Appendix 3a.1 Harvested wood products: Basis for future methodological development

3a.1.1 Methodological Issues

3a.1.1.1 RELATIONSHIP TO THE *IPCC GUIDELINES*[1]

The *IPCC Guidelines* (IPCC, 1997) provide an outline of how harvested wood could be treated in national greenhouse gas (GHG) inventories. This section shows the relation of that outline to the approaches and estimation methods to be presented in this Appendix. Wood and paper products are referred to as harvested wood products (HWP). It does not include carbon in harvested trees that are left at harvest sites. The issue of harvested wood is discussed in Box 5 (*IPCC Guidelines*, Reference Manual, p. 5.17) as follows:

> "*For the purposes of the basic calculations, the recommended default assumption is that all carbon removed in wood and other biomass from forests is oxidised in the year of removal. This is clearly not strictly accurate in the case of some forest products, but is considered a legitimate, conservative assumption for initial calculations."*

and

> "*...the recommended default assumption is that all carbon in biomass harvested is oxidised in the removal year. This is based on the perception that stocks of forest products in most countries are not increasing significantly on an annual basis*." The Guidelines go on to say "*The proposed method recommends 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. If data permit, one could add a pool to Equation (1) in the changes in forest and other woody biomass stocks calculation to account for increases in the pool of forest products. This information would, of course, require careful documentation, including accounting for imports and exports of forest products during the inventory period."*

A note on the relationship between this discussion and this report: The *IPCC Guidelines* recommend that storage estimates only be included in inventories if a country can document a method indicating that stocks are increasing. This Appendix is intended to further the discussion as to when such methods may be available for countries to determine and document increases in HWP stocks. This Appendix is based on the presumption that an effort should be made to enable countries to determine if they may meet the "only if" condition of the *IPCC Guidelines*.

The above outline in the *IPCC Guidelines* provides the starting point in the development of *good practice guidance* for HWP estimation and reporting. The recommended default assumption – basically that harvested wood is oxidised in the removal year – has the same effect as the case where there are no significant changes in product stocks. In this case carbon flux of harvesting equals the decay flux of HWP into the atmosphere, but there could still be a delay in emissions (and substantial but constant HWP stocks). This assumption is called the *IPCC default approach* in the remainder of this section. The outline says that if data permit, positive stock changes in HWP can be reported in national greenhouse gas inventories. There are two alternatives ways to do this:

Approach 1: Estimation of annual carbon stock changes of HWP in a country regardless of wood origin. This would mean that:

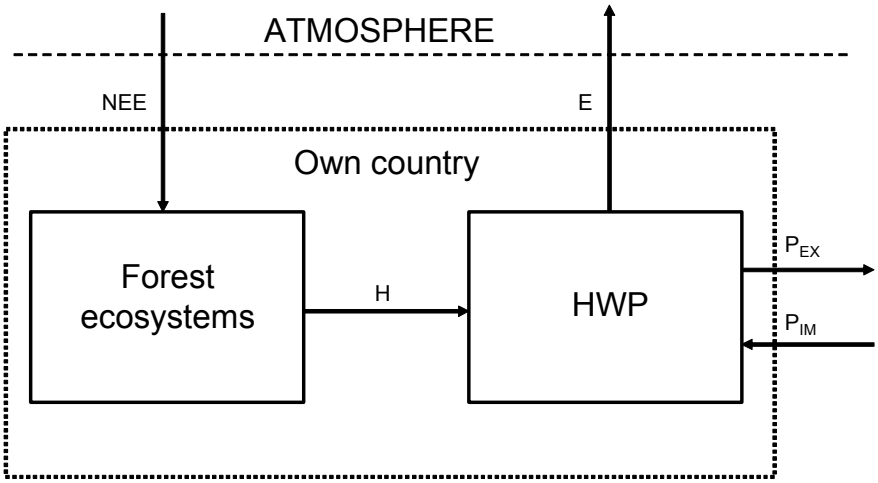
- Wood carbon sources are not spatially specific – that is, product carbon comes from a number of land areas including foreign forests but the carbon ends up in the reporting country.
- Estimates of stock changes would be based on data for what happens to products in uses and waste disposal within the borders of a country – it could include movements of products into and out of the country. Data on uses and disposition would be found in one country.

[1] The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) is abbreviated as *IPCC Guidelines* in this report.

- Wood is from many sources and management activities – possibly outside the country. The change in stock cannot be linked to activities on one land area.
- The approach may be used as part of an evaluation of the effect of factors on the accumulation and loss of HWP carbon stored in a country.
- There are several types of removals (or transfers to HWP) and emissions associated with the estimate of the change in HWP stock in a country. These include the transfer of domestic harvest to products, the transfer of imports to products, and the transfer of products to other countries, and the emissions from products to the atmosphere (see Figure 3a.1.1).
- The positive carbon stock changes would be interpreted as removals or equivalently as negative emissions, expressed in Gg CO_2/year in national greenhouse gas inventories.

Approach 1 is named as the Stock Change Approach.

Figure 3a.1.1 Carbon flows and stocks associated with forests and harvested wood products (HWP) to illustrate the Stock Change and Atmospheric Flow Accounting[2] Approaches.



Variable definitions:
NEE = net ecosystem exchange
H = harvested wood transported from forests
E = emissions from HWP within country borders
P_{EX} = exports of HWP including roundwood, wood-based waste and refined products
P_{IM} = imports of HWP including roundwood, wood-based waste and refined products

Approach 2: Estimation of annual carbon stock changes of HWP where the carbon is from trees harvested in the reporting country. This would mean:

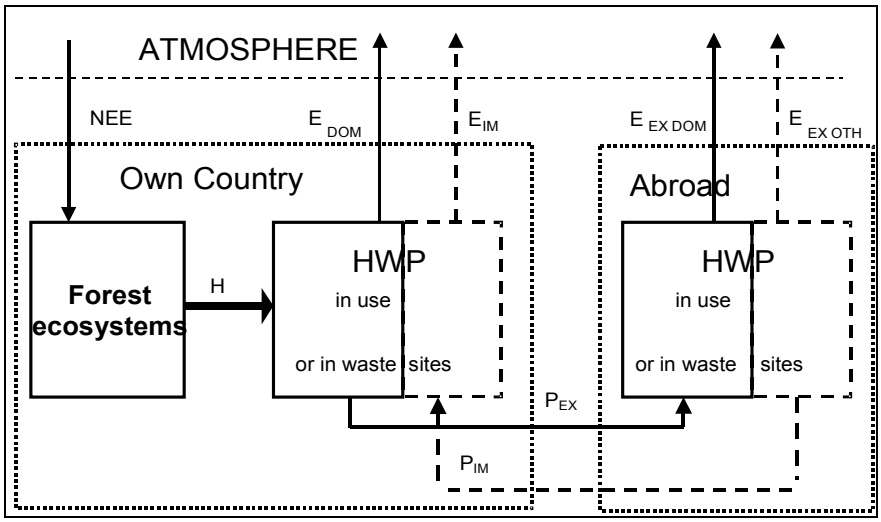
- Estimates of stock changes would be based on what happens to wood carbon that originated from one land area – it could include movement of products out of the country and its disposition in other countries. Data on uses and disposition would potentially be needed from different countries or assumptions may be needed about disposition in other countries.
- Consequently, the reporting boundary would not coincide with national borders.
- Wood is from one land source and carbon stock change would be associated with management activities on that land.
- This approach might be used as part of an evaluation of carbon storage changes associated with management on certain land areas.
- This approach could follow the life cycle of all wood carbon harvested from a specific land area.

[2] Atmospheric Flow Approach is the Approach 3 in this section.

- The positive carbon stock changes would be interpreted as removals or equivalently as negative emissions, expressed in Gg CO_2/year in national greenhouse gas inventories.
- There are several removals (or transfers to HWP) and emissions associated with the estimate of changes in HWP stocks that came from timber in a country. These include the transfer of domestic harvest to products in the country and to other countries, the emissions from HWP in the country that came from domestic harvest and emissions from HWP in other countries that came from domestic harvest (see Figure 3a.1.2).

Approach 2 is named as the Production Approach.

Figure 3a.1.2 Carbon flows and stocks associated with forests and harvested wood products (HWP) to illustrate the Production Accounting Approach.



Variable definitions:

NEE = net ecosystem exchange
H = harvested wood transported from forests
E_{DOM} = emissions from HWP in own country made from wood harvested from domestic forests
$E_{EX\ DOM}$ = emissions from HWP in other countries made from wood exported abroad that were made from wood harvested from own country's forests
E_{IM} = emission from imported HWP in own country
$E_{EX\ OTH}$ = emissions from HWP in other countries made from wood harvested in other countries
P_{EX} = exports of HWP including roundwood, wood-based waste and refined products
P_{IM} = imports of HWP including roundwood, wood-based waste and refined products

Approaches 1 and 2 above were elaborated at an IPCC Expert Meeting on Harvested Wood Products (IPCC, 1998). If either approach was used by an inventory agency, the estimated annual change of HWP stocks would be added to the estimated annual biomass change in Equation 1 in the *IPCC Guidelines* (Reference Manual, p. 5.19). Equation 1 in the *IPCC Guidelines* corresponds to the sum of Equations 3.2.1 and 3.2.21 in Chapter 3 of this report. Equation 3.2.1 indicates carbon change on forest land that remains forest land and Equation 3.2.21 indicates carbon change on non-forest land that is converted to forest land. The Production Approach would add change in HWP carbon where the carbon came from trees in domestic forests (the land sources cited in Equations 3.2.1 and 3.2.21). The Stock Change Approach would add the change in HWP carbon that is resident in the country (includes imports, excludes exports).

A third approach, having no explicit reference in the *IPCC Guidelines*, was also elaborated at the above-mentioned IPCC Expert Meeting.

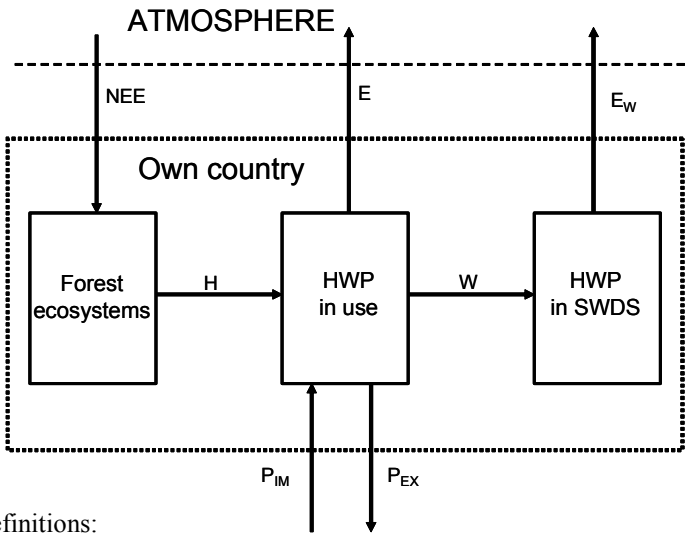
Approach 3: Estimation of annual atmospheric fluxes between the atmosphere and forests/HWP within national boundaries. This would mean that:

- The viewpoint of the approach deviates from the previous ones. Instead of focusing on stock changes (Approaches 1 and 2), the focus is directly on carbon fluxes from and to the atmosphere. It considers the annual carbon removal by forests and emissions from the HWP.

- Instead of reporting the annual HWP stock change as in Approach 1, the annual emissions are reported in Approach 3 (see Figure 3.a.1.1).
- This approach could require modification of the existing reporting practice concerning forests. Instead of reporting only the net annual forest biomass change as growth minus harvest (and the changes in carbon of the other stocks in forest ecosystems), the annual net carbon flux into forest ecosystems (net ecosystem exchange) would be reported along with the estimates of emissions from HWP (see Figure 3.a.1.1).
- Estimates of emissions would be based on data for what happens to products in use and waste disposal within the boarders of a country – it could include movements of products into and out of the country. Data on uses and disposition would be found in the reporting country. In this sense it is similar to Approach 1 (see Figures 3a.1.1 and 3a.1.3.)
- Wood is from many sources and management activities – possibly outside the country. The emissions are linked to the location of emissions but not to the land the wood carbon came from. The latter is analogous to Approach 1.
- This approach may be used to evaluate the effect of all the factors that influence the emissions from wood carbon in a country.
- There are several removals (or transfers to HWP) and emissions associated with the estimate of the emissions from HWP stock in a country. These include the transfer of harvest to products, the emissions from HWP remaining in the country, and the emissions from products imported to the country (see Figure 3a.1.1).
- The carbon flux E in Figure 3a.1.1 would be interpreted as an emission, expressed in Gg CO_2/year in national greenhouse gas inventories.

Approach 3 is named as the Atmospheric Flow Approach.

Figure 3a.1.3 Carbon flows and stocks when products both in use and in solid waste disposal sites (SWDS) are considered (Stock change and Atmospheric flow accounting approaches).



Variable definitions:
HWP = harvested wood products
NEE = net ecosystem exchange
H = harvested wood transported from forests
E = emissions from HWP in use within country borders
P_{EX} = exports of HWP including roundwood, wood-based waste and refined products
P_{IM} = imports of HWP including roundwood, wood-based waste and refined products
W = HWP carbon disposed into SWDS
E_W = emissions from HWP in SWDS within country borders

Objective of this Appendix

This appendix provides information on possible methods to estimate stock changes consistent with the advice in the *IPCC Guidelines*, if data are available. In addition, it would be relevant for any of the three approaches just

outlined, or potentially for other approaches, depending on decisions from the COP and/or COP/MOP on this matter.[3]

The issue of how to account for carbon in wood-based waste

One additional issue to be resolved when deciding on methods is whether or not changes in HWP stocks in solid waste disposal sites (SWDS) should be included in emission/removal estimation and reporting. And if so, how should such stock changes be included? There are several questions to consider:

- First, should assumptions about decay of wood in SWDS be consistent between the Waste Sector and the Forest Sector? That is, if the Waste Sector estimates that a portion of wood carbon stocks in SWDS is not decaying, should the Forest Sector assume the same?
- Second, should the Waste Sector keep track of HWP stored in SWDS sites? If so, how would that be reflected in accounting for HWP in the Forest Sector? The Waste Sector currently accounts for and estimates methane emissions from Solid Waste Disposal Sites (SWDS) (including emissions from wood and paper) but does not estimate corresponding changes in the carbon stock in SWDS.

The above mentioned questions are not resolved in this section but suggestions are presented on methods for estimating changes in HWP carbon stored in SWDS.

The issue of how to account for harvested wood use for energy production

Currently wood energy emissions are noted but not included in emissions accounting for the Energy Sector or other sectors that produce wood energy. These emissions are assumed to be accounted for in the Land Use Change and Forestry (LUCF) Sector. That is, they are part of the emissions from harvested wood. A consideration for an accounting approach for HWP may be that it properly accounts for emissions from wood energy in a country. The Stock Change and Atmospheric Flow Approaches both account for all emissions from wood burned for energy in a country but the Production Approach may not account for all wood burned for energy if some wood is imported and later burned for energy. Such emissions are not accounted for because imported wood (including amounts burned after being imported) is not included in the Production Approach.

Proposed Tier structure

Three tiers of estimation methods are suggested:

Tier 1

IPCC Guidelines Default estimation method is the way of making the Tier 1 estimate. This tier or method assumes that all carbon in biomass harvested is oxidised in the removal year. This would correspond to an estimate of no change in HWP carbon stocks for both the Stock Change Approach and the Production Approach.

Tier 2: First order decay (a flux method)

Estimates are made of stock changes of HWP carbon in products in use and – in the case where waste is included in reporting – HWP carbon in SWDS. The estimates are made by tracking inputs to and outputs from these pools of carbon (also called input and output fluxes). Data beginning a number of decades in the past up to the present time are used to estimate 1) additions to HWP in use, 2) removals from use, 3) additions to HWP in SWDS, and 4) decay from SWDS. This procedure is needed to obtain an estimate of the existing HWP stock accumulated from historical wood use and current year emissions from those stocks as they go out of use (also termed "inherited emissions").

If HWP in SWDS is included, data used for Tier 2 is intended to be consistent with data used for the Tier 2 method used for the Waste Sector (Chapter 5, Waste, *GPG2000*[4]). The numerical factors a country uses to

[3] Decisions about how to treat harvested wood products have been deferred. *The Conference of the Parties decides that any changes to the treatment of harvested wood products shall be in accordance with future decisions of the COP (FCCC/CP/2001/13/Add/1, page 55, paragraph 4)*. The SBSTA, in FCCC/SBSTA/2003/L.3, recalled decision 11/CP.7, paragraph 4, and noted the possible inclusion of methods to estimate the change in carbon stored in harvested wood products as an annex or appendix to the IPCC report on good practice guidance for LULUCF. The purpose of the Appendix is to support the decisions of the Subsidiary Body for Scientific and Technological Advice. Because SBSTA has requested that the UNFCC Secretariat "…*prepare a technical paper on harvested wood products accounting*…" this section focuses on methods that the authors suggest may be used whatever is developed concerning accounting (FCC/SBSTA/2001/8, 4 Feb 2002).

[4] IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000) is abbreviated as *GPG2000* in this report.

compute the methane emissions from SWDS should be consistent with the numerical factors used to compute amounts of HWP carbon retained in SWDS.

Tier 3: Country-Specific Methods
Change in HWP carbon in products in use and HWP carbon in SWDS (if agreed for inclusion) can each be computed by separate methods. These methods may apply to some but not all of the accounting approaches (Flugsrud *et al.*, 2001).

Method A – Estimate Change in inventories (stock methods)

Use inventories of HWP in use or HWP in waste disposal sites at two or more points in time and calculate the change in carbon stored. The HWP pool of products in use in building structures is normally a major part of the total HWP pool. The amount of HWP carbon can be estimated, for example, by multiplying the average HWP content per square metre of floor space times the total floor space for several types of buildings. Change in carbon may 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) and in Pingoud *et al.*, 1996, 2001 (for Finland). In this case no procedure for integration of the existing HWP stock from historical wood use data is needed, which is an advantage compared to the flux methods (Tier 2 and Tier 3/Method B). Similarly, it has been suggested that the change in HWP carbon in SWDS could be estimated using information about the area, average depth, and average wood and paper carbon content per cubic metre in these sites, although no examples of this method have been reported in the literature.

Method B – Track input and output flows using detailed country data (flux methods)

Use detailed country data beginning a number of decades in the past and estimate each year, up to the present time, (i) additions to pools of HWP in use, (ii) removals 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.

Method C – Combine Method A and Method B estimates

An example of combining methods 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).

3a.1.1.2 CHOICE OF METHOD

With default data and country-specific estimates for some parameters, countries can use Tier 2 to make preliminary estimates to evaluate changes in HWP stocks and whether counted increases in stocks would be a key category. If country information is available it is suggested to use Tier 3 custom country methods, such as change between actual inventories of wood products stored in long-lived pools for these purposes. If HWP is a key category it is suggested that work would be done to develop national data for Tier 2 or Tier 3 estimates. If HWP is not a key category, the Tier 1 method may be applied.

3a.1.1.3 CHOICE OF ACTIVITY DATA AND FACTORS IN CALCULATIONS

Tier 1: *IPCC Guidelines* Default
Under Tier 1 the recommended default assumption is that all carbon in biomass harvested is oxidised in the removal year. This is based on the perception that stocks of forest products in most countries are not increasing or decreasing significantly on an annual basis.

Tier 2: First order decay method (FOD)
This method is termed the first order decay method because carbon in each of the carbon pools (products in use and products in SWDS) is estimated to leave the pool at a constant percentage rate. The Tier 2 method for the Waste Sector uses this technique to estimate methane emissions from SWDS (see Chapter 6, Waste, of the *IPCC Guidelines*; and Chapter 5, Waste, of *GPG2000*).

The Tier 2 method is divided into two parts – Tier 2a to estimate HWP carbon changes for products in use and Tier 2b to estimate HWP carbon changes in SWDS (see Figure 3a.1.3). Tier 2b is omitted if carbon changes in SWDS are not included in reporting.

The proposed method for estimating changes in carbon stored in HWP utilizes data on production and international trade of primary HWP (saw wood, panels and paper). Only primary products are used because data are available for virtually all countries. Data on secondary products such as furniture may also be used if available but care is needed to avoid double counting of HWP carbon[5]. Data on input flows and output flows over several decades is used to calculate current year change in the pool of HWP carbon. The input flow to the pool in a country is calculated by adding imports to the national production of primary products, and subtracting the exports. The output of the pool or decay is assumed to be of first order. That is, a constant fraction of each pool is lost each year. The pool of primary products will include wood used in all its final uses. Wood-based material that is not accumulated into the stocks of HWP in use (or HWP in SWDS) in a country is assumed to form emissions. These calculations are valid for Stock Change Approach and may also be used to compute carbon flows for the Atmospheric Flow Approach. Stock Change and Atmospheric Flow Approaches in the case, where both products in use and in SWDS are included, are illustrated in Figure 3a.1.3. The Production Approach requires additional approximations, as typically only a part of the HWP in a country are of domestic origin and, in addition, HWP of domestic origin might be exported (see Figure 3a.1.2).

The Tier 2 equations for the three approaches are as follows:

Tier 2a: Change in HWP carbon in products in use

EQUATION 3a.1.1
ANNUAL CHANGE IN HWP CARBON IN PRODUCTS IN USE AND THE ASSOCIATED CO_2 EMISSIONS

(1A) $\Delta C_{HWP\ IU\ SCA} = P_A - P_L$

CO_2 emissions/removals $_{SCA} = \Delta C_{HWP\ IU\ SCA} \bullet 10^{-3} \bullet 44/12 \bullet (-1)$ (Stock Change Approach)

(1B) $\Delta C_{HWP\ IU\ PA} = PH_A - PH_L$

CO_2 emissions/removals $_{PA} = \Delta C_{HWP\ IU\ PA} \bullet 10^{-3} \bullet 44/12 \bullet (-1)$ (Production Approach)

(1C) $E = -\Delta C_{HWP\ IU\ SCA} + H - P_{EX} + P_{IM} - W$

CO_2 emissions/removals $_{AFA} = E \bullet 10^{-3} \bullet 44/12$ (Atmospheric Flow Approach)

Note 1: The quantity E estimated is the real flux of C from HWP stock into the atmosphere within the borders of the reporting country (see Figures 3a.1.1 and 3a.1.3). The forest sector should then report the real flux of carbon from atmosphere into the forest ecosystems (NEE) or the sum of stock changes in forest ecosystems + H, which is a deviation from the existing reporting practice in which only stock changes are reported (NEE – H).

Note 2: Each term has a year subscript *t* – omitted to simplify the format; each term on the right hand side of the equations has at least two parts: at least one for solidwood products and at least one for paper products.

Note 3: The changes in carbon in HWP are as a rule estimated as tonnes C yr^{-1} and converted to Gg CO_2 for reporting by multiplying with $10^{-3} \bullet 44/12$. The emissions are reported as positive and removals as negative – hence the multiplication with -1 (see also Section 3.7.1 and Annex 3A.2 Reporting Tables and Worksheets).

Where:

$\Delta C_{HWP\ IU\ SCA}$ = annual change in carbon stored in HWP in use in the country, tonnes C yr^{-1}

$\Delta C_{HWP\ IU\ PA}$ = annual change in carbon in HWP in use from wood harvested in the country (includes carbon in exports and excludes carbon in imports, tonnes C yr^{-1}

E = carbon flux from HWP into the atmosphere within the borders of the reporting country, tonnes C yr^{-1}

H = current year wood carbon harvested and removed from sites to be processed into forest products (including fuelwood), tonnes C yr^{-1}

W = current year HWP carbon disposed into SWDS (in case HWP in SWDS is included in reporting, otherwise W = 0), tonnes C yr^{-1}

[5] Use of wood products forms a chain and flow of carbon from round wood through primary and secondary products to final use. Double counting in estimation of the C input flow to the HWP pool is possible if, for instance, the consumption of round wood and primary products or primary products and secondary products are summed up. In the proposed Tier 2a method the consumption of *primary products* is assumed to form the input to the HWP pool.

Each variable below has at least two parts – at least one for solidwood products, and at least one for paper products.

P_A = current year additions to HWP carbon in use from domestic consumption calculated on the basis of the primary products carbon flux, tonnes C yr^{-1}

See Table 3a.1.1 for information on data for these values, tonnes C yr^{-1}

P_L = current year loss of HWP carbon from uses (placed in use in current or prior years) , tonnes C yr^{-1}

PH_A = current year additions to HWP carbon from wood harvested in the country calculated on the basis of the primary products carbon flux, tonnes C yr^{-1}

See Table 3a.1.1 for information on data and calculating PH_A, tonnes C yr^{-1}

PH_L = current year loss of HWP carbon in use (place in use in current or prior years) from wood harvested in the country, tonnes C yr^{-1}

P_{EX} = exports of wood and paper products including roundwood, chips, residue, pulp, and recovered (recycled) paper, tonnes C yr^{-1}

P_{IM} = imports of wood and paper products including roundwood, chips, residue, pulp, and recovered (recycled) paper, tonnes C yr^{-1}.

The procedure to calculate $\Delta C_{HWP\ IU\ SCA}$ and $\Delta C_{HWP\ IU\ PA}$ uses a recursive process shown below rather than calculating losses from HWP use, P_L or PH_L, for the current year directly.

Beginning in, say *j* = year 1900, compute the following equation recursively[6] for each year up to the current year t.

$$C_{HWP\ IU_{SCA}}(j) = (1 / (1 + f_D)) \bullet (P_{A_j} + C_{HWP\ IU_{SCA}}(j - 1)) \qquad \text{(Stock Change Approach)}$$

Or

$$C_{HWP\ IU_{PA}}(j) = (1 / (1 + fH_D)) \bullet (P_{A_j} + C_{HWP\ IU_{PA}}(j - 1)) \qquad \text{(Production Approach)}$$

For the initial year, e.g. *j* = 1900, the value of $C_{HWP\ IU_{SCA}} = 0$ or $C_{HWP\ IU_{PA}} = 0$

For the current year calculate

$$\Delta C_{HWP\ IU_{SCA}}(t) = C_{HWP\ IU_{SCA}}(t) - C_{HWP\ IU_{SCA}}(t - 1) \qquad \text{(Stock Change Approach)}$$

Or

$$\Delta C_{HWP\ IU_{PA}}(t) = C_{HWP\ IU_{PA}}(t) - C_{HWP\ IU_{PA}}(t - 1) \qquad \text{(Production Approach)}$$

Where:

$\Delta C_{HWP\ IU_{SCA}}$ = annual change in carbon stored in HWP in use in the country, tonnes C yr^{-1}

$\Delta C_{HWP\ IU_{PA}}$ = annual change in carbon in HWP in use from wood harvested in the country (includes carbon in exports and excludes carbon in imports), tonnes C yr^{-1}

P_A = current year additions to HWP carbon in use from domestic consumption calculated on the basis of the primary products carbon flux, tonnes C yr^{-1}

t = current year

j = year of data, starting in, for example, 1900, which is long enough in the past so that current decay is very small from HWP placed in use in the early years

f_D = fraction of HWP carbon in use in a country in a given year that is discarded in that year (discarded products include those that are recycled)

fH_D = fraction of HWP carbon in use in a country in a given year (includes exports) that is discarded in that year (discarded products include those that are recycled).

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[6] The recursive formula above for stock change approach is equivalent to the equation: $(C_{HWP\ IU\ SCA(j)} - C_{HWP\ IU\ SCA}(j - 1)) / \Delta t = P_{A_j} - f_D \bullet C_{HWP\ IU\ SCA(j)}$, where Δt is 1 yr.

This implicit Euler method (see Burden and Faires, 2001), is used as an approximation of a constant rate of decay from a HWP pool specified by the differential equation $dC_{HWP\ IU\ SCA}/dt = P_A - f_D \bullet C_{HWP\ IU\ SCA}$.

TABLE 3a.1.1
FAO DATA, AND FACTORS TO ESTIMATE P_A AND PH_A FOR TIER 2 EQUATION 3a.1.1

FAO Product Data (Solidwood products data are in m^3; pulp and paper products are in Gg)	Default conversion factors (Gg of oven dry product per m^3 or Gg of product)	Time period for data	Equation variables (see footnotes)
Roundwood harvest data			
Roundwood harvest (Coniferous)	0.45 (Gg/ m^3)	1961-2000	H
Roundwood harvest (Non-Coniferous)	0.56 (Gg/ m^3)		
Solidwood products data			
Saw wood (Coniferous)	0.45 (Gg/ m^3)	1961-2000	P_{DP} (solidwood) P_{IM} (solidwood) P_{EX} (solidwood)
Saw wood (Non Coniferous)	0.56 (Gg/ m^3)		
Veneer sheets	0.59 (Gg/ m^3)		
Plywood	0.48 (Gg/ m^3)		
Particle board	0.26 (Gg/ m^3)		
Fibreboard Compressed	1.02 (Gg/ m^3)	1961-1994	
Hardboard	1.02 (Gg/ m^3)	1995-2000	
MDF	0.50 (Gg/ m^3)		
Pulp, paper and paperboard data			
Paper and paperboard	0.9 (Gg/ Gg)	1961-2000	P_{DP} (paper) P_{IM} (paper) P_{EX} (paper)
Recovered paper (Values set to zero from 1900 to 1969)	0.9 (Gg/ Gg)	1970-2000	RP IM (RP) EX (RP)
Wood pulp	0.9 (Gg/ Gg)	1961-2000	WP IM (WP) EX (WP)
Recovered fibre pulp	0.9 (Gg/ Gg)	1998-2000	IM (RFP) EX (RFP)
Other fiber pulp	0.9 (Gg/ Gg)	1961-2000	OFP IM (OFP) EX (OFP)
Industrial roundwood data			
Industrial roundwood (Coniferous)	0.49 Gg/ m^3)	1961-2000	IRW
Industrial roundwood (Non-Coniferous)	0.56 Gg/ m^3)		
Industrial roundwood (Coniferous)	0.49 Gg/ m^3)	1990-2000	IM (IRW) EX (IRW)
Industrial roundwood (Non-Coniferous)	0.56 Gg/ m^3)		

Sources: For FAO data see: http://apps.fao.org/page/collections?subset=forestry

Source of Conversion factors: Solidwood factors (Haynes *et al.* 1990, Tables B-7 and B-6)

NOTES:

Paper and pulp factors – One tonne of paper or pulp air dry are assumed to have 0.9 tonne of paper or pulp oven dry.

The equations below indicate how to compute P_A and PH_A for Equation 3a.1.1 using FAO data.

P_A (solidwood) is the sum of solidwood products production; P_A (paper) is the sum of paper products production.

P_A (solidwood) = P_{DP} (solidwood) + P_{IM} (solidwood) – P_{EX} (solidwood)

P_A (paper) = [P_{DP} (paper) + P_{IM} (paper) – P_{EX} (paper)] ● WP_{ratio}

Where WP_{ratio} is the fraction of all pulp that is wood pulp (excludes other fiber pulp).

WP_{ratio} = [(WP + IM (WP) – EX (WP))/ ((WP + IM (WP) – EX (WP)) + (OFP + IM (OFP) – EX (OFP))]

PH_A (solidwood) = P_A (solidwood) ● IRW / (IRW + IM (IRW) – EX (IRW))

PH_A (paper) = [(P_A (paper) + EX (WP) – IM (WP) ● WP_{ratio} + EX (RP) – IM (RP) + EX (RFP) – IM (RFP)] ● IRW / (IRW + IM (IRW) – EX (IRW))

Convert tonnes of dry products P_A and PH_A to tonnes of carbon by multiplying by 0.5 (tonnes carbon / tonnes product).

Tier 2b: Change in HWP carbon in Solid Waste Disposal Sites (SWDS)

If included in reporting, stock changes of HWP in SWDS could be calculated in similar manner as HWP in use:

EQUATION 3a.1.2
ANNUAL CHANGE IN HWP CARBON IN SWDS AND THE ASSOCIATED CO_2 EMISSIONS

(2A) $\Delta C_{HWP\ W_{SCA}} = W_{AP} + W_{AD} - W_L$

CO_2 emissions/removals $_{SCA} = \Delta C_{HWP\ W_{SCA}} \bullet 10^{-3} \bullet 44/12 \bullet (-1)$ (Stock Change Approach)

(2B) $\Delta C_{HWP\ W_{PA}} = WH_{AP} + WH_{AD} - WH_L$

CO_2 emissions/removals $_{PA} = \Delta C_{HWP\ W_{PA}} \bullet 10^{-3} \bullet 44/12 \bullet (-1)$ (Production Approach)

(2C) $\Delta C_{HWP\ W_{AFA}} = W_{AP} + W_{AD} - \Delta C_{HWP\ W_{SCA}} = W_L$

CO_2 emissions/removals $_{AFA} = \Delta C_{HWP\ W_{AFA}} \bullet 10^{-3} \bullet 44/12$ (Atmospheric Flow Approach)

Note 1: Each term has a year subscript t – omitted to simplify the format.

Note 2: Each term on the right hand side of the equations has at least two parts – at least one for solidwood products and at least one for paper products)

Where:

$\Delta C_{HWP\ W_{SCA}}$ = annual change in carbon stored in HWP in SWDS in the country, tonnes C yr^{-1}

$\Delta C_{HWP\ W_{PA}}$ = annual change in carbon in HWP in SWDS <u>from wood harvested in the country</u> (includes carbon in exports and excludes carbon in imports), tonnes C yr^{-1}

$\Delta C_{HWP\ W_{AFA}}$ = carbon <u>emissions</u> from HWP in SWDS, tonnes C yr^{-1}

Each variable below has at least two parts – at least one for solidwood products, and at least one for paper products

W_{AP} = amount of current year additions of HWP carbon to SWDS which are permanent (no decay)[7], tonnes C yr^{-1}

W_{AD} = amount of current year additions of HWP carbon to SWDS which decay over time (note that $W_{AP} + W_{AD} = W$ in Tier 2a), tonnes C yr^{-1}

W_L = loss of HWP carbon from SWDS (placed in sites in current or prior years)

WH_{AP} = amount of current year additions of HWP carbon to SWDS that are permanent (no decay) (<u>from wood harvested in the country)</u>, tonnes C yr^{-1}

WH_{AD} = amount of current year additions of HWP carbon to SWDS which decay over time (<u>from wood harvested in the country)</u>, tonnes C yr^{-1}

WH_L = loss of HWP carbon from SWDS (placed in sites in current or prior years) (<u>from wood harvested in the country)</u>, tonnes C yr^{-1}

We do not provide detailed equations and data to estimate storage in SWDS because more development is needed on default data and methods and this development needs to be coordinated with guidance provided for the Waste Sector on how to calculate emissions from SWDS.

In general terms, estimation of the HWP carbon storage in SWDS requires data on:

(i) The fraction of discarded HWP carbon that goes to SWDS each year;

(ii) The fraction of HWP carbon going to SWDS that goes to anaerobic conditions (versus aerobic conditions);

(iii) The fraction of HWP carbon going to anaerobic conditions in SWDS that decays (a portion does not decay as indicated by the good practice guidance for the Waste Sector (*GPG2000*);

(iv) The rate of decay for the portion of HWP carbon (in anaerobic conditions) that does decay; and

(v) The rate of decay for HWP carbon in aerobic conditions.

[7] Only a portion of degradable organic carbon in SWDS decays as indicated in the *IPCC Guidelines* for the Waste Sector (see variable DOC_F in *IPCC Guidelines*, Reference Manual p 6.5).

Information on default data for items 2 through 5 above are indicated in the good practice guidance for the Waste Sector (*GPG2000*). Country-specific data are needed for item 1 above – the fraction of discarded HWP carbon that goes to SWDS each year.

Tier 3: Custom country methods

EQUATION 3a.1.3
ANNUAL CHANGE IN CARBON IN HWP (EXAMPLE OF A CUSTOM COUNTRY METHOD)

(3A) $\Delta C_{HWP\ BLDG\ SCA} = (A_{BLDG\ t} \bullet f_{C\ BLDG\ t}) - (A_{BLDG\ t-1} \bullet f_{C\ BLDG\ t-1})$ (Stock Change Approach)

(3B) $\Delta C_{HWP\ W\ SCA} = (V_{HWP\ SWDS\ t} \bullet f_{C\ SWDS\ t}) - (V_{HWP\ SWDS\ t-1} \bullet f_{C\ SWDS\ t-1})$ (Stock Change Approach)

Where:

$\Delta C_{HWP\ BLDG\ SCA}$ = annual change in HWP carbon contained in buildings, tonnes C yr^{-1}

$\Delta C_{HWP\ W\ SCA}$ = annual change in HWP carbon contained in SWDS, tonnes C yr^{-1}

A_{BLDG} = floor area of buildings, m^2

$f_{C\ BLDG}$ = HWP carbon in buildings per unit of floor area, tonnes C m^{-2}

$V_{HWP\ SWDS}$ = Volume of HWP waste in disposal sites, m^3

$f_{C\ SWDS}$ = HWP carbon in SWDS per unit volume of SWDS, tonnes C m^{-3}

Data sources for the Tier 2 method

The following bullet points summarise how to obtain the data needed for Tier 2 calculations, identifying defaults which are available in many cases.

Data for variables P_A (carbon in HWP consumed in a country) and PH_A (carbon in HWP products produced by a country) are as follows:

- Default data for HWP production, imports and exports are available in the United Nations FAOSTAT Forestry database since 1961[8] (see Table 3a.1.1). Separate P_A values need to be computed for solidwood and paper products as indicated in the notes to Table 3a.1.1 to allow for different lifetimes in use and disposal patterns.
- Data to convert units of solidwood products to carbon content are shown in Table 3a.1.1.
- Data prior to 1961 can be estimated using a trend in growth back to 1900.

For each forest product in Table 3a.1.1, the values before 1961 can be estimated by:

EQUATION 3a.1.4
EQUATION TO ESTIMATE PRODUCTION AND TRADE FOR YEARS BEFORE 1961

$$V_t = V_{1961} \bullet e^{(r \bullet (t - 1961))}$$

Where *V* is value of the forest product in question, *t* is a year before 1961 and *r* is the estimated growth rate prior to 1961. Default *r* values for growth between 1900 and 1961 are indicated in columns 7 and 8 in Table 3a.1.2.

- See Table 3a.1.1 for factors to convert product amounts from volume or weight measure to tonnes of carbon.

Data for parameters f_D and fH_D (the fraction of HWP carbon put in use in year t that goes out of use in each year)

- Separate f_D and fH_D values are needed for solidwood products and paper products.
- The average f_D and fH_D values for solidwood products could be the weighted average of f_D and fH_D for lumber, panels and other industrial roundwood.
- The average for fH_D would be a weighted average of f_D (for the home country) and for countries where exports are used and later discarded. Weights would be the portion of PH_{A_t} that is from domestic use and the portion of PH_{A_t} that is exported. A starting point would be to assume f_D equals fH_D.

[8] See http://apps.fao.org/page/collections?subset=forestry

- f_D and fH_D values may also be converted from estimates of the half life for products in use or from the average life of a product. The half-life is the number of years until one-half of the products have gone out of use. The average life is the average number of years a product is in use.

  f_D = ln 2 / (half life in years) = 0.693 / (half life in years)

  f_D = 1 / (average life in years)

  average life in years = 1 / f_D

- Half life values of various products used in recent studies, including suggested default values, are shown in Table 3a.1.3. Each country needs to determine values appropriate for their country.

3a.1.2 Completeness

The Tier 2 methods include all primary wood and paper products. By doing so they include the carbon in any secondary wood products made from those primary products. But the methods do not include the effect on stock changes of carbon in imports and exports of secondary wood products, such as furniture or wooden crafts. Methods may need to be adapted to include imports and exports of secondary wood products if HWP is a key category and amounts of secondary wood product traded are notable in comparison to amounts of primary products produced or consumed. The Tier 2 method also omits any estimates of the amount of waste wood that goes from primary or secondary wood and from paper mills directly to SWDS. If these amounts are significant then separate direct estimates may be needed for these wood waste flows to SWDS.

3a.1.3 Uncertainty Assessment

Uncertainty estimates for variables and parameters for the Tier 2 method are shown in Table 3a.1.4. The estimates are based on published studies and expert judgement. If national values are used for variables and parameters, uncertainties should be evaluated consistent with the guidance in Section 5.2, (Identifying and Quantifying Uncertainties) of this report.

The only firm estimates of uncertainty likely to be available are those associated with national surveys of wood and paper products production and trade. For these, the error can be relatively low.

For the Tier 2 method, the effect of uncertainty in production and trade several decades in the past is relatively less if the half-life of products in use and the half-life in SWDS is relatively short. This means that with longer use life, it becomes more important to use country-specific data on production and trade before 1961. Uncertainty in Tier 2 estimates could be quite large particularly if country-specific uncertainty is large in estimates over time in 1) fraction of discarded wood and paper going to SWDS, and 2) proportion of products in SWDS undergoing anaerobic decay. Because of these uncertainties it is desirable to use Tier 3 national level inventory surveys of wood stored in stocks such as housing, if possible. Such surveys may have relatively low uncertainties. Estimating uncertainties associated specifically with the Production Approach would include estimating the uncertainty of decay of products exported to other countries. Overall, uncertainties for Tier 2 or Tier 3 methods may be estimated using Tier 3 (Monte Carlo) methods discussed in Section 5.2, (Identifying and Quantifying Uncertainties). Further work is needed to specify a simpler method to evaluate uncertainties – that is equations that could use uncertainties from Table 3a.1.4 directly to estimate the overall uncertainty rather than to use the Monte Carlo simulation method. Use of the Tier 2 methods with default data, that is, without country-specific data, is unlikely to produce estimates with uncertainly less than ± 50%.

TABLE 3a.1.2
ESTIMATED ANNUAL RATES OF GROWTH FOR INDUSTRIAL ROUNDWOOD PRODUCTION (HARVEST) BY WORLD REGION, FOR SELECTED PERIODS 1900 TO 1961.
(Columns 7 and 8 are rates that may be used to project wood and paper products production and trade data backward in time from 1961 using equation 3A.1.4)

World region	Industrial roundwood Production	Population	Industrial roundwood Production per capita	Population	Industrial roundwood Production with production per capita fixed at 1950 level	Industrial roundwood Production with production per capita deceasing at 1950 to 1975 rate	Industrial roundwood Production with production per capita fixed at 1950 level before 1950	Industrial roundwood Production with production per capita deceasing at 1950 to 1975 rate before 1950
	(1950-1961)	(1950-1961)	(1950-1975)	(1900-1950)	(1900-1950)	(1900-1950)	(1900-1961)	(1900-1961)
	(1)	(2)	(3)	(4)	(5)=(2)	(6)=(3)+(4)	(7) see note	(8) see note
World total	0.0326	0.0182	0.0049	0.0085	0.0182	0.0134	0.0208	0.0169
Europe	0.0296	0.0080	0.012	0.0059	0.0080	0.0179	0.0119	0.0200
USSR	0.0412	0.0173	0.0087	0.0061	0.0173	0.0148	0.0216	0.0196
North America	0.0085	0.0170	0.0016	0.0148	0.0170	0.0164	0.0155	0.0150
Latin America	0.0359	0.0268	0.0054	0.0163	0.0268	0.0217	0.0285	0.0243
Africa	0.0548	0.0226	0.0255	0.0102	0.0226	0.0357	0.0284	0.0391
Asia	0.0492	0.0193	0.0155	0.0078	0.0193	0.0233	0.0247	0.0280
Oceania	0.0412	0.0193	0.0074	0.0155	0.0193	0.0229	0.0233	0.0262

Note:Column 7 is ln (EXP(col 5*50)*EXP(col 1*11))/ 61

Note:Column 8 is ln (EXP(col 6*50)*EXP(col 1*11))/ 61

Data Sources: Column 1 -- 1950-53: (UNFAO 1957), 1954-1960: (UNFAO 1965), 1961: (UNFAO 2002a)

Column 2 – 1950-1960: (UN Pop Div 1998), 1961: (UNFAO 2002b)

Column 3 – Industrial roundwood - 1950-53: (UNFAO 1957), 1954-1960: (UNFAO 1965), 1961-1975: (UNFAO 2002a)

Population – 1950-1960: (UN Pop Div. 1998), 1961-1975: (UNFAO 2002b)

Column 4 – 1900-1950: (UN Pop Div 1999)

Table 3a.1.3
HALF LIFE OF HARVESTED WOOD PRODUCTS IN USE – EXAMPLES FROM STUDIES

Country/ region	Reference	HWP category	Half life in use (years)	Fraction loss each year ($f_{D\,j}$) (ln(2) / Half life in years)
Defaults		Saw wood	35	0.0198
		Veneer, plywood and structural panels	30	0.0231
		Non structural panels	20	0.0347
		Paper	2	0.3466
Finland	Pingoud *et al.* 2001	Saw wood and plywood (based on change in inventory of products)	30	0.0231
Finland	Karjalainen *et al.* 1994	Saw wood and plywood average	50	0.0139
		Paper from mechanical pulp average	7	0.0990
		Paper from chemical pulp average	5.3	0.1308
Finland	Pingoud *et al.* 1996	Average for paper	1.8	0.3851
		Newsprint, household, sanitary paper	0.5	1.3863
		Linerboard fluting and folding boxboard	1	0.6931
		80 % of printing and writing paper	1	0.6931
		20% of printing and writing paper	10	0.0693
Netherlands	Nabuurs 1996	Paper	2	0.3466
		Packing wood	3	0.2310
		Particleboard	20	0.0347
		Saw wood average	35	0.0198
		Saw wood – spruce & poplar	18	0.0385
		Saw wood – oak & beech	45	0.0154
United States	Skog and Nicholson 2000	Saw wood	40	0.0173
		Structural panels	45	0.0154
		Non structural panels	23	0.0301
		Paper (free sheet)	6	0.1155
		Other paper	1	0.6931

Note: It is recommended that use of these estimated half lives be accompanied with verification of the resulting stock change estimates as indicated, for example, in Section 3a.1.5. Adjustments in half lives may be needed as a result.

TABLE 3A.1.4
PARAMETERS, AND ESTIMATES OF UNCERTAINTIES ASSOCIATED WITH DEFAULT VALUES FOR THE TIER 2 METHOD FOR ESTIMATING CHANGE IN CARBON STORAGE IN HWP IN USE

Description of Parameter	Parameter	Values	Uncertainty Range
Roundwood harvest (wood harvested and removed from sites for products including fuelwood)	H	Table 3a.1.1	Country-specific for FAO data
HWP production, imports and exports – FAO data	P_{DP}, P_{IM}, P_{EX} WP, IM(WP), EX (WP) OFP, IM(OFP), EX(OFP) RP, IM(RP), EX(RP) IM(RFP), EX(RFP) Amount of products produced, imported and exported	Table 3a.1.1	Country-specific for FAO data Production and trade – for countries with systematic census or surveys - ±15% since 1961 Production and trade – for countries without systematic census or survey ±50% since 1961
Product volume to product weight	W	Table 3a.1.1	±15%
Oven dry product weight to carbon weight	C	0.5 (Table 3a.1.1)	±10%
Growth rate of production, imports and exports prior to first year of FAO data	r (in Equation 3a.1.4)	Table 3a.1.2, columns 7 and 8	Rate of increase in production prior to 1961 ±15% for a region, larger for country within a region. Rate of increase in trade prior to 1961 ±50% for a region, larger for country within a region.
Fraction of solid wood products discarded from use each year	f_D (solidwood) fH_D (solidwood)	Table 3a.1.3	Half life in years =(0.693 / f_D (solidwood)) Uncertainty in half life = ±50% Uncertainty is greater for fH_D depending on the size and destination of exports
Fraction of paper products discarded from use each year	f_D (paper) fH_D (paper)	Table 3a.1.3	Half life in years =(0.693 / f_D (paper)) Uncertainty in half life = ±50% Uncertainty is greater for fH_D depending on the size and destination of exports

3a.1.4 Reporting and Documentation

It is suggested to document and archive all information used to produce national estimates of stock change. This includes wood and paper production and trade data, 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 could be retraced.

3a.1.5 Inventory Quality Assurance/Quality Control

Regardless of whether or not HWP are a key category it is suggested to conduct quality control checks as outlined in Section 5.5 (Quality Assurance and Quality Control), for data and parameters used for the method selected. If HWP is a key category it is suggested to use additional Tier 2 quality control checks from Section 5.5, (Quality Assurance and Quality Control), particularly development and expert review of data and parameters, and develop, as necessary, national level estimates of data and parameters using national data sources and using expert judgement as outlined in Section 6.2.5, Expert Judgement *(GPG2000)*.

One suggestion to aid in quality control (to verify stock or stock change estimates) if Tier 2 is used, is to make separate estimates of total carbon storage or annual change in specific product groups, e.g., lumber or panels in buildings. The lumber and panels in buildings would be a portion of all lumber stored. The Tier 2 method could be used to estimate the total amount of lumber and panels in buildings, or the change in lumber and panels stored in a recent year. One would need to have an estimate of the portion of wood and panels going to buildings over time. These estimates could be compared to separate estimates of wood in buildings, or change in wood in buildings as follows. The current total of wood and panels in buildings could be calculated as square metres of floor area in buildings times the lumber content per square metre. The change in lumber in buildings could be calculated as square metres of buildings built in a given year times the lumber content per square metre.

Another suggestion, if Tier 2 is used, to aid in checking half life of buildings is to use historical information on the number and age of buildings over time. Data would be needed on the number of buildings of a given age (or age range) at a certain time in the past and the number of those buildings that are standing at more recent points in time. These figures could be used to estimate the fraction loss of buildings per year. The percentage loss per year could be used to estimate a half life. See Table 3a.1.3 for the relation between half life and fraction loss per year under the assumption that a constant fraction is lost each year).