CHAPTER 12

HARVESTED WOOD PRODUCTS

Final Draft

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Contents

Equations

Figures

Tables

Boxes

12 HARVESTED WOOD PRODUCTS (HWP)

12.1 INTRODUCTION

This Chapter updates Chapter 12 of the *2006 IPCC Guidelines*, including updated technical parameters for estimating CO_2 emissions and removals arising from HWP. Using the term "CO_2 emissions and removals arising from HWP" (and sometimes just "CO_2 emissions") in AFOLU guidance is not common practice but has been adopted in this chapter on HWP and the reasons are discussed as part of terms and definitions in Section 12.2.

The guidance in this chapter maintains the existing approaches covered in the *2006 IPCC Guidelines*. The refined guidelines provided here take account of new relevant scientific information, including relevant methodological information and parameters contained in *IPCC KP Supplement* (e.g. carbon conversion factors). The use of this updated guidance is encouraged, in place of the earlier *2006 IPCC Guidelines*. Some cross references are made to the earlier guidance where needed, for example in cases where it may be helpful to show consistency with the earlier guidance. It should also be noted that the HWP Worksheet accompanying the *2006 IPCC Guidelines* (HWP calculator) cannot be used in conjunction with this updated guidance.

The structure of this chapter aims to clarify the relationships between new information and the *2006 IPCC Guidelines* 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 arising from 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 arising 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 DEFINITIONS

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

CO_2 emissions and removals arising from HWP: In Volume 4, Chapter 1, Section 1.2.1 of the *2006 IPCC Guidelines*, it is explained that GHG fluxes in the AFOLU Sector can be estimated in two ways: 1) as net changes in carbon stocks over time (used for most CO_2 fluxes) and 2) directly as gas flux rates to and from the atmosphere (used for estimating non-CO_2 emissions and some CO_2 emissions and removals). Hence, when giving guidance on estimating CO_2 emissions and removals for the AFOLU Sector, usually the focus is on estimating annual carbon stock changes in all relevant pools (e.g. carbon pools in forest land and cropland). The carbon stock changes in the various pools can then be combined and converted to CO_2 emissions and removals of CO_2 (see Volume 4, Chapter 2, Section 2.2 of the *2006 IPCC Guidelines*). Generally, guidance for the AFOLU Sector reflects this by discussing how to estimate annual carbon stock changes in the various relevant pools. The term "CO_2 emissions and removals arising from HWP" is frequently referred to in this chapter on HWP because it is not always possible to refer to "carbon stocks" or "carbon stock changes", for two principal reasons:

Firstly, as explained in this section and discussed in detail in Section 12.3 and Annex 12.A, different "approaches" can be taken to estimating the CO_2 emissions and removals arising from HWP. Guidance on these approaches was given originally in the *2006 IPCC Guidelines*. Amongst these approaches is an example that, conceptually, involves tracking carbon or CO_2 fluxes, rather than tracking changes in annual carbon stocks in the HWP pool. Therefore, sometimes it is necessary to describe how to estimate carbon and CO_2 fluxes, particularly when giving guidance for this approach, otherwise it would not be possible to maintain the approach as provided in the *2006 IPCC Guidelines*.

Secondly, some important elements of carbon in harvested wood (e.g. harvested wood biomass used directly as an energy feedstock) strictly do not enter the HWP carbon pool but are produced and then consumed almost immediately, involving oxidation and release of CO_2 to the atmosphere. Hence, if there is interest in estimating the contributions of these elements of harvested wood towards CO_2 emissions, it is necessary to refer to CO_2 emissions, because the guidance cannot be provided by describing annual carbon stock changes in HWP pools (i.e. because no such pool exists for these products from year to year).

The terms "CO_2 emissions and removals arising from HWP", "CO_2 emissions", "carbon stocks" and "carbon stock changes" are used in this chapter, where these terms are appropriate for describing approaches and methods relevant to HWP.

Removals: The general term "removals" is defined in the Glossary of the *2006 IPCC Guidelines*. In the context of 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 that was 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 to the HWP pool, similarly to when it is transferred 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.

The term removals, as defined here, should not be confused with the use of the term in a different context, i.e. when referring to "wood-removals", as defined in Section 12.4.1.1.

Approach: The term "approach" has a particular meaning in the context of CO_2 emissions and removals arising 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 arising 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 arising from HWP (see UNFCCC 2003; Cowie *et al.* 2006). Thus:

- An approach defines WHAT is to be estimated and reported in an inventory to encompass CO_2 emissions and removals arising 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 arising from HWP, it is possible to apply methods that are 'direct inventory-based', 'flux data-based' or a combination of both methods.

Direct 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 and other wood producing land categories 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 direct measurement, to estimate carbon stocks and stock changes and/or CO_2 fluxes from and to the HWP pool.

The distinction between direct inventory-based and flux data-based methods, with particular reference to Tier 3 methods, is further explained in Section 12.4.4.

12.3 APPROACHES TO ESTIMATING CO_2 EMISSIONS AND REMOVALS ARISING FROM HWP

Different approaches can be taken to estimating and presenting CO_2 emissions and removals arising from HWP. Each individual approach is potentially useful, depending upon the application, i.e. the specific question being addressed, or type of estimate required. This guidance does not judge 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 arising 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 (Section 12.2). The *2006 IPCC Guidelines* also refer to an approach called the ‘simple decay’ approach, which has the same conceptual framework and system boundary as the ‘production’ approach, applied in conjunction with a country-specific calculation method. Hence, the ‘simple decay’ approach is a particular interpretation of how to implement the ‘production’ approach, and further discussion of relevant methods is presented in Section 12.4.4 on Tier 3 methods. The discussion of the conceptual basis of the ‘production’ approach also applies to the ‘simple decay’ concept. 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 arising 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 arising 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 land use categories and carbon pools. Specifically, when carbon stocks in the HWP pool increase over time, this corresponds to net CO_2 removals into HWP; when carbon stocks in the HWP pool decrease over time, this corresponds to net CO_2 emissions arising from HWP.

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 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 for the "producing country").

The 'stock-change' approach for HWP estimates changes in carbon stocks in the HWP pool within the national boundaries. 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 a 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, when applying the 'production' approach 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. When applying the 'atmospheric flow' approach, the CO_2 emissions and removals arising from HWP are thus reported by a country where the wood products are used (i.e. by the "consuming country").

When calculating results for GHG inventories, estimates of CO_2 emissions and removals arising 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 CO_2 emissions and removals are not omitted and/or double-counted in results, e.g. for forests and for HWP. The calculations defined in this guidance for the three HWP 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 arising from HWP reported by different countries are combined to provide global or regional estimates. However, this is only the case if all 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 countries apply different HWP approaches.

In some situations, CO_2 emissions and removals arising from the HWP pool are not estimated explicitly. The circumstances in which this may occur are discussed in Section 12.4.1.2. In these circumstances, the assumption of a "steady-state HWP pool" 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 arising from HWP are not estimated explicitly, the possible approaches to reporting CO_2 emissions and removals arising from HWP are not relevant and are not applied.

12.4 CHOICE OF METHOD FOR WOOD PRODUCTS IN USE

This section provides guidance on the choice of method to apply in conjunction with the available approaches described in Section 12.3 and Annex 12.A. The choice of calculation method and the data used for estimating the CO_2 emissions and removals arising from HWP have an implicit impact on the calculated system boundaries. Therefore, it is necessary to cross-check that any method to be applied corresponds and relates to the selected approach.

12.4.1 Initial steps to estimate CO_2 emissions and removals arising from HWP

To estimate CO_2 emissions and removals arising from HWP, 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 apply the guidance provided for estimating CO_2 emissions and removals arising from HWP, information on the utilization of wood as a material needs to be available. In the case that no such information is available, countries might need to make the assumption of a 'steady-state HWP pool' (see Section 12.4.1.2).

When making decisions about whether to estimate contributions towards GHG emissions and CO_2 removals, generally the key question is: how big is a particular contribution? More specifically, is the magnitude of the contribution sufficiently large, or too small, to be worth estimating? In the case of HWP, one way of answering this question is to carry out the calculations described in this guidance for Tier 1 methods. This is because: (i) the magnitude of the contribution made by HWP will depend on the selected approach to estimation (see Section 12.3), so any calculation methods need to be appropriate for the selected approach, i.e. such as Tier 1 methods; and (ii) the Tier 1 methods are amongst the simplest methods that can be defined for estimating CO_2 emissions and removals arising from HWP. It follows that the more relevant key question in the case of HWP is: are activity data available for implementing at least Tier 1 methods? In this context, the availability of relevant statistics in publicly available databases such as FAOSTAT (see Section 12.4.1.1) indicates that data suitable for Tier 1 (and possibly Tier 2) methods are available. The above points lead naturally to STEP 1.1 below.

STEP 1.1: Check the availability of data for the three default HWP commodity classes of 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 arising 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 method. 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 (see Section 12.3) and follow the guidance provided in Section 12.4.4 to apply Tier 3 for estimating CO_2 emissions and removals arising 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 arising 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.

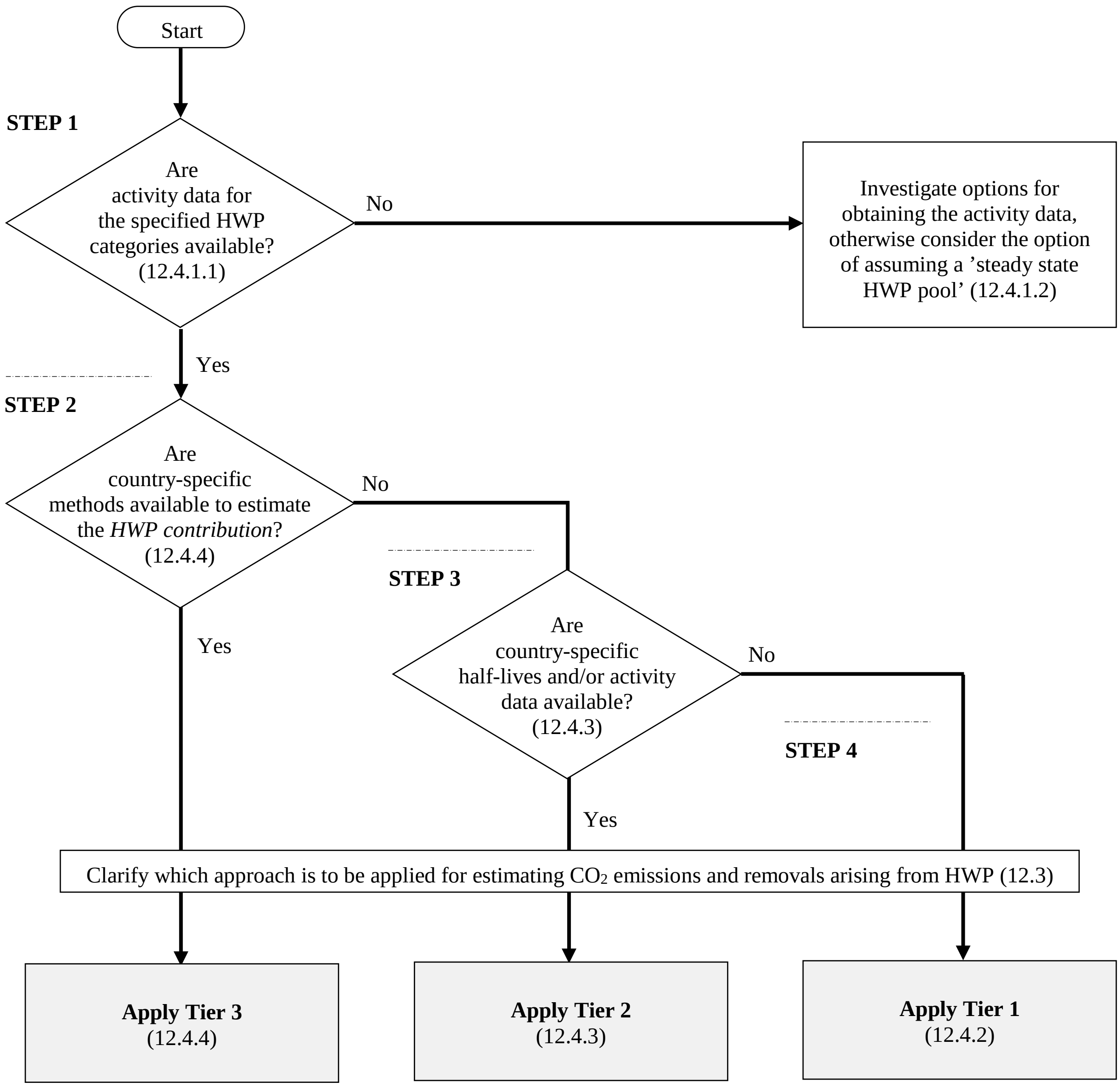
STEP 3.2: Check whether the country-specific activity data are suitable to be used in conjunction with the default method provided and whether they are as accurate as under the Tier 1 method. Further guidance is provided in Section 12.4.3.1. In the case that country-specific emission factors should be used, follow the guidance provided in Section 12.4.3.2 and determine whether such information is compatible with the activity data that are 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: Determine 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 arising from HWP.

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

Determine 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 arising from HWP.

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



12.4.1.1 AVAILABILITY OF ACTIVITY DATA

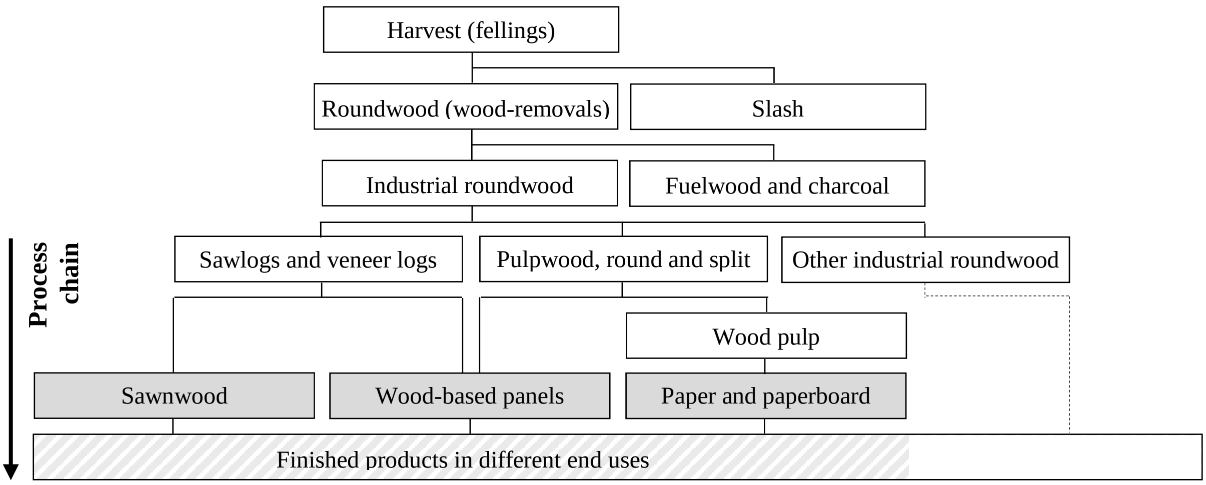
This section provides definitions for the different available HWP commodity classes representing the use of wood as a material as well as for other uses where relevant to estimating CO_2 emissions and removals from HWP. As explained below, for Tier 1 and Tier 2 methods principally this involves three commodity classes of semi-finished wood products (sawnwood, wood-based panels and paper and paperboard), whilst certain other commodity classes may also be relevant, depending on the chosen HWP approach.

The term "harvested wood products" is based on a concept consisting of the two separate elements of "forest harvesting" and "wood products" (Brown *et al.* 1998; UNFCCC 2003). The commodity classes of sawnwood, wood-based panels and paper and paperboard refer to the specific definitions of semi-finished wood products given in the international classification system of forest products, which are also referred to in FAO statistics[1]. These definitions are given below, as well as for other terms commonly used, where these are relevant to the discussion in this section.

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

As shown in Figure 12.2, the forest-wood chain starts with “forest harvesting” (or “fellings”). Forest harvesting is then partitioned into “roundwood” (or “wood-removals”) and “slash” (generally left in the forest). Roundwood is then further subdivided into “industrial roundwood” and types of fuelwood and charcoal. Following the forest products definitions of the FAO, Figure 12.2 also shows the relationship between the aggregate commodity “industrial roundwood” and the three semi-finished wood product commodity classes identified above, in providing the feedstock for the subsequent processing of these semi-finished HWP commodities along the value chain (FAO 2017). The 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 arising from HWP, as described in Section 12.4.2 (Tier 1), are listed below. These definitions are drawn from the Joint Forest Sector Questionnaire (JFSQ) as established by the Intersecretariat Working Group on Forest Sector Statistics[3], which 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 commodity classes 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].

DEFINITIONS FOR SEMI-FINISHED WOOD PRODUCT COMMODITIES

The following three aggregate commodities of semi-finished wood products, by definition, represent data on wood being processed with the intention of using the wood as a material to make products. The definitions given are those referred to in FAO statistics[5].

It should be noted that there are certain specific wood product commodity classes that are explicitly excluded in the following definitions of the three commodity classes of semi-finished wood products. The reasons for these exclusions are explained in the discussion following the presentation of the definitions below.

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,

[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)

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

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 re-sawing previously sawn pieces. It is reported in cubic metres solid volume" (see 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" (see Figure 12.2). See FAO statistics[6] for further definitions of the individual commodity classes.

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" (see Figure 12.2).

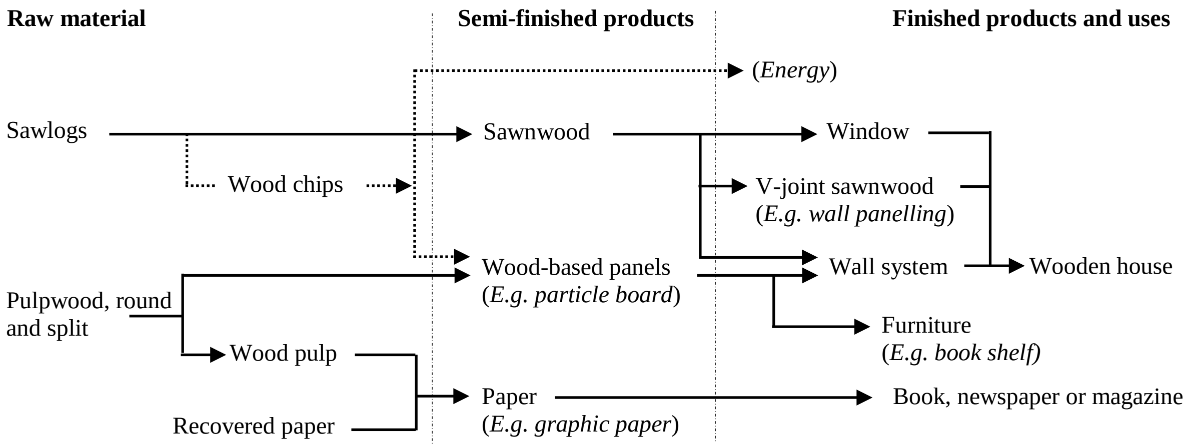
The availability of data for the above three aggregate HWP commodities in publicly available databases of international organizations, such as FAOSTAT, qualifies for estimating CO_2 emissions and removals from HWP on the basis of the 'production' or the 'stock-change' approaches. For example, the presence of relevant statistics in the FAOSTAT database indicates that data suitable for implementation of Tier 1 or Tier 2 methods for these approaches are available. Further guidance for these methods is provided in Sections 12.4.2.1 and 12.4.3. All datasets are reported in cubic metres solid volume or metric tonnes, which is information that enables countries to convert the HWP data into units of carbon.

Certain commodity classes are excluded from the above definitions for semi-finished wood products to avoid double-counting of wood products. For example, sleepers, V-jointed sawnwood and laminated veneer lumber (LVL) are excluded from the definition of sawnwood. This is because these commodities may be the result of subsequent processing of sawnwood and therefore are examples of finished wood products, as illustrated for V-jointed sawnwood in Figure 12.3. This also applies (for example) to wooden flooring that is produced from sawnwood and/or hardboard which belongs to the commodity class of wood-based panels. Wooden flooring is therefore implicitly covered by the semi-finished HWP commodity classes of sawnwood and/or wood-based panels and included in this way in the estimates for CO_2 emissions and removals arising from HWP. Thus, using statistical data for both sawnwood and for wooden flooring could result in double counting. There is a fourth aggregate commodity class of wood products within industrial roundwood, i.e. "other industrial roundwood", as also shown in Figure 12.2. This commodity class is not covered by Tier 1 and Tier 2 methods because the constituent wood products in the commodity class have much less uniform characteristics than is the case for the three commodity classes defined below, including some examples of wood used for finished products (e.g. transmission poles). By excluding products within the commodity class of other industrial roundwood from Tier 1 and Tier 2 methods, in effect, the assumption is made of a "steady-state HWP pool" for these products (see Section 12.4.1.2). Tier 3 methods would need to be developed for a more sophisticated representation of this commodity class.

Countries with available data on finished wood products produced from the default semi-finished wood product commodity classes may consider using these data to develop country-specific methods, following the guidance given in Section 12.4.3.1. Production data on finished wood products processed from the three aggregate semi-finished product commodity classes 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 earlier) does include 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. When using these datasets in calculations, it is *good practice* to consider the associated uncertainties as part of the uncertainty analysis (see Section 12.7).

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

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[7]. The inclusion of the commodity wood pulp under the HWP commodity class of "paper" would for example result in double counting, as wood pulp by definition constitutes the feedstock for the production of paper and paperboard (see definition below and Figure 12.3). However, data on wood pulp are used in the default Tier 1 methods when calculating the share of HWP coming from domestic forests, when the 'production' approach is applied (see Equation 12.7). Wood pulp data may also be used in higher tier methods provided that double counting is avoided.

DEFINITIONS FOR OTHER RELEVANT WOOD PRODUCT COMMODITIES

Data on certain other wood product commodities are needed for the implementation of the 'production' approach and the 'atmospheric flow' approach as discussed and defined below. The definitions are those referred to in FAO statistics[6].

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 commodity classes defined and discussed earlier (see Figures 12.2 and 12.3 and Annex 12.A.1.2). Some possible feedstock commodities are not included in the default method for allocating HWP to domestic forest sources as described in Section 12.4.2.1, because of difficulties in determining sources and multiple uses. For example, some wood chips used in wood-based panel and wood pulp production come from industry co-products, whilst others could be recycled products and others are used for energy purposes (see Figure 12.3). Definitions of some key feedstocks relevant to this aspect of implementing the 'production' approach are provided below.

REMOVALS/WOOD-REMOVALS: "The volume of all trees, living or dead, that are felled and removed from the forest, other wooded land or other felling sites. It includes natural losses that are recovered (i.e. harvested), removals during the year of wood felled during an earlier period, removals of non-stem wood such as stumps and branches (where these are harvested) and removal of trees killed or damaged by natural causes (i.e. natural losses), e.g. fire, windblown, insects and diseases. Please note that this includes removals from all sources within the country including public, private, and informal sources. It excludes bark and other non-woody biomass and any wood that is not removed, e.g. stumps, branches and tree tops (where these are not harvested) and felling residues (harvesting waste). It is reported in cubic metres solid volume underbark (i.e. excluding bark). Where it is measured overbark (i.e. including bark), the volume has to be adjusted downwards to convert to an underbark estimate" (see Figure 12.2).

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

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

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)" (see 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" (see 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" (see 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".

In order to implement the 'atmospheric flow' approach, besides data on the trade of the commodities described above, further activity data are required, covering both feedstocks for processing wood for its use as a material and wood biomass burnt for energy purposes. These data are needed for estimating actual fluxes of carbon from woody biomass from and to the atmosphere within the country in a reporting year (see Sections 12.3.2 and 12.4.2.1). This includes several commodities as defined below. The definitions are those referred to in FAO statistics[8].

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)" (see 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".

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".

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".

12.4.1.2 APPLYING THE ASSUMPTION OF A "STEADY-STATE HWP POOL"

This section provides guidance on when it is in line with good practice to make the assumption that the HWP pool is in a steady state and explains the implications of making such an assumption.

When the assumption is made that the pool of carbon in HWP is in a steady state, this does not imply an assumption that the carbon stock in HWP is zero. Rather, it implies an assumption that the carbon stock in HWP is not changing over time. Implicitly, it is also assumed that the annual carbon inflows into HWP in use are exactly the same in magnitude as the annual losses of carbon from HWP in use (otherwise the carbon stock

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

would be changing). Hence, in practice, making an assumption of a "steady-state HWP pool" leads to results for the CO_2 emissions arising from HWP that are numerically the same as when it is assumed that all the carbon in HWP is oxidised in the year of harvest[9].

When an assumption of a "steady-state HWP pool" is made, this does not result in carbon losses due to biomass harvested and utilised for HWP being ignored. Rather, these carbon losses are included implicitly as part of the carbon stock changes estimated for the living or dead biomass pools of forests and other wood producing land categories. The CO_2 emissions and removals arising from the HWP pool should be estimated explicitly if possible, but activity data are needed to do this, e.g. as required for the Tier 1 methods as a minimum (see Sections 12.4.1.1 or 12.4.2.1). If relevant activity data (e.g. from FAOSTAT or other sources) are not available, then it may be necessary to assume a "steady-state HWP pool".

12.4.2 Tier 1: "first order decay" method

Provided that activity data are available for the three HWP commodity classes of semi-finished wood product commodities of sawnwood, wood-based panels and paper and paperboard, as defined in Section 12.4.1.1, and no country-specific activity data required to apply Tier 2 are available (see Section 12.4.3), estimates of CO_2 emissions and removals arising from HWP should be obtained by application of the Tier 1 method as outlined in this section.

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

The annual emissions and removals arising 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 commodity classes by means of the Equation 12.1.

EQUATION 12.1

ESTIMATION OF TOTAL EMISSIONS AND REMOVALS ARISING FROM THE HWP POOL IN USE

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

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

Where:

i = year

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

C = carbon stock in HWP, in Mt C

$\Delta C_l\left(i\right)$ = changes of the carbon stock C in the particular HWP commodity class l during the year i, in Mt C yr^{-1}

l = index number of the semi-finished HWP commodity class (see Table 12.2, Section 12.4.2.1)

n = number of selected HWP commodity classes of the semi-finished HWP commodities of 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:

[9] Previous IPCC guidance on HWP has referred to making the assumption of "instantaneous oxidation" of HWP (see IPCC 1997, IPCC 2006, 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 and 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 commodity class l at the beginning of the year i, Mt C

k = decay constant of FOD for each HWP commodity class l given in units yr^{-1} (= ln(2)/HL, where HL is the half-life of the particular HWP commodity in the HWP pool in years (see Box 12.1 and Section 12.4.2.2)

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

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

Depending on the choice of the approach for estimating CO_2 emissions and removals arising from HWP, which implicitly determines the system boundaries of the underlying estimated carbon stock in HWP in use, the annual carbon inflow to the carbon stock of the respective HWP commodity class is calculated from different elements of HWP time series according to Equation 12.3 (see 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 commodity class l in the year i, in Mt C yr^{-1}, see Equation 12.6

$Inflow_{PA_l}\left(i\right)$ = Carbon inflow in HWP from the production of the respective HWP commodity class l originating from domestic harvest in the year i, in Mt C yr^{-1}, see 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 ($Inflow_l\ (i)$), 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 HWP stock, 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 disposals from the HWP pool, 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 classes since 1961.[10] But for some countries activity data are available only from a later year (often 1991). This has implications for 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 arising from HWP. As a proxy in the Tier 1 method it is thus assumed that the HWP pool is in a 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 class 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.

The coverage of data on wood product commodities has changed over time. This has occurred for a number of reasons, but not least because the contribution of data by wood industries towards production statistics depends on their size. More specifically, wood processing mills and industries generally contribute data towards statistics if they exceed a certain threshold size. The thresholds referred to in the compilation of statistics on harvested wood have changed relatively little over time. However, the capacities of individual wood processing mills have increased, and also there have been structural developments in the wood industries, leading to greater numbers of larger-capacity mills, and larger industry groupings. The combination of a fairly unchanging threshold size for reporting statistics, and these developments in the wood industries, is very likely to mean that statistics on wood commodity production have become more comprehensive over time. As a result, long time series data on wood commodities (e.g. since 1961) might suggest that production volumes have increased over time, when this may simply reflect to some degree the progressive improvements in the statistics on wood commodities (Palma *et al.* 2017).

Using Equation 12.4 with the average value of $Inflow_l(i)$ over the first 5 years since 1961 (i.e. for the years 1961 to 1965) might thus lead to biased estimates of initial carbon stocks and it is likely to result in the overestimation of subsequent carbon stock increases in the HWP pool. When using historical data (such as for the first 5 years since 1961) to provide values for calculating $Inflow_l(i)$ in Equation 12.4, it is thus *good practice* to verify that any historical trends in the relevant statistics for wood commodities reflect actual changes, rather than changes in the coverage of these statistics. This can help to reduce the uncertainties associated with the estimate of the existing carbon stock in the HWP pool in use. Otherwise, it is *good practice* for Equation 12.4 to be used in conjunction with the average value of $Inflow_l(i)$ over the first 5 years since 1990 (e.g. for the years 1990 to 1994) or later.

By substituting $C_l(t_0)$ in Equation 12.2, the $C_l(i)$ and $\Delta C_l(i)$ in the sequential time points 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 THE HWP POOL 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 commodity class l (see Equation 12.3).

An example of how to implement Equations 12.2 and 12.4 in a spreadsheet[11], e.g. with MS EXCEL, is provided in the Example Box 12.1.

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

[11] It should be noted that the calculations described in Box 12.1 are not implemented as part of the HWP Worksheet accompanying the *2006 IPCC Guidelines* (HWP calculator). See also Section 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 commodity class, 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 commodity classes of sawnwood, wood-based panels and paper and paperboard, either as *aggregates* or for each of their sub-classes 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 (see Section 12.4.2.1), the FOD function implicitly includes finished HWP in the carbon stock estimates. It is assumed that "immediate losses of the HWP pool due to final processing of wood along the processing chain (see Figure 12.A.1, Annex 12.A.2) are described realistically by the exponential decay pattern" (Pingoud and 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 (see Rüter and 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 arising 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 country by applying Equation 12.5. The Equation reflects two components that enable a consistent implementation of this approach.

To explain how Equation 12.5 works, firstly it is assumed that the calculated annual gains of carbon in the HWP pool in use (i.e. $Inflow_{Cl}(i)$) 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. It is also assumed that the annual carbon losses from this HWP pool in use, calculated by means of Equation 12.2, which:

(i) 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

(ii) are not exported

are available for oxidation into the atmosphere in the reporting year (e.g. through combustion) (see IPCC 2006).

Secondly, an estimation of CO_2 emissions and removals arising from HWP following the 'atmospheric flow' approach consistent with estimates of emissions and removals from the forest carbon pools (see Chapter 4) is based on the assumption that only carbon in woody biomass which:

(i) becomes and/or remains available within the reporting country and

(ii) is not fixed in a carbon pool

could eventually also oxidize into the atmosphere in the reporting year. Consequently, all carbon in harvested woody biomass from domestic forests (i.e. "roundwood production", 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 country's 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 (for example as wood fuel or feedstock for further processing and wood utilization along the value chain) becomes available for oxidation (see Figure 12.A.5 in Annex 12.A.3).

As compared to the estimates of the impact of the carbon stock in the HWP pool in use (see 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 12.11).

EQUATION 12.5

ESTIMATION OF TOTAL CO_2 FLUXES ASSOCIATED WITH HARVESTED WOOD BIOMASS WITHIN THE COUNTRY

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

Source: 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 country (i.e. 'stock-change' approach) during the year *i*, in Mt CO_2 yr^{-1}

$\Delta C_{SCA_l}(i)$ = Changes of the carbon stock C in the particular semi-finished HWP commodity class *l* during the year *i*, calculated from domestic consumption (i.e. 'stock-change' approach), in Mt C yr^{-1}, see Equations 12.2 and 12.3

$RC_{EX_j}(i)$ = Exported carbon in the relevant HWP feedstock commodity class *j* serving as wood fuel and/or raw material for the manufacture of semi-finished HWP during the year *i*, in Mt C yr^{-1}, see Equation 12.11

m = number of included HWP feedstock categories, see Table 12.2

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

$RC_{IM_j}(i)$ = Imported carbon in the relevant HWP feedstock commodity class *j* serving as wood fuel and/or feedstock for the manufacture of semi-finished HWP during the year *i*, in Mt C yr^{-1}, see Equation 12.11.

12.4.2.1 ACTIVITY DATA

Depending on the chosen approach (see Section 12.3), activity 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 commodity class ($Inflow_l(i)$), 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 of the particular semi-finished HWP commodity classes 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 COMMODITY CLASSES AND THEIR SUB-CLASSES

Semi-finished HWP commodity classes (*l*)	**Density (oven dry mass over air dry volume) [Mg / m³]**	**Carbon fraction**	**C conversion factor *cf* (per air dry volume) [Mg C / m³]**	**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
Oriented strand board (OSB)	0.573	0.463	0.265	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 sub-classes 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% HDF and 50% 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% sawnwood (Non-Coniferous)

[9] Calculated from the weighted average of included sub-classes 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

To estimate 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 is composed of the three default HWP commodity classes, i.e. sawnwood, wood-based panels, and paper and paperboard).

In order to estimate carbon amounts in the semi-finished HWP commodity classes representing the material use of wood biomass, default conversion factors are provided in Table 12.1. The conversion factors for the HWP default commodities (i.e. aggregates) are largely dependent on the composition of countries' production quantities of the particular sub-classes (e.g. particle board). If countries have disaggregated data on sub-classes 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 sub-classes.

In order to reduce uncertainties associated with assumptions on the conversion factors applied to activity data (i.e. data on semi-finished wood products derived from statistics) (see Section 12.4.1.1), countries may consider using country-specific activity data comprising further items of the HWP sub-classes as listed in Table 12.1. More information can be obtained in Section 12.4.3.1.

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

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

(ii) the production of HWP originating from the forests within the country (‘production’ approach).

For the ’production’ approach, the HWP activity data could be partitioned between the domestically produced and consumed HWP and those HWP which are exported. Furthermore, they could also be assigned to the particular land use category from which their carbon originates within the country (see guidance below within this section).

If the ‘atmospheric flow’ approach is applied, in addition to data on semi-finished HWP for estimating CO_2 emissions and removals arising 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 (see Equation 12.5 and Annex 12.A.3). Table 12.2 includes those relevant wood product commodities including their carbon conversion factors (*cf*) to be applied in Equations 12.6, 12.7, 12.9, 12.10 and/or 12.11. It is *good practice* to consider the relevant definitions provided in Section 12.4.1.1 as well as the classification of wood products (see Figures 12.2 and 12.3) in order to avoid double counting.

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

HWP feedstock commodity classes (*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 sub-classes of the production volumes (average of the years 2006-2010) as for the HWP commodity class ‘paper and paperboard’ (See Table 12.1)

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

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

To calculate the annual carbon inflow to the respective HWP commodity class 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 A PARTICULAR SEMI-FINISHED HWP COMMODITY CLASS 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 commodity class *l* in the year *i*, in m³

cf_l = carbon conversion factor of the particular semi-finished HWP commodity class *l* (see Table 12.1)

$HWP_{P_l}(i)$ = production of the particular semi-finished HWP commodity class *l* in the year *i*, in m³

$HWP_{IM_l}(i)$ = import of the particular semi-finished HWP commodity class *l* in the year *i*, in m³

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

COMPILATION OF ACTIVITY DATA FOR THE 'PRODUCTION' APPROACH

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

EQUATION 12.7
CALCULATION OF CARBON INFLOW IN A PARTICULAR SEMI-FINISHED HWP COMMODITY CLASS 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:

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

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

IRW = HWP feedstock commodity class '*industrial roundwood*'

$PULP$ = HWP feedstock commodity class '*wood pulp*'

$RecP$ = HWP feedstock commodity class '*recovered paper*'

q = recovered paper utilization rate.

In order to exclude carbon in imported HWP, Equation 12.8 allows the calculation of the share of the particular feedstock commodity class *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

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

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

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

Where:

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

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

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

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

If the 'production' approach is to be applied, it is *good practice* to present CO_2 emissions and removals arising 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 commodity class 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 (see Section 12.4.3.2).

EQUATION 12.9
CALCULATION OF CARBON INFLOW INTO A PARTICULAR SEMI-FINISHED HWP COMMODITY CLASS 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 commodity class originating from domestic harvest in the year *i*, in m³.

OPTION TO ALLOCATE HWP TO RELEVANT LAND-USE CATEGORIES UNDER THE 'PRODUCTION' APPROACH

In principle, the carbon in HWP could furthermore be allocated to particular land use categories (e.g. *Forest Land remaining Forest Land*, or any other land use category converted to Forest Land).

If country-specific methods are not available to allocate domestic harvest and subsequently produced HWP to different land use categories (e.g. by track and trace systems), it is possible to apply Equation 12.10 to calculate the carbon inflow to the HWP pool of the particular semi-finished HWP commodity class for the 'production' approach (i.e. $Inflow_{PA_l}(i)$), by considering also the annual fraction of HWP derived from the specific land use category ($f_j(i)$).

EQUATION 12.10
CALCULATION OF CARBON INFLOW INTO A PARTICULAR SEMI-FINISHED HWP COMMODITY CLASS FOLLOWING THE 'PRODUCTION' APPROACH IN CONJUNCTION WITH ALLOCATION TO RELEVANT LAND USE CATEGORIES

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

$$\text{With: } f_l(i) = \frac{harvest_j(i)}{harvest_{Total}(i)}$$

Where:

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

$f_j(i)$ = share of harvest originating from the relevant land use category *j* in the year *i*

j = land use category.

Where countries already collect harvest data discriminating between different land use categories, and between material and energy use of harvested roundwood (i.e. industrial roundwood and fuelwood, see Figure 12.2), this information can be used. This is usually the case where countries apply the gain-loss (i.e. flux data) method[12].

Most countries only report statistics on production of industrial roundwood from forests, and the uncertainties associated with feedstock for HWP production (see Figure 12.2) originating from land use categories other than forest-related are generally expected to be insignificant. Nevertheless, there is also industrial roundwood provided to the markets from land uses other than forests, such as cropland (e.g. short-rotation coppice).

Countries that apply the stock-difference method to estimate carbon stock changes in the living biomass pool need to collect additional data for estimating harvest fractions associated with the particular land use category *j*. When countries cannot track the harvested wood by the land of origin and by different uses of wood (i.e. industrial roundwood, fuelwood), the following guidance could be applied.

For Forest Land converted to other land use categories, the starting information is the standing volume of trees before the land use conversion, which corresponds to the total harvest (i.e. fellings). The following steps apply:

STEP 1: Disaggregate the harvest into roundwood and slash by one of the following methods.

- Either multiply the standing volume by the ratio of roundwood to total harvested removals that has been calculated for other activities or at national level;
- Or divide the standing volume by the biomass expansion factors (BEF_2)[13], thereby deriving the amount of roundwood.

STEP 2: Disaggregate the roundwood into industrial roundwood and fuelwood (see Figure 12.2) by one of the following methods.

- Either multiply the roundwood by the ratio of industrial roundwood to roundwood that has been calculated for other activities or at national level;
- Or multiply the industrial roundwood data (*IRW*) derived from Equation 12.8 by the factor 0.87[14] in order to exclude harvest losses, bark (see FAO roundwood definition, Section 12.4.1.1) and fuelwood not covered by the statistics and subsequently disaggregate the result by using the proportion derived from FAOSTAT production data of the commodities industrial roundwood and wood fuel.

For land use categories converted to Forest Land, the starting information is the standing volume of trees from which fellings is derived according to the age-class structure and/or yield tables and/or information on the timing of harvesting and thinning operations for each management system. Then, STEPS 1 and 2 as described above for Forest Lands converted to other land use categories apply in order to divide harvest into roundwood and slash and disaggregate roundwood into industrial roundwood and fuelwood.

For land use categories that are not covered under any forest-related land use category (see Volume 4, chapters 5 to 9), and that produce identifiable amounts of harvest (i.e. lands from which timber is extracted), then the country may estimate the amount of industrial roundwood annually produced from those land use categories in order to exclude it from the HWP estimation.

Industrial roundwood from the above land use categories could be estimated by one of two methods:

- For each tree species, subtracting the amount of harvest originating from land use categories subject to land-use change from total amount of harvest. The remaining amount is apportioned between *Forest Land remaining Forest Land* and other land use categories from which significant amounts of timber are extracted,

[12] Section 4.2.1.1, Chapter 4, Volume 4 of the *2006 IPCC Guidelines*

[13] To be used in connection to growing stock biomass data

[14] IPCC (2014). Please note that this factor varies between countries depending upon, *inter alia*, the national definition of volume of living stems above stump. Further guidance can be found e.g. in Lawrence *et al.* (2010) and Karjalainen (2004).

based on the proportion of the total area covered by each species under *Forest Land remaining Forest Land* and under those other land use categories;

- By subtracting the amount of fellings originating from land use categories subject to land-use change, as quantified by available data or as estimated according to above-listed guidance, from the total harvest. The remaining quantity can be apportioned on the basis of the proportion of the area under *Forest Land remaining Forest Land* and under the other land use categories.

Once the quantity of fellings has been apportioned to land use categories other than forest-related land from which identifiable amounts of timber are extracted, the industrial roundwood is estimated by applying the same steps as those described for land use categories subject to land use change.

Finally, the amount of industrial roundwood produced from *Forest Land remaining Forest Land* is estimated by subtracting the quantity of fellings originating from land use categories subject to land-use change and those land use categories other than *Forest Land remaining Forest Land*, from the total harvest. The amount of industrial roundwood from *Forest Land remaining Forest Land* can be calculated in line with the guidance given above.

If a ratio of industrial roundwood originated from the identified land use category cannot be estimated for the whole time series, it is suggested to derive missing values from the ratios that have been calculated according to methods of gap-filling as provided in Volume 1, Chapter 5 of this Refinement.

Countries that use the stock-difference method to estimate forest carbon stock changes as outlined in Volume 4, Chapters 2 and 4 of the *2006 IPCC Guidelines*, and that apply the above method for estimating the fellings for the forest-related land use categories subject to land-use change and/or for *Forest Land remaining Forest Land*, are encouraged to ensure the quality of estimated values of harvesting by checking their consistency with the estimated net changes in above-ground biomass.

COMPILATION OF ADDITIONAL ACTIVITY DATA REQUIRED FOR THE ‘ATMOSPHERIC FLOW’ APPROACH

In order to implement the ‘atmospheric flow’ approach, in addition 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 for the manufacturing of semi-finished HWP, is to be calculated. Equation 12.11 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 12.11

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

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

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

Sources: Rüter 2017, p. 259 ff, IPCC 2006

Where:

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

cf_j = carbon conversion factor of the particular HWP feedstock commodity class, see Table 12.2.

If the ‘atmospheric flow’ approach is chosen, it is *good practice* to apply Equation 12.10 to all HWP feedstock commodities listed in Table 12.2, in order to cover all relevant carbon fluxes in traded woody biomass. This ensures that all imported HWP feedstock commodities and all exported HWP feedstock commodities are included, as is consistent with the system boundary of the ‘atmospheric flow’ approach.

12.4.2.2 EMISSION FACTORS

The rate at which carbon in the Tier 1 default HWP commodity classes is removed from the HWP pool in service in a given year is specified by a constant decay rate (k) expressed as a half-life in years (see 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 commodity classes based on information provided in IPCC 2003, IPCC 2006 and IPCC 2014, as given in Table 12.3. The same half-lives apply for the particular sub-classes of these aggregate commodity classes of semi-finished HWP as specified in Table 12.1 (Section 12.4.2.1).

TABLE 12.3
TIER 1 DEFAULT HALF-LIVES[15] OF HWP COMMODITY CLASSES

HWP commodity classes[16]	Default half-life (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 arising 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:

i) Country-specific activity data that are 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) Country-specific emission factors following the concept of service life and half-life information to estimate CO_2 emissions and removals arising from HWP by means of the first order decay (FOD) 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

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

[16] HWP commodity classes refer to the commodities sawnwood, wood-based panels, paper and paperboard, according to the international classification system for forest products (see guidance in Section 12.4.1.1)

domestic use of HWP commodity classes, and also for the importing country in the case of exported HWP commodity classes (where relevant).

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

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 a 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 commodity classes based on the ISO 15686 series in combination with an obsolescence factor and information on market share.

In order to adequately implement Equation 12.2, in conjunction with information on country-specific HWP service life (i.e. the time carbon is held in the HWP pool in use before the products are disposed of or recycled), in addition to the product 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 (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 (see Box 12.2) to take account of the specific in-use conditions (ISO 15686-8:2008);
- Obsolescence arises (according to ISO 15686-1:2011) when a facility can no longer 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, or there is a change in the pattern of use.
  - (iii) Economic obsolescence: Fully functional but less efficient, or more expensive than alternatives. This includes replacement owing 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. defective performance from obsolescence (see ISO 2011).

For example:

In northern Europe, 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 within 20 years for aesthetic or other 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 arising 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, rather than a biological decay profile) or the actual time that products take to go out-of-use.[17]

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

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 = 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 site-work.

- 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 commodity classes (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 composite HWP categories (i.e. categories of wood products made up from more than one semi-finished wood product commodity class) 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,

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

countries are encouraged to allocate the contribution of the different HWP commodity classes or sub-classes (e.g. coniferous sawnwood) to markets and their segments in order to obtain improved service life estimates for the particular HWP commodity classes. Therefore, it is important to note that the assumed service life is driven by the technical properties of products 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 commodity classes, could be combined as illustrated in Table 12.4.

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

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

HWP commodity classes (*here: aggregates*)	Markets*	Market share of HWP commodity class	National estimated service life (ESL), years	National obsolescence factor (O)	Adjusted ESL of HWP commodity class (=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 commodity classes 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 commodity class or sub-class (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 arising from HWP are estimated on the basis of the 'production' approach (Section 12.4.2.1) and country-specific half-life information is to 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 commodity classes and/or sub-classes (see Section 12.4.1.1). Furthermore, in order to ensure that the country-specific half-life information from the importing country complies with the commodity classes of the activity data for the exported HWP, it is *good practice* only to apply country-specific half-life information in the case that the same commodity classes of activity data for the exported HWP in both the exporting and importing country are used. Otherwise the default values from Tier 1 are to be used (Section 12.4.2.2).

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

12.4.4 Tier 3 country-specific methods

12.4.4.1 FLUX DATA METHODS

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

However, it should be noted that, as stated in the *2006 IPCC Guidelines*, depending on the selected approach, it is "more difficult to develop Tier 3 methods", especially in the case where the '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 commodity classes as suggested in Section 12.4.1.1.

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 commodity classes cover the volumes as described by the default HWP commodity classes following the international classification system (see Section 12.4.1.1), in line with the approach (i.e. system boundary) chosen by the country (see 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 commodity classes to the FAOSTAT data to ensure that the data relates to the approach selected by the country.

In the case that the country-specific commodity classes 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 (see 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 (see Section 12.4.4.3).

Furthermore, countries are encouraged to make the country-specific HWP commodity classes broad enough to capture significant carbon volumes contributing to the HWP pool. As a guide, the volumes of these commodity classes may be 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 are applicable for the commodity classes of HWP represented in 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 significantly between and within countries, depending on factors such as construction practices, culture, fashion, and climate. Thus, where 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, include, for example, national surveys on the final market use of wood.

12.4.4.2 DIRECT INVENTORY METHODS

The HWP direct 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 only easy to implement for estimating carbon stocks in the HWP pool located in the reporting country alone. It can be used to estimate the annual change in carbon stock of some specific elements of the HWP pool such as finished products and uses (e.g. wooden houses) (see Figure 12.3). 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 by the total floor area 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.

In direct 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 12.4.1.1., there might be the need to combine direct inventory information with estimates derived by means of flux data methods (see Section 12.4.4.3).

Where estimates follow the ‘production’ approach (see Sections 12.3 and 12.A.2.2), the application of direct inventory methods does not allow the identification of the proportion of the HWP carbon stock originating from domestic forests (see Section 12.4.2.1). It is also not possible to estimate the carbon stock in the exported share of domestically produced HWP by means of inventories themselves (see 12.4.4.3). Following this approach furthermore requires excluding imported HWP from the estimated HWP pool, thereby increasing the uncertainties.

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

In cases where a country applies direct inventory methods for specific HWP end uses (e.g. the housing sector), it is *good practice* to estimate CO_2 emissions and removals arising from HWP for the remaining fraction of the three HWP default commodities representing the material use of wood in combination with a flux data method (e.g. Equation 12.2).

12.4.4.3 COMBINED HWP DIRECT INVENTORY AND FLUX DATA METHODS

The application of a combined method is specifically relevant in the case where direct inventory information is to be used in combination with the 'production' approach. For this purpose, the three semi-finished HWP commodity classes 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). Examples of such combined direct inventory and flux data methods are reported in Gjesdal *et al.* (1996) for Norway, in Pingoud et al., (2001), Statistics Finland (2010) for Finland, and National Institute for Environmental Studies (2018) for Japan.

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 covered in GHG inventories. This includes an explanation of where this activity is represented in different GHG 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 calculation and reporting of CO_2 emissions from wood biomass used for energy purposes depends on the choice of HWP 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 estimated 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 burnt are reported in the AFOLU sector. However, these CO_2 emissions may be estimated as an implicit component of carbon stock changes estimated 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 calculating CO_2 emissions and removals arising from HWP in use.

The CO_2 emissions from wood biomass burnt are not reported in either the Energy sector (burnt for energy purposes) or Waste sector (burnt or lost without energy recovery). This is to avoid the possibility of double counting these emissions in two or more GHG inventory sectors because they are already included in the AFOLU sector.

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. 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. 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 or other wood-producing land categories, 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 HWP 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 not to explicitly report CO_2 emissions and removals arising from HWP (i.e. to assume “a steady-state HWP pool”, see Section 12.4.1.2).

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

<table>
<tr><th>Element of wood biomass</th><th>Assumption of ‘a steady-state HWP pool’</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 included as an implicit component of the CO_2 emissions and removals estimated for forests and other wood producing land categories (i.e. as part of losses from above ground standing biomass, implicitly including biomass burnt on harvesting sites) and are reported by the 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 estimated for the producing country. This is a reflection of the conceptual framework behind the ‘stock-change’ and ‘production’ approaches (see Section 12.3.1), which involve estimating CO_2 emissions and removals arising 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 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’ approaches, 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 estimated for the 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 estimated for the country where the wood biomass is used (i.e. by the 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 the producing country. This reflects the application of approaches following the conceptual framework which focusses on estimating CO_2 emissions and removals arising from HWP on the basis of changes in defined carbon stocks in the HWP pool. Essentially, this is for the same reasons as given for ‘harvested wood biomass used directly as energy feedstocks’. In this case, these industrial residues are by-products of the processes involved in the conversion of industrial roundwood into semi-finished products. A proportion of these residues are not used for energy purposes but instead become feedstocks for wood-based panels and paper products. In such cases, these residues are included in the relevant activity data for these product commodity classes (see Section 12.4.1.1). The remainder, generally consumed for energy purposes, do not form part of the statistics for semi-finished wood products and so are not considered as part of the carbon pool changes in HWP under the ‘stock-change’ and ‘production’ approaches. As a consequence, under these approaches, 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 estimated for the producing country.

Under the ‘atmospheric flow’ approach, a consuming country reports 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 Section 12.4.3 for Tier 2, CO_2 emissions are estimated 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 12.4.2). As a consequence, the representation of CO_2 emissions from these industrial residues (either by a producing country or consuming country) depends on the selected HWP calculation approach. Under the ‘stock-change’ and the ‘atmospheric flow’ approach, CO_2 emissions are estimated by the consuming country. Under the ‘production’ approach, CO_2 emissions are estimated by the producing country.

Note that, under Tier 1 and 2 methods, CO_2 emissions from these industrial residues are estimated, 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 estimation of CO_2 emissions from these industrial residues (either by a producing country or consuming country) is consistent with the selected HWP 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 of non-CO_2 emissions from wood biomass burnt and used for energy purposes

Non-CO_2 emissions from wood biomass burnt and 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 calculating CO_2 emissions and removals arising from HWP in use. When CO_2 emissions from burning wood biomass for energy are estimated for a country for information purposes 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 Vol 2, Chapter 2, Section 2.3.3.4).

12.5.3 Guidance on emissions factors for wood biomass burnt and 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 *2006 IPCC Guidelines* Vol 2, Ch 2 Section 2.3.2. Guidance on how to derive activity data where wood biomass is burnt for energy generation purposes is given in *2006 IPCC Guidelines* Vol 2, Ch 2 Section 2.3.3. Where wood biomass is incinerated as waste (i.e. without energy recovery), guidance is provided in *2006 IPCC Guidelines* Vol 5, Ch 2. Where wood biomass is used as feedstock for biofuels, guidance is provided in *2006 IPCC Guidelines* 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 estimating emissions from HWP in SWDS (Solid Waste Disposal Sites).

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 without modifications to estimate quantities of HWP entering SWDS. It may also be difficult to relate estimates of wood disposed of in SWDS derived from waste statistics to estimates of HWP in use. Consequently, there may be some inconsistency in estimates of CO_2 emissions and removals arising from HWP in the AFOLU sector and estimates for wood disposed of in SWDS in the Waste sector.

12.6.1 Representation of CO_2 emissions from wood biomass in SWDS

In the methods provided in this Chapter, 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 SWDS. It may be useful to quantify the CO_2 emissions from wood biomass disposed of in SWDS to allow checks on consistency in the estimation of emissions in the Waste and AFOLU sectors.

It should be noted that estimates of CO_2 emissions from wood disposed of in SWDS (if estimated to permit checks on consistency) will only be consistent with estimates for 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 guidelines for HWP advise GHG inventory compilers to apply either the Tier 1 method with default parameter values as 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 Volume 5, Annex 3A.1). The Waste Sector guidelines explain how to use Waste Sector default data and parameters to estimate the quantity of discarded solid wood and paper carbon that accumulates in SWDS in the estimating country. When applying the Waste Sector Tier 1 method, estimates of carbon emitted to the atmosphere from 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. It should be noted that Tier 1 FOD model for SWDS provides not only CH_4 emission from degradable organic matter (DOCm) in SWDS, but also CO_2 emissions from DOCm in SWDS, as well as the amount of long-stored carbon (non-degradable carbon) in SWDS (See *2006 IPCC Guidelines*, Volume 5, Chapter 3, Section 3.2). When countries explicitly identify the CH_4 emissions and long stored carbon originating from disposed wood in SWDS, the carbon contained in these elements may be subtracted from the release of CO_2 from HWP.

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

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

12.7 UNCERTAINTY ASSESSMENT

This section provides information on potential sources of uncertainty associated with the estimates of CO_2 emissions and removals arising from HWP. The uncertainties can be divided into uncertainties associated with the methods, with the activity data, and with emission factors and parameters.

METHOD UNCERTAINTIES

When flux data methods are applied, notably as under Tier 1 and Tier 2, the essential sources of uncertainty are related to the assumption that losses from the processing and use of semi-finished wood products can be represented by a first order decay (FOD) process (see Equation 12.2). The alternative to modelling fluxes in this way would be to refer to actual statistics, not only on the rates of wood inflow into classes of semi-finished products, but also on rates of loss (or disposal) of wood material from these classes. As explained in Section 12.4.1.1, statistics (activity data) on rates of inflow are generally available and reasonably reliable. However, there are no extensive or reliable statistics on actual rates of loss/disposal – rather there is only some understanding of the lifespans (or "service lives") of types of wood product. Although the FOD function is assumed to be a good proxy for the carbon losses from the HWP pool consisting of semi-finished products, other decay functions or methodologies could also be used to describe these processes. 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 12.4.3.2). For instance, the demand for wood products is likely to grow during periods of economic prosperity, resulting simultaneously in increasing replacement of old HWP with new ones. Hence, the inflow of wood to HWP is likely to increase during such periods. However, much of this wood consumption may be related to decisions to replace existing HWP in use, thus the rate of loss/disposal from HWP may also increase, implying a shortening of the time for which HWP remain in use. The converse may be true in periods of economic recession, i.e. with reduced inflow but also reduced losses as a result of HWP being retained longer in use. This sort of dynamic interaction between rates of inflow and loss is not represented in the basic FOD modelling methods. Rather, the rates of loss are assumed to be fixed. As a result, the annual carbon stock change in HWP may be overestimated or underestimated during some periods, depending on specific economic circumstances, where these are not well represented by the assumptions implicit in the FOD process and fixed decay rates representing average conditions.

In the Tier 1 method another uncertainty is associated with the initialization of the FOD model. Due to the 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 commodity classes ($C_l(t0)$) 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 commodity classes of sawnwood (with half-life of 35 years) and wood based panels (with half-life of 25 years) 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 arising from HWP, especially from products with high half-life values.

Another model uncertainty is related to the number of HWP commodity classes in the model. In the simplest Tier 1 method there are three HWP sub-pools for the main commodity classes of semi-finished wood products: 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 different half-lives depending upon their end-use (see Table 12.2) or based on sub-classes (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 idealized models with uncertain assumptions on decay pattern, and which may require verification and validation. The direct inventory method could in principle provide more robust and less uncertain estimates of the carbon stock changes in the HWP pool. Sequential direct inventories could also be applied in the calibration of the flux data models and their half-life parameters (see Box 12.2), thus reducing their uncertainties. However, the limitation of the method is that the statistics, if available, contain only some major pools, such as the housing sector, of a country, and there is no information on other pools, e.g. on the use of wood for furniture or packaging. In addition, direct inventory methods are unlikely to be implementable by a producing country for HWP in its export markets. Thus, they must always be combined with flux data methods, introducing a risk of double-counting of semi-finished and final products. Furthermore, direct inventory methods are applicable only in countries where relevant and repeated 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 consequent uncertainties in the estimates of the level of CO_2 emissions and removals arising from HWP, could occur as a result of:

- Lack of time series: some countries were founded relatively recently, 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 wood 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 on commercially traded (market) pulp.

- The scope of data collection: small or occasional producers may not be included. This tends to affect especially the sawmilling industries, as limits to collected 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 assigned to the wrong commodity class or incorrectly processed by the reporter or collecting agency.
- Uncertainties associated with aggregate HWP commodities (e.g. wood-based panels): in general, the sum for the sub-classes is consistent with the value for the aggregate commodities, but some commodities may be underreported because of missing sub-classes (e.g. missing data on veneer sheets result in an underestimate for wood-based panels).

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

The semi-finished HWP commodity classes (i.e. sawnwood, wood-based panels and paper and paperboard) are all subject to the factors listed above. An overall assessment of the influence of these factors on the estimated uncertainty of reported activity data suggests a range from -25% to +5% (based on the authors' expert judgement). The implication is that the combined effect of the factors described above is a tendency to under-reporting in HWP commodity data in international databases, i.e. actual values are generally higher. This is particularly the case in the reported amounts of wood-removals (see Figure 12.2, Section 12.4.1.1). This in turn implies a potential underestimation of the rates of inflow to HWP in the case that information on feedstock is used for calculating in the applied HWP approach.

Further uncertainties associated with activity data are caused by conversion factors. In particular, the conversion factors provided for sawnwood (see Table 12.2) reflect averages which may not be correct for all 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, for example, to various wood species for the specific items (see Section 12.4.2.1).

It is most useful for reducing the uncertainties relating to activity data to cross-check if the amount of domestic production of HWP commodity classes balances with the available supply of wood. It also allows data to be reviewed to check if it fits with a general understanding of the forest products supply in a country. 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 reducing 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 (see Section 12.4.4), or b) with market information as shown in Table 12.4 (see Section 12.4.3.2). The application of stock inventory information, however, is not practical for most countries owing to the lack of appropriate statistics. Furthermore, it does not cover export markets of an estimating country (i.e. relevant where a 'production' approach is applied). A study for Germany including a calibration of the default half-lives by means of market information (Rüter 2017) confirmed the three values in relation to the country's total product portfolio. In contrast, two specific calibration studies (Statistics Finland 2011) indicated that it is likely that the true half-life of sawnwood and wood-based panels in Finland has 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 where reliable, transparent information is available. However, the model calibration procedure for direct inventories of HWP 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 *2006 IPCC Guidelines*, Volume 1, Section 6.8).

The QC procedures should follow the general procedures described in *2006 IPCC Guidelines,* Volume 1, 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 (Section 12.4.3.1) and half-lives (Section 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 improve estimates of CO_2 emissions and removals arising from HWP further, together with checking and revising data for the Tier 1 method and improvements for Tier 2 estimates:

1. Check that country data in the FAO database[18] 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 commodity classes to adjust the values in Tables 12.1 and 12.2 to country specific circumstances.
3. If country specific half-life 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.

12.9 COMPLETENESS

If a country is a significant exporter and/or importer of finished wood products, such as furniture or wooden interior works (e.g. windows, doors) (see Figure 12.3), then methods may need to be adapted to adjust the inflow to the HWP pool in use to include or exclude carbon in traded amounts of finished products in the light of the approach chosen by the country (see 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 (see Section 12.4.1.1). 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 combustion and held as part of a solid chemical or as a gas.

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

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

12.A.1 Introduction

This section describes in detail the different approaches for estimating CO_2 emissions and removals arising from HWP. Before proceeding to the detailed description, several points already discussed in the main chapter should be recalled, as summarised below.

12.A.1.1 TYPES OF APPROACH

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. These estimation approaches were defined in the *2006 IPCC Guidelines* and are maintained in this updated guidance, with a detailed supporting description provided in this annex. The *2006 IPCC Guidelines* also referred to the **'simple-decay'** approach, although specific guidance on implementation was not provided. The 'simple-decay' concept is also maintained in this updated guidance by recognising it as a special case of the 'production' approach, in combination with a specific (essentially Tier 3) calculation method. Hence, regarding the 'simple-decay' concept from the strict perspective of estimation approaches, the description of the 'production' approach given in this annex also applies to the 'simple-decay' concept. Guidance on calculation methods appropriate for the 'simple-decay' concept was not provided in the 2006 IPCC Guidelines and there is no basis for providing specific guidance in this update. However, the general guidance on Tier 3 methods in the main chapter (Section 12.4.4) may be referred to.

12.A.1.2 CONCEPTUAL FRAMEWORKS AND SYSTEM BOUNDARIES OF HWP APPROACHES

The discussion in Section 12.3 of the main chapter has explained how each defined HWP approach is based on a conceptual framework:

- The 'stock-change' and 'production' approaches are based on a conceptual framework focussing on carbon stock changes within defined HWP pools and deriving estimates for CO_2 emissions and removals from these.
- The 'atmospheric flow' approach is based on a conceptual framework that focusses on identifying and tracking CO_2 fluxes.

The conceptual framework of an approach has some implications for the carbon stock changes (or CO_2 emissions and removals) that are included in estimates. Notably, for approaches that involve focussing on carbon stock changes within defined HWP pools (i.e. the 'stock-change' and 'production' approaches), CO_2 emissions from harvested wood biomass used directly as a feedstock for energy purposes are not included as part of estimates of CO_2 emissions and removals arising from HWP. This is because these elements of harvested wood do not enter a defined HWP carbon pool. This does not mean that CO_2 emissions arising from the use of harvested wood biomass for energy purposes are not estimated at all under the 'stock-change' and 'production' approaches. Instead, these CO_2 emissions are implicitly included as part of other AFOLU emissions and removals, as explained in Section 12.5 in the main chapter. In contrast, for approaches that involve focussing on tracking CO_2 fluxes (i.e. the 'atmospheric flow' approach), CO_2 emissions from harvested wood biomass used directly as a feedstock for energy purposes are included explicitly in estimates CO_2 emissions and removals arising from HWP.

In addition to an underlying conceptual framework, each defined HWP approach involves applying a system boundary for the calculation of estimates of CO_2 emissions and removals arising from HWP. The system boundary determines the scope of CO_2 emissions and removals covered by estimates for HWP. This subject is discussed in detail below.

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 12.5).

12.A.2 Estimating CO_2 emissions and removals arising from HWP on the basis of carbon stock changes

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

In order to implement one of the two available pool-based approaches using a flux data method as suggested for Tier 1 (see Section 12.4.2), the annual carbon flux into the HWP pool (i.e. *Inflow,* see 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 possible pool-based approaches, whereas their conceptual differences are described in the following.

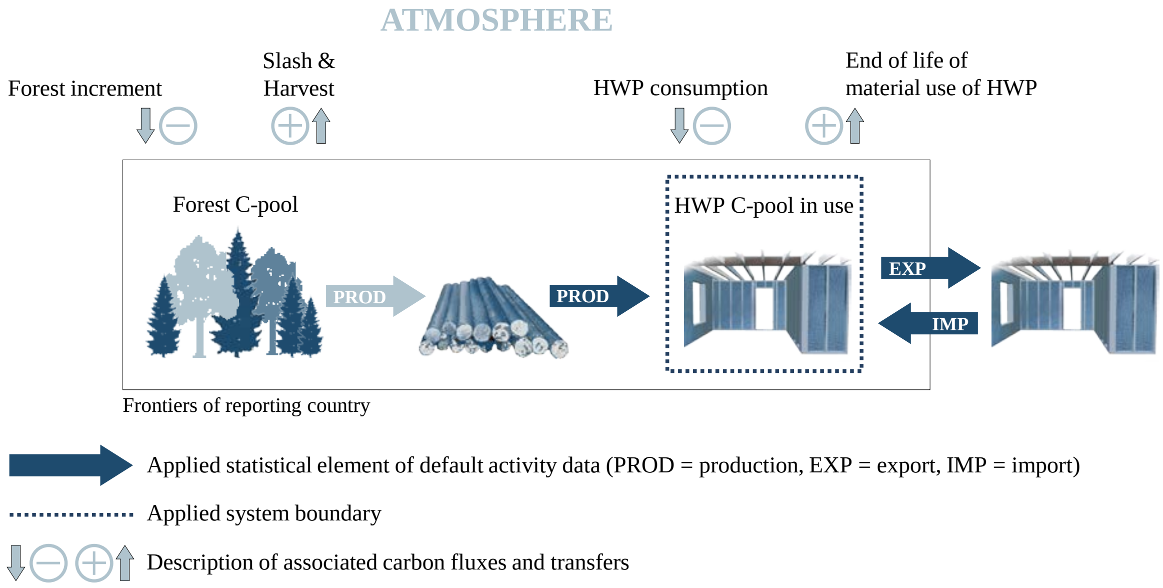
12.A.2.1 THE ‘STOCK-CHANGE’ APPROACH

The ‘stock-change’ approach estimates the net change in carbon stocks in the HWP pool within national boundaries (see e.g. Brown *et al.* 1998, Lim *et al.* 1999, UNFCCC 2003) and supplements the estimation of emissions and removals with changes in the carbon stocks in the above ground biomass pool of forests within the same system boundaries. Where this approach is used to estimate the annual change in carbon stock in “products in use” in a country, it corresponds to Variable 1A in *2006 IPCC Guidelines*.

A conceptual illustration of the ‘stock-change’ approach is shown in Figure 12.A.1. A ‘box-and-arrow’ diagram, indicating the essential relationships between the system boundary and CO_2 emissions and removals, is shown in Figure 12.A.2. It must be cautioned that the ‘box-and-arrow’ diagram does not provide a complete or entirely accurate picture.

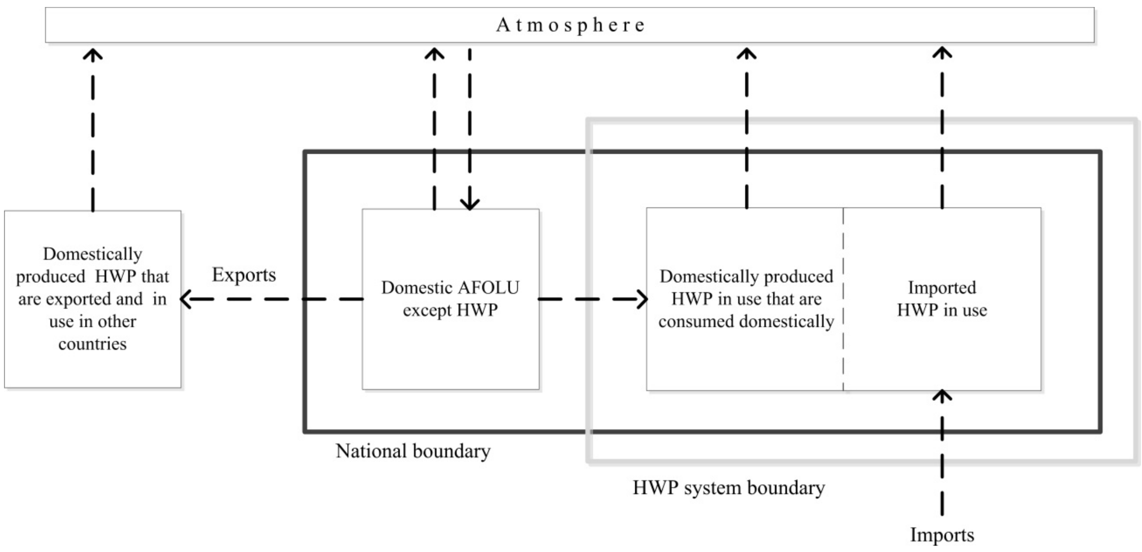
Changes in the pool of products are reported by the country where the products are used, referred to as the consuming country. Where a flux data method is applied to determine the amount of carbon stored in the HWP pool in use within a country, the carbon flux into the pool (i.e. *Inflow*) is quantified 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, whilst imported HWP are included in the estimate of the HWP carbon pool in a specific year (see Figures 12.A.1 and 12.A.2). 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 12.4.2.1.

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



Source: Rüter 2017

Figure 12.A.2 'Box-and-arrow' diagram showing the system boundary of the 'stock-change' approach



NOTES: The dashed lines indicate fluxes that are inferred from changes in carbon stocks in pools in AFOLU and HWP in use, as shown. For the estimation of CO_2 emissions and removals arising from HWP, only those fluxes crossing the HWP system boundary are covered under the 'stock-change' approach.

Other data reflecting the utilization of HWP in use within a country could be derived from information on e.g. the use of wood within a specific commodity class, for instance the national building stock (see Section 12.4.3.1). 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, in a similar way to repeated forest inventories referring to the stock-difference method (see IPCC 2006, p. 2.10).

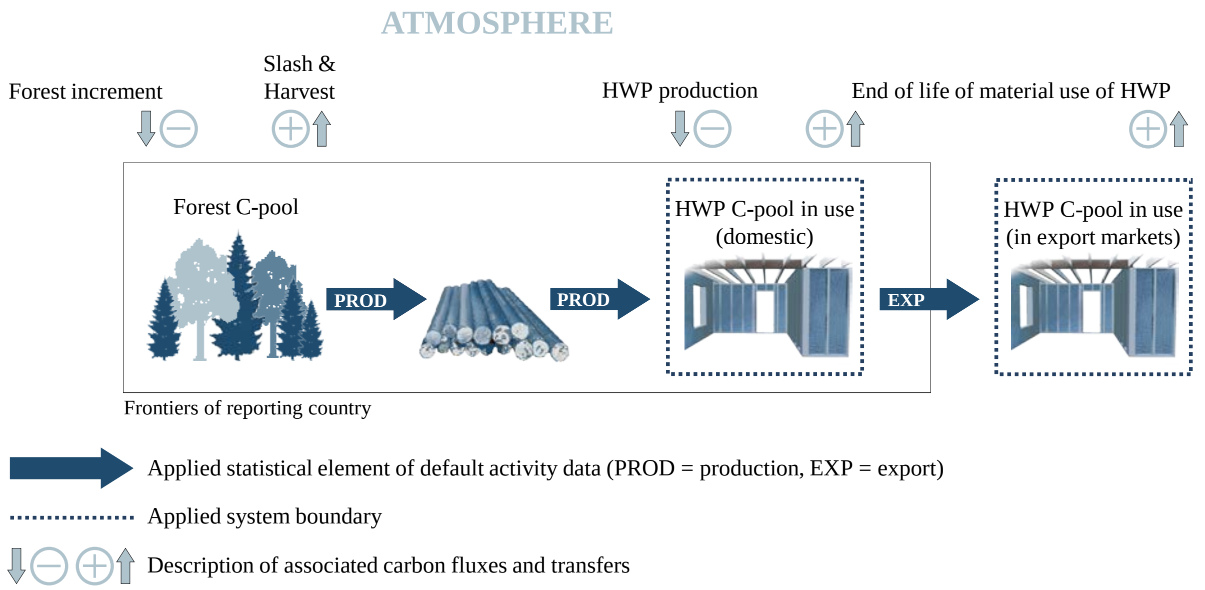
12.A.2.2 THE ‘PRODUCTION’ APPROACH

Similar to the ‘stock-change’ approach, the ‘production’ approach determines emissions and removals from wood coming from domestic harvest in a country. Where the annual change in carbon stock in ‘products in use’ is estimated, this corresponds to Variable 2A in *2006 IPCC Guidelines*.

A conceptual illustration of the ‘production’ approach is shown in Figure 12.A.3. A ‘box-and-arrow’ diagram, indicating the essential relationships between the system boundary and CO_2 emissions and removals, is shown in Figure 12.A.4. It must be cautioned that the ‘box-and-arrow’ diagram does not provide a complete or entirely accurate picture.

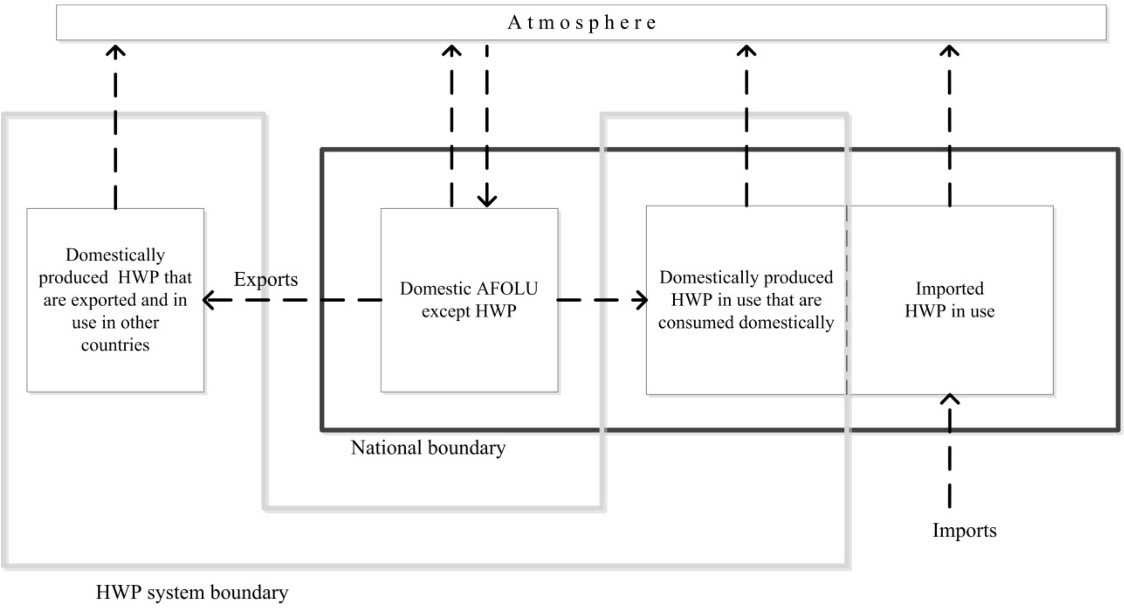
In contrast to the ‘stock-change’ approach described above, which estimates the carbon flux into the carbon pool of HWP in use based on the calculated domestic consumption of HWP, the ‘production’ approach considers the domestic production of wood commodities manufactured from domestic harvest. Thus, the carbon in exported wood products is implicitly included in the HWP estimates of a 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 arising from HWP take place (Figures 12.A.3 and 12.A.4).

Figure 12.A.3 Conceptual illustration 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:. Rüter 2017

Figure 12.A.4 'Box-and-arrow' diagram showing the system boundary of the 'production' approach



NOTES: The dashed lines indicate fluxes that are inferred from changes in carbon stocks in pools in AFOLU and HWP in use, as shown. For the estimation of CO_2 emissions and removals arising from HWP, only those fluxes crossing the HWP system boundary are covered under the 'production' approach.

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 12.4.2.1.

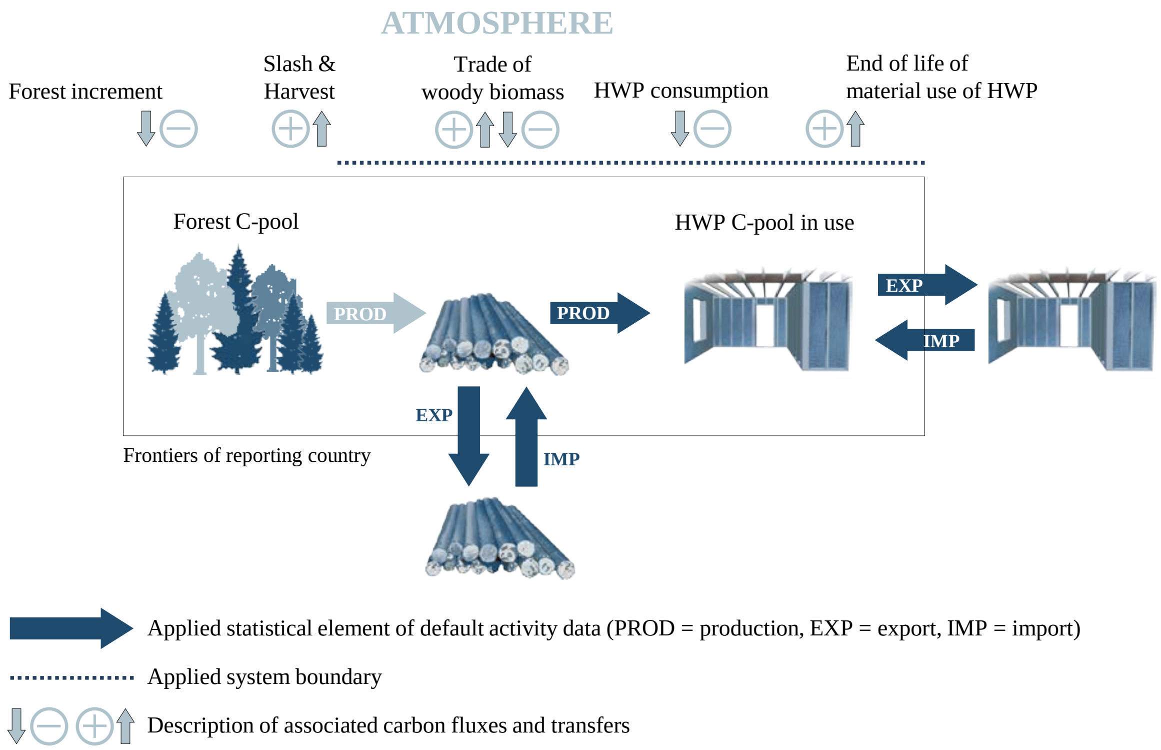
12.A.3 Estimating CO_2 fluxes from wood biomass – the 'atmospheric flow' approach

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 *2006 IPCC Guidelines*.

Carbon fluxes into the atmosphere are, however, particularly 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 (see Ch. 4). It does require, in addition to estimates of the carbon stock changes within the HWP pool in use within a country (i.e. 'stock-change' approach), the estimation of all additional cross-border carbon fluxes in woody biomass feedstock and wood fuel (see Cowie *et al.* 2006).

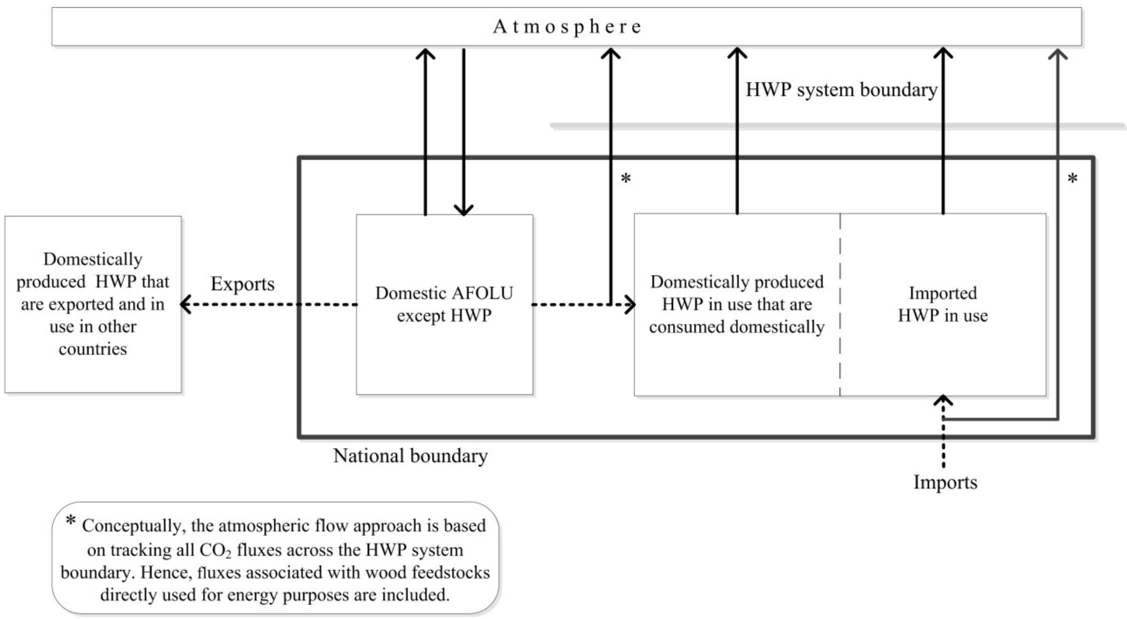
A conceptual illustration of the 'atmospheric flow' approach is shown in Figure 12.A.5. A 'box-and-arrow' diagram, indicating the essential relationships between the system boundary and CO_2 emissions and removals, is shown in Figure 12.A.6. It must be cautioned that the 'box-and-arrow' diagram does not provide a complete or entirely accurate picture. The HWP pools are the same as in the 'stock-change' approach. Further information on the implementation of the 'atmospheric flow' approach on the basis of available statistical data is included in Section 12.4.2.1.

Figure 12.A.5 Conceptual illustration 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:. Rüter 2017

Figure 12.A.6 'Box-and-arrow' diagram showing the system boundary of the 'atmospheric flow' approach



NOTES: The solid lines crossing the grey boundary line indicate fluxes that are tracked across the HWP system boundary under the 'atmospheric flow' approach.

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