CHAPTER 12

HARVESTED WOOD PRODUCTS

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Contents

Equations

Figures

Tables

Boxes

12 HARVESTED WOOD PRODUCTS (HWP)

12.1 INTRODUCTION

The purpose of this chapter is to update technical parameters for estimating emissions and removals of CO_2 in the AFOLU Sector associated with HWP (hereafter called "CO_2 emissions and removals from HWP"). In doing so, existing approaches discussed in the IPCC 2006 GL are maintained. The guidance takes account of new relevant scientific information, including methodological information contained in IPCC KP Supplement (e.g. including parameters such as carbon conversion factors).

The structure of this chapter aims to clarify the relationships between new information and the IPCC 2006 GL and to allow for inclusion and updating of new parameters where appropriate.

The description of the application of methodologies in the light of the inclusion of updated parameters has been clarified. In particular Section 12.2 clarifies some existing terms, definitions and concepts.

Section 12.3 provides guidance on available HWP approaches, describing and clarifying the options for defining a conceptual framework and system boundary for estimating emissions and removals associated with HWP.

The subsequent guidance in this chapter is structured to consider three distinct subject areas relevant to harvested wood biomass: i) wood products in use (i.e. wood utilised as a material); ii) wood biomass used for energy purposes and iii) wood biomass in solid waste disposal sites (SWDS). Section 12.4 gives detailed guidance on wood products in use, specifically providing *good practice* guidance on the choice of method for wood products in use. This includes improved methodological guidance for estimating CO_2 emissions and removals from HWP following different approaches. This section also includes refined guidance for calculating the initial carbon stock in the HWP pool in use as well as parameters such as HWP carbon conversion factors. Section 12.5 addresses wood biomass used for energy purposes. Section 12.6 provides clarification of the treatment of "wood biomass in SWDS".

12.2 TERMS AND DEFINTIONS

This section provides terms and definitions with specific meaning in the context of estimating and reporting CO_2 emissions and removals from HWP.

Approach: The term "approach" has a particular meaning in the context of CO_2 emissions and removals from HWP. An 'approach' is a conceptual framework for the estimation of CO_2 emissions and removals (see *inter alia* Brown *et al.* 1998; UNFCCC 2003; Cowie *et al.* 2006). An approach defines the particular system boundary referred to when calculating quantities of carbon entering, retained in and lost from the HWP pool. The system boundary defines which CO_2 emissions and removals are to be included in estimates and finally reported (see Cowie *et al.* 2006). Approaches need to be defined for the estimation and reporting of emissions and removals from HWP in order to ensure transparency, completeness and consistency in calculations and reported estimates, in particular to avoid double-counting or non-counting of emissions and removals.

Further guidance on available approaches is provided in Section 12.3 and in Annex 12.A.

Method: The term "method" refers to the set of calculations needed to implement a particular approach for estimating CO_2 emissions and removals from HWP (see UNFCCC 2003; Cowie *et al.* 2006). Thus:

- An approach defines WHAT is to be estimated and reported in an inventory for CO_2 emissions and removals from HWP (as determined by a system boundary), whereas
- A method defines HOW to calculate the emissions and removals to be reported, that is, the calculation techniques used in estimation (see Cowie *et al.* 2006).

It follows that different methods could be applied to implement a particular approach and that more than one method may be involved in the implementation of an approach.

When considering methods to estimate CO_2 emissions and removals from HWP, it is possible to apply methods that are 'inventory-based' and 'flux data-based'.

Inventory-based methods involve direct assessment of the HWP carbon pool at two or more points in time, then estimating carbon pool changes from the difference between sequential assessments.

Flux data-based methods on the other hand involve:

- Either measuring fluxes of CO_2 between the atmosphere and the reservoir of carbon contained in harvested biomass;
- Or tracking fluxes of carbon contained in wood biomass that is harvested from forests throughout the stages of the wood processing chain for the purpose of estimating the magnitude of the HWP carbon pool and its change over time.

In practice, most of the flux data-based methods described in the scientific literature involve modelling rather than measurement, to estimate carbon stocks and stock changes and/or CO_2 fluxes from and to the HWP pool.

12.3 APPROACHES TO ESTIMATING CO_2 EMISSIONS AND REMOVALS FROM HWP

Different approaches can be taken to estimating and presenting CO_2 emissions and removals from HWP. Each individual approach is potentially useful, depending on the application, i.e. the specific question being addressed or type of estimate required. The approach to account for HWP is under consideration by the UNFCCC. Accordingly, this guidance does not prejudge whether one particular approach should be preferred. The choice of approach is important for determining the details of calculation methods for estimating CO_2 emissions and removals from HWP. Hence, before considering calculation methods as presented in Section 12.4, this section provides an introduction to the essential features of the different approaches that have been identified for this purpose. Information is also provided on the implications of choosing between the approaches.

Three main approaches have been identified, known as the ‘stock-change’, ‘production’ and ‘atmospheric-flow’ approaches. As explained below, these three approaches have differences in terms of their conceptual frameworks and the system boundaries employed for calculations (cf. Section 12.2). The IPCC 2006 GL also refer to an approach called the ‘simple decay’ approach, which has the same conceptual framework and system boundary as the ‘production’ approach, thus representing a particular interpretation of how to implement the ‘production’ approach. Detailed information about the three main approaches is provided in Annex 12.A whilst an essential introduction is given in this section.

The discussion of approaches presented here focusses on estimating CO_2 emissions and removals from HWP in use, according to the defined approaches. Harvested biomass used for energy purposes and wood biomass disposed of in SWDS are discussed separately in Sections 12.5 and 12.6.

12.3.1 Conceptual frameworks of HWP approaches

The design of HWP approaches involves two conceptual frameworks.

The first conceptual framework focusses on the estimation of CO_2 emissions and removals from HWP on the basis of changes in carbon stocks within defined HWP pools. In effect, this type of approach aims to track changes in carbon stocks in the HWP pool that take place from one year to the next, and then infer net emissions and removals of CO_2 from HWP from these stock changes.

The second conceptual framework focusses on identifying and quantifying actual CO_2 fluxes from and to the atmosphere from HWP.

The ‘stock-change’ and ‘production’ approaches are based on the first conceptual framework and the ‘atmospheric flow’ approach is based on the second conceptual framework. Further details are given in Annex 12.A.

In practice, physically measuring either actual carbon stocks in the HWP pool or actual fluxes between HWP and the atmosphere can be technically challenging. As a consequence, the implementation of the different approaches using Tier 1 and Tier 2 methods tends to employ modelling and calculations that are similar regardless of the conceptual framework of the particular approach and generally involves referring to similar sources of activity data.

Results for CO_2 emissions and removals are defined in the same way as for other AFOLU categories. Specifically, when carbon stocks in the HWP pool increase over time, this corresponds to net CO_2 removals from HWP; when carbon stocks in the HWP pool decrease over time, this corresponds to net CO_2 emissions from HWP. When referring to CO_2 removals, it may be noted that HWP do not directly sequester carbon from the atmosphere. However, carbon retained in HWP constitutes a pool of carbon, sequestered originally by the above ground biomass carbon pool of forests and other wood producing land categories. In this respect, the carbon from CO_2 originally sequestered by vegetation is transferred onto the HWP pool, in a similar sense as from the above ground biomass carbon pool to the litter and soil carbon pools in the AFOLU sector. The only difference is that transfers of carbon from vegetation to HWP are always the result of anthropogenic activity.

12.3.2 System boundaries employed by approaches

The essential differences between the three HWP approaches are related to the system boundaries applied when making calculations. Illustrations of the system boundaries of the 'stock-change', 'production' and 'atmospheric flow' approaches are included in Annex 12.A. The system boundary of an approach is not necessarily the same as the national boundary of a reporting country.

Under all approaches, changes in carbon stocks (or carbon fluxes) in forests and other wood producing land categories are reported by the country in which the wood is grown (i.e. they are reported by a "producing country").

The 'stock-change' approach for HWP estimates changes in carbon stocks in the HWP pool within the national boundary of the reporting country. Hence, carbon stock changes in the HWP pool are reported by the country where the wood products are used (i.e. reported by the "consuming country").

The 'production' approach estimates changes in carbon stocks in the HWP pool consisting of products made from wood harvested in the reporting country. The HWP pool thus consists of all products made from wood that is harvested domestically, i.e. those products that are consumed domestically and also those products that are exported and used in other countries. In other words, the "producing country" reports carbon stock changes from HWP produced by that country, regardless of where the HWP are consumed and used.

The 'atmospheric flow' approach estimates fluxes of CO_2 from and to the atmosphere from HWP, taking place within national boundaries. The CO_2 emissions and removals from HWP are thus reported by a country where the wood products are used (i.e. by the "consuming country").

When reporting GHG inventories, estimates of CO_2 emissions and removals from HWP need to be compatible with results for carbon stock changes in forests and other wood producing land categories. Specifically, it is important that there are no cases of omissions and/or double counting of CO_2 emissions and removals, when results for forests and other wood producing lands and for HWP are combined. The calculations defined in in this guidance for the three reporting approaches are designed to ensure such compatibility.

The system boundaries of the three approaches are also defined so that no double-counting or omissions occur when estimates of CO_2 emissions and removals from HWP reported by different countries are combined to provide global or regional estimates. However, this is only the case if all reporting countries use the same approach. Double counting and/or non-counting of CO_2 emissions and removals associated with forests, other wood producing land categories and HWP can occur if reporting countries apply different HWP approaches.

In some situations, CO_2 emissions and removals from the HWP are not reported distinctly. The circumstances in which this may occur are discussed in Section 12.4.1.2. In these circumstances, the assumption of "instantaneous oxidation" is made. When this assumption is made, the CO_2 emissions associated with harvested biomass are nevertheless included implicitly as part of the CO_2 emissions and removals from the above ground biomass carbon pool of forests and other wood producing land categories. When CO_2 emissions and removals from HWP are not reported distinctly, the possible approaches to reporting CO_2 emissions and removals from HWP are not relevant and are not applied.

12.4 CHOICE OF METHOD FOR WOOD PRODUCTS IN USE

This section provides guidance for the choice of method following the available approaches described in Section 12.3 and Annex 12.A. As the chosen calculation method (i.e. inventory or flux data methods) and the applied data that are used for estimating the CO_2 emissions and removals from HWP have an implicit impact on the calculated system boundaries and in consequence on whether the estimated CO_2 emissions and removals from HWP correspond to the national boarders or not, any method to be applied needs to be cross-checked against whether and how it corresponds and relates to the selected approach.

12.4.1 Initial steps to estimate CO_2 emissions and removals from HWP

To estimate HWP emissions and removals, it is good practice to follow the decision tree (Figure 12.1) and the steps described below.

STEP 1: Check the availability of activity data on HWP in order to clarify the option of not reporting CO_2 emissions and removals from HWP

In order to apply provided guidance for estimating CO_2 emissions and removals from HWP, information on the utilization of wood as material needs to be available. In the case that no such information is available, countries might need to decide not to report on HWP.

In some situations, a decision may be taken not to estimate CO_2 emissions and removals from HWP because the magnitude of these emissions and removals is small (e.g. compared with those from forests and other wood producing land categories).

STEP 1.1: Check the availability of the three default HWP categories sawnwood, wood-based panels and paper and paperboard. Detailed guidance is provided in Section 12.4.1.1. If such information is available, skip the next step and go to STEP 2.

STEP 1.2: Follow the guidance provided in Section 12.4.1.2.

STEP 2: Check the availability of country-specific methods and apply Tier 3

STEP 2.1: Check whether country-specific methods are available that could be used to estimate emissions and removals of CO_2 from HWP. For this purpose, follow the guidance provided in Section 12.4.4. If this is the case go to the next step, otherwise go to STEP 3.

STEP 2.2: Check that the methodologies used are at least as detailed and accurate as under the Tier 1 approach. If this is the case go to the next step, otherwise go to STEP 3.

STEP 2.3: Clarify which approach is to be chosen by the country (cf. Section 12.3) and follow the guidance provided in Section 12.4.4 to apply Tier 3 for estimating CO_2 emissions and removals from HWP.

STEP 3: Check the availability of country-specific data and apply Tier 2

STEP 3.1: Check whether country-specific activity data and/or emission factors are available that could be used to estimate CO_2 emissions and removals from HWP. Guidance is provided in Sections 12.4.1.1 and 12.4.3. If this is the case go to the next step, otherwise go to STEP 4.

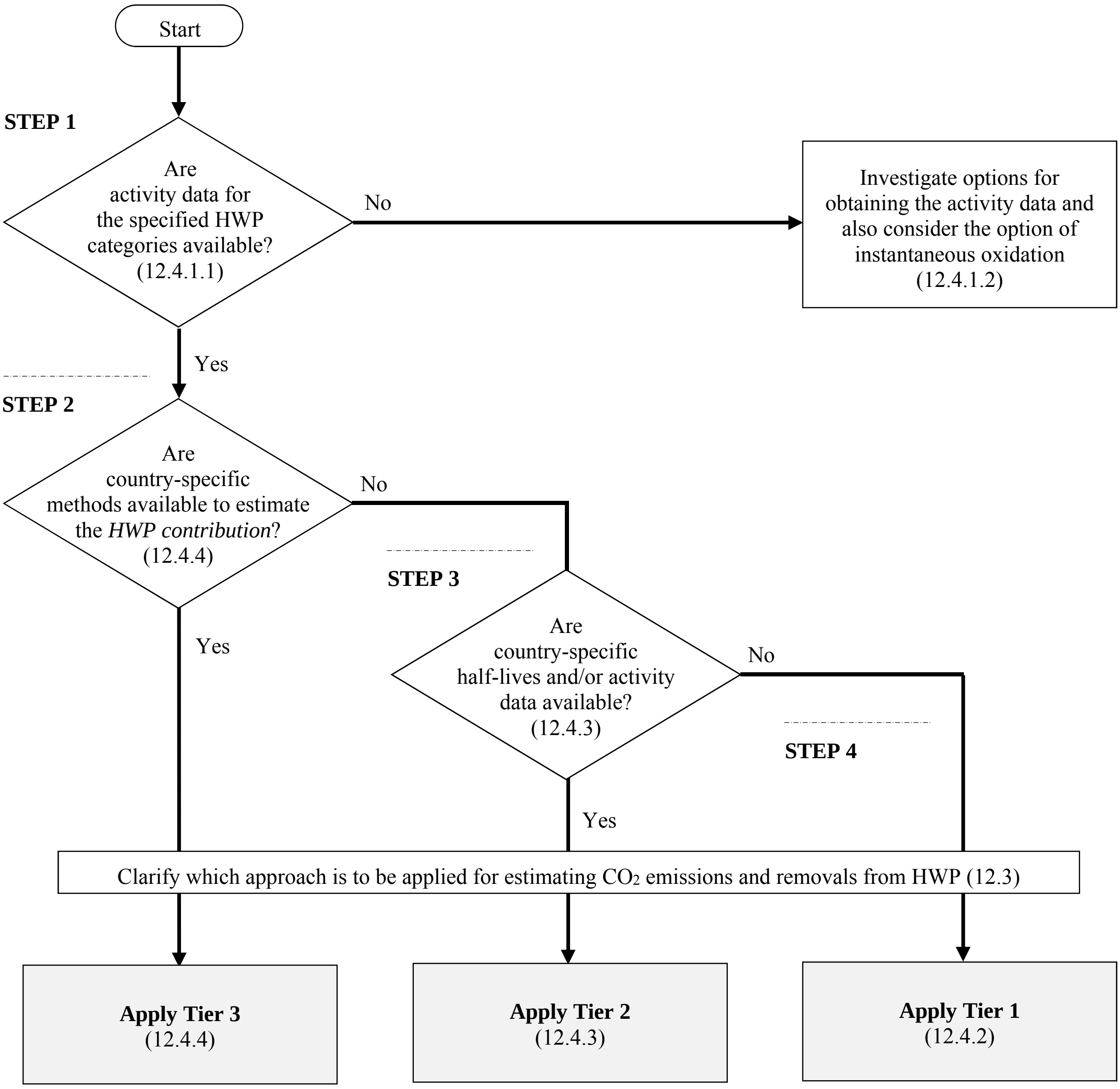
STEP 3.2: Check whether the country-specific activity data meet the requirement to match with the provided default method and whether they are as accurate as under the Tier 1 approach. Further guidance is provided in Section 12.4.3.1. In the case that country-specific emission factors should be used, follow the guidance provided in Section 12.4.3.2 and clarify, whether such information meshes with the activity data that is to be applied for the estimation. If the completion of this step is successful, go to the next step, otherwise go to STEP 4.

STEP 3.3: Clarify which approach is to be chosen by the country (Section 12.3), follow the guidance provided in Section 12.4.3 and apply Tier 2 for estimating CO_2 emissions and removals from HWP.

STEP 4: Clarify which approach is to be chosen to estimate CO_2 emissions and removals from HWP and apply Tier 1

Clarify which approach is to be chosen by the country (Section 12.3) and follow the guidance provided in Section 12.4.2 in order to apply Tier 1 for estimating CO_2 emissions and removals from HWP.

Figure 12.1 Decision tree for choosing the relevant tier method for estimating CO_2 emissions and removals from HWP



12.4.1.1 AVAILABILITY OF ACTIVITY DATA

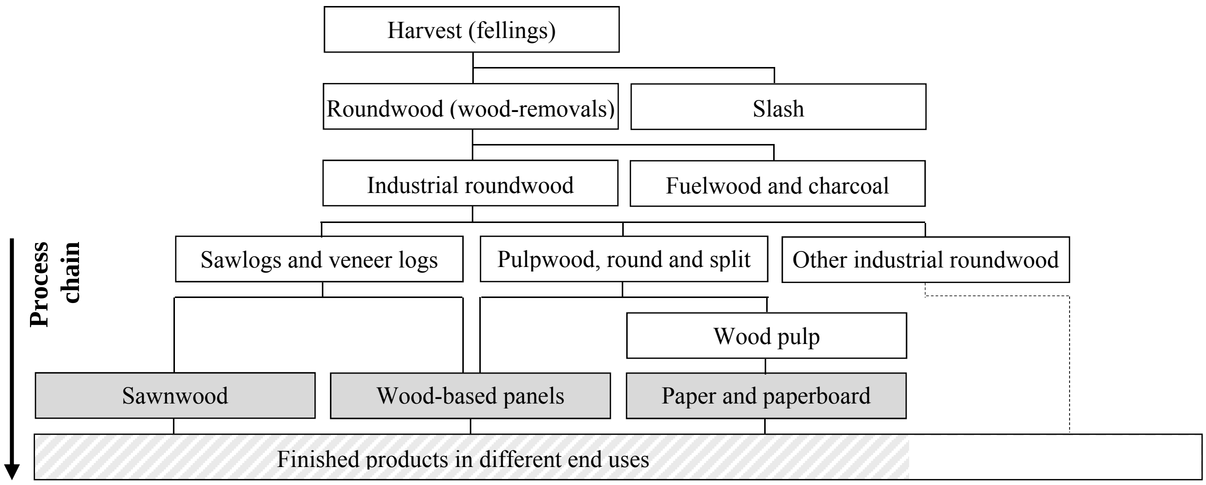
This section provides definitions for the different HWP categories representing the material use of wood (i.e. sawnwood, wood-based panels, and paper and paperboards) as well as additional HWP categories available for estimating CO_2 emissions and removals from HWP.

Whereas the term "harvested wood products" is based on a concept containing the two separate elements "forest harvesting" and "wood products" (Brown *et al.* 1998; UNFCCC 2003), the categories sawnwood, wood-based panels and paper and paperboard refer to the definitions of semi-finished wood products of the international classification system of forest products.[1] Other terms commonly used include "removals" (i.e. roundwood) are a subset of "forest harvesting" of biomass (i.e. fellings) at the beginning of the forest-wood chain (see definitions below). Following the forest products definitions of the FAO, Figure 12.2 furthermore shows the relevance of the aggregate commodity "industrial roundwood". Its subcategories provide the feedstock for the subsequent processing of the three named semi-finished HWP commodities along the value chain (cf. FAO 2017). The

[1] http://www.fao.org/forestry/statistics/80572/en/ (2017/10/18)

international classification system for forest products can be related to the Harmonized Commodity Description and Coding System (HS) of tariff nomenclature provided by the World Customs Organization (WCO).[2]

Figure 12.2 Simplified classification of wood products based on FAO forest products definitions



Source: IPCC 2014

Definitions of wood product commodities, which are relevant for the application of the guidance on estimating CO_2 emissions and removals from HWP as described in Section 12.4.2 (Tier 1), are listed below (cf. Figure 12.2). They are drawn from the definitions of the Joint Forest Sector Questionnaire (JFSQ) as established by the Intersecretariat Working Group on Forest Sector Statistics[3] and form the basis for the forest products statistics provided by FAO for example. The JFSQ also includes conversion factors to be used for converting, for example, from nominal to solid volume in the compilation of statistics if required.[4] Datasets for these aggregate product categories are freely and easily accessible, are updated on at least an annual basis with a 6-month or one year reporting lag, and time series are available for most countries worldwide.[4] The following three aggregate commodities of semi-finished wood products, by definition, represent data on wood being processed with the intention to be used as material.

SAWNWOOD: "Wood that has been produced from both domestic and imported roundwood, either by sawing lengthways or by a profile-chipping process and that exceeds 6 mm in thickness. It includes planks, beams, joists, boards, rafters, scantlings, laths, boxboards and "lumber", etc., in the following forms: unplaned, planed, end-jointed, etc. It excludes sleepers, wooden flooring, mouldings (sawnwood continuously shaped along any of its edges or faces, like tongued, grooved, rebated, V-jointed, beaded, moulded, rounded or the like) and sawnwood produced by resawing previously sawn pieces. It is reported in cubic metres solid volume."[1] (cf. Figure 12.2)

WOOD-BASED PANELS: "This product category is an aggregate comprising veneer sheets, plywood, particle board, and fibreboard. It is reported in cubic metres solid volume."[1] (cf. Figure 12.2) For the definitions of these subcategories please see FAO 2010.

PAPER AND PAPERBOARD: "The paper and paperboard category is an aggregate category. In the production and trade statistics, it represents the sum of graphic papers; sanitary and household papers; packaging materials and other paper and paperboard. It excludes manufactured paper products such as boxes, cartons, books and magazines, etc. It is reported in metric tonnes."[1] (cf. Figure 12.2)

The availability of data for these above mentioned three aggregate HWP commodities sawnwood, wood-based panels and paper and paperboard in publicly available databases of international organizations, such as FAOSTAT (cf. *IPCC 2006 Guidelines*), qualifies for estimating CO_2 emissions and removals from HWP on the basis of the *production* or the *stock-change approaches.* Other than the above three aggregate categories, FAO data on "Other industrial roundwood" appears to be, in general, unreliable (cf. IPCC 2006), which is why it is not listed here. All datasets are reported in cubic metres solid volume or metric tonnes, which is information that

[2] http://www.wcoomd.org/en/topics/nomenclature/instrument-and-tools.aspx (2017/10/18)

[3] Comprising the Forestry Department of FAO, the United Nations Economic Commission for Europe (UNECE), the Statistical Office of the European Communities (EUROSTAT) and the International Tropical Timber Organization (ITTO)

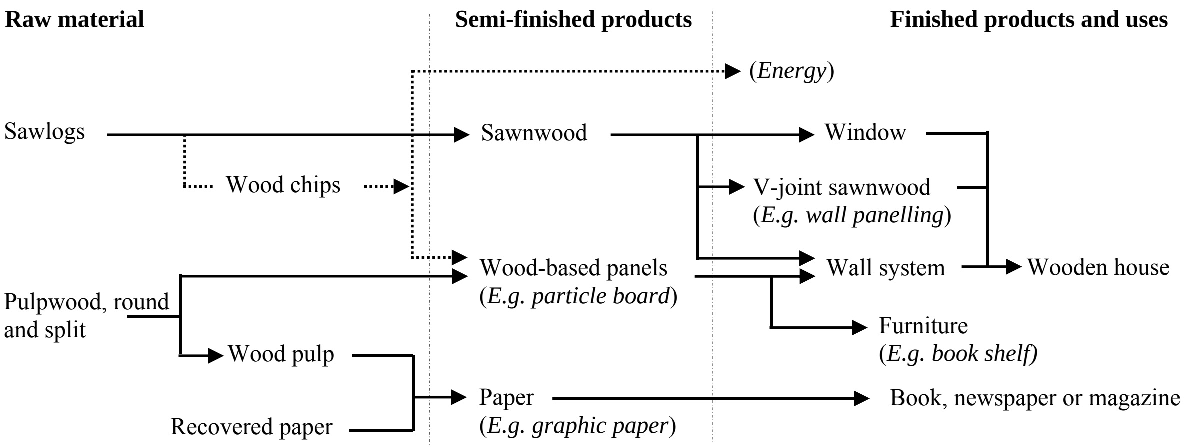
[4] http://www.fao.org/faostat/en/#data/FO (2018/06/20)

enables countries to convert the HWP data into carbon units. Commodities which are excluded from the definitions above (e.g. V-jointed sawnwood or laminated veneer lumber (LVL)) may be the result of subsequent processing and therefore fall under the category of finished wood products as illustrated in Figure 12.3. This also applies e.g. to wooden flooring that is produced from sawnwood and/or hardboard which belongs to the category of wood-based panels; wooden flooring in this case is therefore implicitly covered by the semi-finished HWP categories sawnwood and wood-based panels and included in the estimates for CO_2 emissions and removals from HWP. Thus, using statistical data for both sawnwood and for wooden flooring would result in double counting.

Production data on finished wood products processed from the three aggregate semi-finished product categories sawnwood, wood-based panels and paper and paperboard (see Figure 12.3) are not included in international databases. However, the WCO HS tariff nomenclature (see above) also includes some commodities for finished wood products (e.g. furniture, builders' joinery and carpentry of wood). Accordingly, information on such commodities could be available in national production and trade statistics. It is *good practice* to report on uncertainties related to these datasets (see Section 12.6).

In addition, countries with available data on finished wood products produced from the default HWP categories may consider using these data following the guidance given in Section 12.4.3.1.

Figure 12.3 Examples of different processing stages of wood products along the process and value chain



Source: IPCC 2014

To avoid potential non-counting and/or double counting, countries are encouraged to consult e.g. FAO 2010 for further clarification on the mass flows along the forest wood processing chain depending on the classification and definition of the relevant commodities.[1] The inclusion of the commodity wood pulp under the HWP category “paper” would for example result in double counting, as wood pulp by definition constitutes the feedstock for the production of paper and paperboard (cf. definition below and Figure 12.3). The application of information on wood pulp does, however, enter the default Tier 1 method in order to calculate the share of HWP coming from domestic forests in the case that the ‘production’ approach is applied (cf. Equation 12.7). Wood pulp data may also be used in higher tier methods provided that double counting is avoided.

In order to implement the ‘production’ approach, further information is needed on commodities representing the raw materials eventually used as feedstock for the production of the semi-finished HWP categories listed above (cf. Figure 12.3 and Annex 12.A.1.2). Some possible feedstock commodities are not included in the default method for those approaches to allocate HWP to the domestic forest sources as described in Section 12.3.2, due to difficulties in determining sources and multiple uses, e.g. wood chips used in wood-based panel and wood pulp production as some chips come from industry co-products, others could be recycled products and others go to energy use (see Figure 12.3). Definitions of some key feedstocks used are provided below.

According to the 2006 *IPCC Guidelines*, “**WOOD-REMOVALS** are generally a subset of fellings”.

ROUNDWOOD: “All roundwood felled or otherwise harvested and removed. It comprises all wood obtained from removals, i.e. the quantities removed from forests and from trees outside the forest, including wood recovered from natural, felling and logging losses during the period, calendar year or forest year. It includes all wood removed with or without bark, including wood removed in its round form, or split, roughly squared or in other form (e.g. branches, roots, stumps and burls (where these are harvested) and wood that is roughly shaped or pointed. It is an aggregate comprising wood fuel, including wood for charcoal and industrial roundwood (wood in the rough). It is reported in cubic metres solid volume underbark (i.e. excluding bark)." [1] (cf. Figure 12.2)

INDUSTRIAL ROUNDWOOD (WOOD IN THE ROUGH): "All roundwood except wood fuel. In production, it is an aggregate comprising sawlogs and veneer logs; pulpwood, round and split; and other industrial roundwood. It is reported in cubic metres solid volume underbark (i.e. excluding bark). The customs classification systems used by most countries do not allow the division of Industrial Roundwood trade statistics into the different end-use categories that have long been recognized in production statistics (i.e. sawlogs and veneer logs, pulpwood and other industrial roundwood). Thus, these components do not appear in trade. It excludes: telephone poles."[1] (cf. Figure 12.2)

WOOD PULP: "Fibrous material prepared from pulpwood, wood chips, particles or residues by mechanical and/or chemical process for further manufacture into paper, paperboard, fibreboard or other cellulose products. It is an aggregate comprising mechanical wood pulp; semi-chemical wood pulp; chemical wood pulp; and dissolving wood pulp."[4] (cf. Figure 12.2)

RECOVERED PAPER: "Waste and scraps of paper or paperboard that have been collected for re-use or trade. It includes paper and paperboard that has been used for its original purpose and residues from paper and paperboard production. It is reported in metric tonnes."[1]

In order to implement the 'atmospheric flow' approach, besides data on trade of the above described commodities, further activity data representing both feedstocks for processing wood for its use as material as well as wood biomass burnt is needed which allows estimating actual fluxes of carbon from woody biomass from and to the atmosphere within the country and the reporting year (cf. IPCC 2006 and Sections 12.3.2 and 12.5.2.1). This includes the following commodities:

WOOD FUEL: "Roundwood that will be used as fuel for purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees (where these are harvested for fuel) and wood that will be used for the production of charcoal (e.g. in pit kilns and portable ovens), wood pellets and other agglomerates. The volume of roundwood used in charcoal production is estimated by using a factor of 6.0 to convert from the weight (wt) of charcoal produced to the solid volume (m^3) of roundwood used in production. It also includes wood chips to be used for fuel that are made directly (i.e. in the forest) from roundwood. It excludes wood charcoal, pellets and other agglomerates. It is reported in cubic metres solid volume underbark (i.e. excluding bark)."[1] (cf. Figure 12.2)

WOOD CHARCOAL: "Wood carbonised by partial combustion or the application of heat from external sources. It includes charcoal used as a fuel or for other uses, e.g. as a reduction agent in metallurgy or as an absorption or filtration medium. It is reported in metric tonnes."[1]

WOOD CHIPS AND PARTICLES: "Wood that has been reduced to small pieces and is suitable for pulping, for particle board and/or fibreboard production, for use as a fuel, or for other purposes. It excludes wood chips made directly in the forest from roundwood (i.e. already counted as pulpwood or wood fuel). It is reported in cubic metres solid volume excluding bark."[1]

WOOD RESIDUES: "Other wood processing co-products. It includes wood waste and scrap not useable as timber such as sawmill rejects, slabs, edgings and trimmings, veneer log cores, veneer rejects, sawdust, residues from carpentry and joinery production, and wood residues that will be used for production of pellets and other agglomerated products. It excludes wood chips, made either directly in the forest from roundwood or made in the wood processing industry (i.e. already counted as pulpwood or wood chips and particles), and agglomerated products such as logs, briquettes, pellets or similar forms as well as post-consumer wood. It is reported in cubic metres solid volume excluding bark. "[1]

12.4.1.2 APPLYING THE ASSUMPTION OF "INSTANTANEOUS OXIDATION"

This section provides guidance on when it is in line with *good practice* to not report CO_2 emissions and removals from HWP separately.

The default assumption for the material use of wood is that the annual carbon inflow to the carbon pool in HWP in use is of the same magnitude as the annual amount of carbon leaving this pool. In consequence, this steady-state of the carbon stock in the HWP pool corresponds to an estimate of no change in this carbon stock. This "no change" assumption equals the assumption that all carbon in the biomass harvested is oxidised in the removal year (i.e. leaves the pool immediately the year of harvest) which is why not reporting CO_2 emissions and removals from HWP as a separate pool is also referred to as "instantaneous oxidation" (cf. IPCC 1997, IPCC

2006, IPCC 2014). Carbon losses due to biomass harvest are nevertheless still to be reported in conjunction with other carbon pool estimates for forests and other wood producing lands in the AFOLU sector (cf. Section 12.3.2).

As the use of harvested wood biomass for energy purposes does not belong to a defined and reported carbon pool, any emissions due to such utilization of biomass will be recognized and reported as stock-changes in the living biomass or dead wood pools (see Section Chapter 4).

As the availability of activity data constitutes a prerequisite to estimate CO_2 emissions and removals from HWP, in line with the guidance provided in Sections 12.4.1.1 and 12.4.2.1 countries might furthermore decide to apply the assumption of instantaneous oxidation (e.g. if no activity data as suggested for Tier 1 are available).

In some situations, a decision may be taken not to estimate CO_2 emissions and removals from HWP because the magnitude of these emissions and removals is small (e.g. compared with those from forests and other wood producing land categories). A rough estimate of the potential magnitude of CO_2 emissions from HWP may be derived from data on total wood production or consumption (depending on the approach that may be potentially selected), by applying appropriate general conversion factors for wood density and carbon content.

Further guidance on when and how to apply the assumption that HWP is not to be reported can be found in *IPCC 2006 GL*, Section 12.2.1, and IPCC 2014, Section 2.8.2.

12.4.2 Tier 1: "first order decay" method

Provided that transparent and verifiable activity data are available for the three HWP categories of semi-finished wood product commodities sawnwood, wood-based panels and paper and paperboard, as defined in Section 12.5.1.1, and no country-specific activity data required to apply Tier 2 are available (see Section 12.5.3), estimates of CO_2 emissions and removals from HWP should be obtained by application of the Tier 1 method as outlined in this section.

ESTIMATING CO_2 EMISSIONS AND REMOVALS FROM HWP ON THE BASIS OF CARBON STOCK CHANGES AND BY MEANS OF THE POOL-ORIENTED APPROACHES

The annual emissions and removals from the HWP pool in use ($\Delta CO_{2\,TOTAL}(i)$) are calculated from the sum of net changes of the carbon stocks in the defined HWP product categories by means of the Equation 12.1.

EQUATION 12.1
ESTIMATION OF TOTAL EMISSIONS AND REMOVALS FROM THE HWP POOL IN USE OF THE REPORTING COUNTRY

$$\Delta CO_{2\,TOTAL}(i) = -44/12 \cdot \sum_{l=1}^{n} \Delta C_l(i)$$

Sources: Pingoud und Wagner 2006; IPCC 2006; IPCC 2014; Rüter 2017, p. 259 ff.

Where:

i = year

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

C = carbon stock in HWP, in Mt C

$\Delta C_l(i)$ = changes of the carbon stock C in the particular HWP category l during the year i, in Mt C

l = index number of the semi-finished HWP category (cf. Table 12.2, Section 12.5.2.1)

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

The general method to estimate the magnitude of the defined carbon stock in the HWP pool in use and its net changes (i.e. by means of approaches as described in Section 12.4) is the first-order decay (FOD) function as presented in Equation 12.2. It represents a flux data method that corresponds to Equation 12.1, Chapter 12, Volume 4 of the *2006 IPCC Guidelines* and Equation 2.8.5, Chapter 2 in IPCC 2014:

EQUATION 12.2
ESTIMATION OF CARBON STOCKS AND ANNUAL CARBON STOCK CHANGES IN HWP POOL IN USE

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

$$\Delta C_l\left(i\right)=C_l\left(i+1\right)-C_l\left(i\right)$$

Sources: Pingoud und Wagner 2006; IPCC 2006; IPCC 2014; Rüter 2017, p. 259 ff.

Where:

i = year

$C_l\left(i\right)$ = the carbon stock in the particular HWP category l at the beginning of year i, Mt C

k = decay constant of FOD for each HWP category l given in units yr^{-1} (= ln(2)/HL, where HL is half-life of the HWP pool in years (see Box 12.1 and Section 12.3.2.2).

$Inflow_l\left(i\right)$ = the carbon inflow to the particular HWP category l during year i, Mt C yr^{-1} → Equation 12.3

$\Delta C_l\left(i\right)$ = carbon stock change of the HWP category l during year i, Mt C yr^{-1}

Depending on the choice of the approach for estimating CO_2 emissions and removals from HWP, which implicitly determines the system boundaries of the underlying estimated carbon stock in HWP in use, the annual carbon inflow to the cabon stock of the respective HWP category is calculated from different elements of HWP time series according to Equation 12.3 (cf. also Section 12.3).

EQUATION 12.3
SELECTION OF CARBON INFLOW FOR ESTIMATING THE CARBON STOCK IN THE HWP POOL IN USE DEPENDING ON THE CHOSEN APPROACH

$$Inflow_l\left(i\right):=\begin{cases}Inflow_{SCA_l}\left(i\right) & \textit{for the 'stock-change' approach}\\ Inflow_{PA_l}\left(i\right) & \textit{for the 'production' approach}\end{cases}$$

Source: Rüter 2017, p. 259 ff.

Where:

$Inflow_{SCA_l}\left(i\right)$ = Carbon inflow in HWP from the calculated domestic consumption of the respective HWP cateogory l in year i, in Mt → Equation 12.6

$Inflow_{PA_l}\left(i\right)$ = Carbon inflow in HWP from the production of the respective HWP cateogory l originating from domestic harvest in year i, in Mt → Equation 12.7

Further guidance on the statistical elements for calculating the relevant carbon flux into the HWP pool in use according to the different approaches ($Inflow_l\left(i\right)$), including the associated Equations, is provided in Section 12.4.2.1.

In order to produce an estimate of the existing carbon stock in HWP in use for the application in Equation 12.2, and based on the subsequent changes of this stock to produce an estimate of the current CO_2 emissions and removals from HWP, the historical wood use (i.e. the accumulation of the historic Inflow to the HWP pool) has to be included. This procedure is needed as this also includes the historic and current discard from the HWP pool, which is also termed "inherited emissions" (IPCC 2006).

However, the availability of activity data series, which are described in Section 12.4.2.1, varies. For most countries, the FAO statistics provide data on the HWP commodity categories since 1961.[5] But for some

[5] http://www.fao.org/faostat/en/#data/FO (2017/10/18)

countries activity data are available only from a later year (often 1991). As this has implications on the estimated steady state of the initial carbon stock in HWP in use and in consequence on the uncertainties associated with the estimated CO_2 emissions and removals from HWP, as a proxy in the Tier 1 method it is thus assumed that the HWP pools are in steady state at the initial time t_0 from which the activity data start. This means that as a proxy $\Delta C(t_0)$ is assumed to be equal to 0. This steady state carbon stock $C(t_0)$ for each HWP commodity category l is approximated by means of Equation 12.4 based on the average of $Inflow_l(i)$ during the first 5 years for which statistical data are available (cf. IPCC 2014).

Not least thanks to changing data quality due to increasing milling capacities and industry structures in many countries in combination with rather rarely changing thresholds for the statistical registration the time series of HWP commodities e.g. since 1961, might indicate increasing production volumes (cf. Palma *et al.* 2017). In consequence, their use in Equation 12.4 might thus result in a biased result and even further potentiate the calculated effect of an assumed increasing carbon stock in HWP. In order to further reduce uncertainties associated with the estimate of the existing carbon pool in HWP in use, Equation 12.4 could also be based on the average of $Inflow_l(i)$ during the first 5 years since 1990.

By substituting $C_l(t_0)$ in Equation 12.2, the $C_l(i)$ and $\Delta C_l(i)$ in the sequential time instants can be calculated. In the Tier 1 method, it is *good practice* to use Equation 12.4 for estimating the carbon stock at $t = t_0$.

EQUATION 12.4
APPROXIMATION OF THE CARBON STOCKS IN HWP POOLS IN USE AT THE INITIAL TIME, I.E. FROM WHICH ACTIVITY DATA ARE AVAILABLE

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

$$\text{With: } Inflow_{l_{average}} = \left(\sum_{i=t_0}^{t_4} Inflow_l(i) \right) / 5$$

Source: IPCC 2014; Rüter 2017, p. 259 ff.

Where:

k = decay constant of FOD for each HWP category l (see Equation 12.3).

An example on how to implement Equations 12.2 and 12.4 in a spreadsheet, e.g. with MS EXCEL, is provided in the Example Box 12.1.

BOX 12.1

EXAMPLE FOR IMPLEMENTING EQUATIONS 12.2 AND 12.4 IN A SPREADSHEET (E.G. MS EXCEL)

	A	B	C	D
1		half-life (hl)	35	
2		decay constant k	=LN(2)/C1	
3		term 'e^{-k}' of Eq. 12.2	=EXP(-C2)	
4		term '$[(1-e^{-k})/k]$' of Eq. 12.2	=(1-EXP(-C2))/C2	
5				
6	years	Inflow	*HWPj* carbon stock	stock-change
7	1990	100,00	=AVERAGE(B7:B11)/C2	=C8-C7
8	1991	101,00	=$C$3*C7+$C$4*B7	=C9-C8
9	1992	150,00	=$C$3*C8+$C$4*B8	=C10-C9
10	1993	103,00	=$C$3*C9+$C$4*B9	=C11-C10
11	1994	95,00	=$C$3*C10+$C$4*B10	=C12-C11
12	1995	105,00	=$C$3*C11+$C$4*B11	=C13-C12
13	1996	100,00	=$C$3*C12+$C$4*B12	=C14-C13
14	…	…	…	…

The initial carbon stock for the year 1990 is calculated by means of Equation 12.4 in cell C7. The FOD function as shown in Equation 12.2 is implemented in cells C8:C13. Based on the development of the carbon stock of the particular HWP category, the stock-changes (i.e. carbon pool changes) are calculated in the cells of column D.

It is furthermore *good practice* to apply Equations 12.2 and 12.4 with activity data for the semi-finished wood product categories sawnwood, wood-based panels and paper and paperboard, either as *aggregates* or for each of their subcategories as listed in Table 12.1 in Section 12.4.2.1. Further guidance on how to compile those relevant activity data in accordance with the respective approaches is also provided in Section 12.4.2.1.

In combination with those semi-finished wood product commodities to be used under the Tier 1 method (cf. Section 12.4.2.1), the FOD function implicitly includes finished HWP in the carbon stock estimates, and it is assumed that "immediate losses of the HWP pool due to final processing of wood along the processing chain (cf. Figure 12.A.1, Annex 12.A.1) are described realistically by the exponential decay pattern" (Pingoud und Wagner 2006). The timing of emissions from wood processing residues used for energy purposes along the process chain of HWP are also well described by the FOD function (cf. Rüter und Diederichs 2012).

ESTIMATING CO_2-FLUXES ASSOCIATED WITH HARVESTED WOOD PRODUCTS ('ATMOSPHERIC FLOW' APPROACH)

In the case that the 'atmospheric flow' approach is applied for estimating CO_2 emissions and removals from HWP, it is *good practice* to estimate the annual carbon fluxes into the atmosphere along the timber processing and wood utilization chain within the reporting country following Equation 12.5. The Equation reflects two components to be considered for a consistent implementation of this approach.

Firstly, it is assumed that the calculated annual gains of carbon in the HWP pool in use (i.e. $Inflow_{C_l}(i)$) following the 'stock-change' approach, see Equations 12.2 and 12.3) are not available for oxidation into the atmosphere in the year in which they are added to the pool. At the same time, it is assumed that the calculated annual carbon losses from this HWP pool in use by means of Equation 12.2, which do not enter the carbon stock in HWP in use again due to material recycling (and which would implicitly be included in the annual production data, e.g. of particle board) and which are not exported, are available for oxidation into the atmosphere in the reporting year (e.g. through combustion) (cf. IPCC 2006).

Secondly, an estimation of CO_2 emissions and removals from HWP following the 'atmospheric flow' approach consistent with the estimation results for emissions and removals from the forest carbon pools (cf. Chapter 4) is based on the assumption that only carbon in woody biomass that becomes and/or remains available within the reporting country and which is not fixed in a carbon pool could eventually also oxidize into the atmosphere in the reporting year (cf. IPCC 2006 GL, Chapter 12). In consequence, all carbon in harvested woody biomass from domestic forests (i.e. "roundwood production", by then implicitly included in the forest carbon estimates of emissions and removals as forest carbon pool losses) that is exported in the reporting year is to be subtracted from the countries' remaining carbon amounts in woody biomass available for oxidation. On the other hand, all imported carbon in woody biomass that becomes available within the country as wood fuel or feedstock for further processing and wood utilization along the value chain becomes available for oxidation (cf. Figure 12.A.3 in Annex 12.A.2).

As compared to the estimates on the impact of the carbon stock in the HWP pool in use (cf. Equations 12.1 to 12.4), these estimates of carbon in annual imports and exports of woody biomass to be used as wood fuel or feedstock (*RC*(*i*)) are needed for the reporting year or period only (see Equation 12.10).

Equation 12.5

Estimation of Total CO_2-fluxes associated with harvested wood biomass within the reporting country

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

Sources: cf. IPCC 2006

Where:

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

$C_{SCA_l}(i)$ = Changes of the carbon stock C in the particular semi-finished HWP category l during the year i, calculated from domestic consumption (i.e. 'stock-change' approach), in Mt → Equations 12.2 and 12.3

$RC_{EX_j}(i)$ = Exported carbon in the relevant HWP feedstock category serving as wood fuel and/or raw material for the manufacturing of semi-finished HWP, in Mt → Equation 12.10

j = index number of the HWP feedstock category

m = number of included HWP feedstock categories → Table 12.2

$RC_{IM_j}(i)$ = Imported carbon in the relevant HWP feedstock category serving as wood fuel and/or feedstock for the manufacturing of semi-finished HWP, in Mt → Equation 12.10

12.4.2.1 ACTIVITY DATA

Depending on the chosen approach (cf. Section 12.3), aactivity data include both the carbon stock of the HWP pool in use at the beginning of each year (*C*(*i*)) and the carbon inflow to the HWP pool during each year for each HWP category ($Inflow_l(i)$) as well as data on the remaining woody biomass within a country which does not enter the carbon stock in the HWP pool in use (as material) each year. The latter data are required when implementing the atmospheric flow approach. Table 12.1 provides both an overview on the particular semi-finished HWP categories to be used for the Tier 1 estimation of the carbon stock of the HWP pool in use and their associated carbon conversion factors *cf* to be applied in Equations 12.6, 12.7 and 12.9.

TABLE 12.1
DEFAULT CONVERSION FACTORS FOR THE SEMI-FINISHED HWP CATEGORIES AND THEIR SUBCATEGORIES

Semi-finished HWP categories (*l*)	Density (oven dry mass over air dry volume) [Mg / m^3]	Carbon fraction	C conversion factor *cf* (per air dry volume) [$Mg\ C / m^3$]	Source
Sawn wood (*aggregate*)	0.458	0.5	0.229	1
Coniferous sawnwood	0.45	0.5	0.225	2
Non-coniferous sawnwood	0.56	0.5	0.28	2
Wood-based panels (*aggregate*)	0.595	0.454	0.269	3
Hardboard (HDF)	0.788	0.425	0.335	4
Insulating board (Other board, LDF)	0.159	0.474	0.075	5
Fibreboard compressed	0.739	0.426	0.315	6
Medium-density fibreboard (MDF)	0.691	0.427	0.295	4
Particle board	0.596	0.451	0.269	4
Plywood	0.542	0.493	0.267	7
Veneer sheets	0.505	0.5	0.253	8
	Relative dry mass (oven dry mass over air dry mass) [Mg / Mg]		**C conversion factor *cf* (per air dry mass) [Mg C / Mg]**	
Paper and paperboard (*aggregate*)	0.9	-	0.386	9

[1] Calculated from the weighted average of coniferous and non-coniferous sawnwood production volumes (FAOSTAT average of the years 2006-2010) of the countries as listed in Appendix of the Annex of Decision 2/CMP.7

[2] IPCC 2003, Appendix 3a.1

[3] Calculated from the weighted average of included subcategories of the production volumes (FAOSTAT average of the years 2006-2010) of the countries as listed in Appendix of the Annex of Decision 2/CMP.7

[4] Rüter and Diederichs (2012)

[5] Derived from Environmental product declarations EPD-GTX-2011111-E, EPD-KRO-2009212-E and EPD-GTX-2011211-E provided by IBU e.V. (http://bau-umwelt.de/hp550/Insulating-materials.htm)

[6] Calculated from 50% of HDF and 50% of MDF

[7] Derived from Wilson and Sakimoto (2005) and basic density for non-coniferous species listed in the table above

[8] Calculated from 50% sawnwood (Coniferous) and 50% of sawnwood (Non-Coniferous)

[9] Calculated from the weighted average of included subcategories of the production volumes (FAOSTAT average of the years 2006-2010) of the countries as listed in Appendix of the Annex of Decision 2/CMP.7, including information derived from Fengel and Wegener (1984), Paulapuro (2000), Gronfors (2010) and industry information.

Source: IPCC 2014

For estimating the carbon stock in the HWP pool, Tier 1 uses forest products data for semi-finished HWP commodities from FAO as set out in Section 12.4.1.1. As a default, the annual $Inflow_l$ (i) to the HWP pool comprises of the three default HWP commodity categories, i.e. sawnwood, wood-based panels, paper and paperboard).

In order to estimate carbon amounts in the semi-finished HWP categories representing the material use of wood biomass, also default conversion factors are provided in Table 12.1. In fact, the conversion factors for the HWP default commodities (i.e. aggregates) are largely dependent on the composition of countries' production amounts of the particular subcategories (e.g. particle board). If countries have disaggregated data on subcategories of semi-finished HWP as listed in Table 12.1, it is thus *good practice* to apply Equations 12.2 and 12.4 to the disaggregated subcategories.

In order to reduce uncertainties associated with assumptions on the conversion factors of activity data (i.e. data on semi-finished wood product commodities derived from statistics) (see Section 12.4.1.1), countries may consider using country-specific activity data comprising further items of the HWP subcategories as listed in Table 12.1. More information can be obtained in Section 12.4.2.1.

Depending on which approach is to be applied by the country, different elements of the annual statistics on the above listed HWP categories are to be used for calculating the HWP activity data representing the use of wood as material that are used in Equations 12.2 and 12.4 (cf. Section 12.3.2). Depending on the chosen approach (cf. Equation 12.3), these data either represent

(i) the calculated consumption of HWP within the reporting country (‘stock-change’ approach), or

(ii) the production of HWP originating from the forests of the reporting country (‘production’ approach), or, as a subset, the domestically produced and consumed HWP originating from the forests of the reporting country only

For the ’production’ approach, the HWP activity data could furthermore be also assigned to the particular type of domestic forest land within the reporting country (see below).

In the case that the ‘atmospheric flow’ approach is applied, in addition to data on semi-finished HWP for estimating CO_2 emissions and removals from the HWP pool in use following the ‘stock-change ‘approach, data on carbon in the imports and exports of woody biomass serving as wood fuel and/or raw material (*RC*) for the subsequent manufacturing of semi-finished HWP are required (cf. Equation 12.5 and Annex 12.A.2). Table 12.2 includes those relevant wood product commodities including their carbon conversion factors *cf* to be applied in Equations 12.5 and 12.10. It is *good practice* to consider the relevant definitions provided in Section 12.4.1.1 as well as the classification of wood products (cf. Figures 12.2 and 12.3) in order to avoid double counting.

TABLE 12.2
DEFAULT CONVERSION FACTORS FOR THE HWP FEEDSTOCK CATEGORIES SERVING AS FUEL WOOD AND RAW MATERIAL FOR MANUFACTURING OF SEMI-FINISHED HWP

HWP feedstock categories (*j*)	**Density (oven dry mass over air dry volume) [Mg / m³]**	**Carbon fraction**	**C conversion factor *cf* (per air dry volume) [Mg C / m³]**	**Source**
Industrial roundwood (*aggregate*)	0.458	0.5	0.229	1
Coniferous industrial roundwood	0.45	0.5	0.225	1 & 2
Non-coniferous industrial roundwood	0.56	0.5	0.28	1 & 2
Wood fuel	0.458	0.5	0.229	1
Wood chips and particles	0.458	0.5	0.229	1
Wood residues	0.458	0.5	0.229	1
	(oven dry mass over air dry mass) [Mg / Mg]		**(per air dry mass) [Mg C / Mg]**	
Wood charcoal	0.9	0.85	0.765	3
Wood pulp (*aggregate*)	0.9	-	0.417	4 & 5
Mechanical wood pulp	0,9	-	0.447	5
Chemical wood pulp, sulphate, unbleached	0,9	-	0.422	5
Chemical wood pulp, sulphate, bleached	0,9	-	0.397	5
Chemical wood pulp, sulphite, unbleached	0,9	-	0.422	5
Chemical wood pulp, sulphite, bleached	0,9	-	0.398	5
Recovered paper	0.9	-	0.386	1

[1] IPCC 2014

[2] IPCC 2003, Appendix 3a.1

[3] IPCC 2006

[4] Calculated from the weighted average of included subcategories of the production volumes (average of the years 2006-2010) as for the HWP category ‘paper and paperboard’ (See Table 12.1)

[5] Values derived from Steffen *et al.* 2016

COMPILATION OF ACTIVITY DATA FOR THE 'STOCK-CHANGE' APPROACH

For calculating the annual carbon inflow to the respective HWP category pool for the stock-change approach (i.e. $Inflow_{SCA_l}(i)$), see Equation 12.3), countries should apply Equation 12.6.

EQUATION 12.6
CALCULATION OF CARBON INFLOW IN THE PARTICULAR SEMI-FINISHED HWP CATEGORY FOLLOWING THE 'STOCK-CHANGE' APPROACH

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

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

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

Source: Rüter 2017, p. 259 ff; IPCC 2006

Where:

$HWP_{C_l}(i)$ = calculated domestic consumption of the particular semi-finished HWP category *l* in year *i*, in m^3

cf_l = carbon conversion factor of the particular semi-finished HWP category *l* (cf. Table 12.1)

$HWP_{P_l}(i)$ = production of the particular semi-finished HWP category *l* in year *i*, in m^3

$HWP_{IM_l}(i)$ = import of the particular semi-finished HWP category *l* in year *i*, in m^3

$HWP_{EX_l}(i)$ = export of the particular semi-finished HWP category *l* in year *i*, in m^3

COMPILATION OF ACTIVITY DATA FOR THE 'PRODUCTION' APPROACH

Analogously, Equation 12.7 allows calculating the carbon inflow to the HWP pool of the particular semi-finished HWP category for the 'production' approach (i.e. $Inflow_{PA_l}(i)$, see Equation 12.3) (cf. IPCC 2014).

EQUATION 12.7
CALCULATION OF CARBON INFLOW IN THE PARTICULAR SEMI-FINISHED HWP CATEGORY FOLLOWING THE 'PRODUCTION' APPROACH

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

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

With: $f_R(i) := f_{IRW}(i)$ for HWP categories 'sawnwood' and 'wood-based panels',
and $\left(\left(f_{IRW}(i) \bullet (1-q) \bullet f_{PULP}(i)\right) + q \bullet f_{RecP}(i)\right)$ for HWP category 'paper and paperboard'

With: $f_{IRW}(i) := 0$ if $f_{IRW}(i) < 0$ and $f_{PULP}(i) := 0$ if $f_{PULP}(i) < 0$ and $f_{RecP}(i) := 0$ if $f_{RecP}(i) < 0$

Source: Rüter 2017, p. 259 ff.; IPCC 2014

Where:

$HWP_{DP_j}(i)$ = production of the particular semi-finished HWP category originating from domestic harvest in year *i*, in m³

$f_R(i)$ = Share of woody feedstock category *R* (*IRW*, *PULP* or *RecP*) for the production of the particular semi-finished HWP category originating from domestic harvest in year *i* → Equation 12.8

IRW = HWP feedstock category '*industrial roundwood*'

q = recovered paper utilization rate

PULP = HWP feedstock category '*wood pulp*'

RecP = HWP feedstock category '*recovered paper*'

Equation 12.8 implements the calculation of the share of the particular feedstock category *R* originating from domestic harvest in its total calculated consumption for the manufacturing of the relevant subsequent products in the year i, which is represented by the feedstock factor $f_R(i)$.

EQUATION 12.8

ESTIMATION OF ANNUAL FRACTION OF THE RELEVANT DOMESTICALLY PRODUCED FEEDSTOCK FOR PRODUCTION OF SEMI-FINISHED HWP ORIGINATING FROM DOMESTIC HARVEST

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

$$\text{With: } R := \begin{cases} IRW & \text{for HWP feedstock category '}\textit{industrial roundwood}\text{'} \\ PULP & \text{for HWP feedstock category '}\textit{wood pulp}\text{'} \\ RecP & \text{for HWP feedstock category '}\textit{recovered paper}\text{'} \end{cases}$$

Source: Rüter 2017, p. 259 ff; cf. IPCC 2014

Where:

$R_P(i)$ = Production of the particular HWP feedstock category in year *i*, in m³ or Mt

$R_{IM}(i)$ = Import of the particular HWP feedstock category in year *i*, in m³ or Mt

$R_{EX}(i)$ = Export of the particular HWP feedstock category in year *i*, in m³ or Mt

COMPILATION OF ACTIVITY DATA FOR DOMESTICALLY CONSUMED HWP OF THE 'PRODUCTION' APPROACH

In the case that the 'production' approach is applied, it is *good practice* to report CO_2 emissions and removals from the change in the carbon stock in domestically consumed HWP and the change in the carbon stock in exported HWP separately in order to increase transparency. 'For this purpose, the annual carbon inflow to the HWP pool of the particular HWP category that is domestically consumed ($Inflow_{PADC}(i)$) is to be calculated by means of Equation 12.9. This is particularly relevant in those cases where country-specific emission factors are being applied (cf. Section 12.4.3.2).

EQUATION 12.9
CALCULATION OF CARBON INFLOW IN THE PARTICULAR SEMI-FINISHED HWP CATEGORY FOR ESTIMATING THE FRACTION OF DOMESTICALLY CONSUMED HWP FOLLOWING THE 'PRODUCTION' APPROACH

$$Inflow_{PADC}(i) = HWP_{DC}(i) \bullet cf_l$$

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

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

Source: Rüter 2017, p. 259 ff

Where:

$HWP_{DC_l}(i)$ = domestically produced and consumed HWP of the particular semi-finished HWP category originating from domestic harvest in year *i*, in m³

COMPILATION OF ADDITIONAL ACTIVITY DATA REQUIRED FOR THE 'ATMOSPHERIC FLOW' APPROACH

In order to implement the 'atmospheric flow' approach, additional to the activity data calculated by means of Equation 12.6, the sum of all exported and all imported carbon in woody biomass serving as wood fuel and/or feedstock the manufacturing of semi-finished HWP is to be calculated. Equation 12.10 enables the calculation of carbon in imports and exports as elements of trade in those feedstock commodities for further use in Equation 12.5.

EQUATION 12.10
CALCULATION OF CARBON IN TRADED HWP FEEDSTOCK CATEGORIES SERVING AS WOOD FUEL AND RAW MATERIAL FOR SUBSEQUENT PROCESSING OF SEMI-FINISHED HWP

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

$$\text{With: } TRADE := \begin{cases} IM & \text{for imports of the relevant feedstock category } j \\ EX & \text{for exports of the relevant feedstock category } j \end{cases}$$

Source: cf. Rüter 2017, p. 259 ff, IPCC 2006

Where:

$RC_{TRADE_j}(i)$ = Carbon in the relevant traded HWP feedstock category *R* serving as wood fuel and/or raw material for the manufacturing of semi-finished HWP, in Mt → Table 12.2

cf_j = carbon conversion factor of the particular HWP feedstock category → Table 12.2

In the case that the 'atmospheric flow' approach is chosen, it is *good practice* to apply Equation 12.10 to all HWP feedstock commodities listed in Table 12.3, in order to cover all relevant carbon fluxes in traded woody biomass and thus also into the atmosphere in the year of reporting.

12.4.2.2 EMISSION FACTORS

The rate at which carbon in the Tier 1 default HWP categories is removed from the HWP pool in service in a given year is specified by a constant decay rate (k) expressed as half-life in years (cf. Equation 12.2 and Box 12.1). The 2006 IPCC Guidelines define the half-life as "the number of years it takes to lose one-half of the material currently in the pool''. As the half-life in this context refers to HWP in use (i.e. Section 12.3), the half-life to be applied is a function of the adjusted estimated service life (ESL) of the particular HWP commodities (with *HL = Adjusted ESL * ln (2)*, see Section 12.4.3.2).

The Tier 1 method involves applying the default half-lives of the three semi-finished HWP categories based on information provided in IPCC 2003, 2006 and 2014, as given in Table 12.3. The same half-lives apply for the particular subcategories of these aggregate categories of semi-finished HWP as specified in Table 12.1 (Section 12.4.2.1).

TABLE 12.3
TIER 1 DEFAULT HALF-LIVES[6] OF HWP CATEGORIES

HWP categories[7]	Default half-lives (years)
Paper and paperboard	2
Wood-based panels	25
Sawn wood	35

Source: IPCC 2014

12.4.3 Tier 2 method using country-specific data

Under Tier 2, estimates of the annual CO_2 emissions and removals from HWP are derived using the same Equations as provided for Tier 1 in Section 12.4.2. In following a Tier 2 method, either country-specific activity data and/or country-specific emission factors are to be applied.

This section provides *good practice* guidance on the use of country-specific

i) Activity data that is consistent with the Tier 2 method (Section 12.4.3.1) as appropriate for each approach as described in Section 12.4.2.1, and

ii) Emission factors following the concept of service life and half-life information to estimate CO_2 emissions and removals from HWP by means of the first order decay function (Equation 12.2) as provided for Tier 1 (Section 12.4.3.2).

12.4.3.1 COUNTRY-SPECIFIC ACTIVITY DATA

This section provides guidance on how to derive country-specific activity data that is consistent with the application of the first order decay function.

For this purpose, it is *good practice* for activity data to follow the international classification system for forest products consistent with the Harmonized Commodity Description and Coding System (HS) of tariff nomenclature, presenting data in more detail than implemented in FAOSTAT (see Section 12.4.1.1).

In order to calculate the annual carbon inflow ($Inflow_l(i)$) required for Equation 12.2 and subsequent Equations in Section 12.4.1.2, carbon conversion factors that reflect the commodity definitions should be applied (e.g. density, woody biomass content, and tree species).

12.4.3.2 COUNTRY-SPECIFIC EMISSION FACTORS

In order to reduce uncertainties associated with the assumptions behind the default Tier 1 half-lives of the HWP commodities (see Section 12.7), countries may consider using Tier 2 country-specific half-lives, both for the domestic use of HWP categories, as well as country-specific half-lives as being applied by the importing country in the case of exported HWP categories (where relevant). Further guidance on how to use and obtain country-specific half-life information (i.e. Tier 2) for the relevant HWP categories is available in Section 12.4.3.2.

This section gives guidance on how to derive country-specific service- and half-life information to estimate CO_2 emissions and removals from HWP on the basis of the first order decay function as included in Equation 12.2 (see Section 12.4.2).

[6] Half-lives are based on Table 3a.1.3 of the *GPG-LULUCF*.

[7] HWP categories refer to the commodities sawnwood, wood-based panels, paper and paperboard, acc. to the international classification system for forest products (see guidance in Section 12.5.1.1)

In the following, guidance is provided on how to derive country-specific half-life values that can be used for that purpose, following the ISO 15686 standard series approach, since this is an already established system for service life estimation on a national (not case specific) level in combination with obsolescence on national level (see Box 12.2).

It contains an example on how to improve service life estimates and subsequent HWP half-life calculation for the HWP categories based on the ISO 15686 series in combination with an obsolescence factor and information on its market share.

In order to adequately apply the flux data method as suggested for Tier 1 based on information on country-specific HWP service life (i.e. time carbon is held in HWP pool in use before they are disposed or recycled), apart from the concept of half-life (see Section 12.4.2.2), the following terms and concepts are to be distinguished:

- ISO 15686-1:2011 defines the reference service life (RSL) as the service life of a product, component, assembly or system which is known to be expected under a particular set, i.e. a reference set of in-use conditions;
- The estimated service life (ESL) on the other hand is the service life that a wooden or wood based component would be expected to have in a set of specific in-use conditions. It is determined from RSL data after taking into account any differences from the reference in-use conditions (ISO 15686-1:2011);
- The factor method is used to calculate the ESL. It is a modification of RSL by seven factors to take account of the specific in-use conditions (ISO 15686-8:2008); and
- Obsolescence arises (according to ISO 15686-1:2011) when a facility no longer can be adapted to satisfy changing requirements. Obsolescence tends to result from unexpected changes, often unrelated to the construction, and includes:
    - (i) Functional obsolescence: function no longer required.
    - (ii) Technological obsolescence: new alternatives can offer better performance, change the pattern of use.
    - (iii) Economic obsolescence: Fully functional but less efficient, more expensive than alternatives. This includes also replacement due to changing fashion or taste.

ISO (2011) states that estimates of obsolescence should be based on the designer's and client's experience, and, if possible, documented feedback from practice. In order to estimate the carbon storage of HWP in use and its impact on emissions/removals by means of flux data methods using country-specific service life information, it is thus *good practice* to take into account obsolescence and to distinguish replacement of HWP in use due to e.g. a defective performance from obsolescence (cf. ISO 2011).

For example:

In northern Europe, a wooden decking can last for 50 years or more given proper construction and choice of material. But the same decking is likely to be replaced already after 20 years (or less) e.g. due to aesthetical reasons. Hence, for calculating country-specific ESL or half-life values an obsolescence factor is needed in Tier 3 estimates of CO_2 emissions and removals from HWP to reflect the time actually spent in the HWP carbon pool, not the potential full-service life of a wooden component given by ESL.

In this guidance document, the ESL is applied for estimates on a national level and not for a specific case as suggested in the ISO 15686 standard series. To include the effect of obsolescence:

- Either an additional obsolescence factor (O) is included, with
    - (i) Obsolescence = 1 when there is considered to be no significant effect of obsolescence compared to RSL
    - (ii) Obsolescence is given a value < 1 based on the intensity of obsolescence
    - (iii) Obsolescence can never be larger than 1.
- Or a decay function to be assigned that uses the service life data to estimate the decay profile (based on products leaving the pool, not only biological decay and not a biological decay profile) or the actual time path that products take to go out-of-use.[8]

An example of how to derive national service life estimates by means of the factor method is given in the box 12.2 below.

[8] For more information see IPCC FAQ, Q4-29 (http://www.ipcc-nggip.iges.or.jp/faq/faq.html)

BOX 12.2
EXAMPLE ON THE CALCULATION OF NATIONAL ESL BY MEANS OF FACTOR METHOD

A theoretical example with wooden claddings in Norway is given based on ISO 15686-8:2008, but elevated from the case specific level given in the standard to a national level. Details about RSL and service life estimation are in ISO 15686-8:2008.

A factor of “1” is used when the factor does not deviate from the RSL conditions. A higher value (x>1) is given if the national performance is better than RSL conditions; a lower value (x<1) is given if the national performance is lower than the RSL conditions. Non-relevant factors are excluded from the equation.

The RSL is based on accelerated field trials and the threshold for failure was defined when the mean decay rating reached 2 (on a scale from 0–4 where 0 is no decay and 4 is failure).

National ESL = 55(RSL)*1(A)*1(B)*1(C)*1.2(E)*1(F)*0.9(G) = 59.4 years

Factor D ‘indoor environment’ is excluded because it is not relevant. It is good practice to include factors that do not deviate from the RSL even if they do not contribute in changing the RSL since they are given the value 1. A more detailed explanation for the choice of factors used is to be provided in the countries’ annual reporting.

A = Inherent performance level represents the grade of the component as supplied.

- Here equals the RSL.

B = Design level reflects the component’s installation in the building/constructed asset and is typically based on the level of shelter and protection from agents provided by the design of the building/constructed asset.

- Here equals the RSL.

C = Work execution level considers the level of skill and control in sitework.

- Here equals the RSL.

D = Indoor environment considers the exposure of the object to indoor agents of degradation and their severity.

- Not relevant in this example.

E = Outdoor environment considers exposure to outdoor agents of degradation and their severity.
- In this example, the climate on a national level is less harsh than at the test sites included in RSL.

F = Usage conditions reflects the effect of the use of the building/constructed asset.

- Here equals the RSL.

G = Maintenance level reflects the level of maintenance assumed. For certain components that are inaccessible or require special equipment for access, a particularly low maintenance level should be considered.

- Here slightly lower than RSL intervals.

Another example in Table 12.4 shows how to derive country-specific half-life values for the three default HWP categories (see Section 12.4.2.1) as a function of information on market share of the use of wood (see above), ESL and obsolescence. The use of composed HWP categories in different markets, such as in the construction sector, can be divided further into different segments (e.g. wall systems, flooring, and roof construction). These different segments normally have different service lives and obsolescence factors. Hence, countries are encouraged to allocate the contribution of the different HWP categories or subcategories (e.g. coniferous sawnwood) to markets and their segments in order to obtain improved service life estimates for the particular HWP categories. Thereby, it is important to note that the assumed service life is driven by the products technical properties and, depending on this, its particular application area (e.g. load-bearing beam or wood panelling, both made of sawnwood). Thus, in order to calculate a country-specific emission factor (i.e. service- or half-life), different sources of information, e.g. on the market use of different HWP categories, could be combined as illustrated in Table 12.4.

The definition of half-life and also guidance on how to calculate half-life for Tier 1 is provided in Section 12.4.2.2.

TABLE 12.4
EXAMPLE ON HOW TO DERIVE COUNTRY-SPECIFIC HALF-LIFE FOR HWP CATEGORIES AS A FUNCTION OF INFORMATION ON MARKET SHARE, ESTIMATED SERVICE LIFE (ESL) AND OBSOLESCENCE

HWP categories (*here: aggregates*)	Markets*	Market share of HWP category	National estimated service life (ESL), years	National obsolescence factor (O)	Adjusted ESL of HWP category (=ESL*O* market share adjustment)	Half-life (=Adjusted ESL* ln(2))
Sawn wood	construction	60%	70	0.9	41.0	28.4
	furniture	10%	45	0.6		
	packaging	30%	6	0.3		
	paper	0%	-	-		
Wood-based panels	construction	50%	60	0.7	30.5	21.2
	furniture	45%	35	0.6		
	packaging	5%	6	0.3		
	paper	0%	-	-		
Paper and paperboard	construction	0%	-	-	1.5	1
	furniture	0%	-	-		
	packaging	50%	3	0.3		
	paper	50%	10	2		

* As the use of the HWP categories in different markets, such as the construction sector, consists of different end uses (e.g. wall systems, flooring, roof construction), countries are encouraged to allocate the contribution of the different end uses to the relevant HWP category or subcategory (e.g. non-coniferous sawnwood used for windows).

COUNTRY-SPECIFIC HALF-LIFE DATA TO BE USED FOR EXPORTED HWP UNDER A PRODUCTION APPROACH

In the case that CO_2 emissions and removals of CO_2 from HWP are estimated on the basis of the production approach (Section 12.4.2.1) and country specific half-life information should be used also for the exported HWP, it is *good practice* to use the half-life information from the importing country. For this purpose, it is necessary to quantify export activity data within the HWP categories and/or sub categories (cf. Section 12.4.1.1). Furthermore, in order to ensure that the country-specific half-life information from the importing country complies with the categories of the activity data for the exported HWP, it is *good practice* to only apply country-specific half-life information in the case the same categories of activity data for the exported HWP both in the exporting and importing country are used. Otherwise the default values from Tier 1 are to be used (Section 12.2.2.2).

In order to increase transparency, it is *good practice* to report CO_2 emissions and removals from HWP of domestically consumed and exported wood separately.

12.4.4 Tier 3 country-specific methods

12.4.4.1 FLUX DATA METHODS

In theory, also other decay functions than the one described for Tier 1 could be used to apply a flux data method.

However, it should be noted, that depending on the selected approach it is "more difficult to develop Tier 3 methods", especially in the case a production approach is selected "which requires data on the lifecycle of exported HWP for countries where most of its products are exported." (IPCC 2006)

ACTIVITY DATA USED IN COUNTRY-SPECIFIC FLUX DATA METHODS

In general, activity data could also be established and combined with suitable service life information differently from the HWP categories as suggested in Section 12.5.1.1.

This could include for example statistics on finished products. However, it should be noted that in many cases such information is provided only in units per piece which makes it difficult to convert such data to carbon amounts.

In order to ensure that the country-specific methodology used is at least as accurate as the one described in Section 12.4.2, it is *good practice* to ensure that the country-specific HWP categories cover the volumes as described by the default HWP categories following the international classification system (cf. Section 12.4.1.1), in line with the approach (i.e. system boundary) chosen by the country (cf. Section 12.3 and Annex 12.A).

In the case that the country does provide HWP data in FAOSTAT following the international classification system (see Section 12.4.1.1), it is also *good practice* to explain the relation of the country-specific HWP categories to the FAOSTAT data to ensure that the data relates to the approach selected by the country.

In the case that the country-specific categories representing the carbon flux into the HWP carbon pool do not cover all the relevant HWP elements reflecting the material use of HWP in the selected approach (cf. Section 12.3 and 12.4.2.1), it is furthermore *good practice* to combine the country-specific flux data method with other suitable methodologies (cf. Section 12.4.4.3).

Furthermore, countries are encouraged to make the country-specific HWP categories broad enough to capture significant carbon volumes contributing to the HWP pool. As a guide, the volumes of these categories are deemed significant if they represent at least 5% of the total HWP volumes as described by the particular approach selected by the country.

EMISSION FACTORS USED IN COUNTRY-SPECIFIC FLUX DATA METHODS

In order to derive country-specific service- and half-life information to be used in combination with activity data used in country-specific flux data methods, it is *good practice* to ensure that the country-specific parameters match with the HWP activity data applied under the selected Tier 3 method.

It is furthermore important to note that service- and half-life values representing the material use of wood can differ notably among and within countries depending on factors such as construction practices, culture, fashion, and climate. Thus, in case such country-specific information is used, a national quality control system is encouraged in order to provide transparent and verifiable data.

Potential sources that could be used to derive country-specific service-life values e.g. for combination with data on finished wood products are e.g. national surveys on the final market use of wood.

12.4.4.2 INVENTORY METHODS

HWP stock inventory methods use HWP carbon pool data for two or preferably more separate points in time to estimate changes in the pool. In practice, its application is relevant for HWP pools in the reporting country alone and could be used to estimate the annual change in carbon stock of some specific finished HWP pools (cf. Figure 12.3) such as buildings. The HWP pool of products in use in building structures is frequently a major part of the total HWP pool. The amount of HWP carbon can be estimated, for example, by multiplying the average HWP content per square metre of floor space times the total floor space for relevant building types that use wood taking into account when the buildings were constructed and changes in wood use per square meter over time. Annual change in carbon stock could be estimated by noting the change between inventories estimated at different points in time. Examples of such inventories are reported in Gjesdal *et al.* (1996) for Norway, in Pingoud et al., (2001) and Statistics Finland (2010) for Finland.

In inventory methods, no procedure for adding up wood use data from historical data is needed to estimate the existing HWP stock or annual change in stock, which is an advantage compared to the flux methods (IPCC 2006).

Depending on the selected approach by the country and the availability of activity data other than described in Section 12.5.1.1., there might be the need to combine inventory information with estimates derived by means of flux data methods (see Section 12.5.4.3).

Especially in the case that the estimates follow a ‘production’ approach (Section 12.3.1.2), the application of inventory methods does not allow the identification of the proportion of the HWP carbon stock originated from domestic forests and being thus accountable (see Section 12.5.2.1). It is also hardly possible to estimate the carbon stock in the exported share of domestically produced HWP by means of inventories itself (cf. 12.4.4.3). Following this approach furthermore requires excluding imported HWP from the estimated HWP pool, therefore increasing the uncertainties.

Since in practice inventory data are not available for all finished HWP for domestic and export markets covering the default HWP categories sawnwood, wood-based panels, paper and paperboard (e.g. wooden houses, furniture, newspaper), it is *good practice* to apply inventory methods only in combination with flux data methods.

In cases where a country applies inventory methods for specific HWP end uses (e.g. the housing sector), it is *good practice* to estimate CO_2 emissions and removals from HWP for the remaining fraction of the three HWP default commodities representing the material use of wood in combination with the flux-data method under Tier 2 or 3.

12.4.4.3 COMBINED HWP STOCK INVENTORY AND FLUX DATA METHODS

The application of a combined method is specifically relevant in the case that stock inventory information should be used in combination with the 'production' approach. For this purpose, the three semi-finished HWP categories being used in the housing sector need to be factored out from the flux-data calculation to avoid double-counting (see Section 12.4.1.1).

12.5 HARVESTED WOOD BIOMASS USED FOR ENERGY PURPOSES

This section clarifies how and where wood biomass that is harvested and extracted from forests and other wood producing land categories, and then burnt at some point in time, is considered in GHG inventories. This includes explaining where this activity is represented in different inventory sectors and where to find relevant guidance.

12.5.1 Treatment of CO_2 emissions from wood biomass burnt and used for energy purposes

This section discusses how the reporting of CO_2 emissions from wood biomass used for energy purposes depends on the choice of reporting approach, in terms of the conceptual framework and system boundary of each approach. The main purpose of this discussion is to clarify where CO_2 emissions from wood biomass burnt for energy purposes are reported in GHG inventories, in particular, whether they are reported by a producing country (i.e. a country where wood is harvested) or consuming country (i.e. a country where the wood products are used).

The CO_2 emissions from wood biomass used for energy purposes are reported in the AFOLU sector. However, these CO_2 emissions are reported as an implicit component of carbon stock changes reported for forests and other wood producing land categories, or as part of carbon stock changes in the HWP pool. The details depend on the approach applied for reporting CO_2 emissions and removals from HWP in use.

The CO_2 emissions from wood biomass used for energy purposes are not reported in either the Energy or Waste sectors. This is to avoid the possibility of double counting these emissions in two or more inventory sectors.

When considering CO_2 emissions from harvested wood biomass used for energy purposes, it should be recognised that harvested wood biomass may be burnt or otherwise lost at different stages in the utilisation of harvested wood. In this context, several elements of wood biomass may be identified:

- 'Wood biomass used directly as energy feedstocks': these consist of harvested wood used directly as feedstocks to produce energy. This includes harvested wood biomass burnt directly as fuel wood on a residential, commercial or industrial scale, and harvested wood biomass used directly as a feedstock for biofuels. Also included here is wood biomass burnt for process energy in the manufacture of energy wood products (such as wood chips, briquettes and pellets), and in the manufacture of biofuels.
- 'Industrial residues from manufacturing semi-finished wood products': these consist of industrial residues generated along the process chain in the manufacture of semi-finished wood products. Possibly some of these residues may also be burnt or lost without energy recovery.
- 'Industrial residues from manufacturing finished wood products in use': these consist of industrial residues generated along the process chain in the manufacture of finished wood products from semi-finished wood products. Possibly some of these residues may also be burnt or lost without energy recovery.
- Wood biomass collected and burnt as post-consumer waste: these consist of wood biomass collected and burnt as post-consumer wood (i.e. recovered wood), including industrial-scale incineration, with or without energy recovery.

For clarity, it is also relevant to consider 'unutilized wood harvest residues' in GHG inventories. These consist of residual wood biomass generated as part of harvesting but not extracted from the forest, which is left to rot on site, or burnt on site as waste. This is equivalent to the biomass referred to as slash in Figure 12.2 (Section 12.4.1.1).

Table 12.5 gives a summary of the implications for reporting CO_2 emissions from wood biomass burnt by producing or consuming countries under different reporting approaches, referring to the elements of wood biomass described above. For clarity and to allow comparison, the table also shows the implications of taking the decision to not report CO_2 emissions and removals from the category of HWP (i.e. to assume instantaneous oxidation of HWP, see Section 12.4.1.2).

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TABLE 12.5
REPORTING OF CO_2 EMISSIONS FROM WOOD BIOMASS BURNT BY PRODUCING AND CONSUMING COUNTRIES UNDER DIFFERENT REPORTING APPROACHES

<table>
<tr><th>Element of wood biomass</th><th>Instantaneous oxidation</th><th>'Stock-change' approach</th><th>'Production' approach</th><th>'Atmospheric flow' approach</th></tr>
<tr><td>Unutilized wood harvest residues</td><td rowspan="5">Producing country</td><td rowspan="3">Producing country</td><td rowspan="5">Producing country</td><td>Producing country</td></tr>
<tr><td>Harvested wood biomass used directly as energy feedstocks</td><td rowspan="4">Consuming country</td></tr>
<tr><td>Industrial residues from manufacturing semi-finished wood products</td></tr>
<tr><td>Industrial residues from manufacturing finished wood products in use*</td><td rowspan="2">Consuming country</td></tr>
<tr><td>Wood biomass collected and burnt as post-consumer waste</td></tr>
</table>

* In the case of the 'stock-change' approach, strictly, CO_2 emissions from wood biomass collected and burnt as post-consumer waste are only reported by a consuming country if the finished wood products are consumed and used in the country where they are manufactured and are not exported to another country.

The CO_2 emissions from 'unutilized wood harvest residues' generated as part of harvesting are reported as an implicit component CO_2 emissions and removals reported for forests and other wood producing land categories (i.e. as part of losses from above ground standing biomass) and are reported by a producing country.

In the case of 'harvested wood biomass used directly as energy feedstocks', when applying the 'stock-change' or 'production' approaches, CO_2 emissions are reported by a producing country. This is a reflection of the conceptual framework behind the stock-change approach and production approach (see Section 12.3.1), which involves estimating CO_2 emissions and removals from HWP by means of changes in defined carbon stocks in the HWP pool. Harvested wood biomass used directly as a feedstock for energy purposes is assumed to be burnt in the same year as when it is harvested. Hence, conceptually, there is no carbon pool associated with this use of wood. As a consequence, under the stock-change and production approach, the CO_2 emissions are included implicitly as a component of the net CO_2 emissions and removals associated with forests and other wood producing land categories (i.e. as part of losses from above ground standing biomass), as reported by a producing country,

The 'atmospheric flow' approach focusses on identifying and quantifying CO_2 fluxes to the atmosphere from HWP, taking place within national boundaries. The CO_2 emissions from burning 'harvested wood biomass used directly as energy feedstocks' are thus reported by a country where the wood biomass is used (i.e. by a consuming country).

In the case of 'industrial residues from manufacturing semi-finished wood products', when applying the 'stock-change' or 'production' approaches, CO_2 emissions are reported by a producing country. This reflects the application of approaches following the conceptual framework which focusses on estimating CO_2 emissions and removals from HWP on the basis of changes in defined carbon stocks in the HWP pool. The HWP pool is defined in terms of semi-finished wood products, thus the industrial residues considered here do not form part of the HWP pool and the CO_2 emissions are included implicitly as a component of the net CO_2 emissions and removals associated with forests and other wood producing land categories (i.e. as part of losses from above ground standing biomass), as reported by a producing country, Under the ‘atmospheric flow’ approach, a consuming country reports for the CO_2 emissions from burning biomass generated as ‘industrial residues from manufacturing semi-finished wood products’.

In the case of ‘industrial residues from manufacturing finished wood products in use’, when applying the method as set out in Section 12.4.2 for Tier 1 and Tier 2, CO_2 emissions are reported as an implicit component of the losses from the defined HWP pool in use. These estimated emissions are calculated from data on semi-finished wood products by applying FOD functions to these products (see Section 12.5). As a consequence, the reporting of CO_2 emissions from these industrial residues (either by a producing country or consuming country) depends on the selected reporting approach. Under the ‘stock-change’ and the ‘atmospheric flow’ approach, CO_2 emissions are reported by a consuming country. Under the ‘production’ approach, CO_2 emissions are reported by a producing country.

Note that, under Tier 1 and 2 methods, CO_2 emissions from these industrial residues are reported, regardless of whether the residues are burnt with energy recovery, burnt without energy recovery, or lost (e.g. decay) as waste.

When applying a Tier 3 method, the calculation methods should be designed to ensure that the reporting of CO_2 emissions from these industrial residues (either by a producing country or consuming country) is consistent with the selected reporting approach.

In the case of ‘wood biomass collected and burnt as post-consumer waste’, CO_2 emissions are treated in the same way as industrial residues burnt or lost during the manufacture of finished products in use, as described immediately above.

12.5.2 Treatment non-CO_2 emissions from wood biomass used for energy purposes

Non-CO_2 emissions from wood biomass used for energy purposes are reported in the Energy sector, and are consistently reported by the country in which the biomass is consumed. As a consequence, the CO_2 and non-CO_2 emissions from burning wood biomass for energy purposes may be reported by the same country (i.e. a consuming country) or by different countries, depending on the approach applied for reporting CO_2 emissions and removals from HWP in use. When CO_2 emissions from burning wood biomass for energy are reported by a country as an information item in the Energy sector, these emissions are calculated consistently with the reporting of related non-CO_2 emissions from burning the biomass in the consuming country (see IPCC 2006 GL, Vol 2, Chapter 2, Section 2.3.3.4).

12.5.3 Guidance on emissions factors for wood biomass used for energy purposes

Guidance on emissions factors for CO_2 and non-CO_2 GHG emissions resulting from the burning of wood biomass can be found in IPCC 2006 GL Vol 2, Ch 2 Section 2.3.2. Guidance on how to derive activity data in the case that wood biomass is burnt for energy generation purposes is given in IPCC 2006 GL Vol 2, Ch 2 Section 2.3.3. Where wood biomass is incinerated as waste (i.e. without energy recovery), guidance is provided in IPCC 2006 GL Vol 5, Ch 2. In the case that wood biomass is used as feedstock for biofuels, guidance is provided in IPCC 2006 GL Vol 2, Ch 3.

12.6 CLARIFICATION OF THE TREATMENT OF “WOOD IN SWDS” IN THIS GUIDANCE

This section provides clarification of where the best available guidance may be found for the reporting of emissions from HWP in SWDS.

Great care is needed when interpreting and using activity data derived from waste statistics on the one hand and national and international forest products statistics on HWP production and consumption, which follow the international classification system for wood commodities on the other hand. For example, significant quantities of HWP may be burnt for energy or recycled at the end of life, while waste statistics generally include biomass from sources other than HWP (e.g. garden waste). Therefore, generally wood production and wood consumption statistics cannot be used in a simple way to estimate quantities of HWP in SWDS. It may also be difficult to relate estimates of wood in SWDS derived from waste statistics to estimates of HWP in use. Consequently, there may be some inconsistency in results reported for CO_2 emissions and removals from HWP in the AFOLU sector and results reported for wood in SWDS in the Waste sector.

12.6.1 Reporting of CO_2 emissions from wood biomass in SWDS

Losses of HWP in use are assumed to result in CO_2 emissions to the atmosphere, with no explicit representation of the subsequent retention of disposed wood in SWDS and eventual CO_2 emissions from this pool. Therefore, CO_2 emissions from wood in SWDS are included implicitly in the CO_2 emissions due to losses of carbon from the HWP pool in use as reported in the AFOLU sector. It may be useful to quantify the CO_2 emissions from wood biomass in SWDS for information purposes to permit checks on consistency in the estimation of emissions in the Waste and AFOLU sectors.

It should be noted that, if reporting CO_2 emissions from wood in SWDS as an information item in the AFOLU sector, the results will only be consistent with results reported in the Waste sector (including for methane emissions) if calculated by applying a consistent approach (which, in this specific context, is the 'stock-change' approach). For the estimation of these emissions, the IPCC 2006 GL for HWP advise inventory compilers to apply either the Tier 1 method with default parameter values described in guidance for the Waste sector, or a Tier 2 method for the Waste sector, with country-specific parameter values. If the 'stock-change' approach is applied, the inflow to the Tier 1 or Tier 2 calculation consists of the calculated domestic consumption of wood discarded to SWDS, whilst the outflow is calculated based on a first order decay function (see IPCC 2006 GL, Volume 5, Annex 3A.1). The Waste Sector guidelines explain how to use Waste Sector default data and parameters to estimate the amount of solid wood and paper carbon that accumulates in SWDS in the reporting country. When applying the Waste Sector Tier 1 method, estimates of carbon stock changes in SWDS are calculated by identifying the portion of carbon discarded to SWDS in the current year which is judged to have originated as harvested wood biomass.

12.6.2 Reporting of non-CO_2 (methane) emissions from wood biomass in SWDS

According to guidelines for the Waste sector (IPCC 2006 GL, Volume 5, Chapter 3, Section 3.1), methane emissions from wood in SWDS are reported under the Waste sector in the country where the SWDS are situated, regardless of the national origin of the waste.

12.7 UNCERTAINTY ASSESSMENT

This section provides information on potential sources of uncertainty associated with the estimates of CO_2 emissions and removals from HWP. The uncertainties can be divided into uncertainties associated with the methods as well as parameter uncertainties.

METHOD UNCERTAINTIES

In the flux data method to be used under Tier 1 and Tier 2, the basic model uncertainties are related to the assumption of FOD (Equation 12.2). A model is always a simplification of reality, thereby resulting in method based uncertainties. The reason for using decay models instead of just counting the inflow minus outflow from the defined HWP pools is that there are no extensive and reliable statistics on the real discard flows (unlike on the inflows of semi-finished products), but there is some knowledge on the service life of wood products. Although the FOD decay function is assumed to be a good proxy for the decay of semi-finished products, other decay functions or methodologies could also be used to describe the true decay process. However, the real world is even more complex. The service life and decay pattern of wood products are not just technical issues, but are also related to socio-economic factors (see Section 12.5.3.2). For instance, the demand for wood products is likely to grow in economic booms resulting simultaneously in increasing replacement of old HWP with new ones. Thus, an increase in the discard rate may correlate with increasing consumption of HWP. This is not reflected in the FOD pattern, where the discard rate is a constant fraction of the HWP pools in use over time. As a result, the annual carbon stock change in HWP may be overly influenced by the instantaneous production rate of HWP of domestic origin.

In the Tier 1 method another uncertainty is associated with the initialisation of the FOD model. Due to lack of long historical data series on semi-finished HWP – for some countries data series are only available since the early 1990s – the initial stocks of the HWP categories (C (t0)) are approximated by assuming that the stock change was zero at the initial time. This proxy might slightly overestimate the inherited emissions from the long-lived HWP categories sawnwood (with half-life of 35 years) and wood based panels in cases where the stock was growing when initialization of the time series began, particularly when the calculation in Equation 12.4 only starts from the early 1990s. This could thus potentially increase the uncertainties of CO_2 emissions and removals from HWP provided especially from products with high half-life values.

Another model uncertainty is related to the number of HWP categories in the model. In the simplest Tier 1 method there are three HWP sub-pools for the main categories: sawnwood, wood-based panels and paper and paperboard, each of which follows the FOD pattern but with different half-lives. The uncertainty could be lowered by introducing disaggregated sub-pools (e.g. for sawnwood) with differing half-lives based on their end-use (cf. Table 12.2) or based on subcategories (e.g. wood-based panels disaggregated to particle board, fibreboard etc., see Table 12.2).

In Tier 3, direct inventories of HWP in service (e.g. in the construction sector) could also be used to reduce the uncertainties associated with the flux data based method of Tier 2. The advantage of direct inventories is that they remove the need for idealised models with uncertain assumptions on decay pattern and which may require verification and validation. The inventory method could in principle provide more robust and less uncertain estimates for the carbon stock changes of the included HWP pools. Sequential direct inventories could also be applied in the calibration of the flux-data models and their half-life parameters (see Box 12.2) and thus reducing their uncertainties. However, the limitation of the method is that the statistics, if available, contains only some major pools such as the housing sector of the reporting country: but there is no information e.g. on the use of wood for furniture or packaging. In addition, inventory methods are scarcely implementable by the reporting and producing country for HWP in its export markets. Thus, they must always be combined with flux data methods, inducing a risk of double-counting of semi-finished and final products. Furthermore, inventory methods are applicable only in a few countries where relevant and sequential statistics are available.

UNCERTAINTIES OF ACTIVITY DATA

Uncertainties related to activity data on HWP from international databases (e.g. FAOSTAT, see Section 12.5) and associated uncertainties of the estimates of the level of CO_2 emissions and removals from HWP could arise due to:

- Lack of time series: some Annex I countries were founded in the early 1990s and thus older activity data might not be available (see above).
- Definitional uncertainties (i.e. data provided do not conform to what has been requested): For instance, data on removals tend to originate only from commercial forestry operations or planned cuts, data on sawnwood production is being provided in nominal (not solid m^3), and pulp production data is only commercially sold (market) pulp.
- The scope of data collection: small or spontaneous producers may not be included. This tends to affect especially the sawmilling industries, as limits to collect statistical data might be linked to business volume or number of employees.
- Double counting (e.g. final products counted in semi-finished commodities, such as cut paper being added to paper in rolls).
- Reporting errors in providing correct data: for instance, numbers that are put into the wrong category or incorrectly processed by reporter or collecting agency.
- Uncertainties associated with aggregate HWP commodities (e.g. wood-based panels): in general, the sum of the subcategories accords with the value for the aggregate commodities, but some categories may underreport because of missing subcategories (e.g. missing data on veneer sheets result in an underestimate for wood-based panels).

Concerning data on the feedstock of production of semi-finished HWP categories (i.e. industrial roundwood and wood pulp as proposed in Equations 12.7 and 12.8), uncertainty could be caused by unreported sources, by-product use or trade data.

The semi-finished HWP categories (i.e. sawnwood, wood-based panels and paper and paperboard) are also subject to the above-mentioned conditions. An overall estimate of these factors results in an estimated uncertainty of the reported values between -25% to +5% (based on the authors' expert judgement).

All of these sources of uncertainty together tend to result in an under-reporting of HWP commodity data in international databases, that is, actual figures are usually higher. This is particularly the case in the reported amounts of roundwood production (i.e. wood-removals, see Figure 12.2, Section 12.4.1.1).

Further uncertainties associated with activity data are caused by conversion factors. Especially the provided conversion factors for sawnwood (cf. Table 12.2) reflect averages which may not correct for species and specific items.

In order to reduce uncertainties around conversion factors for carbon, countries may consider using country-specific activity data under Tier 2 where they can make use of commodity specific conversion factors linked e.g. to various wood species of the particular items (see Section 12.5.3.1).

Aside from reviewing the data to check if it fits with a general understanding of the forest products supply in a country, it is most useful for reducing the uncertainties relating to activity data to cross-check if the amount of domestic production of HWP categories balances with the available supply of wood. Other validation methods could include a review of trade unit values and determination of per capita apparent consumption.

UNCERTAINTIES ASSOCIATED WITH EMISSION FACTORS (SERVICE- AND HALF-LIFE ESTIMATES)

The half-life parameters are in general the most uncertain part of the Tier 1 and Tier 2 calculation method. The scientific evidence behind the default values given in Table 12.3 is not robust. For decreasing uncertainty, countries are strongly encouraged to adjust the Tier 1 half-life parameters by calibrating the FOD model either a) with direct inventories of HWP in use (cf. Section 12.5.4), or b) with market information as shown in Table 12.4 (cf. Section 12.5.3.2). The application of stock inventory information, however, due to the lack of appropriate statistics is not practical for most countries. Furthermore, it does not cover export markets of the reporting country (i.e. relevant in the case a 'production' approach is applied). A study for Germany including a calibration of the provided default half-lives by means of market information (Rüter 2017) confirms the three values in relation to the countries' total product portfolio. In contrast, two specific calibration studies (Statistics Finland 2011) indicate that the true half-life of sawnwood and wood-based panels in Finland has likely been shorter in the past than the default half-lives (Table 12.3).

Even though the uncertainty associated with Tier 1 estimates using default data could be high, working through such estimates can be the first step in identifying ways to improve them. Initial improvements can be made using country-specific data with country-specific half-lives instead of the default half-lives in Tier 2.

To decrease uncertainties in Tier 3 countries may consider using direct inventories of HWP in use, to develop more realistic decay patterns for HWP and use more sub-pools in case transparent information is available. However, the model calibration procedure to direct HWP inventories requires in practice a model with very few adjustable parameters.

12.8 QA/QC

It is *good practice* to include Quality Assurance/Quality Control procedures during the development of the inventory for HWP.

QA procedures include external and internal reviews and audits that assess the quality of the inventory and are normally done in addition to the QC procedures. QA reviewers are normally independent national or international experts that have not been involved in the inventory. The QA is normally organized jointly for the entire inventory (see section 6.8).

The QC procedures should follow the general procedures described in section 6.6 related to calculations, data processing, completeness and documentation and section 6.7 related to emission factors and activity data.

Specific steps to improve the calculations of HWP for Tier 2 are described in section 12.4.3 for the use of country-specific activity data (12.4.3.1) and half-lives (12.4.3.2). For Tier 3, steps to improve the applied methodology are described in Section 12.4.4.

The following general steps could help the inventory compiler to further improve estimates of emissions and removals of CO_2 fromHWP including checking and revising data for the Tier 1 method and improvements for Tier 2 estimates.

1. Check that country data in the FAO database[9] agree with best available country sources of data on production and trade, or use detailed country-specific data in place of FAO data to calculate the $Inflow_l$ as described in equation 12.3.
2. Check for country sources for densities and carbon fractions, especially for sawnwood and HWP feedstock categories to adjust the values in Tables 12.1 and 12.2 to country-specific circumstances.
3. If country specific half-live values are developed (see section 12.4.3.2) and used they can be verified by checking the values against any other country with similar market distribution of HWP.

[9] http://www.fao.org/faostat/en/#data/FO (2018/06/20)

12.9 COMPLETENESS

If a country is a notable exporter and/or importer of finished wood products, such as furniture or wooden interior works (e.g. windows, doors) (cf. Figure 12.3), then methods may need to be adapted to adjust the inflow to the HWP pool in use to in- or exclude carbon in traded amounts of finished products in the light of the approach chosen by the country (cf. Section 12.3). This may affect the contribution from both imported and exported HWP.

Some wood may be used directly for finished products not included first in semi-finished product amounts reported in the HWP statistics (cf. Section 12.5.1.1). In such cases, the Tier 1 and 2 methods could underestimate the inflow of carbon to the HWP pool in use.

The methods provided in these guidelines do not include estimates of HWP carbon storage associated with CO_2 that is captured after biomass burning and held as part of a solid chemical or as a gas.

ANNEX 12.A DETAILED DESCRIPTION OF APPROACHES TO ESTIMATING CO_2 EMISSIONS AND REMOVALS FROM HWP

This section describes in detail the different approaches for estimating and reporting emissions and removals associated with HWP. Essentially, three approaches have been defined for the calculation of emissions and removals of CO_2 associated with HWP, known as the 'stock-change' approach, 'production' approach and the 'atmospheric flow' approach. Each of these approaches involves the adoption of a particular system boundary for estimating emissions and removals associated with HWP. The first two of the aforementioned approaches are based on the estimation of carbon stock changes in the HWP pool and are described in Section 12.A.1. The atmospheric flow approach is intended to estimate all CO_2 emissions from woody biomass from and to the atmosphere within a country and is presented in Section 12.A.2. As the so-called 'simple decay' approach (cf. IPCC 2006 GL) corresponds to the system boundaries of the 'production' approach and only differs from it in the theoretically applied methodological pathway on how to calculate the associated emissions and removals (cf. Section 12.3), it is not separately discussed here.

It must be stressed that the choice of approach has implications for the calculation and reporting of emissions and removals across the AFOLU sector (Cowie *et al*., 2006) and the reporting of CO_2 emissions due to wood biomass burnt in the Energy sector (see Section 12.4).

12.A.1 Estimating CO_2 emissions and removals from HWP on the basis of carbon stock changes

The existing practice to estimate CO_2 emissions and removals of CO_2 is to consider carbon stock changes in defined biomass pools, to sum up these changes and define the negative change multiplied by –44/12.

In order to implement one of the two available carbon pool-based approaches using a flux data method as suggested for Tier 1 (cf. Section 12.5.2), the annual carbon flux into the HWP pool (i.e. *Inflow*, cf. Equation 12.2 in Section 12.4.2) is calculated from the combination of the following statistical elements:

1. 'Stock-change' approach → *Inflow* = calculated domestic consumption = domestic production + imports – exports

2. 'Production' approach → *Inflow* = domestic production

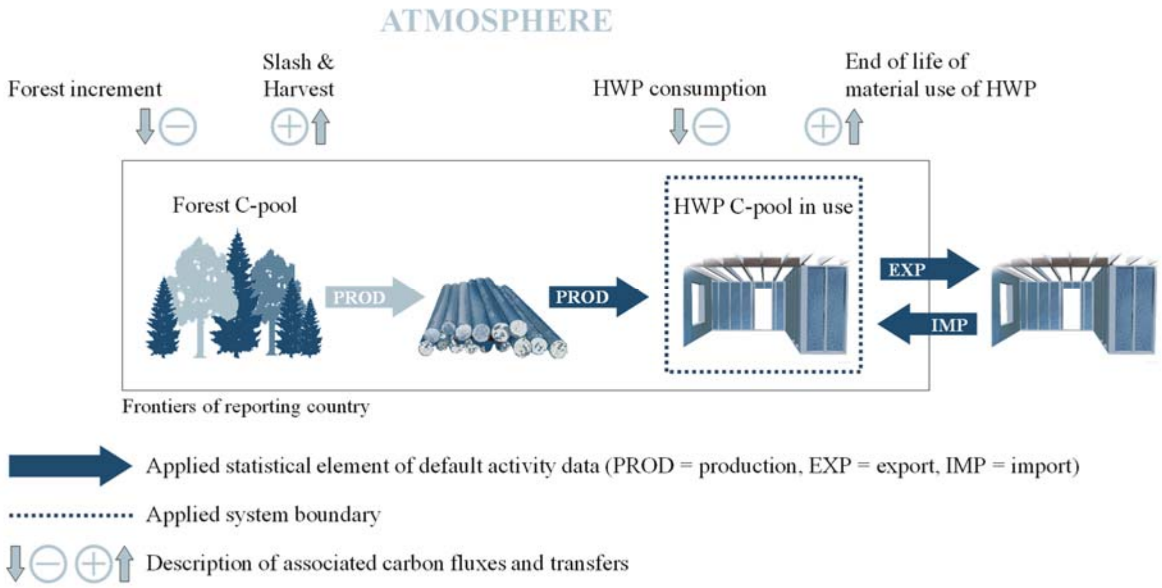
Section 12.5.2 includes the detailed methodological guidance on how to implement these available pool-oriented approaches, whereas their conceptual differences are described in the following.

12.A.1.1 THE 'STOCK-CHANGE' APPROACH

The 'stock-change' approach estimates the net change in carbon stocks in the HWP pool within national boundaries (cf. e.g. Brown *et al.* 1998, Lim *et al.* 1999, UNFCCC 2003) and supplements the estimation of emissions and removals from changes in the carbon stocks in the above ground biomass pool of forests within the same system boundaries (cf. Chapter 4 and IPCC 2006 GL, Vol. 4., Annex 12.A.1). In the case that this approach is used to estimate the annual change in carbon stock in "products in use" in the reporting country; it corresponds to Variable 1a in *IPCC 2006 GL*.

Changes in the products pool are reported by the country where the products are used, referred to as the consuming country. In the case that a flux data method is applied to determine the amount of carbon stored in the HWP pool in use within a country, the carbon flux into the pool (i.e. Inflow) is thus to be quantified by means of the calculated consumption of HWP. The calculated consumption of HWP reflects the annual additions to the carbon pool in HWP in use within a country and it is calculated from the data on domestic production, plus imports and minus exports of HWP. Exported HWP are outside the system boundary, while imported HWP are included in the estimate of the magnitude of the HWP carbon pool in a specific year (see Figure 12.A.1). Further details on the implementation of this approach through a flux data method using statistical data of semi-finished wood product commodities is described in Section 12.5.2.1.'

Figure 12.A.1 Scheme of the 'stock-change' approach, estimating CO_2 emissions and removals associated with the carbon stock in the HWP pool in use on the basis of calculated consumption data of HWP



Source: cf. Rüter 2017

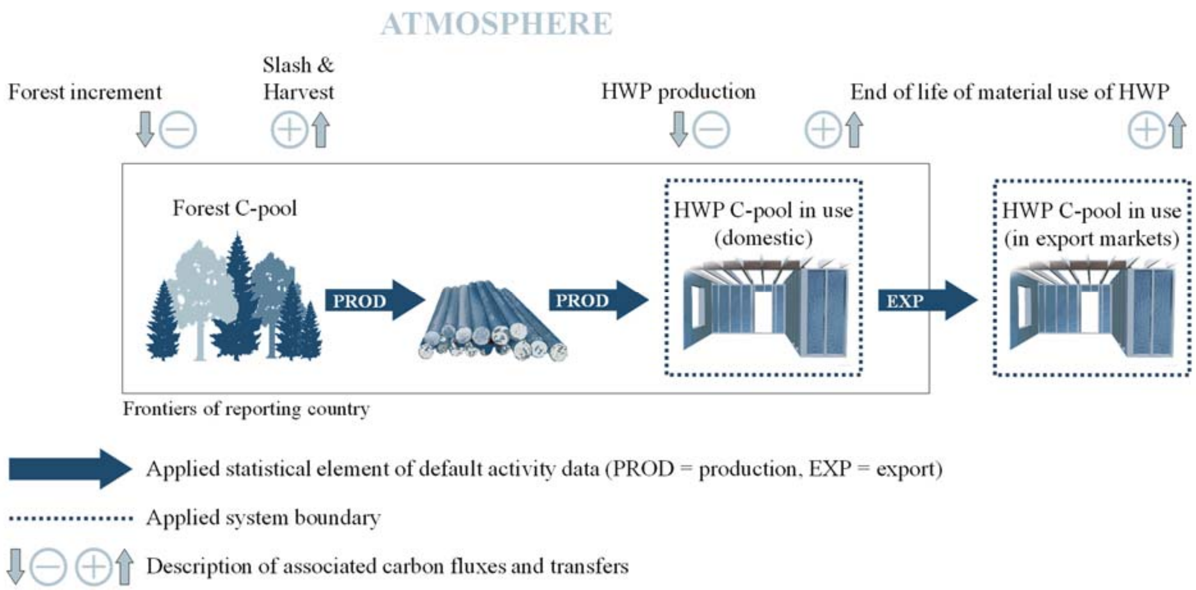
Other data reflecting the utilization of HWP in use within a country could be derived from information e. g. on the use of wood within that category, for instance the national building stock (cf. Section 12.5.3.1). In the case of the use of such inventory information, the amount of carbon stored in HWP within a country would need to be quantified at least at two points in time, similar as repeated forest inventories referring to the stock-difference method (see IPCC 2006, p. 2.10).

12.A.1.2 THE 'PRODUCTION' APPROACH

Similar to the 'stock-change' approach, the 'production' approach determines emissions and removals from wood coming from domestic harvest in the reporting country. In the case that the annual change in carbon stock in 'products in use' are estimated, this corresponds to Variable 2A in *IPCC 2006 GL*.

In contrast to the 'stock-change' approach described above, which estimates the carbon flux into the carbon pool of HWP in use based on the calculated domestic consumption of HWP, the 'production' approach considers the domestic production of wood commodities manufactured from domestic harvest. Thus, the carbon in exported wood products is implicitly included in the estimates of the reporting country and their associated stock changes occur in other countries (where exports are held). The system boundary therefore does not correspond to the national boundaries in which the CO_2 emissions and removals from HWP take place (Figure 12.A.2).

Figure 12.A.2 Scheme of the 'production' approach, estimating emissions and removals of CO_2 associated with the carbon stock in the HWP pool in use on the basis of data on HWP production originating from domestic harvest



Source: cf. Rüter 2017

As a subset of the production approach, the CO_2 emissions and removals from domestically consumed HWP manufactured from domestic harvest can be estimated separately through the compilation of the relevant elements of statistical data of HWP. This hybrid between the 'stock-change' and 'production' approach estimate (Cowie *et al.* 2006), thereby excludes all traded HWP commodities (i.e. imports and exports) from the estimation.

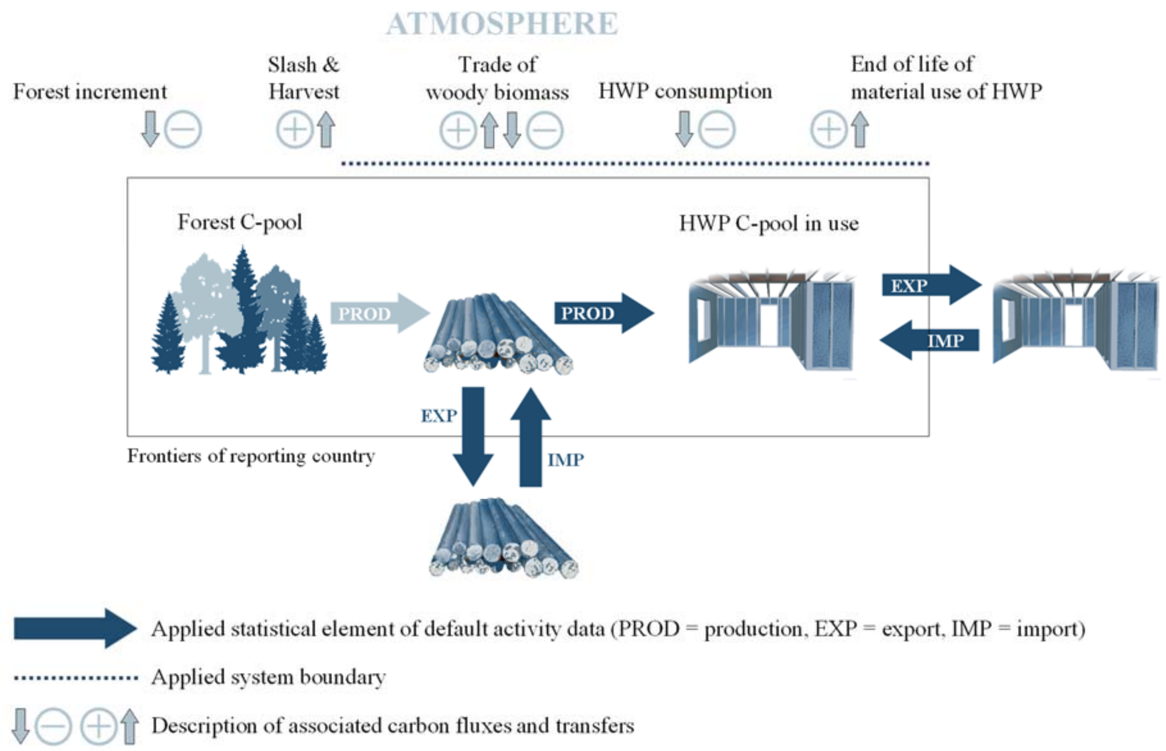
Methodological guidance on how the 'production' approach is implemented through a flux data method using statistical data of semi-finished wood product commodities is described in Section 12.5.2.1.

12.A.2 Estimating CO_2-fluxes from wood biomass – the 'atmospheric flow' approach"

The 'atmospheric flow' approach estimates actual fluxes of carbon associated with HWP from and to the atmosphere within national boundaries. The implementation of this approach is based on all the variables as suggested in Table 12.1 of IPCC 2006 GL.

Especially carbon fluxes into the atmosphere are, however, difficult to estimate directly and to scale up to a national level, In practice, an accurate and consistent application of the 'atmospheric flow' approach thus relies on the availability of relevant data and needs to take into account existing and applied methodologies for estimating CO_2 emissions and removals associated with the forest carbon pools (cf. IPCC 2006 GL, Ch. 4). It does require, in addition to estimates of the carbon stock changes within the HWP pool in use within the reporting country (i.e. 'stock-change' approach), the estimation of all additional cross-border carbon fluxes in woody biomass feedstock and wood fuel (cf. Cowie *et al.* 2006).

Figure 12.A.3 Scheme of the 'atmospheric flow' approach, estimating CO_2 fluxes associated with HWP on the basis of data on the carbon stock in the HWP pool in use and traded woody biomass



Source: cf. Rüter 2017

The system boundary of the 'atmospheric flow' approach and the carbon pools under consideration are shown in Figure 12.A.3. The pools are the same as in the 'stock-change' approach. The difference is that the consistent implementation of the 'atmospheric flow' approach for HWP estimates the atmospheric carbon exchange of the timber processing and wood utilization chain of the reporting country rather than stock changes within the country. Further information on the implementation of the 'atmospheric flow' approach on the basis on available statistical data is included in Section 12.5.2.1.

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