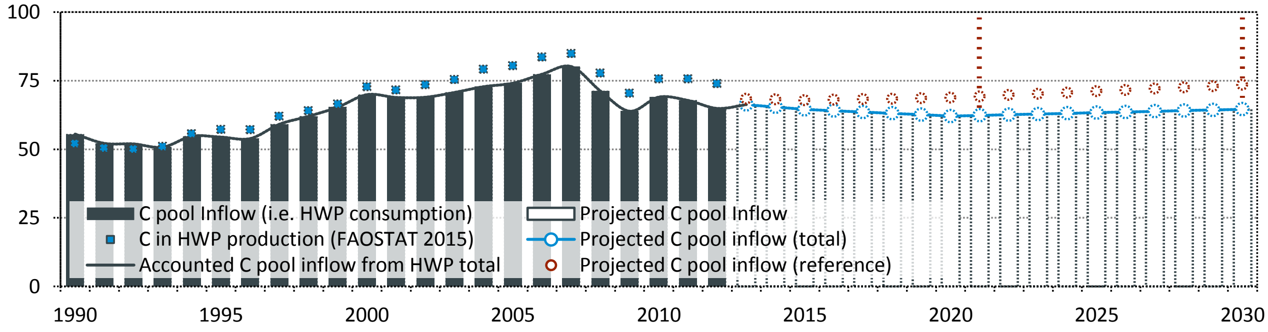

Figure 3-2: Projected annual HWP pool inflow for scenario II and *ClimWood2030 reference* scenario I [in Mt C]

“**Material substitution**” (**parameter l**): The decrease in HWP consumption (cf. parameter h) leads to an increase in the consumption of other (not HWP) materials. Because of their increased carbon footprint, there is an increase of fossil fuel emissions associated to material supply and use, as compared to the *ClimWood2030 reference* scenario.

3.3.3 Potential policy instruments

The policy objectives and instruments underlying the *Increase forest carbon stock in existing EU forests* scenario are the same as those underlying the *ClimWood2030 reference* scenario, with the following exceptions.

The scenario II is driven by lower harvests, despite rising prices, in a situation of reasonably strong demand for wood, especially for energy, and ample availability (as the growing stock is increasing). To achieve this result would necessitate either administrative measures (such as setting harvest levels by regulation), a steep reduction in harvest by state forest organisations, or economic incentives to forest owners to reduce their harvest levels. Economic incentives might take the form of direct payments for carbon sequestration, with the associated issues of defining "compensation thresholds", setting the carbon price, monitoring compliance, and mitigating leakage; these would presumably have to be developed in a broader climate change context. Another possibility would be to remove or reduce economic or fiscal incentives which at present stimulate wood harvest.

3.4 Cascade use – increase recovery of solid wood products (III)

3.4.1 Storyline and assumptions

The scenario examines the consequences for GHG balances of increased “cascading” in the wood forest sector. It focuses on higher post-consumer recovery and use of HWP.

Same as the following scenario VI (cf. chapter 3.5), this scenario describes a future where certain aspects of the cascade principle are applied within the EU in order to minimize the impact on the environment and climate, as well as to prioritise the forest output to where the wood has the highest added-value. The focus within EU-28 would be to increase the cascade use of wood while still fulfilling commitments for renewable energy targets. With the 2013 EU Forest Strategy document, it is specified that: "Under the cascade principle, wood is used in the following order of priorities: wood-based products, extending their service life, re-use, recycling, bio-energy and disposal." In this scenario, EU-28 policies aim to increase cascading use of wood through an increase in the amount of recovered wood used mainly for energy recovered. This would constitute single stage cascading.

Table 3-5: Assumptions in the *Cascade use – increase recovery of solid wood products* scenario (III) as compared to the assumptions of the *ClimWood2030 reference* scenario

ClimWood2030 reference scenario	Cascade use – increase recovery of solid wood products
GDP and population projections according to the EU Reference Scenario of the 2014 EU Impact Assessment study (2014 IA) for climate and energy policies.	Same assumptions
Historic HWP consumption up to 2010 (average of 2008-2012) were derived from FAOSTAT. Projected HWP consumption (2015, 2020, 2025 and 2030) represents model outcomes.	
PRIMES estimated biomass demand for energy purposes is strictly enforced for EU. No substitution is allowed for between feedstock categories, i.e. an increasing use of forest biomass does not reduce the consumption of agricultural biomass.	
Total bioenergy demand for EU develops over time according to the reference (BAU) scenario of the 2014 IA. The 2020 climate and energy package by the Commission has been taken into account and fulfilled, but not the EU proposed climate and energy targets for 2030. This is in line with the assumption as of the EU Reference scenario in the 2014 IA.	
The availability of recycled wood material for HWP and energy production is provided by the WoodCarbonMonitor model. The applied default assumption on end-of-life scenarios for HWP is a collection rate of 68 % in the base year, which increases to 80 % by 2030 2030 and a recycling rate of 10 %, which increases to 11 % by 2030. This is additional information as to the development in the EU Reference Scenario for the 2014 IA. (cf. Section 2.2.2)	From 2015 onwards, an increasing availability of recovered wood for material production is assumed through a fixed imposed increase in the collection rate to 99 % by 2030.[32] The recycling rate is assumed to increase up to 14 % by 2030 (cf. Section 2.2.2).
Data for perennial crops and short rotation coppice (SRC) stay fixed at their 2010 estimates and do not increase nor increase over time - This is not in line with the development in the EU Reference scenario for the 2014 IA.	Same assumptions
Intensification of forest management (both in terms of increasing forest harvest in a stand and in terms of putting more stand under an management strategy for production of timber) is allowed by the model within all non-protected forest in EU and globally. Only sustainable harvest levels are allowed and harvest is never allowed to exceed that of the increment.	
Projections 2030 for FBFUs are based on linear projections according to a business-as-usual market development of future use of wood. These projections are scaled to meet the projected change in consumption of HWP in GLOBIOM.	

[32] cf. Mantau et al. (2010)

3.4.2 Scenario results

Under this scenario, measures are taken to increase recovery and use (for material and energy) of solid wood products (but not paper) after use, while maintaining the levels of bioenergy demand contained in the *ClimWood2030 reference* scenario. However, the scenario shows that increased recovery of solid wood products has no significant influence on the major parameters linked to the EU-28 forest, harvest, roundwood trade, and even to the HWP carbon pool, presumably because the amount of extra material which is recovered is small relative to the flows of virgin fibre. Overall, increasing recovery improves the overall GHG impact of the scenario, compared to the reference scenario, by about 3 % for the period 2021-2030.

The “**gross annual increment**” (**parameter a**) in this scenario slightly increases.

For this scenario, the “**forest carbon pool**” (**parameter b**) shows only very minor increases due to reduced harvest.

In this scenario, the “**forest emissions/removals**” (**parameter c**) are net removals which are practically the same as in the *ClimWood2030 reference* scenario, with the forest sink showing a steady fall between 2010 and 2030.

The total net emissions of the rest of the world (**parameters c’**) are marginally lower in the ‘cascading – increase recovery of solid wood products’ scenario than in the ClimWood2030 scenario. The difference in net emissions as of 2030 is however lower than 1 %. The difference in emissions/removal is mainly related to lower emissions from deforestation in RoW, driven overall by higher domestic prices of wood commodities in specific key countries with price sensitive deforestation rates.

“**Harvest for energy use**” (**parameter d**) and “**harvest for material use**” (**parameter e**): The total harvest in the ‘cascading – increase recovery of solid wood products’ scenario is roughly the same as in the *ClimWood2030 reference* scenario. Only a minor decrease in harvest can be observed, which is in line with the scenario assumptions of slight increase of recycled feedstock for the production of HWP. Indeed, only 14 % of the post-consumer waste is considered to be recycled, the increase in recovery benefits mainly to energy substitution. This effect, however, is compensated by a change in trade of roundwood (see parameter f). Between 2010 and 2030, the average price of wood increases by 42%. The price of harvested stem wood is 22% higher in scenario III as compared to price observed in the reference scenario in 2030.

“**Extra-EU net trade of HWP and their feedstock**” (**parameter f1 and f2**): The increasing trade deficit of the *ClimWood2030 reference* scenario further increases very slightly. It appears that the decreased domestic supply of fresh fibre is compensated by the slight increase of industrial wood imports. At the same time, the EU 28 remains a net exporter of HWP in this scenario, unlike the reference scenario. No change in the “**extra-EU net trade of wood for energy**“ (**parameter g**) can be observed.

Table 3-6: Detailed results for *Cascading – increase recovery of solid wood products* scenario (III)

Sphere	FORESTS									NET TRADE			HWP		SUBSTITUTION*			SCENARIO OVERALL GHG IMPACT
Description	ANNUAL INCREMENT	CARBON POOL	EMISSIONS/REMOVALS (E/R) EU AR	EU FM	EU D	EU Total	NON-EU Total	HARVEST energy	HARVEST material	INDRW & WOOD PULP material	FUEL WOOD energy	HWP material	CARBON INFLOW	CARBON POOL	E/R	energy	material	
Unit	*Mt C*		*Mt CO_2e/year*					*Mt C*							*Mt CO_2/year*			*Mt CO2/year*
Parameter	a	b	c1	c2	c3	**c**	c'	d	e	f1	g	f2	h	i	**j**	**k**	**l**	**c+j+k+l**
ABSOLUTE VALUES																		
ClimWood2030 Reference Scenario																		
#01 (2000-2010)	214	9 584	-34,8	- 261	53,3	- 243	1 377	45,1	75,5	-3,34	0,592	3,79	71,6	1 468	-33,9	-14,95**	-2,91**	-294,65
#02 (2011-2020)	222	10 140	-69,2	- 155	36,2	- 188	2 358	57,3	74,9	-5,29	0,883	2,47	67,9	1 530	-11,7	- 186	-31,7	-417,8
#03 (2021-2030)	226	10 515	-93,3	-62,0	21,3	- 134	2 097	67,8	77,7	-8,76	1,01	-0,0943	71,3	1 568	-16,7	- 222	-34,2	-407,1
#04 (post-2030)																- 32	-03,1	-35,0
VALUES RELATIVE TO REFERENCE SCENARIO																		
Cascading - increased recovery of solid wood products (III)																		
#02 (2011-2020)	⇨ *0,00*	⇨ *0,01*	⇨ *0,00*	⇨ *-0,02*	⇨ *0,00*	⇨ *-0,02*	⇨ *00,2*	⇨ *0,00*	⇨ *0,00*	⇨ *-0,01*	⇨ *0,00*	⇨ *0,12*	⇨ *0,01*	⇨ *0,04*	⇨ *-0,05*	⇨ *-3,92*	⇨ *-0,05*	⇨ *-4,03*
#03 (2021-2030)	⇨ *-0,01*	⇨ *0,03*	⇨ *0,03*	⇨ *-0,09*	⇨ *0,08*	⇨ *0,02*	⇨ *-01,4*	⇨ *1,00*	⇨ *-0,02*	⇨ *-0,02*	⇨ *0,00*	⇧ *0,20*	⇨ *0,01*	⇨ *0,18*	⇨ *-0,03*	⇨ *-11,39*	⇨ *-0,44*	⇨ *-11,83*
#04 (post-2030)																⇘ *-7,57*	⇩ *-1,46*	⇩ *-9,04*

Legend:

- ⇧ Scenario III superior to Reference scenario by more than 25%
- ⇗ Scenario III superior to Reference scenario by more than 25% but less than 10%
- ⇨ Variation between Scenario III and Reference scenario between 10% and -10%
- ⇘ Scenario III inferior to Reference scenario by more than -10% but less than -25%
- ⇩ Scenario III inferior to Reference scenario by more than -25%

- **51** Difference between Scenario III and Reference scenario greater than 50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *10* Difference between Scenario III and Reference scenario beween 10 and 50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *09* Difference between Scenario III and Reference scenario beween -10 and +10 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *-10* Difference between Scenario III and Reference scenario beween -10 and -50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- **-51** Difference between Scenario III and Reference scenario greater than -50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value for the reference scenario is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference.

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

The “**HWP carbon pool inflow**” (**parameter h**) (i.e. consumption) is very similar to that in the *ClimWood2030 reference* scenario. However, the results suggest a slight shift from the consumption of sawnwood towards products based on industrial residues, i.e. wood-based panels and paper and paperboard. The underlying reason for the increase in fibreboard consumption is due to lower prices for the relevant feedstocks (i.e. mainly wood chips) driven partly by the increased recovery rate of post-consumer wood. The decreasing demand by the wood-based panel industry for sawmill residues results in lower profitability of sawmills as the prices of industrial residues fall. This in turn results in lower production of sawnwood.

No significant changes of the “**HWP carbon pool**” (**parameter i**) as well as of the associated “**HWP emissions/removals**” (**parameter j**) compared to the reference scenario can be observed.

Due to a higher recovery rate in the ‘cascading – increase recovery of solid wood products’ scenario, more post-consumer wood is available for energy generation. This results in an “**energy substitution**” potential (**parameter k**) 5 % higher than in the *ClimWood2030 reference* scenario. This effect is relevant also for the time after 2030, as more post-consumer wood as compared to the other scenarios is eventually available both for wood-based panel industry and energy recovery, thus triggering additional substitution effects.

“**Material substitution**” (**parameter l**): For this scenario, the overall consumption of HWP hardly changes although there is a slight shift in densities (see parameter h). Thus, no major impact on material substitution can be observed.

3.4.3 Policy instruments linked to the scenario

The policy instruments underlying this scenario are the same as those underlying the *ClimWood2030 reference s*cenario, with the following exceptions.

This scenario is driven by an increase in the share of post-consumer wood products which are recovered and used, for raw material and energy. Policy instruments which might achieve this objective would include complete implementation of the Landfill Directive, making it more difficult for this material to leave the commercial circuits, as well as measures to improve and structure the markets and logistics of the circuits for post-consumer products (e.g. better market information, improved installations for collecting, sorting and transporting this bulky, low value material). Experience, for example in Germany and the Netherlands, has shown that such measures can be successful. Measures on demolition as well as disposal of HWP could increase availability. It could also be desirable to increase research and development into wood using products and structures which are easier to recycle after use.

3.5 Cascade use – prevent first use of biomass for energy (IV)

3.5.1 Storyline and assumptions

As in scenario III, this scenario describes a future where certain aspects of the cascade principle are applied within EU-28 while still fulfilling commitments for renewable energy targets. In this scenario EU-28 policies strongly discourage the energy use of fresh wood biomass that could be used for material purposes. It is inspired by a 2012 Decree of the Polish Minister of Economy which stipulates that installations that burn biomass cannot burn "full-value wood" and classify the electricity/heat generated from that wood as a renewable energy source. "Full-value wood" meaning here wood feedstock which fulfils certain size and quality requirements specified in Polish standards.

Table 3-7: Assumptions in the *Cascading – prevent first use of biomass for energy* scenario (IV) as compared to the assumptions of the *ClimWood2030 reference* scenario

ClimWood2030 reference scenario	Cascading – prevent first use of biomass for energy
GDP and population projections according to the EU Reference Scenario of the 2014 EU Impact Assessment study (2014 IA) for climate and energy policies.	Same assumptions
Historic HWP consumption up to 2010 (average of 2008-2012) were derived from FAOSTAT. Projected HWP consumption (2015, 2020, 2025 and 2030) represents model outcomes.	
PRIMES estimated biomass demand for energy purposes is strictly enforced for EU. No substitution is allowed by the model between feedstock categories, i.e. an increasing use of forest biomass does not reduce the consumption of agricultural biomass.	The full demand for the PRIMES consumption category stemwood has to be produced from forest based industrial by-products. This implies that roundwood of sufficient quality to be used for subsequent processing to sawnwood and wood-based panels is not allowed to be directly used for large scale energy generation purposes.
Total bioenergy demand for EU develops over time according to the EU Reference Scenario of the 2014 IA. The 2020 climate and energy package by the Commission has been taken into account and fulfilled, but not the EU proposed climate and energy targets for 2030. This is in line with the assumption as of the EU Reference scenario in the 2014 IA.	Same assumptions
The availability of recycled wood material for HWP and energy production is provided by the WoodCarbonMonitor model. The applied default assumption on end-of-life scenarios for HWP is a collection rate of 68 % in the base year, which increases to 80 % by 2030 and a recycling rate of 10 %, which increases to 11 % by 2030. This is additional information as to the development in the EU Reference Scenario for the 2014 IA. (cf. Section 2.2.2)	
The bioenergy 2030 package (and its impact on bioenergy demand) is for this scenario not taken into account.	
Data for perennial crops and short rotation coppice (SRC) stay fixed at their 2010 estimates and do not increase nor increase over time - This is not in line with the development in the EU Reference scenario for the 2014 IA.	
Intensification of forest management (both in terms of increasing forest harvest in a stand and in terms of putting more stand under an management strategy for production of timber) is allowed within all non-protected forest in EU and globally. Only sustainable harvest levels are allowed and harvest is never allowed to exceed that of the increment.	
Projections 2030 for FBFUs are based on linear projections according to a business-as-usual market development of future use of wood. These projections are scaled to meet the projected change in consumption of HWP in GLOBIOM.	

There are a number of different ways in which such restrictions could be imposed and this scenario examines a case where roundwood of the same quality as industrial roundwood may only be used for processing to sawnwood, wood-based panels and paper and paperboard. It may not, under this scenario, be used directly for large scale energy purposes. The scenario thus examines the consequences of a strategy aimed at promoting the cascading use of wood by preventing wood supplied from the forest being directly used for energy. This material would then have to be used in the first instance as raw material and only afterwards as a source of energy (the use of industrial residues for energy is permitted by the model).

3.5.2 Scenario results

Under this scenario, demand for energy from wood must be satisfied in priority from industry residues, safeguarding fresh wood from the forest as a source of raw material for the forest industries. However, industry residues may continue to be used for either energy or raw material. As a result, the HWP sink grows significantly (more than double by 2030), as does the material substitution effect. However, the energy substitution effect falls steeply. As a whole, in this scenario, the downstream part of the model – the carbon storage in the HWP pool and the substitution effects – becomes a larger sink than in the *Climwood2030 reference* scenario (-11.3 Mt CO_2e yr^{-1} on average in period 2021-2030). As would be expected, harvests of energy wood fall, and of wood for raw material rise, and imports of energy wood from outside the EU increase, as the bioenergy targets must still be met. However the sink from forest management (essentially the harvest/increment balance) becomes a small source, although the forest as a whole remains a sink, because of afforestation. The net effect of this scenario in forests outside EU is positive for the climate showing a decrease of 37 Mt CO_2e yr^{-1} linked with lower exports to EU. The overall GHG impact, which does not include impacts outside EU forests, of this scenario is decreasing by 2 % in period 2021-2030 compared to the *ClimWood2030 reference* scenario.

The "**gross annual increment**" (**parameter a**) in this scenario is almost the same as in the *ClimWood2030 reference* scenario.

For the scenario IV, the "**forest carbon pool**" (**parameter** b) is slightly lower than in the *ClimWood2030 reference* scenario, driven by an increased harvest level especially for material purposes (see parameters d and e).

In this scenario, the "**forest emissions/removals**" (**parameter c**) representing a sink are roughly 20 % less than in the reference scenario by 2030. This is directly related to the change in the harvest amounts (cf. parameter d and e). The sink effect in managed forests (i.e. forest management) is about half that of the *ClimWood2030 reference* scenario. The net emissions from deforestation also decrease.

The total net emissions by the rest of the world (RoW) (**parameter c'**) are about 4 % lower in the *Cascading – prevent first use of biomass for energy* scenario than in the *ClimWood2030 reference* scenario. This change is related to the decreasing export from RoW to EU-28 which leads to lower forest management emissions. The change in emissions/removal is also related to lower emissions from deforestation, driven overall by higher prices of domestic wood commodities.

The "**harvest for energy use**" (**parameter d**) in this scenario is lower than in the *ClimWood2030 reference* scenario because of the scenario assumption, which constrains the harvest of roundwood directly used for large scale energy purposes, which could have been used for subsequent processing to solid wood products. However, there is a steep increase of "harvest for material use" (parameter e), driven by higher demand triggered by lower prices of sawnwood and plywood commodities. The lower production price of the relevant commodities is caused by an increased demand for industrial residues (i.e. wood chips, sawdust, sidings) compensating for the reduced availability of fresh fibre for energy. Total harvest under this scenario is the highest of all scenarios. Between 2010 and 2030, the average price of wood increases by 46%. The price of harvested stem wood in scenario IV is 26% higher as compared to price observed in the reference scenario in 2030. Basically the consumption of HWP is driven by the need to produce sufficient amounts of industrial residues/by-products to meet bioenergy demand. This arises because under the scenario assumptions, the targets for renewable energy must be achieved, as well as the "cascading" objective. If this constraint were relaxed, this scenario would not give rise to the high prices for residues and the relatively small changes in material use.

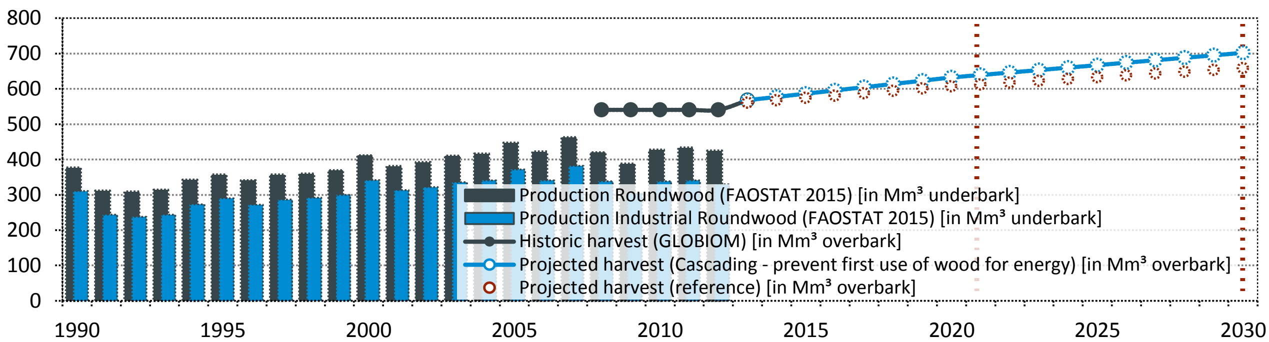

Figure 3-3: Projected annual harvest for scenario IV and the *ClimWood2030 reference* scenario

"**Extra-EU net trade of HWP and their feedstock**" (**parameter f1 and f2**): Because of the increased availability of wood by-products for material use, the EU-28 deficit in industrial roundwood and wood pulp in this scenario is reduces by 30 % as compared to that in the *ClimWood2030 reference* scenario. EU-28 remains a net exporter of HWP, unlike in the reference scenario.

There is a small decrease in the EU trade surplus in the "**extra-EU net trade of wood for energy**" **(parameter g)**, attributable to reduced availability of this assortment.

Table 3-8: Detailed results for "Cascading – prevent first use of biomass for energy" scenario (IV)

Sphere	FORESTS									NET TRADE			HWP			SUBSTITUTION*		SCENARIO OVERALL GHG IMPACT
Description	ANNUAL INCREMENT	CARBON POOL	EMISSIONS/REMOVALS (E/R) EU				NON-EU	HARVEST		INDRW & WOOD PULP	FUEL WOOD	HWP	CARBON INFLOW	CARBON POOL	E/R	energy	material	
			AR	FM	D	Total	Total	energy	material	material	energy	material						
Unit	*Mt C*		*Mt CO₂e/year*					*Mt C*							*Mt CO₂/year*			*Mt CO2/year*
Parameter	a	b	c1	c2	c3	**c**	c'	d	e	f1	g	f2	h	i	**j**	**k**	**l**	**c+j+k+l**
ABSOLUTE VALUES																		
ClimWood2030 Reference Scenario																		
#01 (2000-2010)	214	9 584	-34,8	- 261	53,3	- 243	1 377	45,1	75,5	-3,34	0,592	3,79	71,6	1 468	-33,9	-14,95**	-2,91**	-294,65
#02 (2011-2020)	222	10 140	-69,2	- 155	36,2	- 188	2 358	57,3	74,9	-5,29	0,883	2,47	67,9	1 530	-11,7	- 186	-31,7	-417,8
#03 (2021-2030)	226	10 515	-93,3	-62,0	21,3	- 134	2 097	67,8	77,7	-8,76	1,01	-0,0943	71,3	1 568	-16,7	- 222	-34,2	-407,1
#04 (post-2030)																- 32	-03,1	-35,0
VALUES RELATIVE TO REFERENCE SCENARIO																		
Cascading - prevent first use of biomass for energy (IV)																		
#02 (2011-2020)	→ *-0,05*	→ *-10,92*	→ *0,21*	→ *10,55*	→ *-1,76*	→ *9,00*	→ *02,2*	↘ *-7,36*	↗ *10,54*	↗ *1,23*	↓ *-0,31*	→ *0,25*	→ *3,24*	→ *8,08*	↓ *-10,71*	→ *7,61*	↘ *-7,18*	→ *-1,28*
#03 (2021-2030)	→ *0,05*	→ *-59,82*	→ *0,62*	↑ *33,34*	↘ *-3,57*	↗ *30,38*	→ *-37,3*	↘ *-6,36*	↑ *24,91*	↑ *3,21*	↘ *-0,18*	↑ *1,57*	→ *6,99*	→ *55,59*	↓ *-22,84*	→ *19,91*	↓ *-18,47*	→ *8,98*
#04 (post-2030)																→ *-2,00*	↓ *-3,54*	↘ *-5,54*

Legend:

- ↑ Scenario IV superior to Reference scenario by more than 25%
- ↗ Scenario IV superior to Reference scenario by more than 25% but less than 10%
- → Variation between Scenario IV and Reference scenario between 10% and -10%
- ↘ Scenario IV inferior to Reference scenario by more than -10% but less than -25%
- ↓ Scenario IV inferior to Reference scenario by more than -25%

51 Difference between Scenario IV and Reference scenario greater than 50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
10 Difference between Scenario IV and Reference scenario beween 10 and 50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
09 Difference between Scenario IV and Reference scenario beween -10 and +10 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
-10 Difference between Scenario IV and Reference scenario beween -10 and -50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
-51 Difference between Scenario IV and Reference scenario greater than -50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value for the reference scenario is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference.

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

The total "**HWP carbon pool inflow**" (**parameter h**) that corresponds to the consumption of semi-finished products, during the 2021-2030 period, is about 10 % higher than in the *ClimWood2030 reference* scenario. This is driven by a significant increase of sawnwood and plywood consumption, due to lower prices of these commodities driven the increased revenue from selling by-products to the energy sector. However, consumption of residue based products such as particle board, fibreboard and paper are lower than in the *ClimWood2030 reference* scenario.

Because of the higher consumption mentioned above, the "**HWP carbon pool**" (**parameter i**) and the HWP carbon removals in period 2021-2030 are considerably higher than in the reference scenario. The "HWP emissions/removals" (parameter j) sums up to a sink effect, which is more than double that of the *ClimWood2030 reference* scenario.

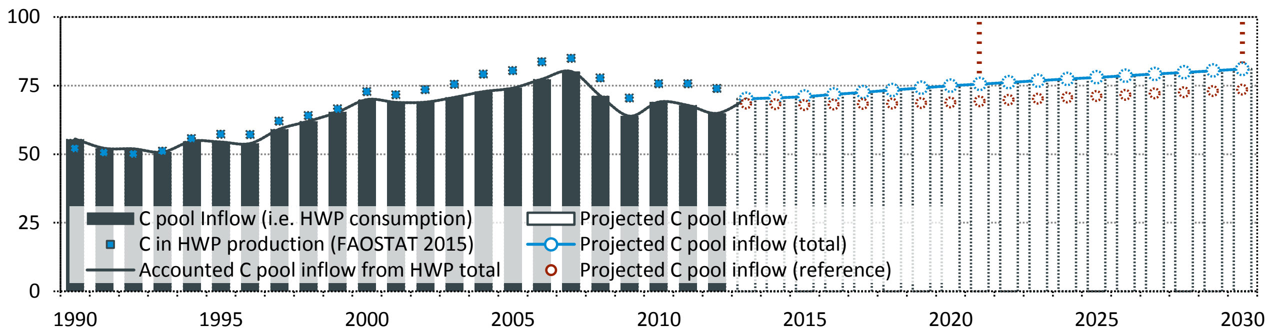

Figure 3-4: Projected annual HWP pool inflow for scenario IV and *ClimWood2030 reference* scenario I [in Mt C]

In this scenario, the potential of "**energy substitution**" (**parameter k**) is less than in the *ClimWood2030 reference* scenario (-10 %). The decrease of bioenergy used outside wood industries, which drives the illustrated potential energy substitution effect, is a result of the scenario assumption of a sharp decline in the direct use of forest energy wood as well as of post-consumer wood (parts of it are used in wood industries). This decline is only partly compensated by an additional production of industrial residual wood that is used for energy purposes outside the wood industries. Note in this context, that the related increase of use of industry residual wood for energy inside the wood industries is reflected in the material substitution parameter not the energy substitution parameter). The total bioenergy consumption (in- and outside wood industries), however, is still assumed to be the same as in the *ClimWood2030 reference* scenario.

The potential "**material substitution**" effect (**parameter l**) under this scenario in period 2021-2030 is 55 % higher than in the *ClimWood2030 reference* scenario, because of the general shift under this scenario from energy to material uses. There is increased consumption of building sector relevant HWP commodities, i.e. sawnwood and plywood.

3.5.3 Policy instruments linked to the scenario

The policy objectives and instruments underlying this scenario are the same as those underlying the *ClimWood2030 reference* scenario, with the following exceptions.

This scenario is driven by the intention to divert wood from energy to material uses, so that the cascade principle can be strengthened by only using wood for energy after use as material. The model's scenario assumption is that only industrial residues can be used for (large scale) energy generation. Designing policy instruments which would ensure that wood is only sold to one category of users is challenging. Possible solutions would be to limit the market options of publicly owned entities: state forest organisations could only sell to wood industries, and publicly owned wood energy plants would only purchase fuel only from wood processing facilities (or imports). Economic/fiscal incentives could also be put in place to reward these choices.

3.6 Strongly increase material wood use (V)

3.6.1 Storyline and assumptions

This scenario explores the consequences for the sector as a whole of successful moves to promote consumption of solid wood products, with the aim of increasing the HWP sink and the material substitution effect. It is based on detailed technical analysis of FBFUs, to estimate where advances might be made, not on more general econometric modelling approach. In short, this scenario explores a future where sawnwood and panels achieve their maximum realistic potential in the analysed FBFUs. It would typically imply that EU housing market profiles (currently about 10% of new houses being built with wood-frames) get closer to US or Japanese market profiles (where wood-frames currently represent about 40% of new constructions).

The scenario describes a future where wood construction develops strongly, resulting in a 100 % increase of wood consumption in the construction sector (core and shell and elements of construction except windows) between 2010 and 2030. The growth rates for the other FBFUs (packaging, furniture, etc.) are based on assumptions about the wood market shares development as well as on extrapolation of actual market trends (all materials). These assumptions come mainly from the literature review and expert knowledge through interviews. Projections on FBFUs, here, are more optimistic than in the previous scenarios. Further details can be found in Annex 1).

Table 3-9: Assumptions in the *Strongly increase material wood use* scenario (V) as compared to the assumptions of the *ClimWood2030 reference* scenario

ClimWood2030 reference scenario		Strongly increase material use
GDP and population projections according to the EU Reference Scenario of the 2014 EU Impact Assessment study (2014 IA) for climate and energy policies.		Same assumptions
Historic HWP consumption up to 2010 (average of 2008-2012) were derived from FAOSTAT. Projected HWP consumption (2015, 2020, 2025 and 2030) represents model outcomes.	For 2020 and 2030, HWP consumption in GLOBIOM is exogenously defined according to input data. A constraint is incorporated in GLOBIOM that HWP consumption on a total aggregated EU 28 level has to match that of data generated through the FBFU analysis, to allow for flexibility between Member States. No additional assumption is taken concerning the sourcing of the HWP commodities, meaning that consumption can be fulfilled based on national production and/or trade.	
PRIMES estimated biomass demand for energy purposes is strictly enforced for EU. No substitution is allowed for between feedstock categories, i.e. an increasing use of forest biomass does not reduce the consumption of agricultural biomass.		Same assumptions
Total bioenergy demand for EU develops over time according to the reference (BAU) scenario of the 2014 IA. The 2020 climate and energy package by the Commission has been taken into account and fulfilled, but not the EU proposed climate and energy targets for 2030. This is in line with the assumption as of the EU Reference scenario in the 2014 IA.		
The availability of recycled wood material for HWP and energy production is provided by the WoodCarbonMonitor model. The applied default assumption on end-of-life scenarios for HWP is a collection rate of 68 % in the base year, which increases to 80 % by 2030 and a recycling rate of 10 %, which increases to 11 % by 2030. This is additional information as to the development in the EU Reference Scenario for the 2014 IA. (cf. Section 2.2.2)		
The bioenergy 2030 package (and its impact on bioenergy demand) is for this scenario not taken into account.		
Data for perennial crops and short rotation coppice (SRC) stay fixed at their 2010 estimates and do not increase nor increase over time - This is not in line with the development in the EU Reference scenario for the 2014 IA.		
Intensification of forest management (both in terms of increasing forest harvest in a stand and in terms of putting more stand under an management strategy for production of timber) is allowed within all non-protected forest in EU and globally. Only sustainable harvest levels are allowed and harvest is never allowed to exceed that of the increment.		
Projections 2030 for FBFUs are based on linear projections according to a business-as-usual market development of future use of wood. These projections are scaled to meet the projected change in consumption of HWP in GLOBIOM.	Projections 2030 on FBFUs are based on a strong development of the wood construction, resulting in a 100 % increase of wood consumption in the construction sector (core and shell and elements of construction except windows) between 2010 and 2030. The growth rates for the other FBFUs (packaging, furniture, etc.) are based on assumptions about the wood market shares development as well as on extrapolation of market trends (all materials).	

3.6.2 Snapshot results

Alongside the doubling of wood use in construction, the bioenergy volumes of the *ClimWood2030 reference* scenario are also retained, so this scenario might be considered a "maximum wood consumption" scenario. In this scenario, the HWP sink in EU-28 is nearly double that of the *ClimWood2030 reference* scenario and the potential material substitution effect is nearly 40 % higher than the ClimWood2030 reference scenario by 2030. Harvests are higher than in the reference scenario, as are imports of raw material. The forest management sink in period 2021-2030 is on average 43 $MtCO_2e\ yr^{-1}$ compared to 62 $MtCO_2e\ yr^{-1}$ in the *ClimWood2030 reference* scenario. Both are much less than the forest management sink of 261 $MtCO_2e$ in the base period. This scenario shows a total impact on the overall GHG balance by the EU-28 wood forest sector 3 % better than the *ClimWood2030 reference* scenario by 2030, resulting in 11 Mt CO_2e yr^{-1} less being emitted between 2021 and 2030.

In this scenario, which focuses on the markets, the "**gross annual increment**" (**parameter a**) is very similar to that in the *ClimWood2030 reference* scenario.

For this scenario, the "**forest carbon pool**" (**parameter b**) is slightly smaller than in the reference case, driven by the increase of harvest of industrial roundwood (see parameter e).

In this scenario, the "**forest emissions/removals**" (**parameter c**) within EU-28 represent net carbon removals which are nearly 15 % less than in the *ClimWood2030 reference* scenario, and less than half the figure for the first period 2000-2010. This is directly related to the change in the harvest amounts in managed forests (cf. parameter d)

The total net emissions for RoW (**parameters c'**) in this scenario are marginally higher in period 2021-2030 as compared to the *ClimWood2030 reference* scenario. This change in emissions/removals for RoW is related to the increasing export to EU-28 from 2020 onwards, which leads to increased emissions from the management of forests outside the EU28.

The "**harvest for energy use**" (**parameter d**) as well as "**harvest for material use**" (**parameter e**) are both higher than in the reference scenario, chiefly due to the scenario assumptions about market expansion, which drive increases in EU-28 harvest. Harvest of industrial wood in 2030 is nearly 5 % higher than in the reference scenario, and the second highest of all scenarios. Between 2010 and 2030, the average price of wood increases by 21%. The price of harvested stem wood in scenario V is almost the same as in the reference scenario in 2030.

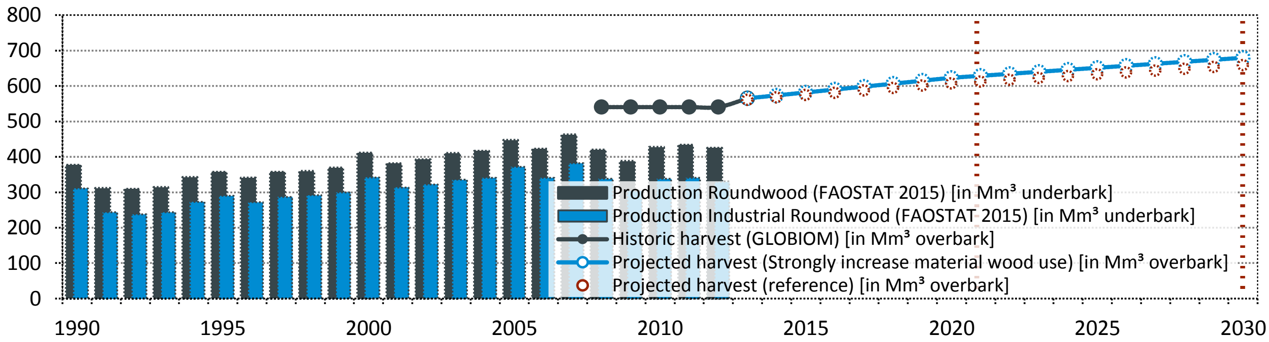

Figure 3-5: Projected annual harvest for scenario V and *ClimWood2030 reference* scenario

Table 3-10: Detailed results for *Strongly increase material wood use* scenario (V)

Sphere	FORESTS									NET TRADE			HWP			SUBSTITUTION*		SCENARIO OVERALL GHG IMPACT
Description	ANNUAL INCREMENT	CARBON POOL	EMISSIONS/REMOVALS (E/R) EU				NON-EU	HARVEST		INDRW & WOOD PULP	FUEL WOOD	HWP	CARBON INFLOW	CARBON POOL	E/R	energy	material	
			AR	FM	D	Total	Total	energy	material	material	energy	material						
Unit	*Mt C*		*Mt CO_2e/year*					*Mt C*							*Mt CO_2/year*			*Mt CO2/year*
Parameter	a	b	c1	c2	c3	**c**	c'	d	e	f1	g	f2	h	i	**j**	**k**	**l**	**c+j+k+l**
ABSOLUTE VALUES																		
ClimWood2030 Reference Scenario																		
#01 (2000-2010)	214	9 584	-34,8	- 261	53,3	- 243	1 377	45,1	75,5	-3,34	0,592	3,79	71,6	1 468	-33,9	-14,95**	-2,91**	-294,65
#02 (2011-2020)	222	10 140	-69,2	- 155	36,2	- 188	2 358	57,3	74,9	-5,29	0,883	2,47	67,9	1 530	-11,7	- 186	-31,7	-417,8
#03 (2021-2030)	226	10 515	-93,3	-62,0	21,3	- 134	2 097	67,8	77,7	-8,76	1,01	-0,0943	71,3	1 568	-16,7	- 222	-34,2	-407,1
#04 (post-2030)																- 32	-03,1	-35,0
VALUES RELATIVE TO REFERENCE SCENARIO																		
Strongly increase use of wood (V)																		
#02 (2011-2020)	→ *-0,08*	→ *-9,32*	→ *0,29*	→ *9,50*	→ *-0,41*	→ *9,38*	→ *02,0*	→ *0,40*	→ *1,63*	→ *-0,03*	→ *-0,05*	→ *-0,11*	→ *1,95*	→ *4,98*	↓ *-6,63*	→ *-2,03*	↘ *-4,60*	→ *-3,89*
#03 (2021-2030)	→ *-0,15*	→ *-44,22*	→ *0,43*	↑ *18,48*	→ *-0,65*	↗ *18,26*	→ *05,4*	→ *1,40*	→ *3,72*	→ *-0,39*	↓ *-0,27*	↓ *-0,39*	→ *4,81*	→ *34,76*	↓ *-14,09*	→ *-5,20*	↓ *-10,01*	→ *-11,04*
#04 (post-2030)																→ *-1,21*	↓ *-1,87*	→ *-3,08*

Legend:

- ↑ Scenario V superior to Reference scenario by more than 25%
- ↗ Scenario V superior to Reference scenario by more than 25% but less than 10%
- → Variation between Scenario V and Reference scenario between 10% and -10%
- ↘ Scenario V inferior to Reference scenario by more than -10% but less than -25%
- ↓ Scenario V inferior to Reference scenario by more than -25%

- **51** Difference between Scenario V and Reference scenario greater than 50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *10* Difference between Scenario V and Reference scenario beween 10 and 50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *09* Difference between Scenario V and Reference scenario beween -10 and +10 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- *-10* Difference between Scenario V and Reference scenario beween -10 and -50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)
- **-51** Difference between Scenario V and Reference scenario greater than -50 MTCO2/year (only for parameters c1, c2, c3, c, j,k,l)

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value for the reference scenario is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference.

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

“**Extra-EU net trade of HWP and their feedstock**” (**parameter f1 and f2**): Part of the increased demand for feedstock (i.e. industrial roundwood and wood pulp) is satisfied from outside the EU-28: by 2030, net imports of industrial wood and wood pulp are around 5 % higher than in the *ClimWood2030 reference* scenario. EU-28 becomes a net importer of HWP, more than in the reference scenario. The recorded increasing trade surplus in the “**extra-EU net-trade of wood for energy**“ (**parameter g**) is slightly lower in this scenario as compared to the development in the *ClimWood2030 reference* scenario.

At the same time, in this scenario, the consumption of HWP, representing the “**HWP carbon pool inflow**” (**parameter h**), increases about 7 % higher than in the *ClimWood2030 reference* scenario, as a result of the scenario assumptions about demand for sawnwood and panels.

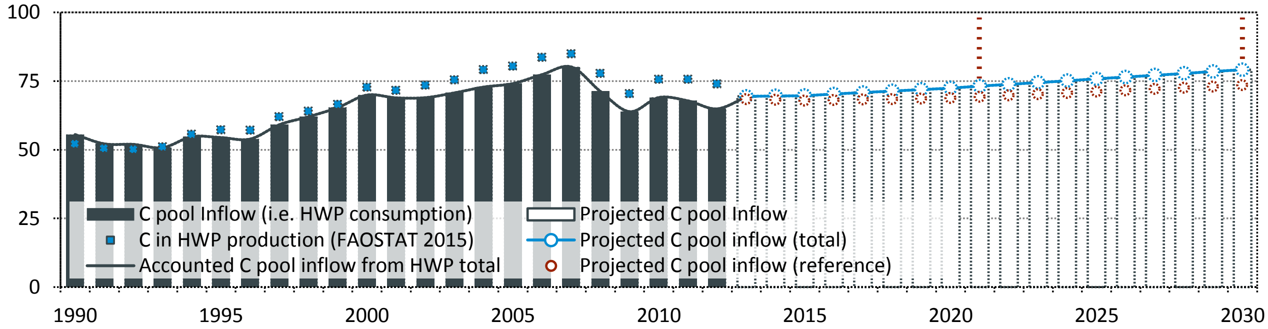

Figure 3-6: Projected annual HWP pool inflow for scenario V and *ClimWood2030 reference* scenario I [in Mt C]

The net removals of carbon (i.e. “**HWP emissions/removals, parameter j**) in the “HWP carbon pool” (parameter i) are nearly twice as high in this scenario as in the reference scenario, reflecting the higher wood consumption.

The potential “**energy substitution**” (**parameter k**) in this scenario is marginally larger than in the *ClimWood2030 reference* scenario.

In this scenario, as would be expected given the scenario assumptions, the potential “**material substitution**” effect (**parameter l**) increases from the base period onwards, and in the last period is nearly 30 % higher than in the *ClimWood2030 reference* scenario.

3.6.3 Policy instruments linked to the scenario

The policy instruments linked to the scenario are the same as those underlying the *ClimWood2030 reference* scenario, with the following exceptions.

This scenario is driven by the assumption that that market developments continue to be favourable and there is successful wood promotion. This is mostly a matter for the private sector, not policy makers, but the latter may have influence in some crucial areas:

- First, construction activity should be at a satisfactory level, notably in those branches where solid wood products have significant market share, especially residential construction (especially low-rise), renovation, extension and maintenance. This is heavily influenced by macroeconomic policy, such as interest rates, GDP growth, disposable income etc., as well as the avoidance of speculative bubbles like that which caused so much damage to the construction sector in 2008.
- Second, construction standards should not hinder the use of wood products in construction. They should take account of the latest technical progress, preferably by being performance based, and neutral with regards to the type of material used, providing a “level playing field” for all construction materials. Voluntary standards, notably for “green building” should also not discriminate between materials without objective justification.
- Finally the awareness and resources available for promotion, of wood products in EU are often considerably lower than those available to competing materials, or to wood products in US or Japan. If policy makers considered that, because of demonstrated climate or environmental benefits, the use of wood products should be encouraged; public funds might be combined with private funds to promote the use of wood as part of a climate change mitigation strategy.

However, to achieve a doubling of wood use in construction which this scenario considers possible, and thus fully achieve the potential of wood products, a significant effort would be needed, chiefly from the private sector, which would have to display high adaptability, innovation and marketing skills. Policy makers could support this effort by contributing more to research and development funding, justifying this investment not only by employment and growth, but also by climate change mitigation objectives. This might be promoted e.g. by making HWP a separate activity in the accounting framework of climate regimes.

3.7 Comparison of scenarios

This section presents an overview, in tabular form, of the results for EU-28 for the five scenarios. The significance of these comparisons is discussed in the next chapter.

Table 3-11: Annual average EU-28 GHG impact of scenarios in absolute value [in Mt $CO_2e\ yr^{-1}$]

Scenario			Snapshots			
			#01 (2000-2010)**	**#02 (2011-2020)**	**#03 (2021-2030)**	**post-2030 effects**
ClimWood2030 reference scenario (I)						
	Emissions/removals	Forests	-242.90	-188.03	-134.02	
		HWP	-33.89	-11.69	-16.71	
	*Substitution potential**	Energy use	-14.95	-186.44	-222.19	-31.86
		Material use	-2.91	-31.68	-34.17	-3.13
	Total		**-294.65**	**-417.84**	**-407.08**	**-35.00**
Increase C stock in existing EU forests (II)						
	Emissions/removal	Forests	-242.897	-265.261	-339.618	
		HWP	-33.89	-2.66	-2.23	
	*Substitution potential**	Energy use	-14.95	-175.39	-188.85	-30.78
		Material use	-2.91	-26.37	-23.39	-1.40
	Total		**-294.65**	**-469.68**	**-554.08**	**-32.18**
Cascading - increased recovery of solid wood products (III)						
	Emissions/removals	Forests	-242.90	-188.05	-133.99	
		HWP	-33.89	-11.74	-16.73	
	*Substitution potential**	Energy use	-14.95	-190.36	-233.57	-39.43
		Material use	-2.91	-31.72	-34.60	-4.60
	Total		**-294.65**	**-421.87**	**-418.90**	**-44.03**
Cascading - prevent first use of biomass for energy (IV)						
	Emissions/removals	Forests	-242.90	-179.03	-103.63	
		HWP	-33.89	-22.40	-39.55	
	*Substitution potential**	Energy use	-14.95	-178.83	-202.28	-33.86
		Material use	-2.91	-38.85	-52.63	-6.68
	Total		**-294.65**	**-419.12**	**-398.09**	**-40.54**
Strongly increase use of wood (V)						
	Emissions/removals	Forests	-242.90	-178.65	-115.76	
		HWP	-33.89	-18.32	-30.80	
	*Substitution potential**	Energy use	-14.95	-188.47	-227.39	-33.07
		Material use	-2.91	-36.28	-44.17	-5.01
	Total		**-294.65**	**-421.73**	**-418.12**	**-38.08**

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

Table 3-12: Annual average EU-28 GHG impact of scenarios as compared to the *ClimWood2030 reference* scenario [in Mt CO_2e yr^{-1}]

Scenario			Snapshots			
			#01 (2000-2010) **	**#02 (2011-2020)**	**#03 (2021-2030)**	**post-2030 effects**
ClimWood2030 reference scenario (I)						
	Emissions/removals	Forests	-242.90	-188.03	-134.02	
		HWP	-33.89	-11.69	-16.71	
	*Substitution potential**	Energy use	-14.95	-186.44	-222.19	-31.86
		Material use	-2.91	-31.68	-34.17	-3.13
	Total		**-294.65**	**-417.84**	**-407.08**	**-35.00**
Increase C stock in existing EU forests (II)						
	Emissions/removal	Forests	–	*-77.23*	*-205.60*	
		HWP	–	*9.03*	*14.48*	
	Substitution potential	Energy use	–	*11.05*	*33.34*	*1.08*
		Material use	–	*5.31*	*10.78*	*1.73*
	Total		**–**	**-51.84**	**-147.00**	**2.82**
Cascading - increased recovery of solid wood products (III)						
	Emissions/removals	Forests	–	*-0.02*	*0.02*	
		HWP	–	*-0.05*	*-0.03*	
	Substitution potential	Energy use	–	*-3.92*	*-11.39*	*-7.57*
		Material use	–	*-0.05*	*-0.44*	*-1.46*
	Total		**–**	**-4.03**	**-11.83**	**-9.04**
Cascading - prevent first use of biomass for energy (IV)						
	Emissions/removals	Forests	–	*9.00*	*30.38*	
		HWP	–	*-10.71*	*-22.84*	
	Substitution potential	Energy use	–	*7.61*	*19.91*	*-2.00*
		Material use	–	*-7.18*	*-18.47*	*-3.54*
	Total		**–**	**-1.28**	**8.98**	**-5.54**
Strongly increase use of wood (V)						
	Emissions/removals	Forests	–	*9.38*	*18.26*	
		HWP	–	*-6.63*	*-14.09*	
	Substitution potential	Energy use	–	*-2.03*	*-5.20*	*-1.21*
		Material use	–	*-4.60*	*-10.01*	*-1.87*
	Total		**–**	**-3.89**	**-11.04**	**-3.08**

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value for the reference scenario is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference.

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

In order to assess potential impacts of the ClimWood2030 scenarios on forests outside the EU, Table 3-13 and Figure 3-8 provide an overview on the forest emissions/removals from forests inside and outside the EU. It should be noted here that the results presented in Table 3-13 do not cover potential substitution effects associated with products from outside EU-28 nor GHG emissions related to the associated increase of transport exports to Europe (cf. chapter 2.2.1).

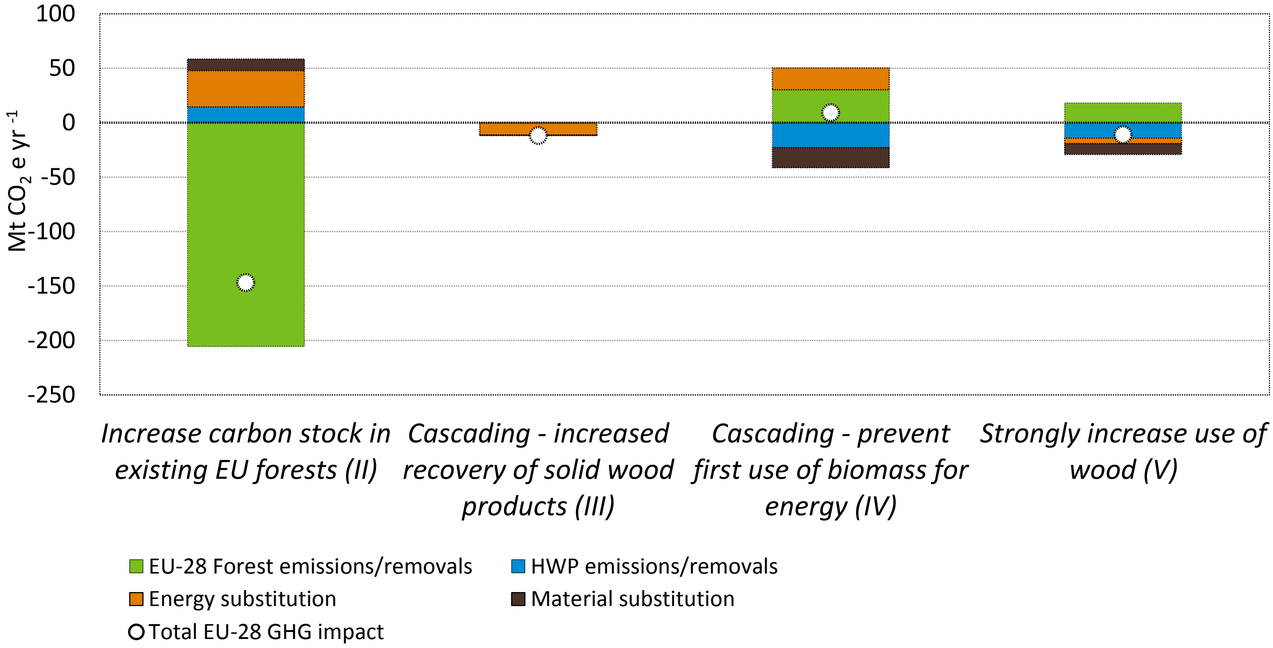

Figure 3-7: Annual average EU-28 GHG impact of scenarios as compared to the *ClimWood2030 reference* scenario, period 2021-2030, detailed per contributor [in Mt CO_2e yr^{-1}].

Table 3-13: Annual average impact of scenarios on EU and non-EU forest emissions/removals as compared to the *ClimWood2030 reference* scenario [in Mt CO_2e yr^{-1}]

Scenario	Snapshots		
	#01 (2000-2010)	**#02 (2011-2020)**	**#03 (2021-2030)**
ClimWood2030 reference scenario (I)			
EU Forests	-242,90	-188,03	-134,02
Non-EU Forests	1377,46	2357,71	2096,79
Increase C stock in existing EU forests (II)			
EU Forests	–	*-77,23*	*-205,60*
Non-EU Forests	–	*+13,51*	*+40,12*
Cascading - increased recovery of solid wood products (III)			
EU Forests	–	*-0,02*	*+0,02*
Non-EU Forests	–	*+0,23*	*-1,39*
Cascading - prevent first use of biomass for energy (IV)			
EU Forests	–	*+9,00*	*+30,38*
Non-EU Forests	–	*+2,23*	*-37,30*
Strongly increase use of wood (V)			
EU Forests	–	*+9,38*	*+18,26*
Non-EU Forests	–	*+2,02*	*+5,35*

Graphical illustrations of the two tables above are given in Figure 3-7 and Figure 3-8.

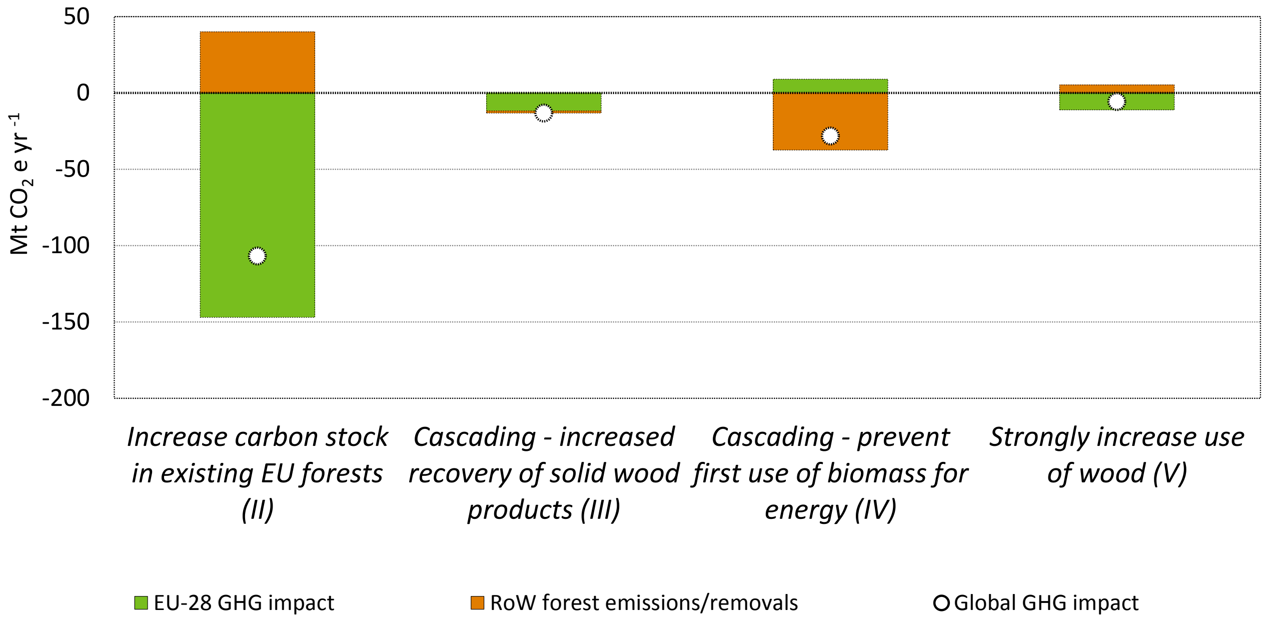

Figure 3-8: Annual average global GHG impact of scenarios as compared to the *ClimWood2030 reference* scenario, period 2021-2030 (including RoW forest emissions and removals) [in Mt CO_2e yr^{-1}].

Table 3-14 provides an overview of the relative changes in the GHG impact within EU 28 for selected snapshot elements relative to the chosen *ClimWood2030 reference* scenario. The elements and parameters included in the table are described in detail in chapter 3.1.

Table 3-14: Overview of snapshot elements with EU-28 GHG impact relative to the *ClimWood-2030 reference* scenario

I	ClimWood2030 reference scenario	II	Increase forest carbon stock in existing EU forests
III	Cascading – increase recovery of solid wood products	IV	Cascading – prevent first use of biomass for energy
V	Strongly increase material wood use		

		I	II	III	IV	V	
		absolute	*relative values**				*Units*
Snapshot #01 (2000-2010)**	a	213.89	–	–	–	–	*Mt C*
	b	9584.30	–	–	–	–	
	c	**-242.90**	–	–	–	–	***Mt CO_2e***
	d	45.06	–	–	–	–	*Mt C*
	e	75.51	–	–	–	–	
	f	0.45	–	–	–	–	
	g	0.59	–	–	–	–	
	h	71.55	–	–	–	–	
	i	1468.33	–	–	–	–	
	j	**-33.89**	**–**	**–**	**–**	**–**	***Mt CO_2e***
	K*	**-14.95**	**–**	**–**	**–**	**–**	
	L*	**-2.91**	**–**	**–**	**–**	**–**	
Total		**-294.65**	**–**	**–**	**–**	**–**	***Mt CO_2e***
Snapshot #02 (2011-2020)	a	222.41	*+0.95*	*0.00*	*-0.05*	*-0.08*	*Mt C*
	b	10140.42	*73.32*	*0.01*	*-10.92*	*-9.32*	
	c	**-188.03**	***-77.23***	***-0.02***	***+9.00***	***+9.38***	***Mt CO_2e***
	d	57.27	*-3.19*	*0.00*	*-7.36*	*+0.40*	*Mt C*
	e	74.91	*-11.85*	*0.00*	*+10.54*	*+1.63*	
	f	-2.83	*-6.43*	*+0.12*	*+1.47*	*-0.14*	
	g	0.88	*-0.58*	*0.00*	*-0.31*	*-0.05*	
	h	67.88	*-3.45*	*+0.01*	*+3.24*	*+1.95*	
	i	1530.43	*-7.19*	*0.04*	*+8.08*	*+4.98*	
	j	**-11.69**	***+9.03***	***-0.05***	***-10.71***	***-6.63***	***Mt CO_2e***
	k	**-186.44**	***+11.05***	***-3.92***	***+7.61***	***-2.03***	
	l	**-31.68**	***+5.31***	***-0.05***	***-7.18***	***-4.60***	
Total		**-417.84**	***-51.84***	***-4.03***	***-1.28***	***-3.89***	***Mt CO_2e***
Snapshot #03 (2021-2030)	a	226.27	*+6.17*	*-0.01*	*+0.05*	*-0.15*	*Mt C*
	b	10515.41	*391.03*	*+0.03*	*-59.82*	*-44.22*	
	c	**-134.02**	***-205.60***	***+0.02***	***30.38***	***18.26***	***Mt CO_2e***
	d	67.81	*-6.87*	*0.00*	*-16.84*	*+0.61*	*Mt C*
	e	77.72	*-33.62*	*-0.02*	*24.91*	*+3.72*	
	f	-8.85	*-18.97*	*+0.18*	*4.78*	*-0.78*	
	g	1.01	*-2.32*	*0.00*	*-0.18*	*-0.27*	
	h	71.32	*-7.86*	*+0.01*	*6.99*	*+4.81*	
	i	1567.78	*-42.60*	*+0.18*	*55.59*	*+34.76*	
	j	**-16.71**	***+14.48***	***-0.03***	***-22.84***	***-14.09***	***Mt CO_2e***
	k	**-222.19**	***+33.34***	***-11.39***	***+19.91***	***-5.20***	
	l	**-34.17**	***+10.78***	***-0.44***	***-18.47***	***-10.01***	
Total		**-407.08**	***-147.00***	***-11.83***	***8.98***	***-11.04***	***Mt CO_2e***
Post 2030	**k**	**-31.86**	*1.08*	*-7.57*	*-2.00*	*-1.21*	***Mt CO_2e***
	l	**-3.13**	*1.73*	*-1.46*	*-3.54*	*-1.87*	
Total		**-35.00**	**2.82**	**-9.04**	**-5.54**	**-3.08**	***Mt CO_2e***

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

3.8 Sensitivity analysis

3.8.1 Why a sensitivity analysis?

The ClimWood2030 scenarios, like all scenarios, are based on a complex network of assumptions, projections and methods, some of which are quite uncertain. It is of interest to users, notably policy makers to know how sensitive the results are to changes in the assumptions. Models, including those used in the ClimWood2030 project, have routine sensitivity analysis carried out as part of their construction and calibration. ClimWood2030 however is based on links between models which have very different approaches and methods, which makes sensitivity analysis more complex.

In this section we present the sensitivity of the *ClimWood2030 reference* scenario to changes in the assumptions about three major aspects, which are not the subject of defined policy scenarios:

- Supply and demand for bioenergy;
- Energy substitution factors.

3.8.2 Sensitivity to assumptions about supply of and demand for bioenergy

Strongly increased demand for and supply of bioenergy, in accordance with key EU policies, underlie all the ClimWood2030 scenarios, notably influencing harvest levels, and thus forest carbon balances, wood prices, raw material availability for the forest based industries, and international trade in wood and forest products.

However there are many uncertainties and challenges to be overcome before these goals can be achieved. For instance what share of bioenergy will come from existing EU forests (the focus of ClimWood2030, alongside the EU forest based value chain) and what from other types of bioenergy, such as agricultural residues, municipal solid waste, short rotation crops on agricultural land, or imports? Will it be possible to mobilise significantly more forest wood than at present without unacceptable damage to other forest functions (biodiversity, recreation, etc.)? If the higher mobilisation required is not possible, what could be the consequences for the EU trade balance and/or for the forest based industries in terms of competition in using wood? Faced with this high degree of uncertainty, the ClimWood2030 team has explored the sensitivity of the policy scenarios by preparing projections assuming only partial success in achieving the bioenergy targets which underlie the *ClimWood2030 reference* scenario. Two sets of sensitivity assumptions have been explored, which differ, from each other and from the reference scenario[33], in the degree to which the official bioenergy goals are achieved. They are as follows:

[33] The basic assumption of the ClimWood2030 reference scenario is a continuation of existing policy, including all policy instruments in place as of 2012, including notably the Renewable Energies Directive and the Effort Sharing Directive and trends over the whole period up to 2030. It incorporates much of the analysis and projection done for other EU studies, notably the EU Reference Scenario.

- *Bioenergy plateau*: No further action for promoting the development of the bioenergy sector comes into play after 2020 and the focus on achieving the GHG emission reduction target is shifted from the bioenergy sector to the other renewable energy sources. This in turn is assumed to lead to a reduced pace of development in the bioenergy sector. From 2020 onward, demand for bioenergy (heat, electricity, and biofuels) no longer increases, but instead decreases in direct relation to the proportional decrease in total energy demand. Up to 2020, the assumptions are exactly the same as for the reference scenario.
- *Bioenergy stagnation*: This set of assumptions describes a future where no significant changes in the current demand for bioenergy take place, resulting in a continuation of the 2010 consumption levels. No action for promoting the development of the bioenergy sector from that of 2010 is assumed and the focus in achieving the GHG emission reduction target is shifted from the bioenergy sector to the other renewable energy sources.

Table 3-15: Sensitivity analysis comparing *ClimWood2030 reference* scenario to alternatives with lower bioenergy demand [in Mt CO_2e yr^{-1}].

			Snapshots	
			#01 (2000-2010)**	**#03 (2021-2030)**
ClimWood2030 Reference scenario				
EU-28	*Emissions/removals*	Forests	-242.90	-134.02
		HWP	-33.89	-16.71
	Substitution potential	Energy use	-14.95	-222.19
		Material use	-2.91	-34.17
	Total		-294.65	-407.08
Non-EU	*Emissions/removals*	Forests	1377.46	2096.79
Sensitivity: Bioenergy plateau (*difference with ClimWood2030 reference scenario*)				
EU-28	*Emissions/removals*	Forests	–	*-13.66*
		HWP	–	*-1.02*
	Substitution potential	Energy use	–	*+12.75*
		Material use	–	*-0.40*
	Total		–	-2.33
Non-EU	*Emissions/removal*	Forests	–	*-3.65*
Sensitivity: Bioenergy stagnation (*difference with ClimWood2030 reference scenario*)				
EU-28	*Emissions/removals*	Forests	–	*-69.68*
		HWP	–	*-0.60*
	Substitution potential	Energy use	–	*+42.06*
		Material use	–	*-1.43*
	Total		–	-29.66
Non-EU	*Emissions/removal*	Forests	–	*-12.70*

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference.

** As regards the average substitution potential within the period 2000-2010 (snapshot #1), only effects for the year 2010 can be observed.

Note: the terms, definitions and concepts for the sensitivity analysis are the same as those in the rest of the study (cf. Chapter 2)

As would be expected, lower bioenergy demand in both hypotheses leads to lower harvests, especially of energy wood, and thus carbon stocks in EU forests which are higher than in the Reference scenario. It also leads to lower consumption of wood for energy, and thus to lower energy substitution potential, as fossil fuels are used instead of wood. Perhaps less expected are the projected consequences for HWP: the material substitution effect in the EU is higher than in the *ClimWood2030 reference* scenario, and the emissions from non-EU forests are lower. The reasons for the latter two consequences are probably to be found in lower wood prices, which stimulate consumption of HWP in the EU and discourage exports from non-EU forests. In short, the change in assumptions about bioenergy causes changes in different parts of the model system, which cancel each other out, at least in part.

If one assumes a “Bioenergy plateau”, and compares the data for the final period (2021-2030) with those of the *ClimWood2030 reference* scenario, it appears that the overall changes are quite minor: carbon removals from the atmosphere are about 10 % higher, but the energy substitution potential is 6.5 % lower, resulting in 2.3 Mt CO_2e yr^{-1} less being emitted on average between 2021 and 2030, overall. Carbon emissions from non-EU forests are just 0.2 % lower than in the *ClimWood2030 reference* scenario.

If one assumes that bioenergy stagnates at the 2010 level, the differences with the *ClimWood2030 reference* scenario are more marked. EU forest removals of carbon from the atmosphere are more than 50 % higher than in the *ClimWood2030 reference* scenario, as harvests are significantly lower. Energy substitution is over 20 % less than in the *ClimWood2030 reference* scenario, resulting in 29.7 Mt CO_2e yr^{-1} less being emitted on average between 2021 and 2030, overall. Carbon emissions from non-EU forests are 0.6 % less than in the reference.

It appears from this sensitivity analysis that the projections are indeed rather sensitive to the assumptions about future demand for bioenergy, which are one of the main drivers of the system. If bioenergy demand – for whatever reason – is significantly lower than in the *ClimWood2030 reference* scenario, outcomes for other parameters, notably EU-28 forest carbon removals and EU energy substitution potential, will be strongly affected.

3.8.3 Sensitivity to assumptions about energy substitution factors

An important part of the ClimWood2030 scenarios is the “energy substitution potential” (parameter k in the snapshots), which estimates what occurs when wood is burnt instead of a fossil fuel for wood flows that are not associated with the material use of wood in FBFUs (see definition and explanation in Section 3.1.4). However the GHG emissions of the various fossil fuels vary widely. In the *ClimWood2030 reference* scenario, it is assumed that wood substitutes for a mix of fossil fuels. If it were to be assumed that wood substitutes for natural gas, then the energy substitution potential would be lower as natural gas is one of the most efficient fossil fuels as regards GHG emissions. For this reason, a sensitivity analysis has been carried out, making a more conservative assumption about the types of fossil fuel which would be substituted by wood.

Table 3-16: Sensitivity analysis comparing displacement factors for different types of fossil fuels

	Gas		Wood	Wood versus gas
	kg CO_2/MJ		kg CO_2/MJ	kg CO_2/MJ
Min	0.0673	Min	0.0018	
Average	0.0741	Average	0.0044	-0.0698
Max	0.0814	Max	0.0111	
	Others			**Wood versus other fuels**
	kg CO_2/MJ		kg CO_2/MJ	kg CO_2/MJ
Min	0.0886			
Average	0.1035	Average	0.0044	-0.0991
Max	0.1324			

Table 3-17: Sensitivity analysis considering natural gas for heat production for the energy substitution effect [in Mt CO_2e yr^{-1}]

Scenario		Snapshot #03 (2021-2030) Reference Mix of fuel	Snapshot #03 (2021-2030) Sensitivity Natural gas	post-2030 effects Reference Mix of fuel	post-2030 effects Sensitivity Natural gas
ClimWood2030 reference scenario (I)					
Emissions/removals	Forests	-134.02	-134.02		
	HWP	-16.71	-16.71		
Substitution potential*	Energy use	-222.19	-168.50	-31.86	-21.78
	Material use	-34.17	-32.45	-3.13	-2.21
Total		-407.08	-351.67	-35.00	-23.99
Scenario : Increase C stock in existing EU forests (II) (difference with ClimWood2030 reference scenario)					
Emissions/removal	Forests	-205.60	-205.60		
	HWP	14.48	14.48		
Substitution potential	Energy use	33.34	24.05	1.08	0.74
	Material use	10.78	10.46	1.73	1.32
Total		-147.00	-156.61	2.82	2.06
Scenario : Cascading – increased recovery of solid wood products (III) (difference with ClimWood2030 reference scenario)					
Emissions/removals	Forests	0.02	0.02		
	HWP	-0.03	-0.03		
Substitution potential	Energy use	-11.39	-7.78	-7.57	-5.18
	Material use	-0.44	-0.30	-1.46	-1.10
Total		-11.83	-8.09	-9.04	-6.28
Scenario : Cascading – prevent first use of biomass for energy (IV) (difference with ClimWood2030 reference scenario)					
Emissions/removals	Forests	30.38	30.38		
	HWP	-22.84	-22.84		
Substitution potential	Energy use	19.91	15.23	-2.00	-1.37
	Material use	-18.47	-18.13	-3.54	-2.74
Total		8.98	4.65	-5.54	-4.11
Scenario : Strongly increase use of wood (V) (difference with ClimWood2030 reference scenario)					
Emissions/removals	Forests	18.26	18.26		
	HWP	-14.09	-14.09		
Substitution potential	Energy use	-5.20	-3.68	-1.21	-0.83
	Material use	-10.01	-9.89	-1.87	-1.48
Total		-11.04	-9.40	-3.08	-2.31

* The illustrated substitution potential for material use only covers applications of wood within the context of the modelling framework and the defined FBFUs. The substitution effect as an absolute value for the reference scenario is calculated only as a modelling artefact to evaluate the substitution effect for each scenario as compared to the reference.

To this end, several datasets contained in ecoinvent 2.2+ representing heat production in industrial (non-domestic) installations were selected and their GHG intensity compared based on 1 MJ of heat produced. The selected fuels are heavy fuel oil, light fuel oil and hard coal and natural gas to be compared with[34].

The energy substitution effect is reduced by around 25 % if woody biomass is assumed to replace natural gas instead of the current mix of fuels for all scenarios for the period 2021-2030. The material substitution effect is also affected by the change of substituted fuel through the energy recovery at the end of life of products. However, given the timing of end of life, the decrease of material substitution when using natural gas as a substitute instead of a mix of fossil fuels is very small (-3 % during the 2021-2030 period) whereas the post-2030 effect shows a 25 % decrease.

On the other hand, if woody biomass is assumed to replace brown coal and hard coal instead of the current mix of fuels, the energy substitution effect is increased by roughly 50 %. In analogy to the above said, the material substitution effect due to waste processing would increase by roughly 5 to 10 % in the 2021-2030 period.

[34] Ecoinvent 2.2 does not contain datasets for the production of heat from lignite (only for the production of electricity).

4 Discussion, conclusions and recommendations

4.1 Discussion

4.1.1 Method and approach

Chapter 2 has described the methods used in this study to quantify and compare changes in GHG emissions due to developments in the forest based sector- from the forest itself, inside and outside the EU, to manufacture, use, recycling, combustion and disposal of wood in all its forms, including not only the flows of wood carbon to, from and between pools, but also the substitution potential for using wood products and fuels instead of functionally equivalent alternatives. To the knowledge of the ClimWood2030 team, this is the first time there has been an attempt to bring all these aspects together in a single framework of comparable data at the European level with an ambitious level of detail.

The team has faced many conceptual, methodological and measurement challenges, and has been completely transparent about the approach taken, the estimates made and data sources and quality issues. The study team hopes for continued expert discussion about the concepts, methods and data it has used, aimed at improving accuracy and understanding of the issues brought to light in this report.

4.1.1.1 Importance of the EU-28 forest based sector for climate change around 2015

On the basis of ClimWood2030 calculations and statistical data, it is possible to quantify the importance of the EU-28 forest based sector relative to other GHG flows. Around 2010, the EU-28 forest had net GHG removals of about -240 Mt CO_2e from the atmosphere every year, which can be compared to emissions in 2012 of 878 Mt CO_2e by European industry, and 502 Mt CO_2e by transport and storage[35], or 3700 Mt CO_2e from global net forest conversion (net emissions/removals from forest conversion[36] (mostly tropical deforestation). Thus already today, the forest of the EU-28 is making a significant contribution to improving the European GHG balance.

In addition, the carbon pool in EU-28 forest products is increasing by nearly 35 Mt CO_2e every year. The carbon pool in products is about 15 % of the carbon pool in forests. The size of the HWP carbon pool depends not only on how many products are consumed, but on their length of life in service.

[35] Eurostat. http://ec.europa.eu/eurostat/statistics-explained/index.php/ File:Greenhouse_gas_emissions_by_economic_activity_2012_(thousand_tonnes_of_CO2_equivalents)_YB15.png

[36] FAOstat. http://faostat3.fao.org/browse/G2/GF/E

4.1.1.2 Reducing emissions by substituting wood for non-renewable materials

In addition to the net flows of carbon to the forest and HWP pools, the production and use of wood products reduces the emission of greenhouse gases compared to the use of functionally equivalent alternatives. Across a wide range of forest based functional units, and taking account of emissions from production, transport, use, recycling and disposal, emissions from wood products have been confirmed in this study to be lower than non-wood equivalents: typically, 1 kg of C stored in a (finished) wood product stands for a substitution of 1.5 kg of CO_2 –C (carbon contained in CO_2) in over its life cycle, including the benefits of recycling and energy recovery in the end-of-life according to current end-of-life scenarios in EU-28.

Under the heading of "substitution potential" ClimWood2030 analyses the differences between GHG emissions associated with material and energy use in each policy scenario and the GHG emissions associated with material and energy use in the reference scenario: it does not focus on the difference between the scenarios and a notional "wood-free world", as such conditions would be unrealistic and hard to quantify. However the calculated displacement factors show that if wood were replaced by other materials in its present uses, fossil GHG emissions associated with the functions performed by wood products would be considerably higher.

4.1.2 The ClimWood2030 scenarios

ClimWood2030 has generated five scenarios to analyse, in a quantified and objective way, the consequences for GHG balances of certain policy choices at present under consideration. It is stressed that these scenarios are thought experiments, and are dependent on the concepts, model structure and assumptions which have been used and which are presented, in detail in Chapter 2. These scenarios are neither forecasts of likely outcomes, nor recommendations of desirable policy choices. The five scenarios are:

I **ClimWood2030 reference** scenario: based on the official EU Reference scenario, and assuming achievement of official EU energy and climate targets for 2020, with continued business-as-usual trend until 2030;

II **Increase forest carbon stock in existing EU forests**: exploring the consequences of a decision to focus policy on increasing the carbon stock in EU-28 forest, notably by reducing domestic harvest rates;

III **Cascade use – increase recovery of solid wood products**: exploring the consequences of decisions to encourage cascade use by improving the recovery of solid wood products, for material and energy purposes;

IV **Cascade use – prevent first use of biomass for energy**: exploring the consequences of decisions to encourage cascade use by ensuring that wood of sufficient quality and dimensions harvested in EU-28 forests is first used as raw material, and only subsequently as a source of energy;

V **Strongly increase material wood use**: exploring the consequences of success in increasing wood consumption in its major markets, especially the construction sector, by innovation, investment and promotion.

The assumptions underlying each of the scenarios and the detailed results, for three ten-year periods[37], and for 12 parameters are presented in Chapter 3. This chapter focuses on the aggregate results, all expressed in the same unit – Mt CO_2e (positive figures show net emissions, negative figures net removals of greenhouse gases from the atmosphere):

- Emissions/removals of greenhouse gases
  - By EU-28 forests
  - By the harvested wood product pool in EU-28
- Substitution potential
  - Energy use
  - Material use
- Emissions/removals of greenhouse gases by forests outside EU-28

It is important to note the limitations and boundaries of the scenarios. Climwood2030 focuses on Europe. The impact on forest management outside EU associated with imports of semi-finished products is integrated in the study but not the impact (positive or negative) of substitution outside Europe, nor the HWP pool outside Europe. For instance, some countries may reduce their use of wood products in order to sell more to Europe if the price is attractive, thus reducing their domestic material substitution effect. In addition, the substitution effect or the carbon storage in HWP associated with European exports to other regions is not integrated in the results.

4.1.3 Comparison of scenarios

The scenarios have rather different profiles, according to the parameters examined (see figure 4-1), so it is an oversimplification to look only at the overall GHG impact. The scenarios are very briefly compared, from several points of view, below.

From a point of view only concerned with *total GHG balances over the whole system*, the approach which has the greatest benefits is scenario II *Increase forest carbon stock in existing EU*

[37] And projections for the period after 2030, for the substitution potential only.

forests, whereby the GHG impact of the EU forest based sector as whole for forests and for HWP, including both emissions/removal and substitution increases from about 290 Mt CO_2e in the base period to 550 Mt CO_2e in 2030. In all the other scenarios, including the *ClimWood2030 Reference* scenario (I), there is also an increase, but smaller, to 400-420 Mt CO_2e. The aggregate GHG removals (inside EU) in 2030 under scenario II are about a third higher than in the other scenarios. However, it should also be borne in mind, that under scenario II, GHG emissions outside the EU-28 increase by 40 Mt CO_2e.

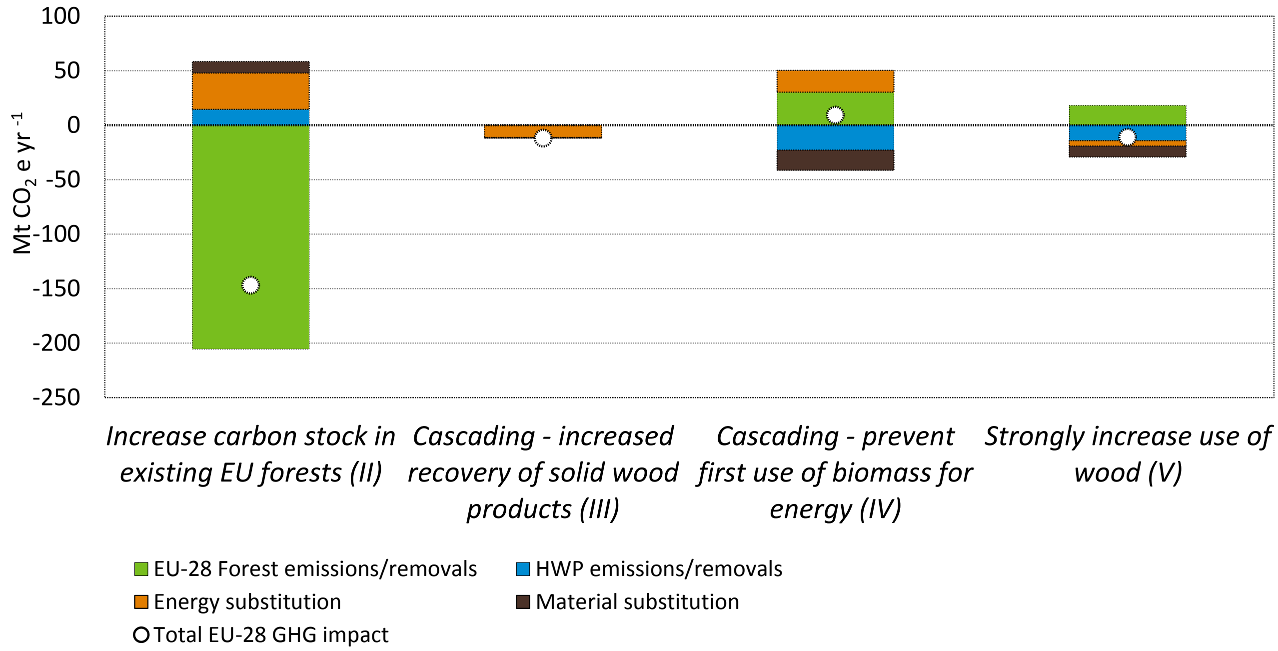

Figure 4-14-1 Annual average EU-28 GHG impact of scenarios as compared to the *ClimWood2030 reference* scenario, period 2020-2030, detailed per contributor [in Mt CO_2e yr^{-1}]

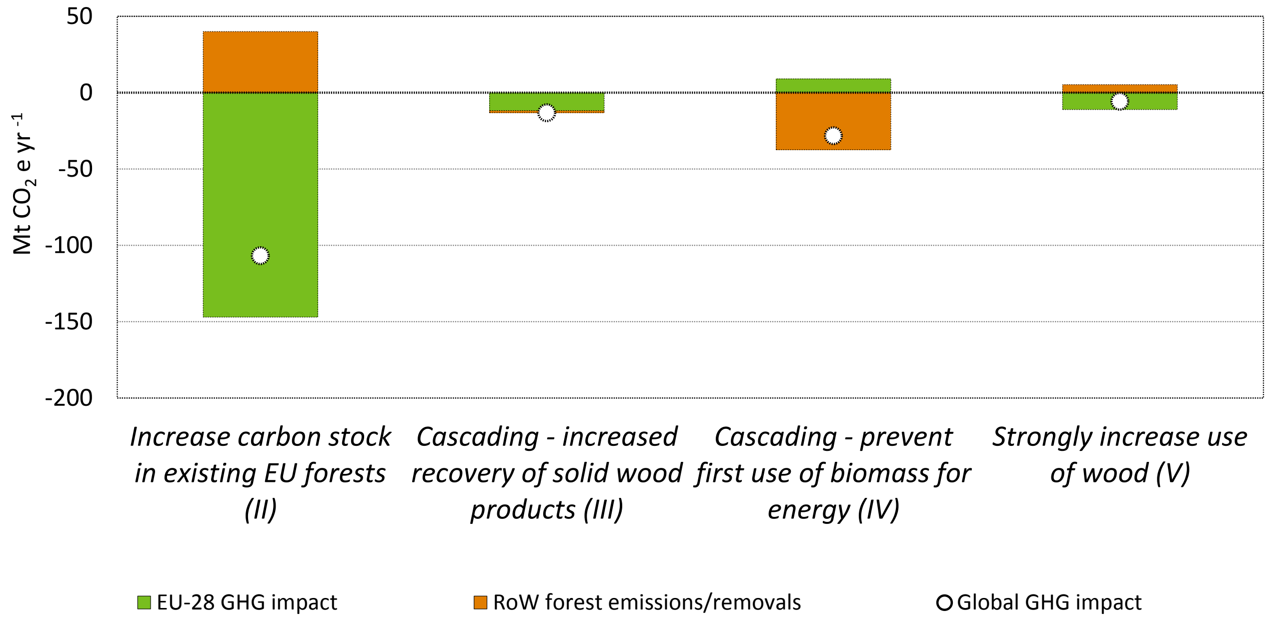

Figure 4-2: Annual average global GHG impact of scenarios as compared to the *ClimWood2030 reference* scenario, period 2020-2030 (including RoW forest emissions and removals) [in Mt CO_2e yr^{-1}].

Note: EU-28 GHG impact is the net effect of all the parameters shown in Figure 4-1. The data for non-EU forests concern the forest pool only, not the HWP pool and not the substitution effects

- From the point of view of the GHG *emissions and removals* from EU-28 forests, the best result is for scenario II *Increase carbon stock in existing EU forests*, which increases the forest carbon sink over time (-340 Mt CO_2e as of 2030). The other scenarios over time decrease the forest carbon sink to around -120 to -130 Mt CO_2e as of 2030.
- From the point of view of the GHG *emissions and removals linked to the HWP pool*, the best result is for scenario IV *Cascading - prevent first use of biomass for energy,* where the net emissions/removals increase slightly from about 34 Mt CO_2e in the base period around 2010 to just under 40 Mt CO_2e in 2030. In scenario V *Strongly increase material use*, this parameter stays roughly constant, while in the others, the sink associated with HWP declines, to negligible levels in the case of scenario II.
- In all the scenarios, *energy substitution* (which does not include wood energy use in the forest industries, as this cannot really be said to substitute for non-wood energies) increases strongly over time, which is not surprising as achieving the bioenergy targets is a major driver for the study as a whole. The energy substitution effect is the main contributor to the EU-28 GHG impact in the *ClimWood2030 reference* scenario. The energy substitution effect declines for the scenarios based on assumptions about declining harvest, whether for carbon sequestration reasons (scenario II *Increase forest carbon stock in existing EU forests*) or to encourage cascading (scenario IV *Cascading – prevent first use of biomass for energy*, especially in the period

between 2020 and 2030, when for these two scenarios, the energy substitution effect is 33 and 19 $MtCO_2e\ yr^{-1}$ higher than in the reference scenario.

- The *material substitution* in 2030[38] in the *ClimWood2030 reference* scenario is just under 30 $MtCO_2e$, compared to the base period. Under scenario V *Strongly increase material wood use*, material substitution in 2030 is 10 Mt CO_2e higher than in the *ClimWood2030 reference* scenario and in scenario IV *Cascading – prevent first use of biomass for energy*[39] 19 Mt CO_2e more. In scenario II *Increase carbon stock in existing EU forests*, where consumption is constrained by limited raw material and rising prices, material substitution is 11 Mt CO_2e less than in the *ClimWood2030 reference* scenario. In general, the changes in this parameter are smaller, in total volume and in rate of change, than for the other main parameters.
- Trends in *emissions/removals by forests outside the EU* are not primarily determined by policy in the areas analysed by ClimWood2030, but by strong independent trends, notably those driving tropical deforestation. Forest outside the EU-28, taken as a whole, show strong GHG emissions, in contrast to the net removals associated with the EU-28 forests. In the *ClimWood2030 reference* scenario, GHG emissions from forests outside the EU rise from 1377 Mt CO_2e in the base period to 2097 Mt CO_2e in 2030. However, emissions from non-EU forests are influenced by the developments for the EU forest based sector modelled in the ClimWood2030 policy scenarios: under scenario II *Increase forest carbon stock in existing EU forests*, emissions from non-EU forests are 40 Mt CO_2e higher than in the *ClimWood2030 reference* scenario, whereas in scenario IV *Cascading – prevent first use of biomass for energy*, they are lower by a similar amount. It should be pointed out that these scenario results for forests outside the EU only concern emissions/removals from the forest carbon pool in those countries: the HWP pool and the substitution effects for material and energy outside the EU were not calculated.

In most policy scenarios, the combined substitution effects, based on consumption of wood for material and energy, counterbalance, as would be expected, developments for the forest carbon pool, based on keeping carbon in the forest ecosystem. Thus, in the period 2020-2030, the combined substitution effect (i.e. material plus energy) in scenario V *Strongly increase material wood use* is about 15 Mt $CO_2e\ yr^{-1}$ higher than in the *ClimWood2030 reference* scenario, while in scenario II *Increase carbon stock in existing EU forests*, it is 34 Mt $CO_2e\ yr^{-1}$ lower. This is one illustration of the trade-offs in the forest-based sector, where developments in one part of the system often have significant consequences in other parts of the system.

The ClimWood2030 scenarios project a sharp increase in forest harvest over time. This is driven by an increase in the demand for wood for material and for energy purposes. The increase in for-

[38] For this parameter, it is not possible to measure the change between the base period and 2030, because of the calculation method. See section 2.2.4.

[39] The reason for the very high material substitution effect in scenario IV is that, because energy wood in this scenario has to come from industrial residues, sawmills become rather profitable – from their sales of residues – and are thus in a position to lower prices for sawnwood, and thus boost consumption. This price-driven process is quite different from the innovation and market development assumed in scenario V.

est harvest as seen here is higher than that projected for the EU Reference scenario. For the EU Reference scenario it has been assessed that the forest harvest within the EU would increase by roughly 16 % from 2010 until 2030. This can be put in perspective with that of the *ClimWood2030 reference* scenario where the increase in harvest is 20 %, rising to 25-27 % for scenarios which project increased use of wood (scenarios IV and V). Only in scenario II *Increase the carbon stock in exiting EU forests*, do harvests fall, by 12 % over the same period.

To achieve the outcomes described in the various scenarios, *policy actions* would be necessary, in addition to the policy instruments in place at present. These are briefly listed below.

- ***ClimWood2030 reference* scenario (I)**
  - Wood mobilisation measures, including investment in logistics and roads, changes to market structures, economic incentives to raise the level of harvest for energy;
  - Economic incentives for more intensive silviculture (for instance improved planting stock, different species, and plantation patterns);
  - Adaptation of forest regulations and national forest programmes to provide for the higher levels of wood energy harvest, while safeguarding the other forest functions, notably biodiversity, to provide clear and accepted rules of the game applicable to, and accepted by, all stakeholders.
- ***Increase carbon stock in existing EU forests* scenario (II)**
  - Economic incentives to store carbon in living forest biomass, notably by reducing harvest levels. One possible instrument would be carbon credits to forest owners, although this has not been adopted, for EU forests, in the wider climate change context. This would be a new type of policy instrument, and would require careful design to ensure effectiveness, efficiency and equity at acceptable cost;
  - The wood mobilisation measures mentioned under the *ClimWood2030 reference* scenario would not be implemented. Other measures to stimulate active forestry, which are in place in many member states, might be removed.
- ***Cascading – increase recovery of solid wood products* scenario (III)**
  - The wood mobilisation measures under the *ClimWood2030 reference* scenario, as well as:
  - complete implementation of the Landfill Directive, making it more difficult for wood material to leave the commercial circuits;
  - measures to improve and structure the markets and logistics of the circuits for post-consumer products (e.g. better market information, improved installations for collecting, sorting and transporting this bulky, low value material);
  - Measures to regulate disposal of demolition waste as well as of other HWP could increase availability of post-consumer wood.
- ***Cascading – prevent first use of biomass for energy* scenario (IV)**
  - The wood mobilisation measures under the *ClimWood2030 reference* scenario, as well as:
  - Regulations to prevent large scale energy plants from consuming forest wood, combined with economic incentives to prefer industrial residues as fuel;

  - Economic incentives to stimulate the flow of wood from forests to wood processing plants.

- ***Strongly increase material wood use* scenario (V)**
  - The wood mobilisation measures under the *ClimWood2030 reference* scenario, as well as:
  - Maintenance of construction activity at a high level, through macroeconomic policy and prevention of speculative property bubbles;
  - Construction standards should not hinder the use of wood products in construction. They should take account of the latest technical progress, preferably by being performance based, and neutral with regards to the type of material used;
  - public funds might be combined with private funds to promote the use of wood as part of a climate change mitigation strategy;
  - Increased R&D funding for innovative and carbon efficient uses for wood products.

4.1.4 Sustainable forest management and ClimWood2030

ClimWood2030 has focused on the outlook for GHG balances, and has not modelled all the aspects of the forest based sector, such as the economic, ecological and social consequences of the scenarios, although these, under the overall heading of "sustainable forest management", are of the highest importance. It is however possible to make a few descriptive remarks, about these aspects.

As regards *sustainability of wood supply*, all the scenarios are fully sustainable (for the EU-28) as the model structure does not allow non-sustainable harvesting levels in EU-28 forests. In all scenarios the forest carbon pool is higher in 2030 than in the base period and in no scenario is the annual forest harvest higher than the annual increment in the EU.

As regards *employment and livelihoods in forestry (only wood related activities*[40]*)*, it may be concluded from Table 3-11 that in all scenarios, except scenario II *Increase carbon stock in existing EU forests*, EU-28 harvests in 2030 would be about 16 % to 27 % higher than today, so employment and livelihoods in forestry would most likely be higher than today, assuming constant labour productivity. Incomes will be determined by price as well as volume. In all scenarios the prices of sawlogs and pulp logs are expected to increase over time due the increasing demand. In the reference scenario these prices increase by roughly 16 % as compared to 2010 values, thereby potentially providing additional sources of revenue to forest land owners. In scenario II, however, harvests in 2030 would be significantly lower than in the base period, which would imply a reduction in wood related employment and income. A policy response to such a loss in employment might include compensation in return for the GHG balance benefits of the increased carbon sink in this scenario and/or a diversification strategy for the people and regions affected.

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[40] The implication of the scenarios in the terms of outlook for forest related activities concerned with biodiversity, recreation, education etc has not been evaluated within the framework of this project.

As regards the level of activity in the *forest based industries* (excluding energy supply and generation), the *ClimWood2030 reference* scenario (I) projects a level roughly equivalent to the present, as do scenarios *Increase carbon stock in existing EU forests* (II) and *Cascading – increase recovery of solid wood products* (III). However scenarios *Cascading – prevent first use of biomass for energy* (IV) and *Strongly increase material wood use* (V) project activity levels about 10% higher than at present, due, in the former case, to supply constraints on forest energy wood and, in the latter, to technical innovation and successful promotion of wood products.

As regards *biodiversity*, in all scenarios, the model allows no harvesting or intense silviculture in nature conservation areas or high conservation value forests, so it appears that biodiversity in these forests is well protected. A question arises however about conservation and biodiversity in production forest: to mobilise the extra volumes of wood foreseen in most of the scenarios, including the reference scenario, it cannot be excluded that tensions arise over such questions as stump and branch harvesting, choice of species and silvicultural methods, etc.

4.1.5 ClimWood2030 and renewable energy targets

It should be pointed out that the analysis presented by ClimWood2030 is very dependent on scenario assumptions about how the EU-28 renewable energy targets will be achieved. All the scenarios are based on the assumption that, in accordance with the EU Impact Assessment, renewables will account for 24.4 % of gross final energy in 2030, and that the share of different types of energy will be as modelled in the Impact Assessment. The ClimWood2030 system does not allow substitution between categories of feedstock, so that for instance the use of wood biomass cannot be substituted by waste biomass. It also assumes that the area of short rotation coppice and perennial crops remains stable at the levels of 2010. Taken together, these assumptions are what drive the ClimWood2030 projections, as in all the scenarios, the targets must be achieved, with a given percentage of wood, and without the possibility of a major contribution of bioenergy from agricultural land. In effect, these assumptions ensure that in the ClimWood2030 model structure, the contribution of wood to renewable energy supply increases strongly and comes in the first place from existing forests. Both of these assumptions are reasonable, and in accordance with policy objectives; however, there are alternative futures, for instance the following:

- wind, solar and other non-biomass renewable energies expand faster than expected in the EU Impact Assessment, so that the targets can be achieved without a major increase in the use of bioenergy;
- the bioenergy targets are achieved by a significant expansion of short rotation coppice and perennial crops on agricultural land, or of non-wood biomass, rather than wood from existing forests.

In both these cases, there would be much less pressure from the model system to raise harvest levels for energy in European forests, with consequences for prices, raw material availability for forest industries, pressure on forest outside the EU and substitution potential.

In effect these assumptions (achieving the bioenergy targets without substitution between renewable energies and without expansion of SRC) bring about a "wood shortage" and high wood prices, which make it difficult to combine the policy choices of the various policy scenarios. For instance, a "win-win" scenario could be conceived whereby wood consumption rises as in scenario V, and there is more cascade use, through improved wood recovery (scenario III) and priority to material use (scenario IV). However given the high and inflexible demand for wood-based energy resulting from the high-level policy choices, and the resulting high wood prices, combined with the requirements of sustainable wood supply, these choices lead to rather marginal differences between the scenarios.

4.1.6 Looking beyond 2030

The ClimWood2030 analysis addresses the period to 2030 in quantitative terms by the use of scenarios. Indeed uncertainty increases the longer the time period that is covered in a modelling framework. However, in one important respect the ClimWood2030 scenarios are misleading, because they do not cover a long enough time period. During the period analysed, the carbon stock of the EU-28 forests continues to grow, as it has over the last decades or centuries. However, this process of accumulating growing stock and carbon cannot be infinite: at some point, it will not be possible to accumulate more carbon in existing forests, which will enter a steady state equilibrium of emissions and removals, or even release carbon as they lose vitality and become more vulnerable to damage and more frequent climate extremes. When that point of saturation is reached, the substitution potential will become the only way of the forest-based sector of the EU-28 to actively mitigate climate change. Furthermore, the effects of an increased or decreased use of wood as material and fuel as a consequence of the scenario assumptions:

a) shift substitution effects over time, e.g. if forest wood is used as a material and burned after this material use, instead of burning it directly as biofuel from forestry; in analogy, the substitution effect from material use occurs at production and then after the service life of the product when it comes to the substitution effects in the end-of-life of the product, and
b) cumulate over time, as each "generation" of sustainably supplied wood product replaces a non-renewable supply of alternative materials: whereas the source of wood is not reduced.

It is possible to estimate the substitution effect for the period after 2030 (only for the wood products brought into the system between 2010 and 2030, with no estimate made for consumption after 2030). Under the *ClimWood2030 reference* scenario, the material substitution effect after 2030 is estimated at 3.1 Mt CO_2e yr^{-1}. Under scenario II *Increase carbon stock in existing EU forests*, which projects low consumption of forest products, the annual substitution effect would be 1.73 Mt CO_2e yr^{-1} less than in the reference scenario, while under scenario III *Cascading – prevent first use of forest biomass for energy*, which projects the highest consumption levels for forest products, it would be 3.5 Mt CO_2e yr^{-1} more. Over the seventy year period 2031-2100, the cumulative effect of these differences is highly significant. This indicates clearly that policy choices adopted for a time frame up to 2030 have implications much beyond 2030.

These issues have been explored for Switzerland by Taverna et al. (2007). This study found that it is after 20 to 30 years that the annual substitution effects become larger than the additional sink effect in the forests and that it will take around 50 years until the overall effect of the wood use scenario is more favourable than that of a scenario focused on carbon sequestration in the forest. If it had been possible to use the ClimWood2030 analytical approach for a much longer period, say to 2100, it is very likely that the relative importance of the forest sink and the substitution potential would have changed radically.

4.2 Conclusions

A holistic approach to quantify carbon pools and flows throughout the forest based sector, as well as substitution effects, along the lines pioneered by ClimWood2030, is necessary to understand the overall effects for the GHG balance of policy choices in the forest based sector. The analysis of the study, discussed in the previous section, can be summarised in a few conclusions, which are set out below.

(1) The ClimWood2030 approach is new and should be widely reviewed and discussed.

(2) Material use of HWP leads to lower GHG emissions over the whole life cycle than the use of functionally equivalent alternatives (1.5 to 3.5 t CO_2 saved per ton of HWP). Reciprocally, if HWP were replaced by other materials, associated fossil GHG emissions would be considerably higher.

(3) ClimWood2030 has constructed five scenarios, a reference scenario (I) and four policy scenarios: *Increase carbon stock in existing EU forests* (II), *Cascade use – increase recovery of solid wood products* (III), *Cascade use – prevent first use of biomass for energy* (IV) and *Strongly increase material wood use* (V). These are thought experiments, not forecasts of likely outcomes or policy recommendations.

(4) In the *ClimWood2030 reference* scenario assumes that the EU and Member States achieve their policy goals in the field of bioenergy for 2020, and that the share of renewable energy rises to 24 % in 2030. In this scenario, energy substitution by wood biomass saves an additional 36 Mt CO_2e yr^{-1} on average for the period 2021-2030 (compared to current levels), as the 2020 bioenergy targets are met and then exceeded. This material is supplied by increased harvests from EU-28 forests to supply the biomass energy called for by the policy targets. Total harvests increase by 21 % between periods 2000-2010 and 2021-2030. Harvest for energy use by nearly 50 %, leading to a steep decline in the EU forest sink: the net removals from EU forests decrease by 45 % in period 2000-2010 to 2021-2030. However, EU forests remain a sink (10 % increase of carbon pool over 30 years). In the base period, energy wood harvest is about 60 % of industrial wood harvest, but in the last decade, this proportion rises to 87 %. The average price observed in the GLOBIOM model for harvested

stem wood increases by 16 % between 2010 and 2030. EU-28 net imports of industrial roundwood and wood pulp more than double, and in 2030, net imports reach about 10 % of domestic harvests. Development of HWP markets remains stagnant in this scenario. The policy imperative to produce more wood for energy through intensified silviculture and increased harvests might cause tension with the need to conserve soils and biodiversity, because of harvest techniques (larger machines), or removal of previously unused biomass (stumps, branches).

(5) Scenario II *Increase forest carbon stock in existing EU forests* shows the best overall GHG impact of all scenarios up to 2030. However, under this scenario, emissions from forest outside the EU increase, wood prices double over 20 years, and employment and livelihoods in forestry are reduced. ClimWood2030 only analyses in quantitative terms the period to 2030. If a longer period had been considered, net carbon removals by EU forests would decline quickly thereafter as saturation is reached, and the substitution factors (which are cumulative and spread over time) or the lack thereof, would become more important. Saturated forests may even release carbon as they lose vitality and become more vulnerable to damage and more frequent climate extremes. Eventually, substitution potential will become the only way of maintaining a system-wide sink in the forest-based sector of the EU-28. Over the seventy year period 2031-2100, the cumulative effect of differences among scenarios is highly significant. This indicates clearly that policy choices adopted for a time frame up to 2030 have implications much beyond 2030.

(6) In all the scenarios, very large amounts of wood are used for energy purposes (e.g. in 2030 477 Mm^3 of wood[41] outside wood industries in the *ClimWood2030 reference* scenario). In effect these assumptions (achieving the bioenergy targets without substitution between renewable energies and without expansion of SRC) bring about a “wood shortage” and high wood prices, which make it difficult to combine the policy choices of the various policy scenarios. For instance, a “win-win” scenario could be conceived whereby wood consumption rises as in scenario V, and there is more cascade use, through improved wood recovery (scenario III) and priority to material use (scenario IV). However, given the high and inflexible demand for wood-based energy resulting from the high-level policy choices, and the resulting high wood prices, combined with the requirements of sustainable wood supply, these choices lead to rather marginal differences between the scenarios.

(7) All the scenarios are very dependent on the underlying assumptions about how renewable energy targets are achieved: If solar and wind energy grow faster than projected by the EU Impact Assessment or if short rotation coppice and/or perennial energy crops and/or non-wood biomass develop rapidly, there would be much less pressure to mobilise large volumes of wood for energy from EU and global forests. The lower demand for energy wood would create more opportunities to develop cascade use and HWP climate benefits.

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[41] This converts into 1.14E+11 oil equivalent, assuming an average wood density of 500 kg/m^3, a heating value of wood of 20 MJ/kg dry wood and 41.868 MJ/oil equivalent

(8) In some scenarios, notably scenario II *Increase carbon stock in existing EU forests*, GHG emissions from non-EU forests are higher than in the reference scenario, but in others, notably Scenario IV *Cascade use – prevent first use of biomass for energy*, it is lower. Extra-EU trade can therefore increase or decrease the pressure on forests of EU trade partners (i.e. the EU forest footprint). In the *Increase carbon stock in existing EU forests* scenario, the emissions/removals from non-EU forests increase by roughly 40 Mt CO_2e in the period 2021-2030 as compared to the *ClimWood2030 reference scenario*. The increase in emissions/removals from non-EU forests is however fully balanced by the increase of the EU forest carbon stock. In the *Cascade use – prevent first use of biomass for energy* scenario, the emissions/removals from non-EU forests decreased by roughly 37 Mt CO_2e in the period in period 2021-2030 as compared to the *ClimWood2030 reference scenario*. It should however be kept in mind that the impacts on emissions/removals from non-EU forests of changes in EU are quite small as compared to the change over time in deforestation/afforestation emission in non-EU countries.

(9) Strongly increasing the use of wood, notably in construction (scenario V) can reduce GHG emissions by alternative materials, compared to the *ClimWood2030 reference* scenario, by 11 Mt CO_2e yr^{-1} on average.

(10) An optimum combination of the forest protection, cascade and substitution approaches outlined in scenarios II-V, coupled with further progress in energy efficiency and renewable energies (beyond the EU Reference Scenario) and probably with an increase in the area of short rotation coppice, might yield additional GHG savings in the 2020-2030 period, and would continue to do so for decades, with sustainable development co-benefits.

(11) The most relevant policy instruments considered to achieve the scenario outcomes include:

(a) Wood mobilisation measures (except scenario II);
(b) Economic incentives to store carbon in living forest biomass, possibly by carbon incentives, or reducing existing incentives for wood production (scenario II only);
(c) Measures to increase recovery of post-consumer wood, including full implementation of the Landfill Directive, improving markets and logistics for post-consumer wood, and regulating disposal of wood-containing waste;
(d) Maintenance of construction activity at a high level;
(e) Performance based construction standards, neutral with regards to the type of material used, so as not to hinder the use of wood products in construction;
(f) Public/private investment in increased R&D for innovative and carbon efficient uses for wood products and for wood promotion as part of an overall climate change mitigation strategy.

(12) The ClimWood2030 scenarios would also influence other aspects of sustainable forest management, including employment, livelihoods and biodiversity, although these parameters have not been explicitly computed in the scenarios. However, in all scenarios, wood supply

is on a sustainable basis and there is no reduction in the area of forest protected to conserve biodiversity.

(13) ClimWood2030 quantifies the importance of the EU-28 forest based sector relative to other GHG flows. Around 2010, the EU-28 forest had net reported GHG removals of about -240 Mt CO_2e from the atmosphere every year, which can be compared to emissions in 2012 of 878 Mt CO_2e by European industry, and 502 Mt CO_2e by transport and storage, or 3700 Mt CO_2e from global net forest conversion (net emissions/removals from forest conversion, i.e. mostly tropical deforestation). Thus already today, the forest of the EU-28 is making a significant contribution to improving the European GHG balance.

(14) In addition, the carbon pool in EU-28 forest products is increasing by nearly 35 Mt CO_2e every year. The carbon pool in HWP is about 15 % of the carbon pool in forests. The size of the HWP carbon pool depends not only on how many products are produced, imported and consumed, but on their length of life in service. Extending HWP life could also bring climate benefits.

4.3 Recommendations

The analysis of ClimWood2030 has demonstrated the complexity of the dynamics of the forest based sector's greenhouse gas balances, and sometimes counterintuitive consequences of policy choices. It has also shown that action on one part of the EU forest wood system has consequences in other parts of the EU forest wood system, and in other parts of the world. The main recommendation should therefore be to consider carefully the complex consequences of the policy choices, over the short and the long term and for all actors and all carbon flows and pools and for all aspects of sustainable forest management, including biodiversity, employment and livelihoods. A holistic approach is the foundation of responsible policy making for a sustainable future. ClimWood2030 has started this analysis but still contains considerable areas of uncertainty and does not claim to provide definitive answers to all the questions.

The recommendations below are based on the reflections of the ClimWood2030 team, based on the analysis presented. The team considers that there is potential for combining some of the projected trends, notably those aimed at increasing the material use of wood, improving recovery of post-consumer wood and encouraging cascade use.

4.3.1 To policy makers at the EU and national levels

(1) Consider the consequences for all parts of the forest-based system for GHG balances, as well as for other aspects of SFM, before setting strategic priorities: carbon in EU forest, carbon in EU HWP, material and energy substitution as well as global forest footprint.

(2) Develop integrated model systems, possibly based on the ClimWood2030 approach, to explore further the interactions and consequences of proposed action in a longer time-frame,

and use them as a basis for evidence based policy making. To this end, it would be desirable to intensify cooperation between experts in this field, especially as regards modelling the operational impacts of cascade approaches and incentives;

(3) Put in place policy instruments to promote the use of wood products in relevant market sectors, i.e. where they have lower GHG emissions than functionally equivalent alternatives;

(4) Consider making HWP a separate activity in accounting frameworks of EU or international climate regimes;

(5) Implement completely the Landfill Directive;

(6) Ensure that construction standards, and green housing codes are performance based, and do not create unnecessary obstacles to using wood products;

(7) Provide regulatory and financial support to developing further the recovery of post-consumer wood products, for instance by improving classifications of this material, improving market information and logistics;

(8) When considering permits for medium and large scale wood energy plants (electricity, heat, combined heat and power), take explicitly into consideration consequences for the forest-based sector as a whole, and its overall GHG emissions, including material substitution effects and changes in the HWP carbon pool, as well as the forest carbon pool;

(9) Promote innovation and competitiveness of the wood processing industries, as one means to promote the sustainable and cascading use of wood, with the aim of keeping the GHG emissions of the forest based sector as a whole to a minimum.

4.3.2 To forest based sector stakeholders and the private sector

(1) Develop, fund and implement an ambitious programme to increase significantly wood's share of the construction market. This effort should be led by the private sector, with public support;

(2) Work together with local authorities and stakeholders to develop increased recovery of post-consumer wood, for material and energy use, notably through "cradle to cradle" design, improved classification systems for this type of material, improved market information, more effective logistics.

(3) Develop ways to extend the service life of wood products.

4.3.3 To researchers

(1) Develop a shared understanding of concepts underlying the quantification of substitution potential for material and energy uses of wood and wood based product, thus improving mutual understanding, aimed at generating comparable evidence on which policy makers can base their decisions;

(2) Explore consequences for forest based sector GHG balances of scenarios based on assumptions not considered in ClimWood2030, for instance:

(a) Better definitions/modelling assumptions for “cascade use”;

(b) A future where renewable energy targets are rather met by fast growth for energies other than biomass, such as wind or solar;

(c) A future where bioenergy goals are met essentially by short rotation coppice and perennial crops on agricultural land, or by noon-wood biomass (e.g. solid waste), reducing the pressure on existing forests to supply energy.

(3) Wood flows should be better studied in all European countries, in particular for end of life and markets for semi-finished products. Differentiation between post-consumer waste reaching the particle board manufacturing plant and post-consumer waste effectively recycled would also help to evaluate which part of this waste stream are burnt and which parts generate further carbon storage;

(4) Combining the market-based, “bottom-up”, analysis used by ClimWood2030 for FBFUs with the partial equilibrium approach of GLOBIOM proved challenging. Further work could include economic/technical modelling of demand for finished products at least in specific markets such as packaging, construction or furniture, in order to improve the link in the model between the market developments and the demand for semi-finished products as well as the trends in net trade of finished wood products[42] (with their associated GHG balances).

[42] Trade in value added wood products such as joinery, doors and windows, glulam, prefabricated houses etc. for instance from China and other Asian countries, has been increasing, but is not normally considered in discussion of the “forest-based sector”, leading to a gap in knowledge which may prove to be significant.

5 Bibliography

Albrecht S, Rüter S, Welling J, Knauf M, Mantau U, Braune A, Baitz M, Weimar H, Sörgel C, Kreißig J, Deimling S, Hellwig S (2008): Ökologische Potenziale durch Holznutzung gezielt fördern. Hamburg, 298 p, Arbeitsbericht aus dem Institut für Holztechnologie und Holzbiologie No. 2008/5.

Alwast H, Birnstengel DB, Deutsch M, Häusler A, Struwe J, Thörner T, Schütz N (2009): Study on the selection of waste streams for End of Waste assessment. Luxembourg: European Commission JRC. Institute for Prospective Technological Studies, 373 p, Final Report.

Bird N (2013): Estimating the displacement of energy and materials by woody biomass in Austria. Graz.

Böttcher, H., Verkerk, P.J., Gusti, M., HavlÍk, P. und Grassi, G. (2012) Projection of the future EU forest CO2 sink as affected by recent bioenergy policies using two advanced forest management models. GCB Bioenergy 4(6): 773-783.

Brown S, Lim B, Schlamadinger B (1998): Evaluating Approaches for Estimating Net Emissions of Carbon Dioxide from Forest Harvesting and Wood Products. Dakar, Senegal, 20 p.

CEI-Bois (2014): Tackle climate change: build with wood. Brussels: Confederation of European wood working industries (CEI-Bois.)

CEN (2014): EN 15804 (2013): EN 15804:2012+A1:2013-11, Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.

CEWEP (2010): Heating and Lightning the way to a sustainable future – Confederation of European Waste-to-Energy plants

Cowie A, Pingoud K, Schlamadinger B (2006): Stock changes or fluxes? Resolving terminological confusion in the debate on land-use change and forestry. Clim Pol 6:161-179.

EOS/OES (2013): EOS; Annual Report 2012/2013. European Organisation of the Sawmill Industry (EOS), Brussels.

European Commission (2013): EU Energy, Transport and GHG emissions trends to 2050: Reference scenario 2013. Luxembourg: European Commission D-GfE, Directorate-General for Climate Action and Directorate-General for Mobility and Transport, 173 p.

European Commission (2014): IMPACT ASSESSMENT: Accompanying the document 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. In: A policy framework for climate and energy in the period from 2020 to 2030. Brussels, p 235 SWD 2014) 15 final.

Eur‘ObservER (2015): Solid Biomass Barometer. http://www.energies-renouvelables.org

FAO/UNECE (2011): European Forest Sector Outlook Study II 2010 - 2030. FAO/UNECE, Geneva.

FCBA, CODIFAB, FBF, DHUP (2014): ACV et déclarations environnementales pour des produits et composants de la construction bois

Grêt-Regamey A, Hendrick E, Hetsch S, Pingoud K, Rüter S (2008): Challenges and Opportunities of Accounting for Harvested Wood Products. In: Harvested Wood Products in the Context of Climate Change Policies, ECE/TIM/DP/55, United Nations Palais des Nations, Geneva, Switzerland, 9-10 September 2008, pp 27-40.

Groen TA, Verkerk PJ, Böttcher H, Grassi G, Cienciala E, Black KG, Fortin M, Köthke M, Lehtonen A, Nabuurs G-J, Petrova L, Blujdea V (2013): What causes differences between national estimates of forest management carbon emissions and removals compared to estimates of large-scale models? Environ Sci Policy 33(0):222-232.

Gustavsson L, Madlener R, Hoen HF, Jungmeier G, Karjalainen T, Klöhn S, Mahapatra K, Pohjola J, Solberg B, Spelter H (2006) The Role of Wood Material for Greenhouse Gas Mitigation. Mitigation and Adaptation Strategies for Global Change 11(5):1097-1127.

Gustavsson L, Pingoud K, Sathre R (2006): Carbon Dioxide Balance of Wood Substitution: Comparing Concrete- and Wood-Framed Buildings. Mitigation and Adaptation Strategies for Global Change 11(3):667-691.

Gusti M (2010): An algorithm for simulation of forest management decisions in the global forest model. Artificial Intelligence N4:45-49.

Havlík P, et al. Climate change mitigation through livestock system transitions. Proceedings of the National Academy of Sciences (2014) 111:3709-3714.

Heikkinen J, Tomppo E, Freudenschuss A, Weiss P, Hylen G, Kušar G, McRoberts R, Kändler G, Cienciala E, Petersson H, Ståhl G (2012): Interpolating and Extrapolating Information from Periodic Forest Surveys for Annual Greenhouse Gas Reporting. For Sci 58(3):236-247.

Hetemäki L, Lindner M, Mavsar R, Korhonen M, Eds. (2014): Forest-based sector: structural changes towards bioeconomy. What science can tell us 6/2014. Joennsu, European Forest Institute.

Lundmark T, Bergh J, Hofer P, Nordin A, Poudel BC, Taverna R, Werner F, Sathre R (2014): Potential Roles of Swedish Forestry in the context of Climate Change Mitigation. Forests (5): 557-578.

IPCC (2003): Good Practice Guidance for Land Use, Land-Use Change and Forestry. In: Penman J, *et al.* (eds) Hayama, Japan: Intergovernmental Panel of Climate Change (IPCC), IPCC/IGES.

IPCC (2006): IPCC Guidelines for Greenhouse Gas Inventories - Vol 4 Agriculture, Forestry and other Land Use. In: Eggleston S, *et al.* (eds) Hayama, Kanagawa, Japan: IEA/OECD, IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit.

IPCC (2014): 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. 268 p.

ISO (2006a): ISO 14040:2006-10, Environmental management – Life cycle assessment – Principles and framework.

ISO (2006b): ISO 14040:2006-07, Environmental management – Life cycle assessment – Requirements and guidelines.

JRC (2010): ILCD handbook; International reference life cycle data system – General guide for life cycle assessment – detailed guidance. Joint Research Center, Ispra.

Mantau U, Saal U, Prins K, Steierer F, Lindner M, Verkerk PJ, Eggers J, Leek N, Oldenburger J, Asikainen A, Anttila P (2010): EUwood - Real potential for changes in growth and use of EU forests. Hamburg/Germany, 160 p.

Nemry F, Uihlein A, Makishi C, Wittstock B, Braune A, Wetzel C, Hasan I, Niemeier S, Frech Y, Kreissig J, Gallon N (2008): Environmental Improvement Potentials for Residential Buildings (IMPRO_Building). Sevilla: Joint Research Centre, JRC Scientific and Technial Reports.

Pingoud K (2002): SIMPLE HWP MODEL (EXPONENTIAL DECAY). Graz, MS Excel Spreadsheet model, internally provided to members of IEA Bioenergy Task 38 in December 2002.

Plevin RJ, Delucchi MA, Creutzig F. (2013): Using attributional life cycle assessment to estimate climate-change mitigation benefits misleads policy makers. Journal of Industrial Ecology, 18(1): 73-83.

Rödl A, Rüter S (2014): Trade flow analysis of harvested wood products; internal study. Thünen Institute of Wood Research, Hamburg.

Row C, Phelps RB (1990): Tracing the flow of carbon through US forest product sector. In: Proceedings of the Presentation at the 19th World Congress of the International Union of Forest Research Organizations, 5-11 August 1990, Montreal, Canada, p 13.

Rüter S (2011): Projection of Net Emissions from Harvested Wood Products in European Countries: For the period 2013-2020. Hamburg, 63 pp. <http://literatur.vti.bund.de/digbib_extern/dn048901.pdf>

Rüter S (2016): Beitrag der stofflichen Nutzung von Holz zum Klimaschutz – das Modell WoodCarbonMonitor. Dissertation. Technische Universität München, Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt, 260 S. (to be published)

Rüter S, Alfredsen G, de Aquino Ximenes F, Guendehou S, Pingoud K, Tsunetsugu Y, McCusker A (2014): Harvested Wood Products (Section 2.8). In: Hiraishi T, *et al.* (eds) 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. Published: IPCC, Switzerland. pp 109-134.

Sathre R, O'Connor J (2010): A Synthesis of Research on Wood Products & Greenhouse Gas Impacts, 2nd Edition. Vancouver, B.C, Canada, 117 p, Technical Report No. TR-19R.

Sikkema R, Schelhaas MJ, Nabuurs GJ (2001): International Carbon Accounting of Harvested Wood Products: Evaluation of two models for the quantification of wood product related emissions and removals. 11 p.

Skog KE (2008): Sequestration of carbon in harvested wood products for the United States. For Prod J 58(6):56-72.

Taverna R, Hofer P, Werner F, Kaufmann E, Thürig E (2007): CO_2 effects of the Swiss forestry and timber industry – scenarios of future potential for climate-change mitigation. Berne: Federal Office for the Environment (BAFU), Report No: Environmental Studies Nr. 0739, 102 p.

Thompson DA, Matthews R (1989): CO_2 in trees and timber lowers greenhouse effect. 18:19-24.

UNFCCC (2003): Estimation, Reporting and Accounting of Harvested Wood Products. In: Technical Paper. Bonn, p 44 FCCC/TP/2003/7.

UNFCCC (2012): Report of the CMP on its seventh session, held in Durban from 28 November to 11 December 2011, Addendum: Decision 2/CMP.7 on Land use, land-use change and forestry. p 27, FCCC/KP/CMP/2011/10/Add.1.

UNFCCC (2015) COP on its twenty-first session, held in Paris from 20 November to 11 December 2015. Draft decision -/CP.21: Adoption of the Paris Agreement. In: Proposal by the President. p 31 FCCC/CP/2015/L.9

Weidema BP (1999): Some important aspects of market-based system delimitation in LCA – with a special view to avoiding allocation. In: Report of a Danish-Dutch workshop on LCA methodologies, September 1999, CML, Leiden, 33-46.

Werner F, Richter K (2007): Wooden building products in comparative LCA; a literature review. International Journal for Life Cycle Assessment, 12(7): 470-479.

Werner F, Taverna R, Hofer P, Richter K (2006): Greenhouse Gas Dynamics of an Increased Use of Wood in Buildings in Switzerland. Climatic Change 74(1-3):319-347.

Werner F., Vial E., Levet A.-L. (2015): Derivation of emission factors and displacement factors for forest based functional units and scenario assumptions on the future material use of wood. Technical report under the ClimWood 2030 project: Study on climate benefits of material substitution by forest biomass and harvested wood products: Perspective 2030. Werner Environment & Development, Zurich, FCBA, Paris, p. 184.

Winjum JK, Brown S, Schlamadinger B (1998): Forest Harvests and Wood Products: Sources and Sinks of Atmospheric Carbon Dioxide. For Sci 44(2):272-284.

Winjum JK, Dixon RK, Schroeder PE (1993): Forest management and carbon storage: An analysis of 12 key forest nations. Water, Air, & Soil Pollution 70(1-4):239-257.

York N (2012): Do alternative energy sources displace fossil fuels? Nature Climate Change 2:441-443.

Figures

Tables

Annex 1: Development of scenarios regarding the future material use of wood

This annex describes the consumption of semi-finished products for the production of the FBFUs under study as well as for other applications that are not covered by FBFUs for:

- the situation in 2010 as the starting point for all scenario calculations (section 3.2);
- the projections up to 2030 as a result of different scenario assumptions (section 3.3 ff).

For the quantification of the substitution effects, it should be borne in mind that we calculate the displacement factors starting from ***the differences in the consumption of wood products for energy and material uses of the different scenarios as compared to the reference scenario***.

This implies several key assumptions that are relevant for the interpretation of the study:

- the substitution effects are quantified as differences in the consumption of wood for energy and material uses between a specific scenario and the reference scenario, assuming the same over-all demand for goods and services supplied by all materials and fuels in EU-28. This means that the policy options under study do not have an effect on the over-all demand for all goods and services (all products including wood products) within EU-28 as compared to the reference scenario. The substitution effects thus reflect the changes in market shares of the FBFUs in their specific area of application.
- Due to restrictions in the models used within the general modelling framework of ClimWood 2030, we cannot model changes in the trade balance of FBFUs as final products – e.g. changes in imports/exports of furniture itself. We have to assume therefore, that the trade patterns for FBFUs remains the same between all scenarios.
- We assume that the selected FBFUs cover the relevant applications for wood where other material alternatives exist and where we therefore, can assume substitution effects. This means on the other hand that wood in other applications either:
  - cannot be replaced reasonably with other materials (i.e. no substitution is reasonably possible) or that,
  - the market share of an application where alternative materials would be conceivable has a negligible market share or,
  - the market share is not affected by the policy options to be assessed (i.e. the consumption for this application does not differ between the scenarios).

  Consequently, we assume equal amounts of wood used in applications that are not covered in FBFUs for all scenarios as defined in the reference scenario.

A1.1 Available information an approach chosen for scenario development for FBFUs

Information on markets of wood products and the forest-based sector are very scarce (Hetemäki *et al.* 2014, p. 13). Most forecasts on future wood use project 1 or 2 years into the future (EOS/OES 2013). Indeed, we have only come across two studies projecting the wood supply on the level of semi-finished products over a longer period (FAO/UNECE 2011, Mantau *et al.* 2010), which however, were not suited to serve as a basis for the projections on FBFU-level within this project.

As regards the projection of wood in core and shell, some interviews were conducted to gather additional insight into the potential of wood in construction, among them with a large French constructor and with representatives of sector associations.

Eurostat was contacted on eventual data on the amount and classes of building land reserves according to national spatial planning on national and EU-28 level, which would have allowed us to estimate the maximum allowed construction activities on “greenfield”. However, such data was confirmed not to be available in Eurostat.

For other FBFUs some market data could be gathered on past and current market shares which allowed the extrapolation of future consumption; such extrapolations were the cross-checked for plausibility with industry experts.

However, we observed a significant mismatch between the projections of the consumption of semi-finished wood products from GLOBIOM and the extrapolation of market data.

To achieve consistency within the over-all modelling framework, two approaches were followed for the definition of the scenarios on FBFU-level:

- “Top-down” scenarios, which specify the consumption of semi-finished products in FBFUs and other applications not covered with FBFUs starting from the consumption data generated in GLOBIOM. In this case, the detailed scenario information was generated as follows:
  - Distinction between wood flows covered/not-covered by FBFUs and attribution of consumption of semi-finished products based on statistical data, composition of FBFUs, etc. for the year 2010;
  - Projection of future consumption of wood used in FBFU based on specific considerations derived from market analysis; these data then are scaled to meet the projected increase in consumption of semi-finished products in GLOBIOM;
  - For the reference scenario: projection of future consumption of wood used in other uses than FBFU via the increase in the consumption of semi-finished products that are not used for FBFUs;

  - For all other top-down scenarios: assumption that the future consumption of semi-finished products in FBFU is not affected by scenario assumptions but is equal to the consumption in the reference scenario.
- “Bottom-up” scenarios where the future consumption of semi-finished products is defined on FBFU-level and GLOBIOM is made to generate the resulting consumption of semi-finished products. In this case, the detailed scenario information was generated as follows:
  - Detailed market analysis and project of trends for the consumption of FBFUs;
  - Survey among experts on wood markets (associations, industries, architects, developers) to cross-check the plausibility of assumptions and possible policy measures to reach the projected development;
  - Scenario definition based on results, taking into consideration the values applied in the “top down scenarios” and over-arching policy targets.

A1.2 Coverage of wood consumption by FBFUs in 2010

Table A1-1 describes the consumption of semi-finished products ending up in the FBFUs as well as the total consumption of FBFUs needed to produce the FBFUs. Besides this, the amounts of semi-finished products (SFP) are estimated that are used in sectors were FBFUs are considered as well as in other sectors that are not considered in this study. The total consumption of semi-finished products corresponds to the total amount of semi-finished products as reported in FAO-Stat.

The table indicates the roughly 30 % of total consumption of semi-finished products are used in applications where we assume a displacement factor and that are covered in the case studies of FBFUs. Roughly, 60 % of total consumption of semi-finished products are used in applications in sectors covered by FBFUs but where we consider no realistic potential for the substitution of other materials with wood, e.g. in pitched roofs or a major share of furniture. 10 % of total consumption of semi-finished products are used in other sectors that we do not cover in this project, such as automotive or household items.

For all sectors covered by FBFU, we conducted a detailed market analysis to derive the current consumption of wood for the different FBFU as well as for applications that are not covered by FBFUs. This market analysis was based on data from Eurostat but also on data from sectorial Federations such as the European Panel Federation (EPF), the European Organisation of Sawmills (EOS) or the European Federation of plywood manufacturers (FEIC).

As a starting point for the attribution of the semi-finished products to the uses covered and not covered in FBFU, we started from the assumption that the distribution for the consumption of semi-finished products largely corresponds to the distribution of sales of the European production (cf. Rödl *et al.* 2014). However, for several reasons, the available data sources were not fully consistent between themselves; some expert guesses were needed to ensure a consistent and plausible description of the reference situation in 2010.

Table A1-1: Consumption of semi-finished products per area of application as well as resulting volume of FBFU and non-FBFUs in 2010 for EU-28 as the reference situation in 2010.

	m^3	%	Source/comments
Total consumption semi-finished products (material use)	**1.42E+08**		Statistics (sum of below)
Sum of semi-finished products from FAOSTAT	1.42E+08		FAOSTAT
Total production = consumption final products	**1.21E+08**		Calculated via the distribution of wood in final uses (excluding transformation losses!)
Covered in FBFUs	3.48E+07	28.8 %	Sum of wood products in FBFUs
Not covered in FBFUs	7.16E+07	59.4 %	Sum of wood products in applications included in ClimWood but not covered with FBFUs
Not covered in FBFUs and outside scope of study	1.43E+07	11.8 %	Sum of wood products (excluding pulp/paper) outside applications included in ClimWood
A. Primary construction			
Total consumption semi-finished products (material use)	***5.43E+07***		Consumption of semi-finished products according to EOS and EPF for "construction + flooring" minus amount of wood consumed for secondary construction
Total production = consumption final products	***4.61E+07***		Assumed conversion losses of 15 %
Wood in core and shell, excl. roofs, industrial construction and infrastructure	1.16E+07	25.1 %	Builder's joinery and carpentry (glulam frame, truss, traditional frame, timber frame wall, stairs): 4326176925 kg in EU in 2010 (source: Eurostat). Assume 464kg/m^3. Prefabricated buildings: 6237680000 euros in EU in 2010 (source: Eurostat). Assumption: 12000€/piece/36m^2 (=18713040 m^2) and 0.12 m^3 of wood/m^2
Roofs, industrial construction and infrastructure (not covered)	3.46E+07	74.9 %	Difference of wood in FBFU and total production = consumption; equals roughly the assumption that 70 % of sawn wood consumption according to FAOSTAT is used for roofing, industrial buildings and civil engineering, minus a transformation loss of 15 % (all guesses by project team)
B. Secondary construction/interior works			
Total consumption semi-finished products (material use)	***1.86E+07***		Calculated from total consumption of final products, assuming an average of 15 % loss during transformation (estimated by project team)
Total production = consumption final products	***1.58E+07***		Sum
Insulation material	2.18E+06	13.8 %	FAOSTAT
Windows	4.47E+06	28.3 %	Assumed consumption = production of wooden windows (29792205 units, according to EUROSTAT), assuming 0.15 m^3 of wood per window. Coverage of Al/wood windows unknown.
Claddings (exterior/ interior)	1.70E+06	10.8 %	Hypothesis: 272000 m^3 of sawnwood for claddings in France (source: FNB 2012)/250000m^3 of claddings (performance rate: 92 %). Assumption: France ~ 15 % of the European claddings market
Flooring: laminates	2.35E+06	14.9 %	Assumed consumption = sales in Europe (290 Mio. m^2 in Western Europe minus 66 Mio in Turkey plus 103 Mio for Eastern Europe minus 24 Mio for Russian Federation minus 9 Mio for Ukraine), according to European Producers of Laminate Flooring (EPLF), assuming 0.008 m^3/m^2
Flooring: parquet	1.41E+06	8.9 %	Assumed consumption = production in Europe (70500000 m^2), according to European Producers of Laminate Flooring (EPLF), assuming 0.02 m^3/m^2
Others (not covered)	3.70E+06	23.4 %	Mainly doors (92494600 pieces in EU in 2010 (source: Eurostat). Assumption: 0.04 m^3 of wood/piece.

	m^3	%	Source/comments
C. Packaging			
Total consumption semi-finished products (material use)	***2.02E+07***		Consumption of semi-finished products according to FAOSTAT, including 10 % loss for transfor-mation of sawn timber into pallets (guess by project team)
Total production = consumption final products	***1.82E+07***		Sum
Pallets	8.13E+06	44.7 %	Assumed consumption = production in Europe (554253594 pallets, according to Eurostat) with 22 kg/piece and 450 kg/m^3; share of multi-use pallets: 30 %
Others (not covered)	1.01E+07	55.3 %	Consumption of semi-finished products for packaging according to FAOSTAT minus 15 % of loss for conversion of semi-finished to final products (guess by project team)
D. Furniture			
Total consumption semi-finished products (material use)	***3.23E+07***		Consumption of semi-finished products according to FAOSTAT
Total production = consumption final products	***2.59E+07***		Consumption of semi-finished products according to FAOSTAT minus 20 % of loss for conversion of semi-finished to final products (guess by project team)
Office furniture: filing racks	2.59E+06	10.0 %	Assumption that FBFU is representative for 10 % of furniture (guess by project team)
Others (not covered)	2.33E+07	90.0 %	Difference to total consumption of final products
E. Chemistry			
Total consumption semi-finished products (material use)			Assumed to be produced from residues from pulp industry, no direct input of semi-fin. products
Total production = consumption final products (t)			Assumed to be produced from residues from pulp industry, no direct input of semi-fin. products
Polyol and/or phenol-formaldehyde from wood	0.00E+00		Assumed to be produced from residues from pulp industry, no direct input of semi-fin. products
Others (not covered)	0.00E+00		Assumed to be produced from residues from pulp industry, no direct input of semi-fin. products
F. Textiles			
Total consumption semi-finished products (material use)			Input of pulp, not covered in FBFU calculations
Total production = consumption final products (t)			Sum
Viscose	4.00E+05	100.0 %	Lenzlinger (2011)
Others (not covered)	0.00E+00	0.0 %	E.g Modal and Tensel; assumed to be covered by inventory of viscose

A1.3 Deriving wood consumption for the different scenarios

A.1.3.1 ClimWood2030 reference scenario

The “Reference scenario” represents the scenario compared to which all other scenarios will be compared. It represents the current economic expectations and political goals set by the European Commission.

Table A1-2 summarises the expected growth rates for the consumption of FBFUs and wood products not covered in FBFUs.

We applied several principles for the projections:

- For some FBFUs, e.g. core and shell and furniture, we assumed that the increase in consumption would be proportional to estimated growth in the total production of semi-finished wood products from GLOBIOM.
- For other FBFU, market projections from specific assessments were used; to meet the overall-consumption projected by GLOBIOM, the results of these specific assessments had to be scaled down, for which the ratio between the projected over-all growth rate between 2010 and 2030 in GLOBIOM (8.3 %) and the projected growth in GPD according to Eurostat (35 %) was used.
- For textiles and chemistry, we used the results of the specific assessments directly as there is no direct link to the consumption of semi-finished products covered in this analysis but rather to by-products from pulp and paper production.
- For wood uses not covered in FBFU, we used the difference between the resulting estimated total consumption of semi-finished products in FBFUs and the total consumption of semi-finished products as projected in GLOBIOM to estimate the growth rate for wood uses not covered in FBFUs.

The growth rates for all applications not covered by FBFUs will be kept constant as we assume that no substitution is reasonably possible in these applications and an increase or decrease of the demand satisfied with these wood flows is not intended or caused by the political measures underlying the different scenarios.

Table A1-2: Expected growth rates in the reference scenario for the consumption of FBFUs and wood products not covered in FBFUs between 2010 and 2030 as compared to the initial situation in 2010.

A. Primary construction		
Expected increase in core and shell	8.3 %	increase in SFP production from GLOBIOM
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
B. Secondary construction/interior works		
Expected increase in consumption: insulation material	3.8 %	specific assessments, corrected for ratio increase in SFP production/extrapolated GDP
Expected increase in consumption: windows	0 %	
Expected increase in consumption: claddings (exterior/interior)	11.7 %	
Expected increase in consumption: flooring, laminates	4.7 %	
Expected increase in consumption: flooring, parquet	4.7 %	
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
C. Packaging		
Expected increase in consumption: pallets	1.2 %	specific assessment, corrected for ratio increase in SFP production/extrapolated GDP
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
D. Furniture		
Expected increase in consumption: wooden filing racks	8.3 %	increase in WFP production from GLOBIOM
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
E. Chemistry		
Expected increase in consumption: polyol/phenol-formaldehyde		no direct use of wood; see below
Expected increase in others		
F. Textiles		
Expected increase in consumption: viscose	45.0 %	specific assessment
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
G. Wood uses not covered in FBFU		
Expected increase in consumption	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM

A.1.3.2 Increase carbon stock in existing EU forests (II)

Linear scaling of baseline development is applied to meet total production of HWP in 2030 of this scenario as provided by GLOBIOM. In addition, slightly less decrease than linear for claddings (to avoid negative flows), compensated with a slightly higher decrease for wood in core and shell.

A.1.3.3 Cascading – increase recovery of solid wood products (III)

Linear scaling of baseline development is applied to meet total production of HWP in 2030 of this scenario as provided by GLOBIOM.

A.1.3.4 Cascading – prevent first use of biomass for energy (IV)

Linear scaling of baseline development is applied to meet total production of HWP in 2030 of this scenario as provided by GLOBIOM.

A.1.3.5 Strongly increase material wood use (V)

This scenario analyses the impacts, especially on substitution effects, resulting from an increasing use of wood for the consumption of FBFU's and other wood products under favourable conditions in terms of overall economic developments, public policies, wood market share, competitiveness of European production. In particular, a 100 % increase of wood consumption in the construction sector (core and shell and elements of construction) between 2010 and 2030 is assumed. Such a scenario is more optimist than the reference scenario for the use of wood but remains realistic in a favourable socio-economic context.

The assumed growth rates are compiled in Table A1-3.

Projections 2030 on FBFUs are based on market analysis which take into account historical data series as well as assumptions related to the market's developments and the future use of wood. These assumptions mainly come from the literature review and expert knowledge. More details on this analysis are provided for each FBFU in the paragraph below.

Table A1-3: Expected growth rates in the FBFU driven scenario V *Strongly increase material wood use* for the consumption of FBFUs and wood products not covered in FBFUs between 2010 and 2030 as compared to the initial situation in 2010.

A. Primary construction		
Expected increase in core and shell	100.0 %	proactive policies and highly favourable economic conditions for the use of wood in construction
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
B. Secondary construction/interior works		
Expected increase in consumption: insulation material	100.0 %	proactive policies and highly favourable economic conditions for the use of wood in construction
Expected increase in consumption: windows	0.0 %	stabilisation due to a slight increase of the windows market over the period but the wood market share will continue to decrease
Expected increase in consumption: claddings (exterior/interior)	100.0 %	proactive policies and highly favourable economic conditions for the use of wood in construction
Expected increase in consumption: flooring, laminates	100.0 %	proactive policies and highly favourable economic conditions for the use of wood in construction
Expected increase in consumption: flooring, parquet	100.0 %	proactive policies and highly favourable economic conditions for the use of wood in construction
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
C. Packaging		
Expected increase in consumption: pallets	5.0 %	growth rate quite lower than the one expected for economic activity due to an increasing use of rental pallet and a stabilisation of wood market share
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
D. Furniture		
Expected increase in consumption: wooden filing racks	10.0 %	growth supported by a more dynamic European production in furniture sector
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
E. Chemistry		
Expected increase in consumption: polyol/phenol-formaldehyde	not defined	no direct use of wood; see below
Expected increase in others	not defined	
F. Textiles		
Expected increase in consumption: viscose	45.0 %	increasing use of wood in non-traditional sectors
Expected increase in others	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM
G. Wood uses not covered in FBFU		
Expected increase in consumption	9.6 %	increase in production of semi-finished products that is not covered in FBFUs from GLOBIOM

A.1.3.6 Market changes in the consumption of FBFUs relative to base year 2010

Table A1-4 summarizes the final consumption of wood in different applications considered within the ClimWood2030 modelling framework for the year 2010 as the starting point of the assessment and for 2030 as the final year of the study period.

The share of wood covered in FBFU and thus subject to material substitution effect starts from 29 % in 2010 and varies from17 % to 43 % in 2030.

Table A1-4: Market changes in the consumption of FBFUs relative to base year 2010.

		ClimWood2030 reference		Increase in C stocks in existing EU forests		Cascading wood use - increase recovery of solid wood products		Cascading wood use - prevent first use of biomass for energy		Strongly increase material wood use	
	2010	**2030**	**change**	**2030**	**change**	**2030**	**change**	**2030**	**change**	**2030**	**change**
A. Core and shell	**Mio. m^3**	**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**	
Total	46.3	50.6	**9.3 %**	41.1	**-11.2 %**	50.6	**9.3 %**	70.3	**51.8 %**	**61.2**	**32.2 %**
Wood in core and shell excl. roofs	11.6	12.5	**8.3 %**	3.04	**-73.8 %**	12.5	**8.2 %**	32.2	**178.5 %**	**23.1**	**100.0 %**
Others (not covered)	34.8	38.1	**9.6 %**	38.1	**9.6 %**	38.1	**9.6 %**	38.1	**9.6 %**	**38.1**	**9.6 %**
B. Secondary construction/interior works	**Mio. m^3**	**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**	
Total	15.8	16.6	**5.1 %**	12.4	**-21.9 %**	16.6	**5.1 %**	26.1	**64.6 %**	**23.8**	**50.6 %**
Insulation material	2.19	2.28	**3.8 %**	1.47	**-33.1 %**	2.28	**3.8 %**	3.99	**81.7 %**	**4.39**	**100.0 %**
Windows	4.47	4.47	**0.0 %**	4.47	**0.0 %**	4.47	**0.0 %**	4.47	**0.0 %**	**4.47**	**0.0 %**
Claddings (exterior/interior)	1.70	1.90	**11.7 %**	0.14	**-91.7 %**	1.90	**11.6 %**	5.98	**251.6 %**	**3.40**	**100.0 %**
Flooring: laminates	2.35	2.46	**4.7 %**	1.39	**-40.9 %**	2.46	**4.7 %**	4.73	**101.1 %**	**4.70**	**100.0 %**
Flooring: parquet	1.41	1.48	**4.7 %**	0.83	**-40.9 %**	1.48	**4.7 %**	2.84	**101.1 %**	**2.82**	**100.0 %**
Others (not covered)	3.70	4.05	**9.6 %**	4.05	**9.6 %**	4.05	**9.6 %**	4.05	**9.6 %**	**4.05**	**9.6 %**
C. Packaging	**Mio. m^3**	**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**	
Total	18.2	19.3	**5.8 %**	18.3	**0.6 %**	19.3	**5.8 %**	21.3	**16.8 %**	**19.6**	**7.5 %**
Pallets	8.13	8.23	**1.2 %**	7.28	**-10.4 %**	8.23	**1.2 %**	10.2	**25.8 %**	**8.5**	**5.0 %**
Others (not covered)	10.1	11.0	**9.6 %**	11.0	**9.6 %**	11.0	**9.6 %**	11.0	**9.6 %**	**11.0**	**9.6 %**
D. Furniture	**Mio. m^3**	**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**	
Total	25.9	28.4	**9.5 %**	26.3	**1.4 %**	28.4	**9.5 %**	32.8	**26.5 %**	**28.4**	**9.6 %**
Office furniture: filing racks	2.59	2.81	**8.3 %**	0.72	**-72.2 %**	2.81	**8.2 %**	7.22	**178.5 %**	**2.85**	**10.0 %**
Others (not covered)	23.3	25.6	**9.6 %**	25.6	**9.6 %**	25.6	**9.6 %**	25.6	**9.6 %**	**25.6**	**9.6 %**
E. Chemistry	**Mio. t**	**Mio. t**		**Mio. t**		**Mio. t**		**Mio. t**		**Mio. t**	
Total											
Polyol and/or phenol-formaldehyde	0.000	0.275		0.275		0.275		0.275		**0.275**	
Others (not covered)											
F. Textiles	**Mio. t**	**Mio. t**		**Mio. t**		**Mio. t**		**Mio. t**		**Mio. t**	
Total											
Viscose	0.400	0.580	**45.0 %**	0.580	**45.0 %**	0.580	**45.0 %**	0.580	**45.0 %**	**0.580**	**45.0 %**
Others (not covered)											
G. Wood uses not covered in FBFU	**Mio. m^3**	**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**		**Mio. m^3**	
Total	14.3	15.6	**9.6 %**	15.6	**9.6 %**	15.6	**9.6 %**	15.6	**9.6 %**	**15.6**	**9.6 %**
Share of final wood consumption covered in FBFU	29 %	28 %		17 %		28 %		43 %		**37 %**	

Annex 2: Derivation of displacement factors

A.2.1 LCA-related methodological background and data sources

For the quantification of the GHG profiles, the methodological settings of EN 15804 have been followed. This holds particularly for the system boundary setting, co-product allocation and for the end-of-life modelling and possible benefits and burdens beyond the product system. This implies for instance:

- The use of secondary materials was modelled based on the cut-off approach, i.e., no environmental burdens from primary production processes were allocated to secondary material;
- System expansion was used to quantify substitution effects; marginal technologies were selected whenever possible; otherwise, substituted processes were selected to be conservative;
- No-co product allocation was needed in the modelling of the GHG profiles.

Although the modelling framework is quite explicit regarding wood flows, it is not explicit on any other material flow. To apply the modelling approach of avoided impacts (= substitution potentials) consistently, we apply the following modelling principles to other materials regarding their recycling and/or energy recovery potentials:

- For metals, the net quantitative and qualitative loss of metal throughout the life cycle is compensated with primary production and attributed to the product under study; this approach is consistent with the modelling approach of EN 15804, including module D. This approach implies that any quantitative and qualitative losses of material over the life cycle have to be compensated with primary material; thus, further consideration on multi-recycling systems are not required/consistent with the consequential modelling framework of the ClimWood2030 project.
- For plastics, the combustion and energy recovery is included in the emission factors and thus substitution potentials.
- For mineral materials, the substitution of primary aggregate used in road construction is assumed.
- Due to a lack of consistent and internationally approved methodologies, carbonation e.g. of cement has not been taken into account.

These settings are required to ensure the practicability and consistency of the over-all modelling framework; they are methodologically justified as regards recycling. However, in the case of plastics, the effect of energy recovery could be considered in principle to be attributable to “energy substitution” instead of considering it in the context of “material substitution”. We refrain from doing so because end-of-life options of one material can include both material recycling and energy recovery and thus a clear distinction is not reasonably feasible for other materials in the context of this project.

Several sources have been used as the sources of background data for the calculation of the emissions profiles and displacement factors:

- Ecoinvent 2.2, updated with the latest datasets available on lc-inventories.ch, which includes, among others, the update of electricity mixes as compared to the original version of ecoinvent 2.2,
- Environmental product declarations (EPD) according to EN 15804, e.g. from the German and the French EPD program,
- Data from the FCBA LCI database on furniture and construction products (FCBA *et al*. 2014)

We have been careful not to mix background data from different sources for the quantification of GHG emission factors for one FBFU or its substitutes.

A.2.2 Variance of displacement factors for the FBFUs under study

For all FBFUs and competing products, several alternatives were considered. The following figures illustrate the range of displacement factors, first for the production, end-of-life, the total of production + end-of-life and the cascading effect for the construction elements included in the core & shell, and the for all FBFUs as integrated in the calculations.

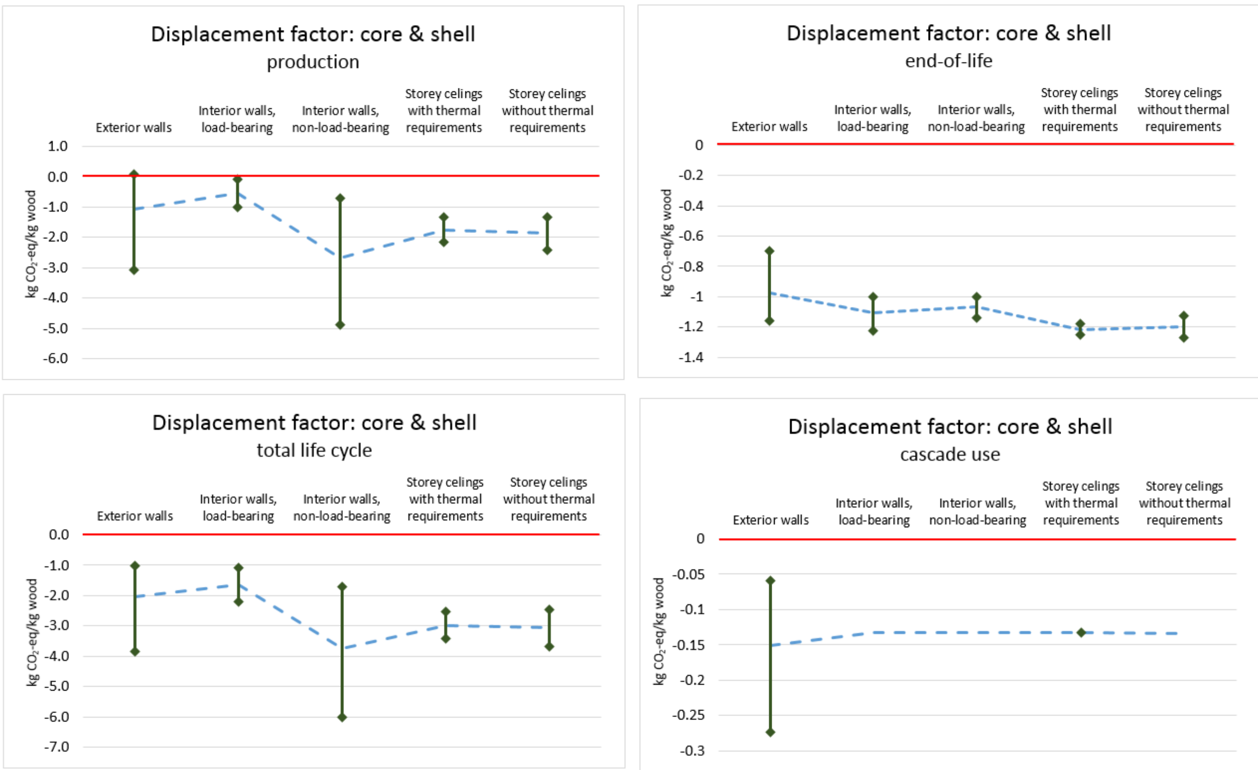

Figure A2-0-1: Range of displacement factors (general values) for the production, end-of-life, the sum of production and end-of-life (total life cycle) and the effect in cascade from recycling, per kg wood product (WP) in construction elements in core & shell (Werner *et. al* 2015). Dotted line: values used in calculations (determined as average or weighted average, depending on the availability of market information).

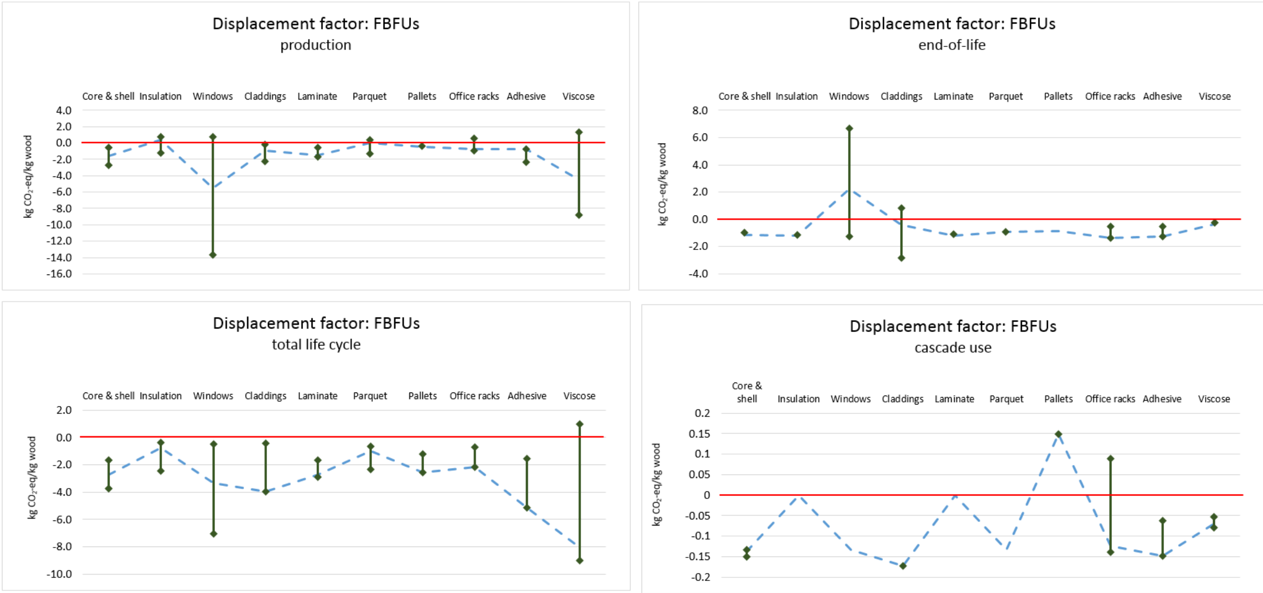

Figure A2-0-2: Range of displacement factors (general values) for the production, end-of-life, the sum of production and end-of-life (total life cycle) and the effect in cascade from recycling, per kg wood product (WP) in FBFU (Werner *et. al* 2015). Dotted line: values used in calculations (determined as average or weighted average, depending on the availability of market information).

The end-of-life and cascading effect assume the default mix of fossil fuels used for industrial heat production for the quantification of energy recovery.

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Herausgeber/Redaktionsanschrift

Johann Heinrich von Thünen-Institut
Bundesallee 50
38116 Braunschweig
Germany

www.thuenen.de

ISBN 978386576160-6