

CHAPTER 12

HARVESTED WOOD PRODUCTS

Authors

Kim Pingoud (Finland) and Kenneth E. Skog (USA)

Daniel L. Martino (Uruguay), Mario Tonosaki (Japan), and Zhang Xiaoquan (China)

Contributing Author

Justin Ford-Robertson (New Zealand)

Contents

12	Harvested Wood Products (HWP)	
12.1	Introduction	12.5
12.2	Methodological issues	12.8
12.2.1	Choice of method	12.8
12.2.1.1	Tier 1	12.9
12.2.1.2	Tier 2: Using country data	12.15
12.2.1.3	Tier 3: Country-specific methods	12.15
12.2.1.4	Estimating carbon release to the atmosphere from the HWP variables	12.16
12.2.1.5	Estimating carbon released to the atmosphere in the form of CO ₂	12.17
12.2.2	Choice of emission factors	12.17
12.2.3	Choice of activity data	12.17
12.3	Uncertainty assessment	12.21
12.4	Quality assurance/ Quality control	12.23
12.5	Completeness	12.23
12.6	Reporting and Documentation	12.24
12.7	Reporting Tables and Worksheets	12.24
Annex 12.A.1	Some Approaches	12.26
References		12.32

Equations

Equation 12.1	Estimation of carbon stock and its annual change in HWP pools of reporting country	12.11
Equation 12.2	Estimation of HWP products produced annually from domestic consumption	12.11
Equation 12.3	Estimation of HWP products produced annually from domestic harvest	12.12
Equation 12.4	Estimation of annual change in carbon in HWP in domestic SWDS where HWP came from domestic harvest	12.14
Equation 12.5	Estimation of carbon release using HWP variables	12.16
Equation 12.6	Equation to estimate production, imports or export variables in Table 12.5 for years before 1961	12.18
Equation 12A.1	Emissions from AFOLU by the Stock-Change Approach	12.27
Equation 12A.2	Stock-Change Approach: <i>HWP Contribution</i>	12.27
Equation 12A.3	Emissions from AFOLU as by the Atmospheric Flow Approach	12.28
Equation 12A.4	Atmospheric Flow Approach: <i>HWP Contribution</i>	12.29
Equation 12A.5	Emissions from AFOLU by the Production Approach	12.30
Equation 12A.6	Production Approach: <i>HWP Contribution</i>	12.30

Figures

Figure 12.1	Decision tree for reporting an <i>HWP Contribution</i> of zero or selecting a tier.	12.10
Figure 12.A.1	System boundary of the Stock-Change approach.	12.26
Figure 12.A.2	System boundary of the Atmospheric Flow Approach.	12.28
Figure 12.A.3	System boundary of the Production Approach.	12.29

Tables/Worksheets

Table 12.1	HWP Variables used to estimate annual <i>HWP Contribution</i> to AFOLU CO ₂ emissions/removals.....	12.8
Table 12.2	Default half-lives for “products in use” carbon pools and associated fraction retained each year.....	12.17
Table 12.3	Estimated annual rates of increase for industrial roundwood production (harvest) by world region for the period 1900 to 1961	12.18
Table 12.4	Default factors to convert from product units to carbon.....	12.19
Table 12.5	UN FAO activity data needed for Tier 1 variables, and default conversion factors	12.20
Table 12.6	Uncertainty associated with activity data and parameters (emission factors) for the Tier 1 method to estimate the five annual HWP variables.....	12.22
Table 12.7	Sectoral background data for AFOLU.....	12.25
Table A12.1	Summary of How to compute <i>HWP Contribution</i> using variables in Table 12.7.....	12.31

12 HARVESTED WOOD PRODUCTS (HWP)

Currently there are several different approaches for reporting the storage of carbon in wood products and its subsequent release as CO₂ (see e.g., Brown *et al.*, 1998; and Ford-Robertson, 2003; in Annex 12A.1). This chapter does not prefer any of these and does not attempt to prejudge whether these, or any other approach, should be used to account for this storage and emission¹.

This guidance concentrates on some of the variables needed for particular approaches and shows how they can be estimated from default data or more detailed country-specific data. Although some of these variables are stock-changes, this guidance should not be interpreted as implying that stock-change approaches are better or worse than any other approach, the variables discussed here are simply tools needed to estimate the quantities required by differing individual reporting approaches.

The guidance here generally assumes that the amount of woody material in use declines following a first-order decay: again this is not the only assumption possible. Different possibilities include linear decay and more detailed approaches based on studies of the real use of these materials. Again no preference on this choice is implied.

This text:

- clarifies the option of reporting “zero”;
- provides default Tier 1 methods and guidance on higher Tiers; and
- provides guidance on reporting whatever accounting approach is used.

The alternative approaches to estimate and report the contribution of HWP to annual AFOLU CO₂ emissions/removals (which will be referred to as the *HWP Contribution*) that have been proposed differ in how they allocate the *HWP Contribution* between wood producing and consuming countries, and what processes (atmospheric fluxes or stock changes) they focus on. They therefore give different results for the overall annual emissions or removals of CO₂ in AFOLU that a given country would report in a given year (see Annex 12A.1). The differences are partly based on different interpretations of some key terms such as emissions/removals or source/sink in the AFOLU reporting framework (Cowie *et al.*, 2006). Estimation, reporting and accounting of the *HWP Contribution* is under consideration by the UNFCCC.

The approaches that have been identified are mutually exclusive in the sense that a global or regional estimate of annual *HWP Contribution* would only be correct if all the different countries provided estimates using the same approach.

12.1 INTRODUCTION

Much of the wood that is harvested from Forest Land, Cropland and other types of land use remains in products for differing lengths of time. This chapter provides guidance on how to estimate and report the contribution of these harvested wood products (HWP) to annual AFOLU CO₂ emissions/removals.

HWP includes all wood material (including bark) that leaves harvest sites. Slash and other material left at harvest sites should be regarded as dead organic matter in the associated land-use category in Chapters 4, 5, 6, 8 and 9 of the *Guidelines* and not as HWP. HWP constitutes a carbon reservoir². The time carbon is held in products will vary depending on the product and its uses. For example, fuelwood and mill residue may be burned in the year of harvest; many types of paper are likely to have a use life in uses less than 5 years which may include recycling of paper; and sawnwood or panels used in buildings may be held for decades to over 100 years. Discarded HWP can be deposited in solid waste disposal sites (SWDS) where they may persist for long periods of time. Due to

¹ SBSTA 21 noted “...the intent of the IPCC to develop for the purpose of compiling GHG inventories under the UNFCCC, methods that are neutral in relation to potential accounting approaches for harvested wood products (FCCC/SBSTA/2004/13, pp 7-8, para 30.) The idea to develop an approach neutral set of HWP variables was suggested by participants at a HWP workshop requested by SBSTA that was held in Lillehammer, Norway. “...participants noted the need to develop a set of methods that is neutral to the approaches, which could, for example, include methodological guidance on a minimum set of “quantities” required to estimate emissions and removals under any approach.” (UNFCCC, 2004).

² Article 1 of the UNFCCC defines reservoirs as follows: “Reservoir” means a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored.

this storage in products in use and in SWDS, the oxidation of harvested wood products in a given year could be less, or potentially more, than the total amount of wood harvested in that year. Worldwide - according to a study by Winjum *et al.* (1998) and a report by the UNFCCC secretariat (2003) - the amount of carbon held in harvested wood products is likely to be increasing.

The 1996 IPCC Guidelines (IPCC, 1997) did not provide methods for estimating carbon held in HWP, and recommended, for the purpose of basic calculations, a default assumption expressed as "... that all carbon biomass harvested is oxidised in the removal [harvest] year"³. This was based on the perception that HWP stocks are not changing. That is, the annual carbon inflow and outflow for the HWP reservoir were assumed to be equal and the oxidation from pre-existing wood products stocks could be replaced (and hence omitted) by an implied oxidation directly after harvesting. More precisely therefore the IPCC default assumption was that inputs to the HWP reservoir equals outputs. Since the only significant output is oxidation, this means that the amount of oxidation equals the harvest, where the oxidation includes oxidation of some of the wood harvested in the current year and oxidation of some of the HWP placed in use in prior years.

Given that inputs do not in general equal outputs and that carbon can remain stored in HWP for extended periods of time, this storage time needs to be taken into account when providing guidelines for estimating the contribution of HWP to AFOLU CO₂ emissions/ removals.

This chapter also provides guidance on when a country may report a *HWP Contribution* as zero without necessarily making detailed estimates. This guidance differs from that provided in earlier IPCC guidance.⁴

Estimates of *HWP Contribution* are designed to be consistent with those for other sectors of these guidelines, specifically:

1. All CO₂ released from HWP is included in the AFOLU Sector;
2. CO₂ released from wood burnt for energy in the Energy Sector is not included in the Energy Sector totals (although CO₂ emissions from biofuels are reported as a memo item for QA/QC purposes). CH₄ and other gases from HWP used for energy is included in the Energy Sector;
3. CO₂ released from HWP in SWDS is not included in the Waste Sector totals although CH₄ emissions from HWP are included.

Methods in this chapter estimate release of carbon: this carbon may also be counted as methane emissions in the Waste Sector. This potential double counting of carbon release to the atmosphere can be corrected by subtracting the carbon emitted in the methane emissions from HWP in landfill from the carbon emissions estimated in this chapter (see guidance on how to make an optional correction in Section 12.2.1.5).

In order to make estimates of the *HWP Contribution* for the various approaches, there is a generic set of annual variables that can be used to make the estimates. Using estimates of these annual variables, the *HWP Contribution* can be estimated for any of the currently proposed approaches (see Annex 12.A1). While not all of the data are required for every approach, the complete set would allow any of the proposed approaches to be adopted. These "HWP Variables" are:

1. Annual change in carbon stock in HWP in the reporting country, including HWP stocks from both domestic harvest and imports (Gg of carbon per year)
2. Annual change in carbon stock in HWP made from wood harvested in the reporting country including annual change in carbon stock in HWP exported to other countries (Gg of carbon per year)
3. Annual imports of all types of wood and paper material to the reporting country (Gg of carbon per year)
4. Annual exports of all types of wood and paper material from the reporting country (Gg of carbon per year)
5. Annual harvest for wood products in the reporting country⁵ (Gg of carbon per year).

This chapter provides methods to estimate these HWP variables which can then be used, according to the requirements of different approaches, to estimate the *HWP Contribution* to AFOLU CO₂ emissions / removals.

³ The 1996 IPCC Guidelines (Vol. III, p.5.17, Box 5)

⁴ The 1996 IPCC Guidelines recommended that storage of carbon in forest products be included in a national inventory only in the case where a country can document that existing stocks of long term forest products are in fact increasing.

⁵ Annual harvest for products includes all wood and bark removed for products including fuel from all land categories not just Forest Land. It does not include timber cut down and left at harvest sites. In some countries, other tree parts such as branches and needles and roots or stumps are collected and used for bioenergy. All these tree parts should be included. See Section 12.2.1.1 text on estimating harvest which indicates how it is linked to estimates of $L_{\text{wood-removals}}$ and L_{fuelwood} in Chapters 2 and 4.

This chapter provides tiered methods that countries may use annually to estimate the HWP variables for any year from 1990 to the current year. To do this, data from years before 1990 are needed as explained below. For Tier 1, default values are suggested for all activity data and parameters required. Excel worksheets are provided to implement the calculations and produce the Sectoral Background Table 12.7. This table indicates how these variables may be used to estimate the *HWP Contribution* under the alternate approaches. Table 12.7 shows the HWP variables estimated in Gg C yr^{-1} and uses these values to compute *HWP Contribution* and converts the contribution amount to $\text{Gg CO}_2 \text{ yr}^{-1}$ by multiplying by $-44/12$. A negative *HWP Contribution* value decreases overall emissions from AFOLU and a positive value increases overall emissions from AFOLU.

If countries provide all the HWP variables from Table 12.7 in AFOLU Background Reporting Table 3.10 then it will be possible to calculate each country's *HWP Contribution* for any of the different approaches.

Annex 12A.1 to this chapter provides examples of some approaches and how the HWP variables are used to estimate *HWP Contribution*. This chapter does not provide guidance on the selection of an individual approach for a country to use. Section 12.6 indicates options for reporting the *HWP Contribution* in country inventory reports. The options for reporting include reporting zero as the *HWP Contribution*.

In addition to indicating how to combine the HWP variables to estimate the *HWP Contribution* to AFOLU CO_2 emissions and removals, information is provided in Section 12.2.1.4 on how to compute annual carbon release to the atmosphere from the five HWP variables.

Carbon release estimates from HWP are presented in order to indicate clearly the role annual carbon release from HWP plays in the overall AFOLU system of carbon removals and release. Showing annual carbon release explicitly demonstrates how it compares with annual harvest. Carbon release variables used in Section 12.2.1.4 are as follows:

- $\uparrow C_{\text{HWP DC}}$ = annual release of carbon to the atmosphere from HWP contained in the reporting country. This includes carbon release from all wood harvested and retained in the country and from wood imports into the country but excluding exports, Gg yr^{-1} . This amount of carbon release corresponds to $(E + E_{\text{W}})$ in Annex Figures 12A.1 and 12A.2.
- $\uparrow C_{\text{HWP DH}}$ = annual release of carbon to the atmosphere from HWP that came from wood harvested in the reporting country. This includes carbon release from all wood harvested in the country including wood that is exported but excluding imports, Gg yr^{-1} . This carbon release amount corresponds to $(E_{\text{DOM}} + E_{\text{EX DOM}})$ in Annex Figure 12A.3.

DEFINITION OF VARIABLES

Tier 1 and Tier 2 methods provide annual estimates for a set of five variables that can be used to estimate the *HWP Contribution* for different approaches. Two of the variables have two parts – corresponding to annual additions to a) HWP in “products in use”, and b) HWP in solid waste disposal sites (SWDS). Table 12.1 introduces the variables. While variables 1A, 1B, 2A and 2B are stock changes, this does not imply that any reported *HWP contribution*, or any other data, should be a stock change: these are simply items that can be used to calculate the desired results under different accounting approaches. Inventory compilers should also note that modified or new accounting approaches may change the HWP variables that are needed and how they are estimated. For example, there could be changes in what is included in HWP or changes in how decay of stocks is allocated among reporting countries. For the approaches identified, Equation 12.5 shows the relationship between these HWP variables and two estimates of release of carbon to the atmosphere from HWP. The relationship among the variables may be seen in flow diagrams in the Annex Figures 12A.1, 12A.2 and 12A.3.

Variable definition	Variable names	
	HWP in “products in use”	HWP in SWDS
1. Annual change in carbon stock in a) HWP in use, and b) in HWP in solid waste disposal sites in the reporting country, this is wood carbon that came from domestic consumption of products , $\Delta C_{HWP\ DC} = \Delta C_{HWP\ IU\ DC} + \Delta C_{HWP\ SWDS\ DC}$	Variable 1A $\Delta C_{HWP\ IU\ DC}$	Variable 1B $\Delta C_{HWP\ SWDS\ DC}$
2. Annual change in carbon stock in a) HWP in use, and b) in HWP in solid waste disposal sites where the wood in the products came from domestic harvest -- trees harvested in the reporting country, this includes exported HWP to other countries, $\Delta C_{HWP\ DH} = \Delta C_{HWP\ IU\ DH} + \Delta C_{HWP\ SWDS\ DH}$	Variable 2A $\Delta C_{HWP\ IU\ DH}$	Variable 2B $\Delta C_{HWP\ SWDS\ DH}$
3. Carbon in annual imports of HWP to the reporting country including all wood-based material - roundwood, solidwood products, paper, pulp and recovered paper	P_{IM}	
4. Carbon in annual exports of HWP from the reporting country including all wood-based material:- roundwood, solidwood products, paper, pulp and recovered paper	P_{EX}	
5. Carbon in annual harvest of roundwood for products – wood removed from harvest sites in the reporting country, including fuelwood	H	

12.2 METHODOLOGICAL ISSUES

12.2.1 Choice of method

This section provides:

1. Guidance on when it is consistent with good practice to report a HWP Contribution value of zero;⁶
2. Guidance on when it is consistent with good practice to assume that the annual change in HWP carbon in SWDS is zero (i.e., assume annual carbon release from SWDS is the same as HWP additions to SWDS); and
3. Three tiers of methods to estimate the five HWP variables which may be used to compute HWP Contribution. Figure 12.1 presents a decision tree as a guide in making these choices.

The *HWP Contribution* can be reported as zero if the inventory compiler judges that the annual change in carbon in HWP stocks is insignificant. Either the stocks in the country (Variable 1A + Variable 1B), or the annual change in carbon in HWP stocks originating from wood harvested in the country (including exported HWP) (variable 2A + variable 2B) may be considered. The term ‘insignificant’ in this context means that the annual change in carbon in HWP stocks, using one of the measures of carbon change above, is less than the size of any key category. Countries are encouraged to use the Tier 1 methods to estimate HWP variables to aid in judging if the annual change is insignificant. Parties that wish to report *HWP contribution* to AFOLU where the focus is on carbon fluxes to and from the atmosphere may want to report HWP even where there is no significant stock change.

If an inventory compiler judges that the annual change in carbon in total HWP stocks is significant, they may still separately judge if the annual change of HWP carbon in SWDS is significant. If it is not significantly increasing or decreasing it may be assumed to be zero (Variables 1B and 2B are zero). It is suggested that an estimate be made if annual change in carbon in TOTAL HWP stocks is likely to be of a comparable size to other

⁶ This guidance replaces the guidance in the 1996 IPCC Guidelines on when to report HWP contribution of zero.

key categories. Countries are encouraged to use the Tier 1 methods to estimate HWP variables to aid in judging if the annual change in SWDS is insignificant.

If the annual change in HWP carbon stocks are judged to be significant, or a country chooses to make estimates, then one of three tiers may be selected to make estimates of the five HWP variables to make an estimate of *HWP Contribution*. Tier 1 uses forest products data from FAO (the default activity data) which are freely and easily available to most countries. The Tier 1 method specifies that changes in carbon held in SWDS (Variables 1B) is to be calculated using the Waste Sector Tier 1 methods, default data, and worksheets. A Tier 1 method is provided to estimate Variable 2B from Variable 1B.

The decision tree in Figure 12.1 indicates how to choose a Tier to estimate HWP Variables on the basis of data availability. Default data are provided for Tier 1. Tiers 2 and 3 aim to improve the accuracy of the estimates by using more accurate country-specific data and methods.

Until the Parties to the UNFCCC decide on the approach to be used, it will not be possible to identify definitively whether or not HWP is a key category, since the magnitude of the *HWP Contribution* depends on the approach chosen. Thus, whether or not the sector is a key category cannot be used to guide the choice of tier. In order to facilitate current reporting and allow for future decisions, there are two options. First, they could elect to use a particular approach and determine if this is a key category in the normal way, according to guidance provided in Volume 1, Chapter 4. Alternatively, they could use their judgment to determine if the source is likely to have a significant (equal or greater than other key categories) impact on the national greenhouse gas emission estimates. If the source is judged to be significant, then a Tier 2 or 3 method should be used.

12.2.1.1 TIER 1

HWP Variables 1A, 2A, 1B and 2B are estimates of annual changes in stock of HWP carbon which are each estimated using a flux-data method with lifetime-analysis. The decay of HWP is assumed to be of first-order⁷. This means the annual loss from the stock of products is estimated as a constant fraction of the amount of the stock. Estimates of change of carbon held in “products in use” (Variables 1A and 2A in Table 12.1), are made by tracking inputs to and outputs from the “products in use” carbon pool. The carbon inflow to the pool is estimated from historical production or consumption rates of HWP. Waste Sector Tier 1 methods are used to estimate change in HWP carbon stock in SWDS (Variable 1B) (see Volume 5, Chapter 3). A Tier 1 method is provided to estimate Variable 2B from Variable 1B.

In the case of the “products in use” pool, the outflow from the pool is calculated based on estimated half-life and associated decay rates of HWP from use assuming first-order decay rates.

The intent is to provide valid estimates of the total release of carbon from HWP for any UNFCCC reporting year. This requires knowledge of change to the total existing HWP pool. In the absence of surveys or census data of HWP in use, it is recommended that inputs to and outputs from HWP stocks since 1900 are used in order to make valid estimates for recent years. Excluding current year carbon release or stock change associated with HWP placed in use in years prior to the reporting period would overestimate current year net additions to HWP carbon stocks (underestimate current year carbon release), and would therefore not be consistent with the Good Practice Guidance objective to neither over- nor under-estimate as far as can be judged.⁸

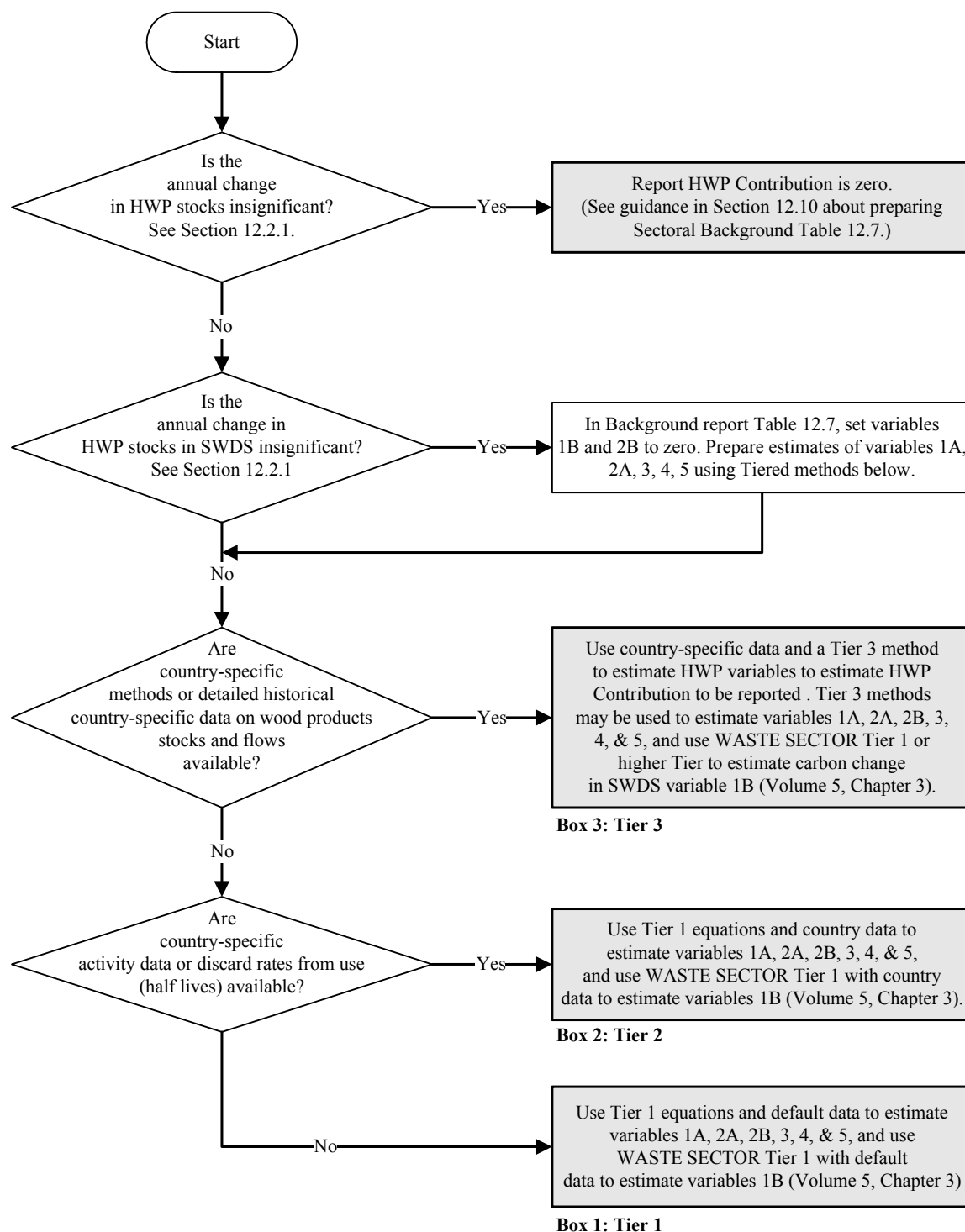
Data beginning in 1900 are used to estimate additions to HWP in use while the discard from use of this HWP is estimated assuming a first order decay. This procedure is needed to produce an estimate of the existing HWP stock accumulated from historical wood use, and hence the current year carbon release from the total stock as it goes out of use (also termed “inherited emissions”).

HWP Variables 3, 4 and 5 (i.e., P_{IM} , P_{EX} , and H, respectively) are estimates of carbon in annual product imports and exports, as well as carbon in annual harvest for products and fuelwood. They are estimated by adding together – aggregating – various forest products variables from the FAO database.

⁷ Other decay profiles have been suggested (Ford-Robertson, 2003) and these could be used in place of the FOD assumption. In this case the estimation procedure would differ from Equation 12.1 and the decay of each year’s Inflow would be tracked individually up to the current year. The remaining discussion about default data would still apply.

⁸ The year 1900 was chosen based on the judgement that contributions to the current year HWP Contribution due to products entering the product pool prior to 1900 would be insignificant, therefore to exclude years prior to 1900 would not violate good practice neither over- nor under-estimate as far as can be judged.

Figure 12.1 Decision tree for reporting an *HWP Contribution* of zero or selecting a tier.



GENERAL METHOD TO ESTIMATE VARIABLES 1A AND 2A -- ANNUAL CHANGE IN CARBON STOCK IN “PRODUCTS IN USE”

Estimation of changes in carbon stock in “products in use” may be obtained by using Equation 12.1:

EQUATION 12.1
ESTIMATION OF CARBON STOCK AND ITS ANNUAL CHANGE IN HWP POOLS OF THE REPORTING COUNTRY

Starting with $i = 1900$ and continuing to present year, compute

(A) $C(i+1) = e^{-k} \cdot C(i) + \left[\frac{(1 - e^{-k})}{k} \right] \cdot Inflow(i)$ with $C(1900) = 0.0$

(B) $\Delta C(i) = C(i+1) - C(i)$

Note: For an explanation of technique used in Equations 12.1A to estimate first-order decay see Pingoud and Wagner (2006).

Where:

i = year

$C(i)$ = the carbon stock of the HWP pool in the beginning of year i , Gg C

k = decay constant of first-order decay given in units, yr^{-1} ($k = \ln(2) / \text{HL}$, where HL is half-life of the HWP pool in years. A half-life is the number of years it takes to lose one-half of the material currently in the pool.)

$Inflow(i)$ = the inflow to the HWP pool during year i , Gg C yr^{-1}

$\Delta C(i)$ = carbon stock change of the HWP pool during year i , Gg C yr^{-1}

Estimating Variable 1a – Annual change in carbon stock in “product in use” in the reporting country

Equation 12.1 is used to estimate carbon change in each of two pools in the Tier 1 spreadsheets (discussed below). The two pools are:

1. Solidwood products in use; and
2. Paper products in use.

Where products in use are held in the reporting country, more than one pool is used because it is believed there is a significant difference in half-life of products in use between the two pools. Annual change in these two carbon pools, when added together, gives Variable 1A. The carbon Inflow variable to these pools is from annual consumption in the reporting country of semi-finished wood products, including sawnwood, wood panels and other solidwood products or paper and paperboard. Consumption equals domestic production plus imports minus exports as shown in Equation 12.2. The rate at which solidwood or paper is lost from the pools in a given year is specified by a constant loss rate (k) and for convenience is also specified by half-life in years. A half-life is the number of years it takes to lose one-half of the material currently in the pool. Production, imports and exports of solidwood or paper are converted from cubic meters or air dry Gg to tonnes of carbon (see Table 12.4).

EQUATION 12.2
ESTIMATION OF HWP PRODUCTS PLACED IN USE ANNUALLY FROM DOMESTIC CONSUMPTION

$$Inflow_{DC} = P + SFP_{IM} - SFP_{EX}$$

Where:

$Inflow_{DC}$ = carbon in annual consumption of solidwood or paper products that came from wood harvested in the reporting country (that is, from domestic harvest), Gg C yr^{-1}

P = carbon in annual production of solidwood or paper products in the reporting country, Gg C yr^{-1}

SFP_{IM} and SFP_{EX} = imports and exports of semi-finished wood and paper products. For solidwood this includes sawnwood, panels, and other industrial roundwood. For paper products this includes paper and paperboard, Gg C yr^{-1}

In order to make estimates of change in these pools for the reporting year, the method uses data on Inflow (Product Consumption = Production + Imports – Exports) back to 1961 from the FAO database⁹. For the period prior to 1961 back to 1900, it is assumed that change in consumption prior to 1961 was the same as change in industrial roundwood production for the region the country is in. Data and parameters used are as follows:

- FAO variables used to estimate product consumption are shown in Table 12.5.
- Default factors to convert solidwood and paper from volume units to carbon units is shown in Table 12.4. Countries are encouraged to estimate factors using wood densities in Tables 4.13 and 4.14 in Chapter 4 (Forest Land).
- Regional rates of change in industrial roundwood production prior to 1961 are shown in Table 12.3.
- Half-lives for products in use are shown in Table 12.2

The rest of harvested wood material transported from the harvest site – any material except the semi-finished products noted above – is assumed to be oxidized in the year of harvest, and it is thus not transferred to the HWP pools.

Estimating Variable 2a – Annual change in carbon stock in “products in use” where wood came from harvest in the reporting country (includes exports)

General Equation 12.1 is used again to estimate carbon change in each of two pools (as for Variable 1A) in the Tier 1 spreadsheets to estimate the annual change of carbon in solidwood and paper products in use separately *where wood to make the products came from wood harvested in the reporting country (domestic harvest)*. This includes products exported and held in use in other countries. Annual change in carbon stock in solidwood products in use and paper products in use reservoirs when added together give Variable 2A. The Inflow variable to these pools is the production of all products from wood harvested in the reporting country.

This annual carbon inflow variable is estimated using Equation 12.3. If the ratio in parenthesis is <1 then the country is a net importer of industrial roundwood (IRW), wood chips and wood residues that are used to make products and less than the full amount of HWP produced (P) would have used domestically harvested IRW. If the ratio in parenthesis is >1, then this means there is a net export of IRW, chips, and residues by the country. The HWP production inflow calculated by the equation needs to be greater than HWP production (P) in this case because exported wood is used to make products in other countries. The implicit assumption being used is that the importers of the exported IRW, chips and residues will use them to produce solidwood or paper products in the same proportion as in the reporting country.

<p>EQUATION 12.3</p> <p>ESTIMATION OF HWP PRODUCTS PRODUCED ANNUALLY FROM DOMESTIC HARVEST</p> $Inflow_{DH} = P \cdot \left[\frac{IRW_H}{IRW_H + IRW_{IM} - IRW_{EX} + WCH_{IM} - WCH_{EX} + WR_{IM} - WR_{EX}} \right]$

Where:

$Inflow_{DH}$ = carbon in annual production of solidwood or paper products that came from wood harvested in the reporting country (that is, from domestic harvest), Gg C yr⁻¹

P = carbon in annual production of solidwood or paper products in the reporting country, Gg C yr⁻¹. Note that paper product production includes wood fibre and excludes non-wood fibre. An equation to estimate the wood fibre in paper products production is shown in Note 1 of Table 12.5.

IRW_H = industrial roundwood harvest in the reporting country. This is the harvest of wood to make solidwood and paper products including IRW for export. [The FAO variable is called Industrial RW Production], Gg C yr⁻¹

IRW_{IM} , IRW_{EX} = industrial roundwood imports and exports, respectively, Gg C yr⁻¹

WCH_{IM} , WCH_{EX} = wood chip imports and exports, respectively, Gg C yr⁻¹

WR_{IM} , WR_{EX} = wood residues from wood products mills imports and exports, respectively Gg C yr⁻¹

Just as for Variable 1A, estimates of annual change in the two product-in-use pools require data on total product production, and industrial roundwood production, imports and exports from the current year back to 1900. As for

⁹ See <http://faostat.fao.org/>

Variable 1A, FAO data are used back to 1961 and data back to 1900 is estimated by assuming the annual rate of change from 1900 to 1961 is the same as the annual rate of change in industrial roundwood production between 1900 and 1961.

The half-life values for product-in-use pools are assumed to be the same as for variable 1A and the carbon conversion factors are assumed to be the same. Data and parameters used are as follows:

- FAO variables used to estimate total product production and industrial roundwood production, imports and exports are shown in Table 12.5.
- Default factors to convert solidwood and paper from volume units to carbon units are shown in Table 12.4. Countries are encouraged to estimate factors using wood densities in Tables 4.13 and 4.14.
- Regional rates of change in industrial roundwood consumption prior to 1961 are shown in Table 12.3.
- Half-lives for products in use are shown in Table 12.2

Estimating Variables 1B and 2B - Annual change in carbon stock in SWDS in the reporting country; and Annual change in carbon stock in SWDS where wood came from harvest in the reporting country

Tier 1 methods are provided to estimate accumulation of HWP carbon in SWDS because a number of studies have indicated very long storage times for HWP carbon in SWDS in some cases (NCASI, 2004; Gardner *et al.*, 2002; Micales and Skog, 1997).

Variable 1B, $\Delta C_{\text{HWP SWDS}_{\text{DC}}}$, i.e., the carbon stock change of HWP from domestic consumption discarded to SWDS of the reporting country is estimated directly by the Waste Sector Tier 1 methods and spreadsheets (Volume 5, Chapter 3, Section 3.2.1.1 “Spreadsheet model” and Section 3.4). The Waste Sector guidelines explain how to use Waste Sector default data and parameters to estimate the amount of solidwood and paper carbon that accumulates in SWDS in the reporting country. A key point about the Waste Sector Tier 1 estimate is that it estimates carbon change in SWDS by identifying the portion of carbon discarded to SWDS in the current year which is judged to have originated as HWP. It is assumed that HWP carbon equates to the “garden”, “wood” and “paper” waste categories. The spreadsheet gives the amount of “long-term” stored carbon from HWP in the “HWP” sheet. The individual waste type sheets give the amount of decomposable, degradable organic carbon stored. Together these give the change in the amount of stored HWP carbon. No carbon release to the atmosphere is reported from this long-life pool in the SWDS Chapter.

To estimate Variable 2B, $\Delta C_{\text{HWP SWDS}_{\text{DH}}}$, it is necessary to estimate the portion of Variable 1B that is from domestic harvest. The Tier 1 estimate of Variable 2B is limited to estimating the carbon change in domestic SWDS only. It is judged that potential Tier 1 methods to estimate carbon change in SWDS in other countries could lead to substantial over- or under-estimates so it is best to not include an estimate of carbon change in SWDS in other countries.

The portion of Variable 1B that is from domestic harvest is approximated by multiplying by the fraction of wood carbon consumed in the country in the current year that came from domestic harvest (Equation 12.4). This ratio will be a reasonable approximation of the fraction of HWP carbon discarded to SWDS that came from domestic harvest if imported wood material has been a relatively stable fraction of all wood consumed over a period of years.

EQUATION 12.4
ESTIMATION OF ANNUAL CHANGE IN CARBON IN HWP IN DOMESTIC SWDS WHERE HWP CAME FROM DOMESTIC HARVEST

$$\Delta C_{HWP\ SWDS_{DH}} = \Delta C_{HWP\ SWDS_{DC}} \cdot \left[1 - \left(\frac{\text{Imported wood material}}{\text{Produced wood material} + \text{Imported wood material}} \right) \right]$$

$$\text{Imported wood material} = \left[\begin{array}{l} IRW_{IM} + WCH_{IM} + WR_{IM} + \text{Sawn}W_{IM} + WPan_{IM} + \\ P\&PB_{IM} + WPulp\&RecPap_{IM} \end{array} \right]$$

$$\text{Produced wood material} = IRW_H$$

Where:

$\Delta C_{HWP\ SWDS_{DH}}$ = Variable 2B = annual change in carbon in HWP in domestic SWDS where HWP came from domestic wood harvest, Gg C yr⁻¹

$\Delta C_{HWP\ SWDS_{DC}}$ = Variable 1B = annual change in carbon in HWP in SWDS in the reporting country, Gg C yr⁻¹

IRW_H and IRW_{IM} = industrial roundwood harvest in the reporting country and industrial roundwood imports, respectively, Gg C yr⁻¹

WCH_{IM} = wood chip imports, Gg C yr⁻¹

WR_{IM} = wood residues from wood products mills imports, Gg C yr⁻¹

$\text{Sawn}W_{IM}$ = sawn wood imports and, Gg C yr⁻¹

$WPan_{IM}$ = wood panel imports, Gg C yr⁻¹

$P\&PB_{IM}$ = paper and paperboard imports, Gg C yr⁻¹

$WPulp\&RecPap_{IM}$ = wood pulp and recovered paper imports, Gg C yr⁻¹

Data to be used for Equation 12.4 are FAO variables shown in Table 12.5.

Estimating Variables 3, 4, and 5 – Annual imports and exports of HWP to and from the reporting country, and annual HWP harvest

Estimates of annual imports, exports and harvest for Variables P_{IM} , P_{EX} , and H are needed for the most recent years only (see Annex Equations 12A.3 and 12A.4). No data are needed for years before the reporting period. Default import, export and harvest data may be obtained from the FAOSTAT database. The specific FAO variables that are needed are shown in Table 12.5. Factors to convert from cubic meters or air dry tonne of product are shown in Table 12.4.

H (Variable 5), total annual HWP harvest, is defined here as all wood and bark that leaves harvest sites including fuelwood. It is intended to include the total of the $L_{\text{wood-removals}}$ and L_{fuelwood} values as defined in Volume 4, Chapter 2, Equations 2.12 and 2.13. Guidelines for estimation of $L_{\text{wood-removals}}$ and L_{fuelwood} for Forest Land is in Volume 4, Chapter 4, Section 4.2.1. Default estimate for this variable is the FAO database value for industrial roundwood times a bark expansion factor plus the FAO database value for fuelwood. A default bark expansion factor is shown in Table 12.5, Note 4.

Spreadsheet MODELS: step by step guidance

The IPCC Harvested Wood Product Model: Estimating Variables 1A, 2A, 2B, 3, 4, and 5

The model may be used to estimate the HWP variables and produce Table 12.7 which may be used to fill in AFOLU Sectoral Background Table 3.10. Default parameters are already included to make Tier 1 estimates or may be changed to make Tier 2 estimates. Variable 2B may be estimated if Variable 1B has been estimated using the Waste Sector Tier 1 spreadsheets.

Here are general instructions on how to use the model spreadsheet to estimate the HWP variables and generate Table 12.7 and AFOLU Sectoral Background Table 3.10. Please see detailed instructions under the “Instructions” tab of the model spreadsheet.

1. Download country activity data (wood and paper products production, imports and exports) from the FAOSTAT web site and place in columns of one of the “Data” sheets (years 1961 to reporting year).
2. Transfer estimates of carbon stored in SWDS from the Waste Sector Tier 1 Model spreadsheet to the last two columns of the same “Data” sheet (years 1990 to reporting year as needed).
3. Type the country name in cell A1 of the Data sheet.
4. Check / change default parameters as needed that are shown in yellow in the “Parameters” sheet.
5. See results in a completed Table 12.7 on the sheet named “Result”. Results from this table may be transferred to the AFOLU Sectoral Background for Harvested Wood Products in Table 3.10.
6. See detailed results in tables, graphs, and diagrams in “Parameters” and “Result” sheets.

Waste Sector Tier 1 Model: Estimating Variable 1B

To prepare the estimate of carbon stored in HWP in the reporting country that can be inserted in the model spreadsheet, see Volume 5, Chapter 3, Section 3.2.1.1 “Spreadsheet model” and Section 3.4. In Section 3.2.1.1 there is a link to the spreadsheet model. Details on how to use the model can be found in the “Instructions” spreadsheet.

12.2.1.2 TIER 2: USING COUNTRY DATA

Tier 2 uses country-specific data to improve estimates of annual carbon change in “products in use” and in SWDS. Improved data could include country data on:

- annual production, imports and exports by product types and wood species;
- factors to convert activity data to carbon;
- rate at which products are discarded from use (half-life). If information indicates various wood products have different half-lives (e.g., sawnwood versus panels) then Equation 12.1 can be used to track carbon change for separate pools and not just solidwood and paper products;
- Waste Sector annual activity data and parameters for Waste Sector Tier 1 method including DOCf - the fraction of wood and paper that decays in SWDS.

12.2.1.3 TIER 3: COUNTRY-SPECIFIC METHODS

Countries may wish to develop more complex, detailed country-specific methods to estimate Variables 1A, 1B, 3, 4, and 5. Typically these will be more complex models and will be focused on a single approach (Flugsrud *et al.*, 2001). Tier 3 models could also use decay functions other than first order decay – e.g., linear decay. It is more difficult to develop Tier 3 methods for Variables 2A and 2B which require data on the lifecycle of exported HWP for countries where most of its products are exported. Estimates for Variables 2A and 2B could be improved by obtaining decay information for countries where most products are exported.

METHOD A – ESTIMATE ANNUAL CHANGE IN INVENTORIES (STOCK METHODS)

Inventories of HWP in use or HWP in waste disposal sites, at two or more points in time, could be used to estimate the annual change in carbon stock – Variables 1A and 1B. 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 meter of floor space times the total floor space for relevant building types that use wood taking into account when the buildings were constructed and changes in wood use per square meter over time. Annual change in carbon stock could be estimated by noting the change between inventories estimated at different points in time. Examples of such inventories are reported in Gjesdal *et al.*, 1996 (for Norway); Pingoud *et al.*, 1996, 2001 (for Finland); and Hashimoto and Moriguchi, 2004 (for Japan). In this case, 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 (Tier 1 and Tier 2).

METHOD B – TRACK INPUT AND OUTPUT FLOWS USING DETAILED COUNTRY DATA AND DECAY PATTERNS

Use detailed country data beginning with a number of decades in the past and estimate each year, up to the present time, including (i) additions to pools of HWP in use, (ii) discards from use, (iii) additions to pools of HWP in SWDS, and (iv) decay from SWDS. Estimates for SWDS may use survey estimates of the amount of HWP placed in SWDS each year, rather than the amount of HWP going out of use and the portion going to SWDS. This method is also based on flux data and lifetime analysis just as for Tier 1 and Tier 2 methods, but the rate at which products are discarded from use may differ from the first-order decay assumption used in Tiers 1 and 2.

METHOD C – FLUX DATA METHOD WITH DIRECT OUTPUT ESTIMATES

Instead of the flux-data method with lifetime analysis, a flux-data method using direct estimates of the output of the HWP pool could also be used in principle. Examples would be information on carbon wood burned for energy each year or carbon contained in buildings demolished in a year. The advantage of this method is that long historical input data for the HWP pool are no longer required. On the other hand, the method would have a serious disadvantage - the outflow and oxidation data of HWP are much more uncertain than the input data and are likely to be underestimated, as a result a significant part of decay would not be identified and net additions to carbon held in HWP would be overestimated (see Flugsrud *et al.*, 2001; Pingoud *et al.*, 2003).

METHOD D – COMBINE METHODS A, B AND C

An example of a combined method that uses the most accurate information available about different products is: 1) to use changes in inventory to estimate carbon changes in buildings and furniture; and 2) to use input and output flows to estimate changes of carbon in paper products (see example for Norway, Flugsrud *et al.*, 2001; and for Japan, Hashimoto and Moriguchi, 2004). Or alternatively, the inherited carbon stock of HWP in some recent year could be estimated by direct inventory, Method A – instead of estimating it from historical consumption rates as in Method B and Tier 1. Then taking this carbon stock as initial value, carbon stock and stock changes in subsequent years can be estimated by using decay rates from Method B. HWP inventory data could also be used to help determine the half-life parameters in the first-order decay method. Instead of using default half-lives these parameters could be chosen to obtain the best fit of the first-order decay method (or other decay function) with the real inventory data (see e.g., Pingoud *et al.*, 2001).

12.2.1.4 ESTIMATING CARBON RELEASE TO THE ATMOSPHERE FROM THE HWP VARIABLES

Annual carbon release to the atmosphere from HWP may be estimated for two cases using the five HWP variables as follows:

<p>EQUATION 12.5 ESTIMATION OF CARBON RELEASE USING HWP VARIABLES</p> <p>For annual carbon release from wood stocks in the reporting country</p> $(A) \quad \uparrow C_{HWPDC} = H + P_{IM} - P_{EX} - \Delta C_{HWP IU DC} - \Delta C_{HWP SWDS DC}$ <p>For annual carbon release from wood harvested in the reporting country</p> $(B) \quad \uparrow C_{HWP DH} = H - \Delta C_{HWP IU DH} - \Delta C_{HWP SWDS DH}$
--

The carbon release variables are defined in Section 12.1. These equations may be used to compute CO₂ release to report in Table 12.7 and AFOLU background reporting Table 3.10 as described in Section 12.7. If estimates of carbon release are available these equations may be solved for the total stock change amounts ($\Delta C_{HWP IU DC} + \Delta C_{HWP SWDS DC}$ or $\Delta C_{HWP IU DH} - \Delta C_{HWP SWDS DH}$) and the resulting equation could be used to calculate these total stock changes using the carbon release variables.

12.2.1.5 ESTIMATING CARBON RELEASED TO THE ATMOSPHERE IN THE FORM OF CO₂

Carbon that is released in the form of CO₂ may be calculated if the methane emitted from HWP in landfills is known as follows:

- $\uparrow C_{\text{HWP DC CO}_2} = \uparrow C_{\text{HWP DC}} - E_{\text{W CH}_4}$. Annual release of carbon to the atmosphere as CO₂ from HWP accounting for carbon emitted as methane emitted from HWP in SWDS. $E_{\text{W CH}_4}$ is the carbon in CH₄ emitted from the decomposition of HWP in SWDS in the year concerned. It can be estimated using the methodology in Chapter 3, Section 3.2 of Volume 5. The IPCC Waste Model spreadsheet estimates this automatically for the “Waste Composition” option (it is the sum of the carbon in CH₄ emitted in the inventory year from wood, paper and garden waste on the HWP sheet).
- $\uparrow C_{\text{HWP DH CO}_2} = \uparrow C_{\text{HWP DH}} - E_{\text{EX DOM CH}_4}$. Annual release of carbon to the atmosphere as CO₂ from HWP that came from wood harvested in the reporting country, accounting for carbon emitted as methane emitted from HWP in SWDS. $E_{\text{EX DOM CH}_4}$ is the carbon in CH₄ emitted from SWDS (as carbon) from domestic harvest whether in country or exported. It can be estimated using the methodology in the Chapter 3, Section 3.2 of Volume 5. To use the IPCC Waste Model spreadsheet, the waste inputs into the SWDS would need to be adjusted to account only the HWP from domestic harvest including domestically harvested HWP exported and put into SWDS in other countries.

12.2.2 Choice of emission factors

Tier 1 and Tier 2 use the assumption that HWP are discarded from use at a constant rate, k , applied to the carbon present in the pool. This constant rate of discard can be specified by an associated half-life in years for products in the pool. The half-life is the number of years until half of the amount goes out of use. Default half-life values, and associated discard rates (k) are provided in Table 12.2 for solidwood products and paper products.

	Solidwood products	Paper products
Half-life (years)	30	2
Decay rate k ($k = \ln(2)/$ half-life)	0.023	0.347

Source: Based on values used in previous studies summarized in HWP Appendix Table 3a.1.3 of the IPCC report on *GPG-LULUCF* (IPCC, 2003). Table 3a.1.3 gives values for more product categories.

12.2.3 Choice of activity data

ACTIVITY DATA FOR TIER 1 VARIABLES

FAO datasets needed to estimate production, imports and exports of solidwood and paper products needed to estimate HWP Variables 1A, 2A, P_{IM} , P_{EX} , and H, for 1961 to the present, including default conversion factors, are provided in Tables 12.4 and 12.5. In order to include current year carbon release from HWP placed in use many decades ago, estimates are needed for HWP data prior to 1961. In order to estimate total harvest (Variable H) including bark, multiply the FAO estimate of harvest for products (Table 12.5) by a default bark expansion factor of 1.13 (Jenkins *et al.*, 2003).

In order to estimate the variables in Table 12.5 prior to 1961, they are extrapolated backward to 1900 using Equation 12.6. Equation 12.6 uses a rate of change variable U to estimate values prior to 1961.¹⁰ The rate of

¹⁰ Countries formed after 1961 may not have data in the FAO database back to 1961. A way to extend more recent production, import and export data back to 1961 is to look at data back to 1961 for the “old” country that the “new”

change taken to approximate change in production, imports and exports prior to 1961 is the rate of change in industrial roundwood production. Default values for U are shown in Table 12.3 for major world regions.

EQUATION 12.6
EQUATION TO ESTIMATE PRODUCTION, IMPORTS OR EXPORT VARIABLES IN TABLE 12.5 FOR YEARS BEFORE 1961

$$V_t = V_{1961} \cdot e^{[U \cdot (t-1961)]}$$

Where:

V_t = annual production, imports or exports for a solidwood or paper product for year t , Gg C yr⁻¹

t = year

V_{1961} = annual production, imports or exports for a solidwood or paper product for the year 1961, Gg C yr⁻¹

U = estimated continuous rate of change in industrial roundwood consumption for the region that includes the reporting county between 1900 and 1961 (see Table 12.3), yr⁻¹

TABLE 12.3 ESTIMATED ANNUAL RATES OF INCREASE FOR INDUSTRIAL ROUNDWOOD PRODUCTION (HARVEST) BY WORLD REGION FOR THE PERIOD 1900 TO 1961	
Region	Annual Rate of Increase U
World total	0.0148
Europe	0.0151
USSR	0.0160
North America	0.0143
Latin America	0.0220
Africa	0.0287
Asia	0.0217
Oceania	0.0231

Source: See Table 3a.1.2 in HWP Appendix of *GPG-LULUCF* (IPCC, 2003).

Note: For each region the average rate of change over the period 1900 to 1961 is formed by combining a documented actual rate of change from 1950 to 1961 and an estimated rate of change from 1900 to 1950. The estimated rate from 1900 to 1950 is formed by adding together the annual percent change of population growth from 1900 to 1950 and one half the annual percent change in industrial roundwood harvest per capita for the period 1950 to 1975.

country was a part of (e.g., Czechoslovakia for the Czech Republic and Slovakia) and extend “new” country variables back to 1961 using the rate of change in each variable for the “old” country back to 1961.

TABLE 12.4
DEFAULT FACTORS TO CONVERT FROM PRODUCT UNITS TO CARBON

	Roundwood, industrial roundwood, sawnwood, other industrial roundwood, pulpwood, chips, particles, wood fuel, wood residues		Charcoal	Average for wood panels	Paper and paperboard, pulp, recovered fibre pulp, recovered paper
1. Density (oven-dry tonnes per m ³ of solidwood product or oven dry per air dry tonne of pulp or paper product)	Temperate species	Tropical species			
	0.45 oven-dry tonne m ⁻³	0.59 oven-dry tonne m ⁻³	0.9 oven-dry tonne (air dry tonne) ⁻¹	0.628 oven-dry tonne m ⁻³	0.9 oven-dry tonne (air dry tonne) ⁻¹
2. Carbon fraction (tonnes carbon per oven dry tonne of wood material)	0.5	0.5	0.85	0.468	0.5
3. Carbon factor (tonnes carbon per m ³ of product or per air dry tonne of product) (row 1) x (row 2)	A = 0.225 tonne C m ⁻³	A = 0.295 tonne C m ⁻³	B = 0.765 tonne C (air dry tonne) ⁻¹	C = 0.294 tonne C m ⁻³	D = 0.450 tonne C (air-dry tonne) ⁻¹
Source: Temperate species density: Average from Table 4.14, Volume 4, Chapter 4; Tropical species density: Average from Table 4.13, Volume 4, Chapter 4.					

TABLE 12.5 UN FAO ACTIVITY DATA NEEDED FOR TIER 1 VARIABLES, AND DEFAULT CONVERSION FACTORS			
Aggregate variable	FAO database variables needed to compute aggregate variable (m ³ for wood Gg for pulp and paper)	Time period (Inv. Yr = Inventory reporting year)	Carbon factor (Gg carbon per m ³ for wood products or per Gg for paper & pulp) (see Table 12.4 for values)
Variable 1A – Consumption of solidwood or paper products			
Production of solidwood products	Other industrial roundwood	1961- Inv. yr.	A
	Sawnwood	1961- Inv. yr.	A
	Wood panels	1961- Inv. yr.	C
Imports and exports of solidwood products	Other industrial roundwood	1961 - 1989	A
	Sawnwood	1961- Inv. yr.	A
	Wood panels	1961- Inv. yr.	C
Production of paper and paperboard from wood [see note 1 below]	Paper and paperboard – production (P _{PAPER})	1961- Inv. yr.	D
	Other fibre pulp – production (OFP _P), imports (OFP _{IM}), and exports (OFP _{EX})	1961- Inv. yr.	D
Imports and exports of paper and paperboard	Paper and paperboard	1961- Inv. yr.	D
Variable 2A – Production of solidwood and paper products from wood harvested in the reporting country			
Production of solidwood products from domestic harvest [see note 2 below]	Production of solidwood products as for Variable 1A above (P _{SW})	1961- Inv. yr.	A
	Industrial roundwood harvest (IRW _H), imports (IRW _{IM}), exports (IRW _{EX})	1961- Inv. yr.	A
	Chips and particles imports (CP _{IM}), and exports (CP _{EX})	1961-Inv. yr.	A
Production of paper and paperboard from domestic harvest [see note 3 below]	Production of paper and paperboard products from as for Variable 1A above (P _{PAPER})	1961- Inv. yr.	D
	Industrial roundwood harvest (IRW _H), imports (IRW _{IM}), exports (IRW _{EX}) – same as above	1961- Inv. yr.	A
	Other fibre pulp – production (OFP _P), imports (OFP _{IM}), and exports (OFP _{EX}) – same as above	1961- Inv. yr.	D
	Exports of wood pulp, recovered paper and recovered paper pulp (PP _{EXPORTS})	1961- Inv. yr.	D
Variables 3 and 4 – Imports and exports of all solidwood and paper products and wood fiber			
Imports and exports	Roundwood (includes fuelwood)	1961- Inv. yr.	A
	Chips and particles	1961- Inv. yr.	A
	Wood residue	1961- Inv. yr.	A
	Charcoal	1961- Inv. yr.	B
	Sawnwood	1961- Inv. yr.	A
	Wood panels	1961- Inv. yr.	D
	Wood pulp	1961- Inv. yr.	D
	Recovered paper	1961- Inv. yr.	D
Variable 5 – Harvest for products			
Harvest for products [see note 4 below]	Industrial roundwood (IRW _H), fuelwood	1961- Inv. yr.	A
Notes:			
1. Production of paper and paperboard from wood = P _{PAPER} - (OFP _P + OFP _{IM} - OFP _{EX})			
2. Production of solidwood products from domestic harvest = P _{SW} * IRW _H / (IRW _H + IRW _{IM} - IRW _{EX} + CP _{IM} - CP _{EX})			
3. Production of paper products from domestic harvest = (P _{PAPER} +PP _{EXPORTS} - (OFP _P + OFP _{IM} - OFP _{EX})) * IRW _H / (IRW _H + IRW _{IM} - IRW _{EX} + CP _{IM} - CP _{EX})			
4. Variable H = IRW _H * BF + Fuelwood, BF (bark factor) default value = 1.13 ; Softwoods (1.11), Hardwoods (1.15) (Jenkins <i>et al.</i> , 2003)			
Source of variables and data: FAOSTAT Forestry database (FAO 2005).			

12.3 UNCERTAINTY ASSESSMENT

Uncertainty in the five HWP variables using Tier 1 methods arises in two ways:

1. More accurate country data may differ from the default data in Tables 12.2, 12.3, 12.4 and 12.5; and
2. The estimation method is a simplification of real world processes.

The uncertainty associated with using default product production and trade (the activity data) and parameters are provided in Table 12.6. The uncertainty estimates are based on published studies and expert judgment. If national data and parameters are used, uncertainties should be evaluated consistent with the guidance in Volume 1, Chapter 3.

Some FAO activity data – such as Other Industrial Roundwood Production – needed in calculation of Variables 1A and 2A may have high uncertainty.

An estimate of the effect of the uncertainty in the default data on each of the five HWP variables could be obtained by using the error propagation approach or the Monte Carlo simulation approach as discussed in Volume 1, Chapter 3.

There is also uncertainty in the estimates because the calculations simplify a more complex real world process of additions to and discards from “products in use” and SWDS. One simplification for Tier 1 and Tier 2 methods is the tracking of additions and discards only in the form of semi-finished products (solidwood and paper). Ideally it would be possible to track additions and discards of carbon in end-uses (such as buildings, furniture, books, etc.). The end-use pools (such as buildings, books, etc.) are assumed to be included in these semi-finished product pools. Additional simplifications include the assumptions that there are two stocks of products in use (solidwood and paper) and that discards are a constant fraction of the contents of the product pools in use over time. If country information is available to indicate more product stock groups with differing discard patterns, including variation in discards over time, then a Tier 3 method is recommended allowing for a different discard pattern.

Given the potential differences between the default data and actual country data estimates for Variables 1A, 1B, 2A and 2B estimates using Tier 1 methods could have uncertainties of $\pm 50\%$ or more.

There will be higher uncertainties associated with estimation of Variables 2A and 2B than Variables 1A and 1B because of the practical difficulties to estimate changes in carbon pools in countries where HWP are exported. The simplified assumption for Variable 2A (carbon stock changes in HWP pools from domestic harvest) is that the lifecycle of harvested wood in the importing countries is similar to that for domestic use. The simplified assumption for Variable 2B is that there is no significant storage of exported products in SWDS after their use in other countries. The uncertainty in Variables 2A and 2B will be greater for countries that have higher levels of exports and/or imports. To reduce the uncertainties concerning Variable 2B a conservative estimate is made which includes only carbon stock changes in domestic SWDS.

Uncertainties in Variables P_{IM} , P_{EX} , and H are associated with the accuracy of this default country data and their conversion factors into amounts of carbon – not with such modeling uncertainties as in case of Variables 1 and 2.

Amounts of wood-based materials in international trade of *final products* (e.g., prefabricated houses, furniture, books, etc.) are not included in FAO statistics and in order to avoid double-counting those could not be used in the Tiers 1 and 2 methods that are focused on *semi-finished products* (e.g., lumber and paper).

For a discussion of the uncertainty associated with the Waste Sector Tier 1 method see Volume 5, Chapter 2.

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 Tier 2, including use of country data, and use of validation steps suggested in the next section on quality control and quality assurance.

TABLE 12.6
UNCERTAINTY ASSOCIATED WITH ACTIVITY DATA AND PARAMETERS (EMISSION FACTORS) FOR THE TIER 1 METHOD TO ESTIMATE THE FIVE ANNUAL HWP VARIABLES

Description of data or parameter	Data or parameter	Values	Uncertainty range – possible difference from default for individual countries
Roundwood harvest (wood harvested and removed from sites for products including fuelwood)	H in Table 12.5	FAO database	- Country-specific for FAO data
HWP production, imports and exports – FAO data	See Table 12.5	FAO database	<ul style="list-style-type: none"> - Country-specific for FAO data - Production and trade – for countries with systematic census or surveys, $\pm 15\%$ since 1961 - Production and trade – for countries without systematic census or survey, $\pm 50\%$ since 1961
Product volume to product weight factors	See Table 12.4	See Table 12.4	~ $\pm 25\%$
Oven dry product weight to carbon weight	See Table 12.4	0.5	~ $\pm 10\%$
Growth rate of production, imports and exports prior to first year of FAO data	U (in Table 12.3)	See Table 12.3	<ul style="list-style-type: none"> - Rate of increase in production prior to 1961, $\pm 15\%$ for a region, larger for country within a region. - Rate of increase in trade prior to 1961, $\pm 50\%$ for a region, larger for country within a region.
Decay (or discard) rate for solidwood and paper from the “products in use” pool	K	See Table 12.2	<ul style="list-style-type: none"> - For estimating Variable 1A, uncertainty in half-life ~ $\pm 50\%$, $k = \ln(2)/(\text{half-life})$; (preliminary – further study needed, half-life likely to vary over time) - For estimating Variable 1B, uncertainty in half-life of products in use would be greater given the extra uncertainty of discard rates for exported products on other countries.

12.4 QUALITY ASSURANCE/ QUALITY CONTROL

This section suggests steps to improve estimates of the five HWP variables including checking and revising data for the Tier 1 method and improvements for Tier 2 estimates.

1. Check that country data in the FAO database (Table 12.5) agree with best available country sources of data on production and trade, or use country data in place of FAO data. (this can improve **Variables 1 through 5**).
2. Check for country sources for densities of wood and paper products to revise the values in Table 12.4. Review wood density information provided in the IPCC Emission Factor Database (EFDB) and in relevant Tables 4.13 and 4.14 in Chapter 4 (Forest Land) of these guidelines (this can improve **Variables 1 through 5**).
3. Use the following steps to validate the estimate of **Variable 1A** - Annual change in carbon stock in HWP products in use in the reporting country – by comparing two estimates of amounts of wood and paper deposited in SWDS.
 - (i) Use the Waste Sector Tier 1 method and Excel worksheets (or other Waste Sector methods and data) to estimate of the amount of solidwood and paper products deposited in SWDS for several years (e.g., 1961 to the present).
 - (ii) Prepare a second estimate of the amount of solidwood and paper products deposited in SWDS in the following way:
 - a. Use the HWP Tier 1 Excel worksheets to estimate the amount of solidwood and paper products in use that are discarded each year for 1961 to the present.
 - b. Reduce the amount of paper discards each year by the amount of paper that is recovered for recycling each year using FAO data on amount of recovered paper produced.
 - c. Obtain an estimate of the portion of discarded wood and paper (excluding recovered amounts) that is sent to SWDS. This would likely be the fraction not burned.
 - d. Estimate the amount of solidwood and paper deposited in SWDS each year by multiply the discard amount (after recovery for recycling) by the fraction that goes to SWDS.
 - (iii) Compare the yearly deposit estimates from the Waste Sector Tier 1 method and the method based on HWP Tier 1 discard data.
 - (iv) To reconcile differences in estimates, it is recommended that changes be made to HWP Tier 1 parameters so that the SWDS deposit estimates based on HWP numbers match the SWDS deposit from the Waste Sector estimates. HWP parameters to change include: 1) half-life for solidwood and paper products in use (Table 12.2), or 2) factors to convert HWP product data to carbon units (Table 12.4).
4. An additional step to help verify **Variable 1A** - annual change in HWP carbon in products in use - would be to use Equation 12.2 to make separate estimates of annual change in solidwood carbon held in buildings, such as residential buildings and separately for all other uses. A different half-life would be used for solidwood products in residential buildings. Compare this estimate of carbon change in residential buildings to a second estimate made in the following way. Compute the total carbon held in residential buildings at two points in time. For each point in time multiply the number of residential buildings, times average square meters per building, times cubic meters of solidwood use per square meter of house, times carbon per unit of solidwood. Take the difference in carbon in residential buildings between the two points in time and divide by the number of years to estimate carbon change per year. To reconcile the two estimates of annual change in solidwood carbon, adjust the half-life assumed for solidwood use in residential buildings.

12.5 COMPLETENESS

Tiers 1 and 2 methods, for estimating **Variables 1A and 1B** (annual change in HWP carbon in products in use and in SWDS, respectively, in the reporting country), include carbon additions in the form of all semi-finished wood and paper products that are consumed. By doing so, they include carbon in any secondary wood products made in the country from those semi-finished products. If the country is a notable exporter or importer of secondary wood products, such as furniture or wooden crafts, then methods may need to be adapted to adjust HWP consumption to exclude exports of secondary products and/ or include imports of secondary products.

Tiers 1 and 2 methods to estimate **Variables 2A and 2B** (annual change in HWP carbon in products in use from domestic harvest) are likely to include all semi-finished and secondary product carbon from domestic harvest (sawnwood, panels and paper) unless some wood is used directly for secondary products (e.g., furniture) and not included first in a semi-finished product amounts reported in the FAO or country data (e.g. sawnwood). If some sawnwood is used directly to make furniture (and not included in FAO country data on sawnwood) then the Tiers 1 and 2 methods would underestimate the inflow of carbon to products in use and products in SWDS.

The methods provided in these guidelines do not include estimates of HWP carbon storage associated with CO₂ that is captured after biomass burning and held as part of a solid chemical or as a gas.

12.6 REPORTING AND DOCUMENTATION

It is *good practice* to document and archive all information used to produce national estimates of stock change. This includes wood and paper production and trade data, and parameters used. Changes in parameters to make estimates of stock change from one year to the next should be documented. The national inventory report should contain summaries of methods used and references to source data so that the steps used in making the estimates can be retraced.

12.7 REPORTING TABLES AND WORKSHEETS

To report the *HWP Contribution* an approach should be selected. It is *good practice* to report the following in the AFOLU sectoral background Table 3.10 (see Table 12.7 and Table A12.1):

- The HWP Contribution
- The approach used to estimate the HWP Contribution. If the HWP Contribution is assumed to be zero (Section 12.2.1) then the reason for this should be stated instead of the approach chosen,
- The amounts harvested, imported and exported should be given in Table 12.7 even if the HWP Contribution is assumed to be zero.
- CO₂ release to the atmosphere from HWP --- $(44/12 * \uparrow C_{\text{HWP DC}})$ and/or $(44/12 * \uparrow C_{\text{HWP DH}})$ as appropriate.
- Any other HWP variables used to estimate the reported HWP Contribution should also be given.

The inventory compiler is encouraged to report additional information that would increase the comparability and transparency of the report. This could include:

- Any of the remaining HWP variables defined in Table 12.1 not covered above.
- Other additional items may also be reported for specific approaches if an inventory compiler believes this would add to the transparency of the inventory.

If the Simple Decay approach is used for reporting, the compiler should indicate in the Documentation Box of Background Table 3.10 (Table 12.7) which of the following options is used: 1a) CO₂ equivalent of carbon in annual harvest of HWP is retained with (deducted from) the net emission/ removals estimate reported separately for each land area [e.g., $(-44/12 * H)$ for Forest Land], and 1b) *HWP Contribution* entered in Table 3.10 equals the CO₂ release from harvest in the country $(44/12 * \uparrow C_{\text{HWP DH}})$; OR 2) *HWP Contribution* in Table 3.10 equals $[-44/12 * (H - \uparrow C_{\text{HWP DH}})]$.

TABLE 12.7 SECTORAL BACKGROUND DATA FOR AFOLU
ANNUAL CARBON *HWP CONTRIBUTION* TO TOTAL AFOLU CO₂ REMOVALS AND EMISSIONS AND BACKGROUND INFORMATION

	Variable number										
	1A	1B	2A	2B	3	4	5	6	7	8	9
Inventory year	Annual change in stock of HWP in use from consumption	Annual change in stock of HWP in SWDS from consumption	Annual change in stock of HWP in use produced from domestic harvest	Annual change in stock of HWP in SWDS produced from domestic harvest	Annual imports of wood, and paper products + wood fuel, pulp, recovered paper, roundwood/ chips	Annual exports of wood, and paper products + wood fuel, pulp, recovered paper, roundwood/ chips	Annual domestic harvest	Annual release of carbon to the atmosphere from HWP consumption (from fuelwood & products in use and products in SWDS)	Annual release of carbon to the atmosphere from HWP (including fuelwood) where wood came from domestic harvest (from products in use and products in SWDS)	<i>HWP Contribution</i> to AFOLU CO ₂ emissions/ removals	Approach used to estimate <i>HWP Contribution</i> ¹
	$\Delta C_{HWP IU DC}$	$\Delta C_{HWP SWDS DC}$	$\Delta C_{HWP IU DH}$	$\Delta C_{HWP SWDS DH}$	P_{IM}	P_{EX}	H	$\uparrow C_{HWP DC}$	$\uparrow C_{HWP DH}$		
	Gg C yr ⁻¹									Gg CO ₂ yr ⁻¹	
1990											
.....											
Report Col 6 or 7 as needed for the approach used. Col 6 or 7 may be computed using Cols 1 through 5 or by a Tier 3 method. Always report Cols 3, 4, and 5. Report Cols 1A, 1B, 2A, 2B if they are used. The <i>HWP Contribution</i> and approach should be reported in Cols 8 and 9 together with a description of the approach chosen and main assumptions in the Documentation Box. Additional variables calculated and used should be reported to enhance the transparency of the results (e.g., CH ₄ from SWDS if this was used). Add additional columns if needed.											
Note: $\uparrow C_{HWP DC} = H + P_{IM} - P_{EX} - \Delta C_{HWP IU DC} - \Delta C_{HWP SWDS DC}$ AND $\uparrow C_{HWP DH} = H - \Delta C_{HWP IU DH} - \Delta C_{HWP SWDS DH}$											
Documentation Box:											

Annex 12.A.1 Some Approaches

This annex provides descriptions of some approaches for HWP. The descriptions included here are based on the original descriptions of the approaches (Brown *et al.*, 1998; and Ford-Robertson, 2003) and are provided here as additional background information for inventory compilers. The inclusion of an approach here does not imply any endorsement of that approach or any guidance on what approach to use. The special inventory terms "emissions", "removals" and "sinks" are used without any judgment that they are correctly used given their special definitions.

STOCK-CHANGE APPROACH

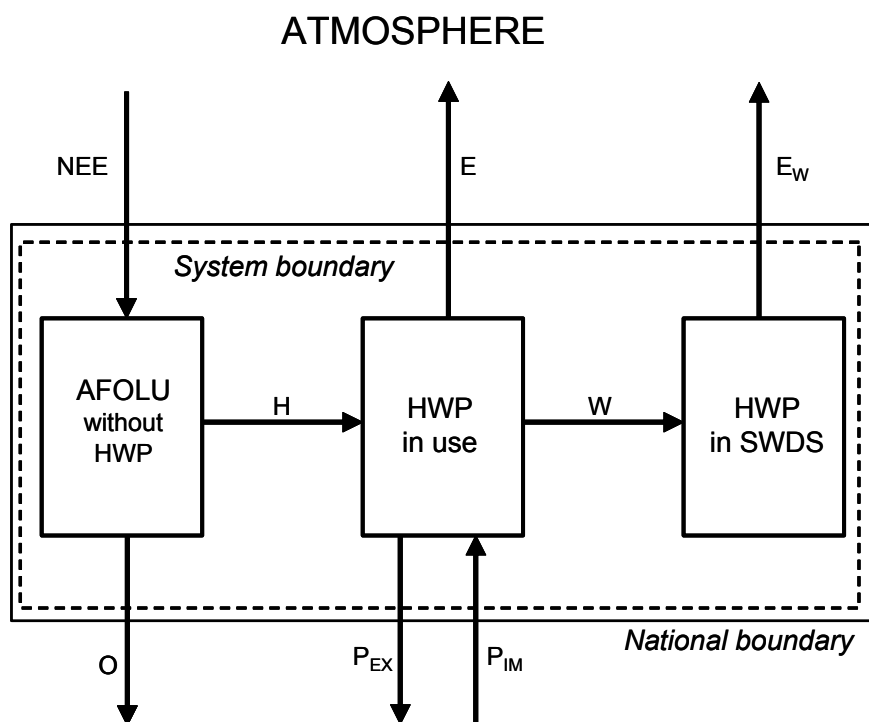


Figure 12.A.1 System boundary of the Stock-Change approach.

Note: NEE = net ecosystem exchange of carbon, E = carbon release to the atmosphere from HWP in use, E_w = carbon release to the atmosphere from HWP in SWDS, H = carbon transfer in the form of harvested wood biomass transported from harvest sites, W = carbon transfer in the form of wood waste into SWDS, P_{EX} = carbon transfer in the form of HWP exports, P_{IM} = carbon transfer in the form of HWP imports, O = possible other cross-border carbon transfers from rest of AFOLU (assumed zero here).

The Stock-Change Approach (SCA) estimates changes in wood carbon stocks in the forest pool (and other wood producing lands) and wood-products pool in the reporting country. Changes in carbon stock in forests and other wood producing land categories are reported by the country in which the wood is grown, referred to as the producing country. Changes in the products pool are reported by the country where the products are used, referred to as the consuming country. Because the stock changes actually occur in the reporting country the report indicates when and where the stock changes occur.

The system boundary of the Stock-Change Approach and the carbon pools under consideration are shown in Figure 12A.1. In the Stock-Change Approach all the national annual C-stock changes in biomass pools of the AFOLU Sector are summed up and the national carbon dioxide emissions are approximated using Equation 12A.1:

EQUATION 12A.1**EMISSIONS FROM AFOLU BY THE STOCK-CHANGE APPROACH**

$$\begin{aligned} \text{Annual CO}_2 \text{ emissions from AFOLU} &= -44/12 \bullet [\Delta(\text{AFOLU without HWP}) + \Delta(\text{HWP in use}) + \\ &\quad \Delta(\text{HWP in SWDS})] \\ &= -44/12 \bullet [\Delta(\text{AFOLU without HWP}) + \Delta C_{\text{HWP IU}_{\text{DC}}} + \Delta C_{\text{HWP SWDS}_{\text{DC}}}] \\ &\quad \text{or} \\ &= -44/12 \bullet [\Delta(\text{AFOLU without HWP}) + \mathbf{H} + \mathbf{P}_{\text{IM}} - \mathbf{P}_{\text{EX}} - \uparrow C_{\text{HWP DC}}] \end{aligned}$$

Where:

Δ means annual change in carbon stock of the pool within the brackets. Note that the variables $\Delta C_{\text{HWP IU}_{\text{DC}}}$ and $\Delta C_{\text{HWP SWDS}_{\text{DC}}}$ are defined in Table 12.1.

Figure 12A.2 may be used to express Equations 12A.3 and 12A.4 using either carbon stock change variables ($\Delta C_{\text{HWP IU}_{\text{DC}}} + \Delta C_{\text{HWP SWDS}_{\text{DC}}}$) or carbon release variables and carbon transfer variables ($\uparrow C_{\text{HWP DC}}$, \mathbf{H} , \mathbf{P}_{IM} , \mathbf{P}_{EX}).

Where:

\mathbf{H} = Harvest of wood to be used for HWP (including fuelwood)

$\uparrow C_{\text{HWP DC}} = \mathbf{E} + \mathbf{E}_W$

\mathbf{E} = carbon release to the atmosphere from HWP in use

\mathbf{E}_W = carbon release to the atmosphere from HWP in SWDS. (Note that here the carbon release is not considered as a sum of C-stock changes as in the Stock-Change and Production approaches. HWP in use include all harvested wood products consumed in the reporting country and HWP in SWDS include all wood-based waste disposed into the solid waste disposal sites (including both open dumps and landfill sites) of the reporting country).

\mathbf{P}_{EX} = carbon transfer in the form of exported wood-based biomass

\mathbf{P}_{IM} = carbon transfer in the form of imported wood-based biomass

As the quantity $-44/12 \bullet \Delta(\text{AFOLU without HWP})$ is already reported in the rest of AFOLU, the *HWP Contribution* to be reported in the HWP module is given by Equation 12A.2:

EQUATION 12A.2**STOCK-CHANGE APPROACH: HWP CONTRIBUTION**

$$\begin{aligned} \text{HWP Contribution to AFOLU Net CO}_2 \text{ emissions}_{\text{SCA}} &= -44/12 \bullet [\Delta C_{\text{HWP IU}_{\text{DC}}} + \Delta C_{\text{HWP SWDS}_{\text{DC}}}] \\ &\quad \text{or} \\ \text{HWP Contribution to AFOLU Net CO}_2 \text{ emissions}_{\text{SCA}} &= -44/12 \bullet [\mathbf{H} + \mathbf{P}_{\text{IM}} - \mathbf{P}_{\text{EX}} - \uparrow C_{\text{HWP DC}}] \end{aligned}$$

In the specific case when stock change of carbon in the HWP pools is zero, *HWP Contribution* is reported as zero (Equation 12A.2).

ATMOSPHERIC FLOW APPROACH

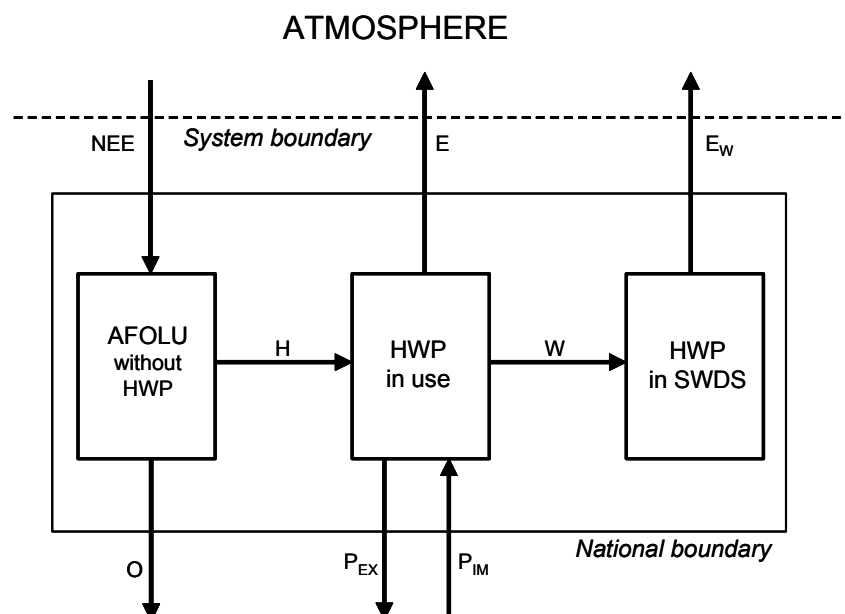


Figure 12.A.2 System boundary of the Atmospheric Flow Approach.

Note: NEE = net ecosystem exchange of carbon, E = carbon release to the atmosphere from HWP in use, E_w = carbon release to the atmosphere from HWP in SWDS, H = carbon transfer in the form of harvested wood biomass transported from harvest sites, W = carbon transfer of wood waste into SWDS, P_{EX} = carbon transfer in the form of HWP exports, P_{IM} = carbon transfer in the form of HWP imports, O = possible other cross-border carbon transfers from rest of AFOLU (assumed zero here).

The Atmospheric Flow Approach (AFA) estimates fluxes of carbon to/from the atmosphere for the forest pool (and other wood producing lands) and wood products pool within national boundaries, and reports where and when these emissions and removals occur. A country includes in its estimate of emissions/ removals the gross removals of carbon from the atmosphere due to tree biomass growth in forests and other wood producing land categories (net of decay within forests), and the carbon release to the atmosphere from oxidation of harvested wood products that are consumed in their country. The carbon release to the atmosphere from harvested wood products includes carbon release from imports to the reporting country.

The system boundary of the Atmospheric Flow Approach and the carbon pools under consideration are shown in Figure 12A.2. The pools are the same as in the Stock-Change Approach. The difference is that the Atmospheric Flow Approach estimates the atmospheric carbon exchange of the AFOLU Sector of the reporting country rather than stock changes within the country. The national carbon dioxide emissions are given by Equation 12A.3:

EQUATION 12A.3

EMISSIONS FROM AFOLU AS BY THE ATMOSPHERIC FLOW APPROACH

$$\begin{aligned} \text{CO}_2 \text{ emissions from AFOLU} &= -44/12 \bullet (\text{NEE} - E - E_w) = -44/12 \bullet (\text{NEE} - \uparrow C_{\text{HWP DC}}) \\ &= -44/12 \bullet [\Delta(\text{AFOLU without HWP}) + \Delta C_{\text{HWP IU}_{\text{DC}}} + \Delta C_{\text{HWP SWDS}_{\text{DC}}} + P_{\text{EX}} - P_{\text{IM}}] \\ &\text{or} \\ &= -44/12 \bullet [\Delta(\text{AFOLU without HWP}) + H - \uparrow C_{\text{HWP DC}}] \end{aligned}$$

Figure 12A.2 may be used to express Equations 12A.3 and 12A.4 using either carbon stock change and carbon transfer variables ($\Delta C_{\text{HWP IU}_{\text{DC}}}$, $\Delta C_{\text{HWP SWDS}_{\text{DC}}}$, P_{IM} , P_{EX}) or carbon release variables and carbon transfer variables ($\uparrow C_{\text{HWP DC}}$, H).

Where:

NEE = net ecosystem exchange of C

E , E_w , $\uparrow C_{\text{HWP DC}}$, P_{EX} , P_{IM} and H are define above

As the quantity $-44/12 \bullet \Delta(\text{AFOLU without HWP})$ is reported elsewhere, the *HWP Contribution* to be reported is given by Equation 12A.4:

EQUATION 12A.4
ATMOSPHERIC FLOW APPROACH: *HWP CONTRIBUTION*

$$\text{HWP Contribution to AFOLU Net CO}_2 \text{ emissions}_{\text{AFA}} = -44/12 \bullet [\Delta C_{\text{HWP IU}_{\text{DC}}} + \Delta C_{\text{HWP SWDS}_{\text{DC}}} + P_{\text{EX}} - P_{\text{IM}} + \text{O}]$$

or

$$\text{HWP Contribution to AFOLU Net CO}_2 \text{ emissions}_{\text{AFA}} = -44/12 \bullet [\text{H} - \uparrow C_{\text{HWP DC}}]$$

In the specific case when stock change of carbon in the HWP pools is zero the *carbon imports minus carbon exports* must still be reported as the *HWP Contribution* to AFOLU net CO₂ emissions (see Equation 12A.4).

PRODUCTION APPROACH

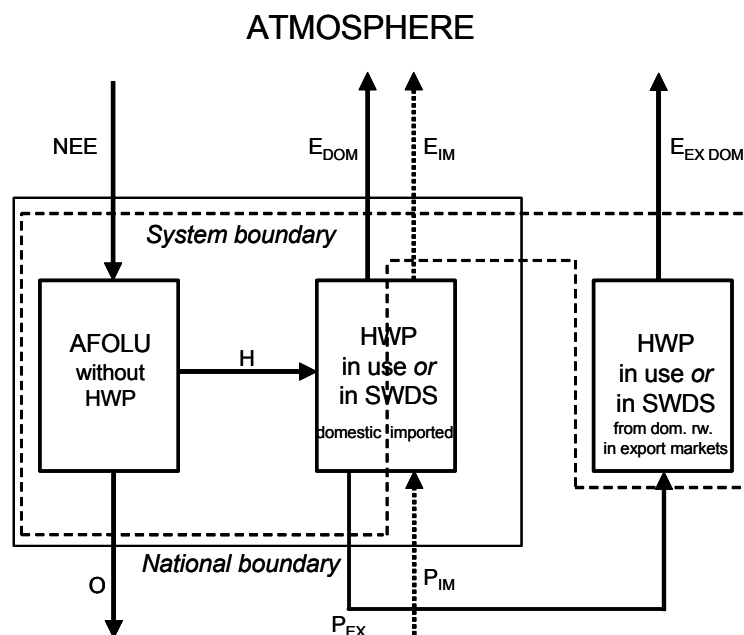


Figure 12.A.3 System boundary of the Production Approach.

Note: NEE = net ecosystem exchange of carbon, E_{DOM} = carbon release to the atmosphere from the pools of domestically grown HWP in use and in SWDS, E_{IM} = carbon release to the atmosphere from the pools of imported HWP in use and in SWDS, E_{EX DOM} = carbon release to the atmosphere from the pools of domestically grown but exported HWP in use and in SWDS, H = carbon transfer in the form of harvested wood biomass transported from harvest sites, P_{EX} = carbon transfer in the form of HWP exports, P_{IM} = carbon transfer in the form of HWP imports, O = possible other cross-border carbon transfers from rest of AFOLU (assumed zero here). Note: Only those HWP in the export markets that are produced from domestic roundwood are within the system boundary, not those only processed in the reporting country but made from imported roundwood. The transfer P_{EX} can in principle include both.

The Production Approach (PA) estimates changes in carbon stocks in the forest pool (and other wood producing lands) of the reporting country and the wood products pool containing products made from wood harvested in the reporting country. The wood products pool includes products made from domestic harvest that are exported and stored in uses in other countries. This approach inventories carbon in wood products from domestically harvested wood only and does not provide a complete inventory of wood carbon in national stocks. Because some of the stock changes reported by a country may occur in other countries (where exports are held), the stock change report indicates when changes occur but not where they occur.

The system boundary of the Production Approach and the carbon pools under consideration are shown in Figure 12A.3. The national carbon dioxide emissions are approximated using Equation 12A.5:

EQUATION 12A.5**EMISSIONS FROM AFOLU BY THE PRODUCTION APPROACH**

$$\text{CO}_2 \text{ emissions from AFOLU} = -44/12 \bullet [\Delta(\text{AFOLU without HWP}) + \Delta C_{\text{HWP IU}_{\text{DH}}} + \Delta C_{\text{HWP SWDS}_{\text{DH}}}]$$

or

$$= -44/12 \bullet [\Delta(\text{AFOLU without HWP}) + \mathbf{H} - \uparrow C_{\text{HWP DH}}]$$

Figure 12A.3 may be used to express Equations 12A.5 and 12A.6 using either carbon stock change and carbon transfer variables ($\Delta C_{\text{HWP IU}_{\text{DH}}}$, $\Delta C_{\text{HWP SWDS}_{\text{DH}}}$) or carbon release variables and carbon transfer variables ($\uparrow C_{\text{HWP DH}}$, \mathbf{H}). Where variables $\Delta C_{\text{HWP IU}_{\text{DH}}}$ and $\Delta C_{\text{HWP SWDS}_{\text{DH}}}$ are defined in Table 12.1 and $\uparrow C_{\text{HWP DH}} = E_{\text{DOM}} + E_{\text{EX DOM}}$.

As the quantity $= -44/12 \bullet \Delta(\text{AFOLU without HWP})$ is reported in the rest of AFOLU, the *HWP Contribution* to be reported in the HWP module is given by Equation 12A.6:

EQUATION 12A.6**PRODUCTION APPROACH: HWP CONTRIBUTION**

$$\text{HWP Contribution to AFOLU Net CO}_2 \text{ emissions}_{\text{PA}} = -44/12 \bullet [\Delta C_{\text{HWP IU}_{\text{DH}}} + \Delta C_{\text{HWP SWDS}_{\text{DH}}}]$$

or

$$\text{HWP Contribution to AFOLU Net CO}_2 \text{ emissions}_{\text{PA}} = -44/12 \bullet [\mathbf{H} - \uparrow C_{\text{HWP DH}}]$$

In the specific case when stock change of carbon in the above HWP pools is zero, and the *HWP Contribution* to net CO₂ emissions HWP is reported as zero (Equation 12A.6).

SIMPLE DECAY APPROACH

This approach estimates and reports the net emissions or removals of carbon to/from the atmosphere when, but not where they occur if wood products are traded. Removals of carbon from the atmosphere due to forest growth, and emissions resulting from oxidation of harvested wood products are reported by the producing country.

This approach to estimate and report from HWP (simple decay) has been proposed by Ford-Robertson (2003). Just as the Production Approach differs from the Stock-Change Approach (for the production approach all stock changes are accounted for and reported by the producer and for the Stock-Change Approach all stock changes are reported by the country where they occur) the Simple Decay Approach (SDA) is similarly related to the Atmospheric Flow Approach (for the Simple Decay Approach all CO₂ release is reported by the country where the HWP was harvested and for the Atmospheric Flow Approach all CO₂ release is reported by the country where the release occurs). The Simple Decay Approach differs from Production Approach in that HWP pool is considered to be related to activities in the forest and hence does not assume instant oxidation of wood in the year of harvest. This means the amount of harvest in a year (Variable \mathbf{H} , remains part of the AFOLU carbon pool (e.g., forest or other land area) and not counted as a part of emissions. The amount estimated for simple decay is the amount of emissions from HWP each year ($\uparrow C_{\text{HWP DH}}$). This suggestion to include and report annual harvest as part of the land area CO₂ removals, and report the *HWP Contribution* as $(44/12 * \uparrow C_{\text{HWP DH}})$ is only a proposal at this point. For these guidelines, compilers are requested to report the *HWP Contribution* for Simple Decay Approach as $[-44/12 * (\mathbf{H} - \uparrow C_{\text{HWP DH}})]$.

TABLE A12.1 SUMMARY OF HOW TO COMPUTE <i>HWP CONTRIBUTION</i> USING VARIABLES IN TABLE 12.7		
Approach	How to estimate <i>HWP Contribution</i> using HWP Variables 1-5	How to estimate <i>HWP Contribution</i> using carbon release estimates (Variables 6 and 7) and HWP Variables 3-5
Stock-Change	$-44/12 \bullet \Delta C_{HWP\ DC}$, [i.e. $-44/12 \bullet (\text{Var } 1A + \text{Var } 1B)$]	$-44/12 \bullet (H + P_{IM} - P_{EX} - \uparrow C_{HWP\ DC})$, [i.e. $-44/12 \bullet (\text{Var } 5 + \text{Var } 3 - \text{Var } 4 - \text{Var } 6)$]
Atmospheric Flow	$-44/12 \bullet (\Delta C_{HWP\ DC} + P_{EX} - P_{IM})$, [i.e. $-44/12 \bullet (\text{Var } 1A + \text{Var } 1B - \text{Var } 3 + \text{Var } 4)$]	$-44/12 \bullet (H - \uparrow C_{HWP\ DC})$, [i.e. $-44/12 \bullet (\text{Var } 5 - \text{Var } 6)$]
Production	$-44/12 \bullet \Delta C_{HWP\ DH}$, [i.e. $-44/12 \bullet (\text{Var } 2A + \text{Var } 2B)$]	$-44/12 \bullet (H - \uparrow C_{HWP\ DH})$, [i.e. $-44/12 \bullet (\text{Var } 5 - \text{Var } 7)$]
Simple Decay	NA	Under these guidelines report <i>HWP Contribution</i> as $-44/12 \bullet (H - \uparrow C_{HWP\ DH})$, [i.e. $-44/12 \bullet (\text{Var } 5 - \text{Var } 7)$] Proposal for a change in reporting report ($-44/12 \bullet H$) as part of the AFOLU land area (forest or land area) removals report <i>HWP Contribution</i> as CO ₂ release from HWP ($44/12 \bullet \uparrow C_{HWP\ DH}$)

References

- Brown, S., Lim, B. and Schlamadinger, B. (1998). Evaluating Approaches for Estimating Net Emissions of Carbon Dioxide from Forest Harvesting and Wood Products. Report of a meeting sponsored by the IPCC held in Dakar, Senegal, 5-7 May, 1998. <http://www.ipcc-nggip.iges.or.jp/public/mtdocs/pdfiles/dakar.pdf> and <http://www.ipcc-nggip.iges.or.jp/public/mtdocs/dakar.htm>
- Cowie, A., Pingoud, K. and Schlamadinger, B. (2006). Stock changes or fluxes? Resolving terminological confusion in the debate on land use change and forestry, *Climate Policy*, Vol. 6, No. 2.
- Flugsrud, K., Hoem, B., Kvingedal, E. and Rypdal, R. (2001). Estimating net emissions of CO₂ from harvested wood products. SFT report 1831/200. Norwegian Pollution Control Authority, Oslo 47 p. <http://www.sft.no/publikasjoner/luft/1831/ta1831.pdf>
- Food and Agriculture Organization (2005). FAOSTAT Forestry data. Web site <http://faostat.fao.org/faostat/collections?subset=forestry> accessed January 3, 2005.
- Ford-Robertson, J.B. (2003). Implications of Harvested Wood Products Accounting - Analysis of issues raised by Parties to the UNFCCC and development of a Simple Decay approach. MAF Technical Paper No 2003/5, 30p. Ministry of Agriculture and Forestry, Wellington, New Zealand. <http://www.maf.govt.nz/forestry/publications/index.htm>
- Gardner, W.D., Ximenes, F., Cowie, A., Marchant, J.F., Mann, S. and Dods, K. (2002). Decomposition of wood products in the Lucas Heights landfill facility. Presented at the Third Australian Conference on 'Life Cycle Assessment – "Life Cycle Decision-making for Sustainability"'. Queensland, Australia, 17 – 19 July, 2002. State Forests of New South Wales, Sydney, Australia. (<http://www.greenhouse.crc.org.au/crc/ecarbon/eneews/gardner.pdf>)
- Gjesdal, S.F.T., Flugsrud, K., Mykkelbost, T.C. and Rypdal, K. (1996). A balance of use of wood products in Norway, Norwegian Pollution Control Authority SFT, Report 96:04, 54 p.
- Haygreen, J.G. and Bower, J.L. (1989). Forest Products and Wood Science – An Introduction, 2nd edition. Iowa State University Press. Ames, Iowa. 500 p.
- Hashimoto, S. and Moriguchi, Y. (2004). Data Book: Material and carbon flow of harvested wood in Japan. CGER-D034-2004. National Institute for Environmental Studies, Japan. Tsukuba. 40p. <http://www-cger.nies.go.jp/publication/D034/D034.pdf>
- IPCC (1997). Revised 1996 IPCC Guidelines for National Greenhouse Inventories. Houghton J.T., Meira Filho L.G., Lim B., Tréanton K., Mamaty I., Bonduki Y., Griggs D.J. Callander B.A. (Eds). Intergovernmental Panel on Climate Change (IPCC), IPCC/OECD/IEA, Paris, France.
- IPCC (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry. Penman J., Gytarsky M., Hiraiishi T., Krug, T., Kruger D., Pipatti R., Buendia L., Miwa K., Ngara T., Tanabe K., Wagner F. (Eds). Intergovernmental Panel on Climate Change (IPCC), IPCC/IGES, Hayama, Japan.
- Jenkins, J.C., Chojnacky, D.C., Heath, L.S. and Birdsey, R.A. (2003). National-scale biomass estimators for United States tree species. *Forest Science*. 49(1):12-35. http://www.fs.fed.us/ne/newtown_square/publications/other_publishers/OCR/ne_2003jenkins01.pdf
- Micales, J.A and Skog, K.E. (1997). The decomposition of forest products in landfills. *International Biodeterioration and Biodegradation* 39(2-3): pp. 145-158
- National Council for Air and Stream Improvement, Inc. (NCASI). (2004). Critical Review of Forest Products Decomposition in Municipal Solid Waste Landfills. Technical Bulletin No. 0872. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc. <http://www.ncasi.org/publications/Detail.aspx?id=97>
- Pingoud, K., Perälä, A.-L. and Pussinen, A. (2001). Carbon dynamics in wood products. *Mitigation and Adaptation Strategies for Global Change*, Vol. 6, No. 2, pp. 91-111, 2001.
- Pingoud, K., Savolainen, I. and Seppala, H. (1996). Greenhouse impact of the Finnish forest sector including forest products and waste management. *Ambio* 25:pp. 318-326.
- Pingoud, K., Perälä, A.-L., Soimakallio, S. and Pussinen, A. (2003). Greenhouse gas impacts of harvested wood products. Evaluation and development of methods. VTT Research Notes 2189, 138 p. <http://www.vtt.fi/inf/pdf/tiedotteet/2003/T2189.pdf>.
- Pingoud, K. and Wagner, F. (2006). Methane emissions from landfills and decay of harvested wood products: the first order decay revisited. IIASA Interim Report IR-06-004

- UNFCCC Secretariat (2003). Estimation, reporting, and accounting of harvested wood products - Technical paper. FCCC/TP/2003/7 27 October 2003. Bonn, Germany. <http://unfccc.int/resource/docs/tp/tp0307.pdf>
- UNFCCC Secretariat (2004). Report on the workshop on harvested wood products [held in Lillehammer, Norway, from 30 August to 1 September 2004.] FCCC/SBSTA/2004/INF.11 25 October 2004. Bonn, Germany <http://unfccc.int/resource/docs/2004/sbsta/inf11.pdf>
- Winjum, J. K., Brown, S. and Schlamadinger, B. (1998). Forest harvests and wood products: Sources and sinks of atmospheric carbon dioxide. *Forest Science* **44** (2):272-284.