



**Methodics for defining the half-lives of  
harvested wood products as country specific  
ones for Estonia (Metoodika raietoodete  
riiklike poollagunaegade leidmiseks.)**

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## Introduction

The aim of the work is to prepare a methodology for finding the half-lives of harvested wood products (HWP) in the subcategory of greenhouse gas inventory (hereinafter GHG) land use, land use change and forestry (hereinafter LULUCF) sector harvested wood products (HWP) sub-category default half-lives (lose the one-half of the material currently in the pool eg. half-decomposition) suitable methodology for Estonian conditions.

The 2006 IPCC Guidelines define the half-life as “the number of years it takes to lose one half of the material currently in the pool”. This indicates that the simple decay method is used with a constant  $k$  equivalent to  $\ln(2)$ . It was stipulated in the guideline that to achieve country-specific half-lives there must be national information on service life of the default HWP commodities or their sub-categories. The information about the procedure for determining country specific half-life can be sourced from chapter 12 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (page 12.28 – 12.31) and 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (page 2.123- 2.134).

## 1. An overview of the methodologies for finding half-lives

### 1.1. IPCC-19 Calculation method of the country specific half-lives

The country-specific half-life is calculated using the **ISO 15686** standard series method, which is a well-established system for estimating service life on a national (not case-specific) level, in conjunction with obsolescence on a national level. The **estimated service life (ESL)** is used to calculate the country-specific half-life. It is the projected service life of a wooden or wood-based component under a set of precise in-use conditions. **ESL** can be determined by using an **obsolescence (O)** factor or a **decay function that estimates the decay profile (based on items leaving the pool rather than a biological decay profile) or the actual period that products take to become obsolete.**

**Obsolescence (O)** is defined in **ISO 15686-1:2011** as the reference service life (**RSL**) of a product, component, assembly, or system which is known to be expected under a particular (reference) set of in-use conditions). It states when a facility can no longer be adapted to meet changing needs. Obsolescence (**O**) tends to result from unexpected changes, often unrelated to the construction, and includes:

1. **Functional O** (function no longer required).
2. **Technological O** (new alternatives can offer better performance, or there is a change in the pattern of use).
3. **Economic O** (Fully functional but less efficient, or more expensive than alternatives. This includes replacement owing to changing fashion or taste).

For instance, such example given by IPCC (2019 refinement to 2006 (page 12.29) mentions that a wooden decking in northern Europe with an expected service life of 50 years could end up being replaced after 20 years due to aesthetic or other reasons. The IPCC 2019 refinement to 2006 guidelines (page 12.29) stipulates that the estimation of obsolescence should be based on the **designer's** and **client's experience**, and, if possible, **documented feedback from practice**.

Estimation of **O** are as below

- $O = 1$  (no significant impact of obsolescence compared to RSL).
- $O < 1$  (depends on the intensity of the obsolescence).
- $O$  can never be  $> 1$ .

## 1.2 Methodologies used for country specific half-lives in scientific texts

The following equation (see page 12.30 of 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, also available on page 2.128, Chapter 2 of 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol) is used to estimate **ESL**.

$$\text{National ESL} = \text{RSL} \times (A) \times (B) \times (C) \times (D) \times (E) \times (F) \times (G) \quad \text{equation (1)}$$

- A Inherent performance level represents the grade of the component as supplied.
- B Design level reflects the component's installation in the building/constructed asset and is typically based on the level of shelter and protection from agents provided by the design of the building/constructed asset.
- C Work execution level considers the level of skill and control in site-work.
- D Indoor environment considers the exposure of the object to indoor agents of degradation and their severity.
- E Outdoor environment considers exposure to outdoor agents of degradation and their severity.
- F Usage conditions reflects the effect of the use of the building/constructed asset.
- G Maintenance level reflects the level of maintenance assumed. For certain components that are inaccessible or require special equipment for access, a particularly low maintenance level should be considered.

The example below for wooden claddings in **Norway** presented in 'Box 12.2 (page 12.30)' and **Table 12.4** (page 12.31) of Chapter 12 of HWP IPCC guidelines show how to derive the country specific half-lives based on application of **O** factor or function of information market share (with ESL and O).

**Example 1** (Norwegian case study):

Wooden claddings = RSL of 55 years (**ISO 15686-8:2008**)

$$(A = 1) \times (B = 1) \times (C = 1) \times (D = \text{NOT RELEVANT IN THIS CASE}) \times (E = 1.2) \times (F = 1) \times (G = 0.9).$$

$$\text{Hence National ESL} = 55 \times (1) \times (1) \times (1) \times (1.2) \times (1) \times (0.9) = \mathbf{59.4 \text{ years.}}$$

$$\text{Half-life (simple decay) based on the national ESL} = \mathbf{59.4 \times \ln(2) = 41.17 \text{ years.}}$$

**Example 2: Using HWP classes and market share**

TABLE 12.4 EXAMPLE OF HOW TO DERIVE COUNTRY-SPECIFIC HALF-LIFE FOR HWP COMMODITY CLASSES AS A FUNCTION OF INFORMATION ON MARKET SHARE, ESTIMATED SERVICE LIFE (ESL) AND OBSOLESCENCE						
HWP commodity classes ( <i>here: aggregates</i> )	Markets*	Market share of HWP commodity class	National estimated service life (ESL), years	National obsolescence factor (O)	Adjusted ESL of HWP commodity class (=ESL*O* market share adjustment)	Half-life (=Adjusted ESL* ln(2))
Sawn wood	construction	60%	70	0.9	41.0	28.4
	furniture	10%	45	0.6		
	packaging	30%	6	0.3		
	paper	0%	-	-		
Wood-based panels	construction	50%	60	0.7	30.5	21.2
	furniture	45%	35	0.6		
	packaging	5%	6	0.3		
	paper	0%	-	-		
Paper and paperboard	construction	0%	-	-	1.5	1
	furniture	0%	-	-		
	packaging	50%	3	0.3		
	paper	50%	10	2		

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

In this example referred from **Table 12.4** of the IPCC 2019 refinement to 2006 guidelines (page 12.31), the HWP commodity class is used with the market share and combined with ESL and obsolescence factor to determine the half-life of the product.

For HWP Sawn wood aggregates = Construction, furniture, packaging, and paper.

**Adjusted ESL** = HWP market share of commodity × National ESL × National O factor

It is important to apply obsolescence factors as defined by the IPCC. i.e., based on the **designer's** and **client's experience**, and, if possible, **documented feedback from practice** as aforementioned. This will require data and information from the above classes on the HWP commodity categories in **Estonia** to be able to determine the right obsolescence or national obsolescence factor. Half-life information are often obtained through studies. For instance, there have been no extensive studies of product lifespans in New Zealand, although where estimates have been produced, they largely conform to the IPCC default half-life values (35 years sawn timber; 25 years for panels; 2 years for paper and paperboard) (Wakelin *et al.*, 2020). This is an example showing that in similar study of the product lifespan needs to be done in Estonia, following the above point about obtaining data and information from documented feedback etc. In the case of absence of such extensive study, the HL estimates could be made based on such data.

- The data sources used in country-specific estimations should be made publicly available for the benefit of openness and verifiability. As a result, diverse sources of information, such as market usage of different HWP product classes, might be integrated to determine a country-specific half-life. For instance, (Braun *et al.*, 2016) investigated the dynamics of apparent half-lives and carbon content within three important categories of wood utilization (construction, furniture, and packaging) considering sales on the wood product level in Austria for the period 2002 to 2011.

**Static half-lives for finished products** derived from literature or direct communication with experts in the field were used by Braun *et al.*, 2016 (see Table 5) for upscaling information about carbon flows and associated HL to semi-finished HWP. Averaged over 10 years, the following half-lives for finished products are derived: 33.0 years for construction, 8.5 years for furniture, and 1.4 years for packaging (also shown in Table 1).

In cases where data on the country-specific service life for HWP commodities are not available, data sources that are closely related or can represent the country condition have been considered (Aryapratama and Pauliuk, 2019). Furthermore, Manley and Evison, 2018, showed that data on the application of the HWP commodity in the importing country is essential to applying half-lives. For instance, for logs exported to China from New Zealand, it was found that the half-life is under 2 years since logs have been applied to produce temporary construction material (46%), packaging (13%) and appearance products (9%). The amount of radiata pine used to make long-lasting goods, however, causes 10% of the carbon storage as HWP for about 23 years, and 5% after 52 years.

Based on the available information on export and import, Estonia is a net producing country and it would suffice that the **production approach** (PA), which is currently used to estimate the contribution to CO<sub>2</sub> emission or removal by HWP is necessary. According to the IPCC, when using the PA to estimate CO<sub>2</sub> emissions or removals, country-specific half-life data from the importing nation should be employed. Quantifying export activity data within HWP commodity classes and/or sub-classes is required. “To ensure that the country-specific half-life information from the importing country is consistent with the commodity classes of the activity data for the exported HWP, it is best practice to use country-specific half-life information only when both the exporting and importing countries use the same commodity classes of activity data for the exported HWP. **Otherwise, the Tier 1 default settings are to be used.**”

**Hence, half - lives for semi-finished HWP** (sawn wood and wood-based panels) For each category the shares of **semi-finished HWP** (sawn wood and wood-based panels) are determined. It is important to note that half-life on a national level is likely to change over time. Furthermore, the estimated **uncertainties for half-life range up to  $\pm 50\%$**  (IPCC 2003).

**Table 1.** Country-specific half-life of HWP published by Chang *et al.*, 2014 and from other sourced literature.

Country	Reference	Half-life (years)							
		Sawn wood & plywood	Paper		Construction	Furniture	Packaging	Particle board/Wood panel	fences, window frames, floors
			Mech. pulp	Chem. pulp					
Finland	Karjalainen, Kellomäki and Pussinen, 1994.	30 (0.0231)	7 (0.0990)	5.3 (0.1308)					
	Pingoud, Perälä and Pussinen, 2001.	50 (0.0139)							
	Pingoud, Savolainen and Seppälä, 1996.	–	1.8 (0.3851)						
Europe	Eggers, 2002.	50	1 (printing paper), 4 (books & posters)		50	16	1		16
Europe (15 countries) without Estonia, etc	Kohlmaier <i>et al.</i> , 2007	24.3	1.4		55.4	27.7		24.3	6.9
Netherlands	Nabuurs, 1996	35	2 (0.3466)				3 (0.2310)	20 (0.0347)	
	Sikkema and J. Nabuurs, 1995					15			
Germany	Burschel <i>et al.</i> , 1993		1		65	15			
United States	Skog and Nicholson, 1998	40 (0.0173)	1(0.6931): other paper – 6 (0.1155): free sheet			30			6
Canada (adopted HL from the US)	Chen <i>et al.</i> , 2014	20	2.5	50–85 **					
Austria (2002-2011)	Braun <i>et al.</i> , 2016	9.5–16.6			33 *	8.5*	1.4 *	9-11	1.6
Korea (determined by mass flow)	Chang <i>et al.</i> , 2014	15.1 (plywood)						15.5, 14.9 MDF	
China	Yu <i>et al.</i> , 2022				70 <sup>a</sup> /20–30 <sup>b</sup>	40–50 <sup>b</sup>			
Lithuania	Aleinikovas <i>et al.</i> , 2018	IPCC default						IPCC default /45 <sup>c</sup>	3
Czech Republic	Jasinevičius <i>et al.</i> , 2018	IPCC default	IPCC default		45 <sup>d</sup>				3
Spain	Canals-Revilla <i>et al.</i> , 2014				25	10–20			



Japan	Kayo, Tsunetsugu and Tonosaki, 2015	2	35	20
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() Represents the fraction loss  $(\ln(2)/\text{Half-life in year})$

\* Only the category HL is shown.

\*\* single-family house construction, multi-family house construction

<sup>a</sup> Structural.

<sup>b</sup> Wood-based panel-Sawn wood.

<sup>c</sup> Cross laminated timber (CLT).

<sup>d</sup> Wood for log houses.

<sup>e</sup> French technological institute FCBA (Forêt, Cellulose, Bois-Construction, Ameublement)

### 1.3 Methodological overview of country specific half-life for Estonia

Information provided in **section 1.2**, showed that to apply country specific half-life in Estonia, the data about the HWP commodity service life is essential. As it was previously highlighted it is important to apply obsolescence factors as defined by the IPCC. This will require data and information specific to **Estonia**. Regarding exported commodities, the country specific half-lives of the importing country for the HWP commodity should be applied where available. However, it is not uncommon for data insufficiency with regards to the exported products, because of a lack of knowledge about the application of HWP in the importing country. In this regard, the exporting countries have often applied the same lifetimes and products domestic end use as a bases for the estimation of the HWP carbon stock (Iordan *et al.*, 2018). This implies the use of the exporting countries HWP commodity half-life. But these assumptions could introduce errors into national emission estimates. Regardless, data on the service life of HWP commodities can be acquired from the following:

- Expert interviews
  - Designers, architects, engineers, and constructors with product knowledge on the service life of HWP commodities in use in Estonia.
- Scientific library of research
  - Publication about HWP service life data specific to Estonia or similar to the Estonian climate of the various categories of HWP, available in scientific medias.
- Experimental data
  - Documented feedback from practice.
- Client database/Market survey
  - Information on end use of the products. Estonian State Forest Management Centre has published data on assortments of wood cut and sold with carbon lifetime (lifespan)- in Table 2. Such information can be suitable for application in applying the half-life of HWP in Estonia. The lifetime of was determined using the method described by IPCC for product life based on the customer's main product and the carbon sequestration time. To calculate the half-lives the product lifespan should be multiplied with  $\ln(2)$ .

**Table 2.** Estonian State Forest Management Centre harvested and sold logs assortments with lifespan of carbon

Assortment	Wood species	C Lifespan (y)
House log	pine	37.5
Softwood log	pine, spruce, larch	25.4
Softwood post	pine, spruce	24.2
Hard Hardwood log	oak, ash	18.2
Softwood low quality wood	pine, spruce	17.3
Plywood-, veneer log	birch	16.4
Hardwood log	aspen, black alder	13.0
Softwood smaller diameter log (puulatt)	pine, spruce	9.6
Firewood logs	softwood, hardwood	3.6
Pulpwood logs	spruce, pine, aspen	2.9
Pulpwood logs	birch	2.6

For comparison, the half-life (lifespan multiplied with  $\ln(2)$ ) of pulpwood log with half-life for paper in the default values IPCC it was found to be lower (Table 3).

**Table 3.** IPCC default half-lives of HWP categories (Table 12.3, page 12.28, IPCC refinement to 2006 guideline).

HWP categories	Default half-lives (years)
Paper	2
Wood panels	25
Sawn wood	35

Most data acquisition process could involve the following to provide reliable information.

Emphasis should be on having a data management system between the HWP production to utilization. In Estonia, the quantity and type of HWP used in construction should be sufficient. There is a need for the interrelation between Estonian statistics management, building contractors, and material suppliers. What structures were built that year, what stock of HWP was used, and when was any type of reconstruction done? Consequently, a case study will be conducted to investigate sampling in various active construction projects to create the Estonian-specific SL of HWP in building construction. What is the year of construction, how much HWP was used, and what is the estimated SL of the structure before considering renovation? Such data may subsequently be used to replicate nation-specific information; however, data on the actual volume of HWP entering the country, particularly in Estonia, is required. Stocks based on new buildings are simply added for the year when the CS is estimated. It was also aforementioned that to estimate the country-specific half-lives, in the case of Estonia, where such study has not been done before. To overcome an inadequate data problem, the questionnaires/interviews with experts (designers, architects, constructors, engineers and users) could be gathered through sampling to get an idea of the service life of buildings with HWP.

The tier 3 methodology estimates for half-life that suited for Estonian conditions (National), the question is in availability of national data i.e. imports and exports of industrial wood and commodities tracked well for commercial products.

- From the example below in the table we see that the HL has been calculated to bear varying values.

Category	Reference	end use	Half-life (year)
Residential construction	Skog and Nicholson (S. & N.) 1998	Single-family(SF) homes (pre-1980)	80
		SF homes (post-1980)	100
		Multifamily(MF) homes	70
		Mobile homes	20
	Skog 2008	Solidwood in SF 1920 and before (years)	75
		Solidwood in SF 1921 and 1939 (years)	80
		(Increase in HL for each 20 year period after 1921 to 1939 (years))	5

Comparing the HL of wood used for construction to Germany is as follows,

Category	Reference	end use	Half-life (year)
Construction	Germany (Burschelet al.1993)	Construction	65
	Europe(Eggers 2002)	sawn timber, plywood, PB for Building, civil engineering	50

There is a need to consult with the international experts who have calculated HL for the specific list of studies. The following topics for consulting with external expert are recommended:

1. At first the longest-lifespan wood products are used in construction. It is recommended to conduct the study to make data inventory of HWP used in construction of the buildings based on year of construction and quantity of wood used per sqm. Carbon sequestration is defined in inventory year and will be compared with the previous inventory usually 10y ago results. Norway included in revised model of building stock inventory HWP in uninhabited buildings (cabins, outbuildings, and garages).
2. Analysis of country specific statistics data and validation by using expert opinions (Estonian wood balance reports). There are problems with reporting sawnwood and planed sawnwood in statistics. No reliable data about internal consumption of semifinished harvested wood products (SF-HWP). The socio-economical surveys for determining the internal consumption SF-HWP in finished harvested wood products (F-HWP). How much local woodpanelproducts (semi-finished HWP category) is used in furniture industry is also unclear.
3. Development of **service life** prediction models to provide reliable service life estimates for of SF-HWP used in construction, furniture and packaging. The service-life of F-HWP is mainly defined by physical, chemical conditions and socio-economic factors (Pingoud et al., 1996). Wood Life-Cycle Cost analysis (WoodLCC) project (2022-2025) is making a comparison of service life prediction using pre-fabrication of wooden building elements and modules vs on-site full assembly technologies. Comparison is done by using existing service life prediction modules combined with data from studies related with given building techniques, where service life prediction is done by hygrothermal modelling based on experimental data.
4. For the country specific half-life determination, the realistic service life should be determined with real wood decay experiments should be carried out. Using mathematical functions enables to model decay in large scale.
5. There is no information available for lifespan of the wood products used in households. Socio-economical surveys are needed to collect information from stakeholders and private users (e.g., studies of the average lifespan of the furniture or study of life expectancy of home components) the real service life should be determined (ESL+ Obsolescence factor).
6. Combining the scientific research data with data collected from surveys of socio-economic factors in methodology. Half-life on national level is likely to change over times (Braun, et. Al 2016).
7. Uncertainty analysis of the data
8. Quality assessment of the method used

To address some of the reliability issues regarding half-life data, uncertainty using a normal distribution with 95% confidence level can be used as shown below (Skog and Nicholson, 1998):

Probability distributions for uncertain data and parameters for United States.

Variable	Value(s)	Uncertainty (95% confidence interval)
1. Solid wood production and trade, 1961 to current year	FAO database 1961–2000	Normal distribution $\pm 15\%$
2. Paper production and trade, 1961 to current year	FAO database 1961–2000	Normal distribution $\pm 15\%$
3. Solidwood conversion to carbon weight	2.25E-07 TgC/m <sup>3</sup>	Normal distribution $\pm 14\%$
4. Paper conversion to carbon weight	4.50E-07 TgC/adt	Normal distribution $\pm 14\%$
5. Increase rate in production and trade, 1900–1961	0.47%/year	Normal distribution $\pm 80\%$ (resulting confidence interval for production in 1900, $\pm 30\%$ of mean)
6. Solidwood in use discard rate/service life	1.98%/year (half-life = 35 years) (Skog and Nicholson 1998)	Normal distribution $\pm 30\%$ (Half-life confidence interval, 27–50 years)
7. Paper in use discard rate/service life	69.3%/year (half-life = 1 year)	Normal distribution $\pm 30\%$ (Half-life confidence interval, 0.8 to 1.4 years)
8. Fraction solidwood to anaerobic decay, 1900–1950	7.5%	Uniform distribution range $-100\%$ to $+100\%$ of mean (i.e., of 7.5%)
9. Fraction solidwood to anaerobic decay, 1950–2000	See Figure 1	Weighted transition from 1950 to 2000 Uniform distribution $\pm 100\%$ of 7.5% in 1950, to normal distribution $\pm 30\%$ in 2000
10. Fraction paper to anaerobic 7.5% decay, 1900–1950	7.5%	Uniform distribution range $-100\%$ to $+100\%$ of the mean (i.e., of 7.5%)
11. Fraction paper to anaerobic decay, 1951–2000	See Figure 2	Weighted transition from 1950 to 2000 Uniform distribution $\pm 100\%$ of 7.5% in 1950 to normal distribution $\pm 30\%$ in 2000
12. Solidwood decay limit, anaerobic SWDS	3% (Micales and Skog 1997)	Triangular distribution, mode 3%, minimum 0%, maximum 15%
13. Paper decay limit, anaerobic SWDS	28% (Micales and Skog 1997)	Normal distribution $\pm 30\%$
14. Decay rate in SWDS	5%/year (half-life = 14 years) (IPCC 2000, waste sector)	Triangular distribution, mode 5%, minimum 3%, maximum 15%

These uncertainties are adopted for instance already from 2003 IPCC guideline.

**As an example: In understanding that HWP half-life is dynamic, Category HL calculation Braun *et al.*, 2016 estimated the HWP commodity specifically for Austria, using HL from literature and direct communications from experts.**

The average HL has been calculated first for each category (construction, furniture, packaging) and subsequently total HL value by applying equation (2)

$$0.5 = \sum_{CAT} CAT_i * \exp((- \ln(2) * x) / HL_i), \quad (2)$$

where

$i$  – number of category or subcategory,

$CAT_i$  – share of category  $i$  (osakaal),

$HL_i$  – semi-finished harvested wood product (SF-HWP) half-life in years,

$x$  – weighted average half-life (HL) for HWP for one year (variable).

The equation (1) is solved with respect to variable  $x$  by using Excel Solver and GRG non-linear engine.

The value of the  $x$  can be computed for each HWP category separately as well as for total HL over all HWP categories.

The equation (1) should be solved for each particular year separately.

Table 4 demonstrates the calculation example how to calculate weighted average half-lives for sold finished HWP produced in Austria in 2002 Braun (2016). The HL categories and sub-categories were

calculated in the same manner setting the amount of carbon (gigagrams of carbon Gg C) for each category based on available literature data (Table 5). The paper and paper products are not covered by Braun (2016)

**Table 4.** Calculation example how to calculate weighted average half-lives for sold finished HWP produced in Austria in 2002 Braun (2016).

Sold production 2002					
Category	Subcategory	Sub-subcategory	Gg C	Share	HL years
Construction	Formwork		25.0	7.27%	0.75
	Railroad ties		0.6	0.19%	20.80
	Fences		5.2	1.50%	16.00
	Poles and posts		4.3	1.24%	20.80
	Windows		6.9	2.02%	20.80
	Doors		13.1	3.81%	19.10
	Floors		15.0	4.38%	20.80
	Carpenter work	Glue laminated/cross laminated timber	86.5	25.16%	48.80
		Wall-elements	6.6	1.93%	48.80
		Stairs	1.1	0.33%	20.80
		Sauna cabinets	0.2	0.06%	16.00
		Floors	6.3	1.84%	20.80
		Wood-glass-constructions	0.4	0.11%	16.00
		Other wooden goods for construction	18.5	5.38%	36.00
		Other carpenter work	6.8	1.99%	36.00
		Barracks	8.0	2.31%	24.30
		Houses	33.5	9.75%	71.00
	<i>Category HL 31.4 years</i>				
Furniture	Outdoor		3.2	0.92%	3.50
	Office		16.7	4.86%	6.90
	Private		12.4	3.61%	17.00
	<i>Category HL 8.8 years</i>				
Packaging	Boxes/other		12.6	3.67%	1.00
	Packaging				
	Pallets		60.8	17.68%	1.60
	<i>Category HL 1.5 years</i>				
Total	<i>Total HL 14.6 years</i>		343.8	100.00%	

**Table 5.** Data sources and factors for product-specific half-lives (Braun, 2016).

Category	HL [years]	Source
Formwork	0.75	Stolz (2013)
Railroad ties	20.8	Pfabigan (2013)
Fences	16	Eggers (2002)
Poles and Posts	20.8	Vial (2008)
Windows	20.8	Bundesamt für Konjunkturfragen (1995)
Doors	24.3	Bundesamt für Konjunkturfragen (1995)
	6.9	Lochu (1998)
	13.9	Lochu (1998)
	20.8	Lochu (1998)
	13.9	Bundesamt für Konjunkturfragen (1995)
	34.7	Bundesamt für Konjunkturfragen (1995)
Floors	20.8	Lochu (1998)

	20.8	Sikkema and Nabuurs (1994)
Gluelam/CLT	[cf. wall elements]	
Wall-Elements	36	Wirth et al. (2004)
	65	Burschel et al. (1993)
	80	Thompson and Matthews (1989)
	45.1	Burschel et al. (1993)
	149	Burschel et al. (1993)
	10.4	Sikkema and Nabuurs (1994)
	24.3	Anderle et al. (2002)
	55.5	Hoen and Solberg (1997)
	55.5	Wimmer (1992)
	27.7	Lochu (1998)
	52	Scharai Rad and Frühwald (2002)
	52	Vial (2008)
	39.5	Rüter (2008)
	38.8	Rüter (2008)
	27.7	Lochu (1998)
	34.7	Kaipainen et al. (2004)
	36	Wirth et al. (2004)
	50	Eggers (2002)
Stairs	20.8	Lochu (1998)
Sauna Cabinets	16.0	Eggers (2002)
Floors	20.8	Lochu (1998)
	20.8	Sikkema and Nabuurs (1994)
Wood-Glass-Constructions	16.0	Eggers (2002)
Other Wooden Constr	36.0	Wirth et al. (2004)
Other Carpenter	36.0	Wirth et al. (2004)
Barracks	27.7	Lochu (1998)
	20.8	Lochu (1998)
Houses	80.0	Burschel et al. (1993)
	127.5	Kohlmaier et al. (2007)
	69.3	Gustavsson et al. (2006,)
	62.4	Holzabsatzfonds (2008)
	34.7	Lochu (1998)
	52.0	Börjesson and Gustavsson (2000)
Outdoor	3.5	Vial (2008)
Office	6.9	Vial (2008)
Private	13.9	Lochu (1998)
	15.0	Burschel et al. (1993)
	16.0	Eggers (2002)
	18.0	Wirth et al. (2004)
	8.3	Lochu (1998)
	10.4	Burschel et al. (1993)
	10.4	Sikkema and Nabuurs (1994)
	34.7	Burschel et al. (1993)
	13.9	Vial (2008)
	15.0	Burschel et al. (1993)
	27.7	Wimmer (1992)
	13.0	Burschel et al. (1993)
	29.8	Burschel et al. (1993)
	10.0	Burschel et al. (1993)
	20.8	Burschel et al. (1993)
	13.9	Hoen and Solberg (1997)
	9.0	Vial (2008)

	17.3	Bundesamt für Konjunkturfragen (1995)
	17.3	Vial (2008)
	18.0	Burschel et al. (1993)
	38.8	Burschel et al. (1993)
	9.0	Vial (2008)
	10.4	Vial (2008)
Boxes	1.0	Eggers (2002)
	2.1	Anderle et al. (2002)
	0.7	Lochu (1998)
	0.1	Lochu (1998)
Pallets	0.06	Vial (2008)
	1.39	Sikkema and Nabuurs (1994)
	1.39	Hoen and Solberg (1997)
	3.425	Burschel et al. (1993)

When using finished HWP category information with static half lives data for sub-categories from the literature (see Tables 4 and 5) and changing material flow for deriving semi-finished HWP half-lives the changes of it are influenced by the finished HWP distribution to the categories: construction, furniture or packaging. Using the wood balance data 2020 the energetic use forms 5.9 M m<sup>3</sup> and construction material 0.14 M m<sup>3</sup>, furniture industry 0.07 M m<sup>3</sup> and paper and cardboard 0,5 M m<sup>3</sup> of domestic HWP consumption. Leaving energetic use out of calculation leaves only 0,717 M m<sup>3</sup> of HWP in domestic use in HWP. The export forms 9.4 M m<sup>3</sup> that is majority of HWP produced in Estonia and sold as semi-finished or finished HWP. In PA approach only, those semi-products produced from wood from Estonia are considered. The annual change in bound carbon should be calculated for each group of logging products, considering the stored carbon and the simultaneous decomposition of the products. If we compare the export data from wood balance report and the export data that from foreign trade (See the Table A1 and Figure A1) then for instance exported plywood amount differs 10 times. In foreign trade statistics the monetary value of exported goods is given. Thus, the conversion coefficients based on wood densities used to convert the data into quantity units. The data is also collected from different statistical sources and in some cases the producer data with expert evaluation is used.

The most difficult part for the dynamic half-life calculation is dividing exported product groups of semi-finished HWP under finished HWP categories: construction, furniture or packaging. Especially exported HWP-s. Based on Estonian national foreign trade statistics of wood products for every HWP category the half-lives for particular countries where the products were sold, the country specific data with weights can be used. The development and implementation of the methods for calculating dynamic half-lives needs more study.



## 2. Methodological Approach Suitable for Estonia to Estimate HWP Contribution to CO<sub>2</sub> stock

It was stipulated in the required deliverables to ascertain how Estonia can apply country-specific HL towards estimating CS, as well as the method to estimate the CS. This chapter captures the methods to estimate the CS and simply explains that the PA approach is sufficient considering that Estonia is an HWP producer.

The benefit of this chapter is that it provides an easy understanding of why a certain method is suitable and per adventure, any changes occur in the future it could be a point of reference. It also shows how country-specific data can be used in conjunction with the methods to estimate CS. The chapter mentions that PA is applied for the calculation of CS, more so applied in Europe which provides for more consistent calculation of the CS globally. Also the PA accounts for the stock changes in the producing country.

The International Panel on Climate Change (IPCC) provides for four approaches to estimate the carbon stock in HWP: (1) Stock change approach, (2) the production approach, (3) the atmospheric-flow approach, and (4) simple decay approach.

### 2.1 Stock-Change Approach (SCA)

The stock-change approach estimates changes in wood carbon stocks in the forest pool and wood-products pool in the reporting country. Stock changes in forests are accounted for in the producing country, whereas stock changes in wood products are accounted for in the consuming country (Winjum *et al.*, 1998).

### 2.2 Production Approach (PA)

The Production Approach (PA) estimates changes in carbon stocks in the forest pool of the reporting country and the wood products pool containing products made from wood harvested in the reporting (Chapter 12., IPCC Guidelines) country. Stock changes derived from forests are accounted for in the producing country. The carbon contained in exported wood products remains accounted for in the carbon stock of the producing Country.

### 2.3 Atmospheric-flow approach (APA)

The Atmospheric Flow Approach (AFA) estimates fluxes of carbon to/from the atmosphere for the forest pool and wood products pool within national boundaries, and reports where and when these emissions and removals (Chapter 12., IPCC Guidelines) occur. Any emissions associated with carbon stocks that cross a system boundary are boundary is transferred from one country's inventory to another.

The International Panel on Climate Change provides guidelines on the three tier methods; these tiers of methods are applied based on the input data available.

### 2.4 Simple Decay Approach

The Simple Decay 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. Removal of carbon from the atmosphere due to forest growth and emissions resulting from oxidation of HWP are reported by the producing country (Chapter 12., IPCC Guidelines).

Among the different approach the common approach under Kyoto Protocol is the Production Approach (PA), accuracy of the approach is also scale dependent for greater accuracy at higher tiers. The difference between tier2 and tier 3 are studied as described below (table 7).

The PA has been used or compared with other approach (Table 6) and appears to show a more accurate estimation of the carbon stock, especially for HWP producing countries. Furthermore, the results published by Yu et al., 2022 especially shows that using the PA from the latest IPCC guidelines of 2019 provides a better estimation of carbon stocks compared to that of 2013. According to Green et al., 2006 the use of this strategy would necessitate governments being required to disclose carbon pools that are located outside of national borders. Adoption of this method would also have consequences for other carbon pools in terms of consistency. Countries are expected to face technological challenges. Besides the carbon accounting approach, the IPCC tier 1, 2 and tier 3 methods have been compared. The tier 1 method assumes that the HWP carbon stock is constant over time (can be applied by developing countries only), hence not recommended for Estonia. Tier 2 uses default HWP categories and Food and Agriculture Organization (FAO) activity data on HWP. While tier 3 uses country specific HWP activity (more transparent and reliable data) is the most recommended for reliable result, where data on the HWP activity and commodities specific to the countries involved are available. Table 8 shows the system boundary between tier 2 and 3 highlighted in a recent study by Aleinikovas et al., 2018b. It is observed that the application of tier 3 would require information on country specific half-life values.

The research used the domestic wood resources in South Korea to determine the carbon storage impacts by comparing Tier 2 and tier 3 methods. Exported HWP were excluded (Jang *et al.*, 2021) see the Table 6.

**Table 6.** The four approaches to estimate the carbon stock in HWP provided by IPCC with system boundaries

HWP approaches		System boundaries (Pools in which carbon stock changes are estimated)			
Pool-based method	Flux-based method				
Instantaneous Oxidation	-	Forest land carbon pools	HWP pool domestically produced and utilized	HWP pool exported and utilized in other countries	HWP pool imported and utilized domestically
SCAD	-	Forest land carbon pools	HWP pool domestically produced and utilized	HWP pool exported and utilized in other countries	HWP pool imported and utilized domestically
Production	Simple-decay	Forest land carbon pools	HWP pool domestically produced and utilized	HWP pool exported and utilized in other countries	HWP pool imported and utilized domestically
Stock-change	Atmospheric-flow	Forest land carbon pools	HWP pool domestically produced and utilized	HWP pool exported and utilized in other countries	HWP pool imported and utilized domestically

Each HWP approach includes the components with grey color and exclude the components with write color

Based on literature research in publications about HWP activities in different countries where carbon stock change studies were conducted. An overview of the approach used in estimating HWP contribution to carbon emissions/recovery research results is given in **Table 7**.

**Table 7.** An overview of the approach used in estimating HWP contribution to carbon emissions/recovery based on publications and countries where studies were conducted.

s/n	Country	Description of HWP activities	Approach for estimation of carbon stock (CS)
1.	<b>China</b> (Yu <i>et al.</i> , 2022)	Estimation of HWP carbon stock in China from 1961 to 2019, followed by an examination of potential changes in HWP carbon stock in China under various wood and recovered paper use scenarios from 2020 to 2050.	Compared the production approach (PA) method of 2013 IPCC guideline with that of the latest guideline (2019). The 2019 guideline gives a more accurate version of the world's growing share of paper and paperboard products made from recovered paper. - <b>PA2019 and the chi-square decay model were used to determine the annual inflow and outflow of the HWP carbon pool, respectively.</b>
2.	<b>Lithuania</b> (Aleinikovas <i>et al.</i> , 2018b)	IPCC Tier 2 method (data on HWP from statistics or the literature, default half-life values, and default HWP categories) and material flow analysis, which is compatible with the IPCC Tier 3 method (material flow data on HWP, country-specific half-life values, and country-specific HWP categories).	Tier 3 with FAOSTAT (material flow data on HWP, country-specific half-life values for CLT and pallets were used (sawn wood and other wood-based panel half-lives taken as default (IPCC), and country-specific groups of HWP) data from 1992–2015. ○ highest carbon stock in HWP (19.5 Mt). Tier 2 with national statistics from 1940–1991: (data on HWP from statistics or literature, default half-life values, and default HWP categories) ○ lowest carbon stock in HWP (11.2 Mt).
3.	<b>Canada</b> (HWP producer) (Chen <i>et al.</i> , 2014)	Used life-cycle carbon stocks and emissions of HWP of producing country, regardless of where the HWP are used and disposed of.	Production approach (PA): Estimate (a) carbon stocks of HWP in use, (b) carbon stocks of discarded HWP and mill residue in landfills, dumps, and stockpiles, (c) fossil fuel-based GHG emissions from HWP production, (d) methane (CH <sub>4</sub> ) emissions from decomposing wood residue and HWP disposed of in landfills, (e) avoided emissions from using wood residue and collected landfill CH <sub>4</sub> in place of fossil fuels to produce energy, and (f) avoided fossil fuel emissions from using HWP to replace energy-intensive materials in residential construction.
4.	<b>Czech Republic</b> exports to neighbouring countries, mainly to Austria and Germany.(Jasinevičius <i>et al.</i> , 2018)	Use country-specific data for key categories of HWPs to enable for more accurate evaluations. The amount of carbon stored in the HWP pool may be underestimated if simpler methods such as tier 1 is used.	Using material flow analysis (MFA). Carbon inflow and stock change (SCA) were used with tier 2 (IPCC guidelines) and tier 3 methods (national statistics) were compared. Applying the tier 3 method resulted in a 15.8% higher annual carbon inflow in the pool of HWPs compared to the tier 2 IPCC default method.
5.	<b>Spain</b> (Canals-Revilla <i>et al.</i> , 2014)	During the years 1990-2002, the <b>Stock Change Approach (SCA)</b> provided the highest carbon stock accounting. However, since 2002, the <b>Production Approach</b> has presented greater carbon stock levels.	Tier 3 method was used to compare results of SCA, PA and atmospheric approach (AFA). Only carbon stock in particleboard and fibreboard, for the period 1990-2006 was estimated. <b>PA appears to be the best approach for estimation of CS.</b> An uncertainty analysis was also carried out with Monte Carlo simulation.
6.	<b>Portugal</b> (Dias, Arroja and Capela, 2012)	Solid waste disposal stations (SWDS) were and/or continue to be a significant end-of-life option for HWP in Portugal. As a result, a suitable approach should incorporate carbon accumulation in both HWP	Tier 1 & tier 2 methods were compared. The HWP contribution was calculated for three approaches: SCA, PA and AFA. An uncertainty analysis was carried out with Monte Carlo simulation. <b>Tier 2 method gave a better accounting with PA.</b>

		disposed of in SWDS overseas and HWP undergoing anaerobic degradation in Portuguese SWDS.	
7.	<b>Ireland</b> (Green <i>et al.</i> , 2006)	“Using a model, the C stock both in use and in solid waste disposal sites (SWDS) at a national scale in Ireland was estimated and compared for the period 1961–2003 with uncertainty in the estimates generated using a Monte Carlo analysis.”	Three approaches (SCA, PA and AFA) were compared to the IPCC default approach, which considers no change in the HWP pool, i.e., stock change equivalent to 0. SCA approach showed the highest carbon sink.
8.	<b>New Zealand</b> (Wakelin <i>et al.</i> , 2020)	Harvesting has more than quadrupled in New Zealand since 1990, but log exports have increased by a factor of 11 due to previous afforestation and very little development in local processing. <b>“Choice of system boundary has a large impact for a country with a small domestic market and significant HWP exports”</b>	Stock changes in planted forests and HWPs rate highly as essential categories under the <b>PA</b> used for New Zealand's greenhouse gas inventory reporting. Because emissions from exported HWPs are not included in the <b>AFA</b> , the contribution from HWPs is significantly larger. Because the domestic market is tiny, the <b>SCA</b> reduces the contribution of HWPs. Using country-specific data back backfilling data from 1900 to 1960 has minimal influence but utilizing country-specific parameters instead of IPCC settings resulted in a lower HWP sink. This is due to the dominance of plantation forestry, which is based on a softwood that is mostly employed in very short-lived goods.
9.	<b>Japan</b> (Kayo, Tsunetsugu and Tonosaki, 2015)	New model for model for evaluating the HWP carbon balance in Japan. Based on old model that determined that domestic wood's carbon stock may become an emission source rather than a sink unless future supply and demand levels are increased by variables such as regulations promoting wood use.	Carbon storage volume and its future changes are estimated using the production approach with country-specific methods.
	(Sato and Nojiri, 2019)	To identify the cases of global double-counting and non-counting of HWP using 6 approaches: instantaneous oxidation, SCA, PA, SCA for HWP of domestic origin (SCAD), simple-decay and AFA. <b>2006 IPCC guidelines was applied.</b>	“Instantaneous oxidation remains a pragmatic approach for countries in which wood production is not a dominant part of the economy”. Combining instantaneous oxidation with the PA, SCAD, or simple decay techniques might be a viable strategy for realizing a worldwide HWP accounting system that prevents duplicate counting.
10.	<b>European community</b> (EU-15 countries: Austria, Belgium, Luxemburg, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom. (Kohlmaier <i>et al.</i> , 2007)	HWP in use and in landfills were considered in this study. When methane outgassing is considered, which occurs as a 1:1 mixture with CO <sub>2</sub> under the current anaerobic conditions, the GHG balance results in minus 10.0 Mt C equivalent/and minus 10.6 Mt C equivalent/for the Stock Change Approach and the Production Approach, respectively, under the parameters chosen.	SCA and PA approach was applied to estimate HWP in 15 EU countries (minus Estonia and other Baltic states).
11.	<b>The United States</b> (Stockmann <i>et al.</i> , 2012)	The IPCC accounting technique and the California Forest Project Protocol (CFPP) were used to estimate HWP carbon storage for the USFS Northern Region,	The CFPP 100-year average uses harvest year data was compared to the IPCC using The PA approach.

		which encompasses forests in northern Idaho, Montana, South Dakota, and eastern Washington, from 1906 to 2010.	
	(Skog, Pingoud and Smith, 2004)	The main goal is the estimation method rather than the accounting approach such as PA, SCA etc.	Tier 2 estimation method was used with stock change approach as the illustrative accounting approach. And first-order decay method was used to estimate the annual change in carbon stored in HWP.
12.	<b>Switzerland</b> (Camin <i>et al.</i> , 2020)	The report focuses on harvested wood products (HWP) in the Swiss GHG inventory. Description of time series modelling methodology and results used for accounting HWP under the Kyoto Protocol. It shows the methods applied to estimate the carbon stock (CS) changes in HWP in Switzerland under the Kyoto protocol.	<p>The CS was calculated for three categories of HWP under semi-finished wood product: sawn wood, wood-based panels and paper and paperboard. FAOSTAT data and survey information from the Swiss wood industry were used with Tier 2 &amp; 3 methodologies.</p> <ul style="list-style-type: none"> <li>- CS changes were calculated using default first order decay (Tier 2).</li> <li>- HWP from deforestation activities were accounted for using instantaneous oxidation (Tier 1) (imported HWP not counted): for the solid waste disposal sites.</li> </ul> <p><b>The total inflow of carbon to the HWP pool in 2016 amounted to 640 kt C and outflow in 2015 was 582 kt C, implying net C gain of 58 kt C.</b></p>
13.	<b>South Korea</b> (Jang <i>et al.</i> , 2021)	This research accounted for the carbon sequestered in domestic HWPs used in compliance with the seventh CMP agreement (2013 IPCC Guidelines). Carbon accounting methods can influence the accuracy of carbon accounting value.	<p>The research used the domestic wood resources in South Korea to determine the carbon storage impacts by comparing Tier 2 and tier 3 methods. Exported HWP were excluded.</p> <ul style="list-style-type: none"> <li>- Tier 2 (data: sawn woods and wood panels produced) &amp; Tier 3 (ratio of each type of wood product used in each industry for the last 5 years used i.e., the amount of sawn wood and wood-based panels divided into each industry from the total amount of production).</li> <li>- Default half-life was applied (Tier 2). Applied to Industries by primary products (Tier 3 (see Table 2 of paper)).</li> <li>- Significant difference was obtained between both methods with tier 2 methods presenting two times the value obtained in tier 3.</li> <li>- For net importing countries, the tier 2 method could cause overestimation of carbon storage.</li> </ul>

**Table 8.** The comparison between Tier 2 and Tier 3 methods (Aleinikovas *et al.*, 2018b)

Characteristics	Tier 2	Tier 3
Approach	Default method (IPCC 2014)	Material flow analysis
System boundaries	Primary HWP (sawn wood, wood-based panels, and paper and paperboard)	Primary and secondary HWP (sawn wood, wood-based panels, paper and paperboard, pulp for viscose, sawn wood [for EURO pallets], carpentry products, packaging, flooring, and wooden construction, and flooring) Country specific (wood flow through the production processes of primary and secondary HWP, derived from survey results; see Country-Specific Data on Harvested Wood Products); data on forest harvest and exports derived from national statistics (CZMA1993–2013; preceding 1993 from FAOSTAT and country-specific factors)
Data source	FAOSTAT (production, imports, and exports for primary HWP)	
Proportion of domestic wood harvest in HWP	Estimated from apparent consumption (FAOSTAT data)	Imports of HWP excluded from the material flow analysis
Carbon conversion factors (dry wood density)	Default factors (IPCC 2014)	Country-specific factors derived from local studies (Vavřík and Gryc 2012; Zeidler 2012; Gryc <i>et al.</i> 2011) (see table S1-6 in supporting information S1 on the Web) Country-specific values derived from survey results for log houses, viscose pulp, and EURO pallets; default values for sawn wood, paper, and wood-based panels (IPCC 2014)
Half-life values	Default values (IPCC 2014)	

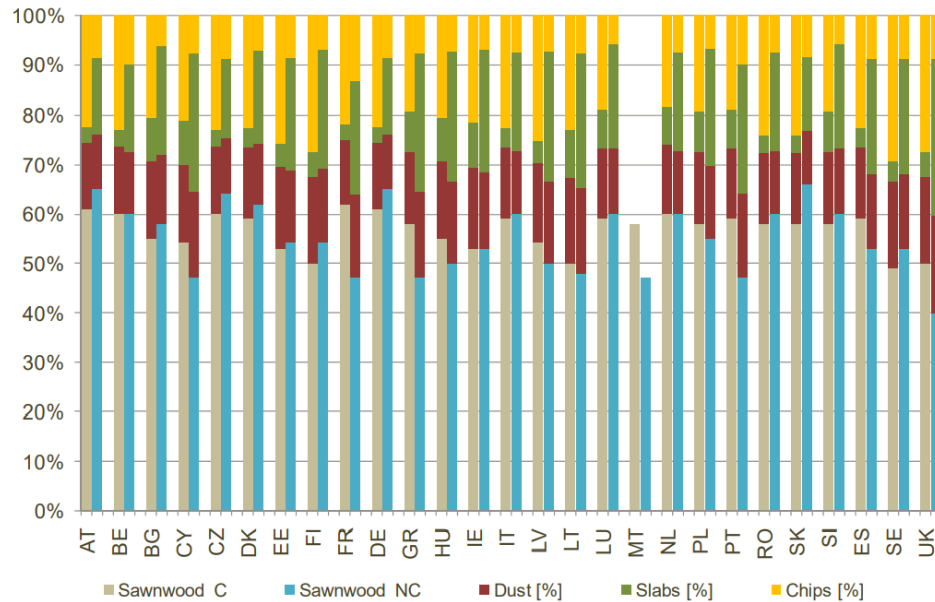
## 2.5 Tier 2 with available country specific data

To optimize the HWP accounting one needs to start by looking at what data are relatively easily available on an annual basis. The main challenges in calculating a comprehensive view on a resource flow are data availability and data reliability about the sectors with many small entities (forest landowners, sawmills) are systematically underestimated because of cut-off thresholds of official statistics or internal use (Mantau, 2015). In the- wood resource balance calculation in a bottom-up approach. If the consumption and the resource mix of all sectors are known, the domestic availability can be calculated. In the following example (Fig. 3) it adds up to 100 hm<sup>3</sup>. In a next step the domestic supply is extended by imports (10 hm<sup>3</sup>) and reduced by exports (5 hm<sup>3</sup>). Changes in stock are seldom captured in statistics.

Also, for half-lives the availability of data is of importance before one starts the study of improving half-lives. It might be necessary with quite a lot of data collection. The problem is that it takes time to do service life testing if this data is not available.

Estonia is among the forest rich countries with Finland, Sweden, Norway, and Latvia which produce and export HWP. According to (Bache-Andreassen, 2009) the difficulty in PA approach is not exactly knowing the fate of exported HWP and it is assumed that exported HWP is used in the same manner as if it were in domestic use. Therefore, the complexity and uncertainty of PA is high, and it is difficult to use national statistics to estimate emissions/removals of CO<sub>2</sub>. The carbon storage time in HWP varies greatly depending on how the particular final product is used and where the wood product ends up at its life cycle. The lifespan of a wood product can be days for a disposable product (paper, packaging) and even several centuries for a long-lasting durable wood product used in construction (Soimakallio, Häkkinen and Seppälä, no date), but on the other hand buildings are also demolished before their planned service life and demolished wood waste has been burned, which shortens the carbon storage time in wood products. Increasing the number of long-lived wood products and extending the life cycle of the carbon content of wood products by improving recycling, reuse, and remanufacturing (Geng *et al.*, 2017). In the EUwood project (2010) future scenarios for supply and

demand for woody biomass is estimated to increase from almost 800 M m<sup>3</sup> (A1) to nearly 1,400 M m<sup>3</sup> in the A1 scenario and about 100 M m<sup>3</sup> less in the B2 scenario. Industrial wood products production yield and residues (by products of sawmill, wood panels) are analyzed by (Mantau *et al.*, 2010) by the EU27 HWP producing countries.



**Figure 1.** Material recovery from C/NC sawnwood production and SBP shares (Mantau (2010))

From this Figure 1. the 52% can be estimated as production yield for coniferous soft wood sawn material and 53 % for non-coniferous sawn material, the rest are by products that are counted as direct oxidation. The by-products of sawmilling can be used as raw material for wood panels or pulp mill industry or by energy sector. The by-product end-use is difficult to follow in the basis of national statistics. Quantification of wood flows and the cascade use of wood are discussed by Mantau (2015) who made total assessment of resources in 2010 the volume of all products of the pulp and wood industries in the EU27 was 354.5 hm<sup>3</sup> (s). 32.0% (113.6 hm<sup>3</sup>) of this volume or the equivalent of 104.0 Mt CO<sub>2</sub> (Fig. 7) is stored in the long range. In EUwood project (Mantau 2010) the Wood Resource balance results for Estonia in 2010 and 2030 were estimated based on high wood demand scenario A1 In the period between 2010 and 2030 the wood consumption of material uses will rise up to +36% which equals an annual growth rate of +1.8 %. Based on foreign trade statistics the demand for the detachable wood buildings, engineered wood product sawn timber and furniture increased during COVID-19 in total for export values from 1.6 billion € (2013) to about 2.4 billion € (2020).



**Annex 1-12: Fact sheet on Wood Resource Balance results for ESTONIA**

Wood Resource Balance							
Region	ESTONIA			IPCC Scenario:			A1
potential	2010	2020	2030	2010	2020	2030	demand
	M m <sup>3</sup>			M m <sup>3</sup>			
stemwood C, ME	4.6	4.7	4.6	3.7	4.5	5.4	sawmill industry
stemwood NC, ME	5.3	4.9	4.6	0.2	0.2	0.3	veneer plywood
forest residues C+NC, ME	0.9	0.9	0.8	0.3	0.5	0.7	pulp industry
bark, C+NC, ME	0.5	0.4	0.4	0.5	0.7	1.0	panel industry
landsc. care wood (USE) ME	0.4	0.5	0.5	0.1	0.1	0.1	other material uses
				0.9	1.6	1.9	producer of wood fuels
sawmill by-products (POT)	1.7	2.1	2.5	0.5	0.6	0.7	forest sect. intern. use
other ind. res. reduced (POT)	0.3	0.4	0.5	1.7	2.0	3.1	biomass power plants
black liquor (POT)	0.2	0.3	0.4	0.0	0.0	0.0	households (pellets)
solid wood fuels (POT)	0.9	1.6	1.9	1.1	1.1	1.1	households (other)
post-consumer wood (POT)	0.2	0.2	0.3	0.0	0.0	0.0	liquid biofuels
<b>total</b>	<b>15.0</b>	<b>16.0</b>	<b>16.5</b>	<b>8.9</b>	<b>11.3</b>	<b>14.3</b>	<b>total</b>

Wood Resource Balance (without solid wood fuels)							
Region	ESTONIA			IPCC Scenario:			A1
potential	2010	2020	2030	2010	2020	2030	demand
	M m <sup>3</sup>			M m <sup>3</sup>			
forest woody biomass	11	11	10	5	6	7	material uses
other woody biomass	3	3	4	3	4	5	energy uses
<b>total</b>	<b>14</b>	<b>14</b>	<b>15</b>	<b>8</b>	<b>10</b>	<b>12</b>	<b>total</b>

**Figure 2.** The resource balance results for Estonia in EUwood project estimations (Mantau 2010).

## 2.6 National statistics

Statistics Estonia provides the industrial production statistics that can be downloaded from their webpages processed as Excel tables. Based on this information, summary Production Indexes and Production volumes reports are prepared. Foreign trade statistics provide the data about the exported and imported goods in monetary values that can be calculated in quantities based on production statistics and using the conversion factors. Statistical database TO67: MANUFACTURING PRODUCTION, 2019 by TTL code and name of product and indicator. Statistics Estonia web page provides data for exports and imports of goods by commodity and country. [VK10 3: Exports and imports of goods by commodity \(CN\) and country 2018-2022 \(stat.ee\)](#).

Based on foreign trade statistics data in wood balance 2020 report the consumption of paper, cardboard and paper products has slightly decreased since 2015 (in 2015 680,000 m<sup>3</sup>, in 2016 580,000 m<sup>3</sup>, 540,000 m<sup>3</sup> in 2017, 500,000 m<sup>3</sup> in 2020).

It is five years since last wood balance report from 2017. The total volume of the wood balance in 2020 was 16,028,000 m<sup>3</sup>, which is nearly 5% less than the total volume of 2017 (See Appendix 1 Figure A1 Puidubilanss (keskkonnaportaal.ee)). The main sources of wood were logging from forest land (10.4 million m<sup>3</sup>) and import (4.1 million m<sup>3</sup>). When preparing the wood balance, the wood stockpiled from forest land in Estonia was also assessed. Actual use: 46% (4.8 million m<sup>3</sup>), as paper wood 21% (2.2 million m<sup>3</sup>) and 33% as firewood (3.4 million m<sup>3</sup>). In 2020 wood balance the export of wood and wood products formed 9.4 million m<sup>3</sup> and the consumption of wood fuels in energy 5.9 million m<sup>3</sup> made up by far the largest part of the total volume of the wood balance. The main export items were wood pellets, softwood shavings and chips, and softwood lumber. Large-scale exports of raw materials for the paper industry (high-quality chips and pulpwood) remain a problem and have remained at the level of 2.7 million m<sup>3</sup>.

The biggest problem in preparing the 2020 annual wood balance report was the temporary lack of data, which was particularly noticeable in assessing the internal consumption of wood and wood products. Wood and wood products more detailed statistics hardly reflect final consumption. In

theory, it is possible to find with different cross-calculations also more detailed final consumption, but such a method involves a large estimation error. Accurate data there are also no data on the use of raw materials by wood processing companies, but thanks to the Estonian Private Forest Centre, these deficits have been reduced for the direct contacts of Estonian Forestry and Woodworking Association, EPHA and State Forest Management Centre. Better supply of source data would allow to reduce the proportion of expert assessments. As it can be seen from the Appendix Table A1 (foreign trade-based statistics), the exported values data should be converted into cubic metres or tons of wood products and thus the conversion coefficients are used. This is making difficult to get reliable data on HWP product groups/ subcategories that Estonia is exporting. Another problem is to develop the precise model the use of harvested and produced HWP in Estonia.

## 2.7 Criteria for evaluating approaches

The criteria for countries to prepare national inventories with completeness, consistency, comparability, variability, transparency, and accuracy.

The choice of approach is based on the viability of available data, the tiered methods for all approaches require critical data. All the three approaches need the following data of production, imports, exports, and the commodities.

The criteria for evaluating approaches to estimate carbon from harvesting forest and wood products are classified under four categories (Table 9).

- 1) Feasibility of approach.
- 2) Accuracy of approach.
- 3) Relevance to the reporting needs of the UNFCCC and the Kyoto Protocol.
- 4) Relevance to national policies.

**Table 9.** The main issues of the evaluation.

<b>Feasibility of approach</b>	<b>Accuracy of approach</b>	<b>Relevance to the reporting needs of the UNFCCC and the Kyoto Protocol</b>	<b>Relevance to national policies</b>
Complexity of approaches	Assumptions in the approaches	Types of approaches for reporting needs	Usefulness for national planning
Availability of data	Quality of underlying data	Verification and transparency	Ability to track the effects of measures
Cost and ease of data collection	Applicability at various spatial and temporal scales	Applicability at various spatial scales	Applicability at various spatial scales
Availability of national expertise	Consistency at various spatial and temporal scales, and across tiers	Consistency with other sectors of the Guidelines	Consistency with sustainable forest management
Applicability at various spatial scales	Precision of definitions	Understandability	Ability to gauge the effects of national measures
	Completeness of accounting	Potential for adaptability	Ability to use for projections
	Uncertainty of emissions estimates		
	Scientific acceptability		
	Repeatability of estimates		
	Potential for continued inventory improvement		

## 1) Feasibility of approaches

### a. Complexity of approaches.

At the simplest level, all the 3 approaches can be applied. Our consideration we work with the Production approach which is Internationally accepted and the complexity for the approach increases across the tier 2 and tier 3 (Chapter 12, 2006 IPCC guidelines).

### b. Availability of data.

The higher tiers are data intensive due to its complexity, thus limiting the potential of using this method and only a few countries can apply them.

The constraint with the production approach is the stock data required from all countries to which the product is exported to, however for the higher tier of the production approach such data is not needed (FAO, *Estonia*).

### c. Costs and ease of data collection.

The cost for collection of data is varies widely across countries, data collection for higher tier methods can be expensive compared to the lower tiered method as it is data intensive.

### d. Availability of national expertise.

The higher tier method calculation can be complicated with the availability of data as compared to the simpler lower tier method in relation with the data availability.

## 2) Accuracy of approaches

### a. Assumptions in the approaches.

It is understood that the accuracy will improve with higher tier methods, the estimate of the values is directly related to the sensitivity of the data and assumption of the calculation (Zhang *et al.*, 2020).

### b. Quality of the underlying data.

Traditionally countries share data under specific trade agreements, the FAO collects data through questionnaires and the quality of the data is variable.

Production data are not reliable as there are no independent checks to verify them (Lim, Brown and Schlamadinger, 1999)

### c. Uncertainty of estimates.

The uncertainty of emissions from land use and forest industry is said to be large. In, a few cases, the uncertainty of emission wood products would be lost as 'noise' among these emission estimates. Belgium, the United Kingdom, New Zealand and Slovakia countries, the uncertainty of emissions estimates from wood products might be similar to or lower than the uncertainty of estimates from LULUCF. For the data-poor countries, the uncertainty of emissions estimates from wood products may be considerably greater.

### d. Other criteria

But the production approach may be more accurate at the national than the project level.

## 3) Relevance to the reporting needs of the UNFCCC and the Kyoto Protocol

An approach should provide information that meets the reporting requirements of the Convention. Several criteria were identified according to their relevance to the reporting needs of the UNFCCC and the Kyoto Protocol ([UNFCCC, 1997a](#)). The key ones

were: verification and transparency of approaches, applicability at various spatial scales and consistency with other sections of the *Guidelines*.

#### 4) Relevance to national policies

- a. Promotion of sustainable forest management. Wood harvested from forest land and converted into products are in the subcategory of greenhouse gas (hereinafter GHG) land use, land use change and forestry (hereinafter LULUCF). The national policy should apply policy measures to ensure increase in carbon sequestration by the forest land and forest and to increase carbon stocks of long life-span HWP and to use more wood internally in the country to reduce net CO<sub>2</sub> emissions.

- b. Other criteria

Can the approaches be used as a national planning tool and to track the effects of measures? For all approaches, the default method does not provide adequate information for national planning nor for tracking the effects of measures. Only the higher tiered methods will satisfy these criteria.

## Summary

In this study an overview of the methodologies for finding half-lives was given on the basis of the information published in scientific texts. Carrying out of the work, the methodologies for finding country-specific half-lives in the IPCC guidance materials and other scientific texts were analysed. The carbon change in logging products is considered at the level of semi-products, assuming that each final product also passes through the semi-product stage. Harvested products are divided into three (semi-product) categories, each of which has its own half-life, i.e. the time when the product loses half of its original amount. In its reporting, Estonia currently uses the default half-life values resulting from the IPCC methodology, which are: 35 years for lumber, 25 years for wooden boards, and two years for paper and cardboard. As a special feature of Estonia, as a fourth category of semi-finished products, the chemical-thermo-mechanical wood pulp produced in AS Estonian Cell factory has been added to the calculation of harvested wood products.

The **estimated service life (ESL)** is used to calculate the country-specific half-life. It is the projected service life of a wooden or wood-based component under a set of precise in-use conditions. **ESL** can be determined by using an **obsolescence (O)** factor or a **decay function that estimates the decay profile (based on items leaving the pool rather than a biological decay profile) or the actual period that products take to become obsolete**. **Obsolescence (O)** is defined in **ISO 15686-1:2011** as the reference service life (**RSL**) of a product, component, assembly, or system which is known to be expected under a particular (reference) set of in-use conditions). It states when a facility can no longer be adapted to meet changing needs. **Obsolescence (O)** tends to result from unexpected changes, often unrelated to the construction, and includes: **functional O** (function no longer required); **technological O** (new alternatives can offer better performance, or there is a change in the pattern of use); **economic O** (Fully functional but less efficient, or more expensive than alternatives. This includes replacement owing to changing fashion or taste). The IPCC 2019 refinement to 2006 guidelines (page 12.29) stipulates that the estimation of obsolescence should be based on the **designer's** and **client's** **experience**, and, if possible, **documented feedback from practice**. Estimation of **O** are: **O** = 1 (no

significant impact of obsolescence compared to RSL);  $O < 1$  (depends on the intensity of the obsolescence);  $O$  can never be  $> 1$ . It is important to apply obsolescence factors as defined by the IPCC. i.e., based on the **designer's** and **client's experience**, and, if possible, **documented feedback from practice** as aforementioned. This will require data and information from the above classes on the HWP commodity categories in **Estonia** to be able to determine the right obsolescence or national obsolescence factor. Half-life information are often obtained through literature review of the studies.

Based on the available information on foreign trade statistics about export (See the Appendix Tables A1 and A2) and import, Estonia is a net producing country and it would suffice that the **production approach** (PA), which is currently used to estimate the contribution to CO<sub>2</sub> emission or removal by HWP is necessary. The PA has been used or compared with other approach (Table 6) and appears to show a more accurate estimation of the carbon stock, especially for HWP producing countries. The results published by recent study (Yu et al., 2022) especially shows that using the PA from the latest IPCC guidelines of 2019 provides a better estimation of carbon stocks compared to that of 2013.

According to the IPCC, when using the PA to estimate CO<sub>2</sub> emissions or removals, country-specific half-life data from the importing nation should be employed. Quantifying export activity data within HWP commodity classes and/or sub-classes is required. "To ensure that the country-specific half-life information from the importing country is consistent with the commodity classes of the activity data for the exported HWP, it is best practice to use country-specific half-life information **only when both the exporting and importing countries use the same commodity classes** of activity data for the exported HWP. **Otherwise, the Tier 1 default settings are to be used.**" The tier 1 method assumes that the HWP carbon stock is constant over time (can be applied by developing countries only), hence not recommended for Estonia. Tier 2 uses default HWP categories and Food and Agriculture Organization (FAO) activity data on HWP. While tier 3 uses country specific HWP activity (more transparent and reliable data) is the most recommended for reliable result, where data on the HWP activity and commodities specific to the countries involved are available. Table 8 shows the system boundary between tier 2 and 3 highlighted in a recent study by Aleinikovas et al., 2018b. It is observed that the application of tier 3 would require information on country specific half-life values.

**Half - lives for semi-finished HWP** (sawn wood and wood-based panels) for each category the shares should be determined. It is important to note that half-life on a national level is likely to change over time. Furthermore, the estimated uncertainties for **half-life range up to  $\pm 50\%$**  (IPCC 2003). Thus, the development of **service life** prediction models to provide reliable service life estimates for of SF-HWP used in construction, furniture and packaging is needed. The service-life of F-HWP is mainly defined by physical, chemical conditions and socio-economic factors (Pingoud, 1996).

WoodLCC project (2022-2025) is making a comparison of service life prediction using pre-fabrication of wooden building elements and modules vs on-site full assembly technologies. Comparison is done by using existing service life prediction modules combined with data from studies related with given building techniques. For the country specific half-life determination, the real wood decay experiments should be carried out. Using mathematical functions enables to model decay in large scale.

There is no information available about the half-lives of the finished HWP used as furniture in Estonian households, thus the socio-economical surveys are needed to collect information from public sector, local authorities and private users (eg. studies of the average lifespan of the furniture items or study of life expectancy of other wood products and components used in interior design of the buildings).

In current study an overview of the approaches used in estimating HWP contribution to carbon emissions/recovery based on publications and countries where studies were conducted (See Table 7).

As a result, diverse sources of information, such as market usage of different HWP product classes, might be integrated to determine a country-specific half-life. For instance, (Braun *et al.*, 2016) investigated the dynamics of apparent half-lives and carbon content within three important categories of wood utilization (construction, furniture, and packaging) considering sales on the wood product level in Austria for the period 2002 to 2011.

**Static half-lives for finished products** derived from a literature study is used for upscaling information about carbon flows and associated HL to semi-finished HWP. Averaged over 10 years, the following half-lives for finished products are derived: 33.0 years for construction, 8.5 years for furniture, and 1.4 years for packaging. Calculating the country specific half-lives needs the development of a national method. For calculating country specific half-lives, the availability of activity data is of great importance before one starts the study of implementing Tier 3 method. It might be necessary with quite a lot of data collection. If this data is not available the problem solving takes more time to plan and conduct the experiments for service life testing. To optimize the HWP accounting one needs to start by looking at what data are relatively easily available at an annual basis. For Tier 3 revised model collection of the data of HWP used in long life-span products as construction of the buildings based on year of construction and quantity of wood used per sqm.

The carbon storage time in HWP varies greatly depending on how the particular final product is used and where the wood product ends up at its life cycle. The lifespan of a wood product can be days for a disposable product (paper, packaging) and even several centuries for a long-lasting durable wood product used in construction (Soimakallio, Häkkinen and Seppälä, no date), but on the other hand buildings are also demolished before their planned service life and demolished wood waste has been burned, which shortens the carbon storage time in wood products.

**It was difficult to develop a country specific half-lives methodological approach suitable for Estonian conditions. National statistics Estonia does not have detailed foreign trade statistics on the exported quantities of all wood commodity groups (See Appendix Tables A1, A2 and Figures A1-A4). There is no sufficient information on internal consumption of HWP. The quantities of wood used in construction are unclear. There are no scientific studies on the time required for the biological decomposition of wood in the Estonian climate.**

**To develop country-specific half-lives it is necessary to have emphasis on a data management system between the HWP production to utilization. In Estonia, the quantity and type of HWP used in construction should be sufficient. There is a need for the interrelation between Estonian statistics management, building contractors, and material suppliers What structures were built that year, what stock of HWP was used, and when was any type of reconstruction done? Consequently, a case study will be conducted to investigate sampling in various active construction projects to create the Estonian-specific SL of HWP in building construction What is the year of construction, how much HWP was used, and what is the estimated SL of the structure before considering renovation? Such data may subsequently be used to replicate nation-specific information; however, data on the actual volume of HWP entering the country, particularly in Estonia, is required. Stocks based on new buildings are simply added for the year when the CS is estimated.**

**Estonia is currently using the default half-life values resulting from the IPCC methodology and it seems to be the best solution in current situation where country specific scientific research based information or statistical data about the HWP half-lives is not available.**

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## Appendix 1

Table A1 Foreign trade statistics 2020-2021 show the export of wood products in € and in exported amount (t, m³).

Product Group	2020 in €	2021 in €	2020 quantity	2021 quantity	Unit
Puidust ehitusdetailid	342 952 743,1	438 163 215,9			
Puidust kokkupandavad ehitised 9406 10 00	373 892 771,4	476 360 761,0	236 746,35	249 557,40	t
Saematerjal 4407	297 685 833,2	451 902 831,0	1 105 486,78	1 100 537,55	m³
Puitmööbel ja selle osad 9403...?	243 420 986,1	292 944 621,6	66 538,05	76 967,35	t
Graanul 4401 31 00	163 601 798,8	214 225 295,5	1 090 073,78	1 559 212,52	t
Puit pidevprofiiliga 4409	191 221 805,1	276 747 954,0			
Vineer 4412	123 772 496,2	158 378 407,7	176 038,76	205 869,87	m³
Ümarpuuit 4403	79 351 563,9	92 957 336,9	1 583 489,01	1 733 837,49	m³
Kemi-termo-mehaaniline puitmass	67 569 931,4	89 218 402,3	157 507,69	189 841,48	t
Jagamata 44 - 44	46 170 639,7	45 072 974,4			
Pleegitamata paber	39 983 273,0	57 484 313,4	61 017,29	68 062,63	t
Spoon 4408	39 833 526,5	57 725 567,2	57 057,83	91 840,55	m³
Puitpakendid 4415	37 511 884,7	48 725 988,3			
Muu44 - 4421	44 764 077,4	66 524 508,1			
Puitlaastud ja pilpad 4401 2100 + 4401 22 00	34 000 988,7	27 987 665,9	796 250,63	873 169,91	t
Puitlaastplaadid 4410	23 171 879,4	29 117 178,3	83 838,07	103 969,29	m³
Puitkiudplaadid 4411	19 283 871,8	22 819 108,3	78 136,39	82 758,05	m³
Tselluloos	19 269 666,0	23 734 745,8	40 248,06	34 916,35	t
Küttepuit	16 531 907,1	25 569 464,6	131 097,71	186 905,30	t
Paberi- või papijäätmetest mass ja paberi- või papijäätmed	12 211 556,3	16 548 761,4	68 973,60	68 805,52	t
Muu paber ja papp	10 910 632,4	15 859 682,8	10 342,15	15 429,40	t
Vitsapuit, lõhestatud teibad, vaiad jne 4404	7 487 709,1	9 130 303,7	20 166,70	22 777,61	t
Presspuit 4413 00 00	8 170 895,8	15 178 400,1	19 397,39	23 067,19	m³
Puitraamid maalidele, fotodele, peeglitele jms 4414 00	4 685 890,4	7 083 438,2	1 312,21	1 452,57	t
Puidujäätmed 44014090	1 322 616,1	388 985,3	21 515,46	289,44	t

<b>Puitlaekad, kastikesed, puidust dekoratiivesemed 4420</b>	<b>127 624,4</b>	<b>218 551,8</b>		<b>4,49</b>	<b>17,81</b>	
<b>Puidust püttsepatooted ja nende puitosad 4416 00 00</b>	<b>3 032 885,5</b>	<b>4 233 013,0</b>		<b>741,64</b>	<b>964,12</b>	t
<b>Brikett 44013900</b>	<b>1 061 864,8</b>	<b>1 665 770,2</b>		<b>15 880,64</b>	<b>27 656,68</b>	t
<b>Puidust tööriistad 4417 00 00</b>	<b>656 143,6</b>	<b>847 539,9</b>		<b>300,72</b>	<b>382,94</b>	t
<b>Puidust lauanõud ja köögitarbed 4419</b>	<b>746 881,7</b>	<b>1 172 846,8</b>		<b>217,60</b>	<b>240,87</b>	t
<b>Puusüsi 4402</b>	<b>509 257,3</b>	<b>875 616,6</b>		<b>398,25</b>	<b>529,71</b>	t
<b>Puitvill, puidujahu 4405 00 00</b>	<b>130 653,4</b>	<b>124 558,6</b>		<b>19,51</b>	<b>15,13</b>	t
<b>Raudteede ja trammiteede puitliiprid 4406</b>	<b>9 280,0</b>	<b>0,0</b>		<b>64,00</b>	<b>0,00</b>	m 3
<b>Saepuru 4401 40</b>	<b>26 429,5</b>	<b>127 099,9</b>		<b>130,36</b>	<b>188,82</b>	t
<b>Kokku</b>	<b>2 255 081 963,86</b>	<b>2 969 114 908,41</b>				

Table A2 Foreign trade statistics 2017-2019 show the export of wood products in € and in exported amount (t, m<sup>3</sup>).

Product group	2017 in €	2018 in €	2019 in €	2017 quantity	2018 quantity	2019 quantity	Unit
Puidust kokkupandavad ehitised	320 560 719,7	394 562 690,4	416 170 569,4	190 670,3	215 838,7	229 908,0	t
Puidust ehitusdetailid	294 434 554,6	311 269 886,7	320 676 921,2				
Saematerjal	296 506 135,7	318 911 599,9	299 433 367,5	1 097 572,3	1 170 429,8	1 125 859,5	m3
Puitmööbel ja selle osad	254 214 886,4	269 888 152,9	266 764 721,6	71 926,0	73 692,8	72 016,8	t
Graanul	159 317 745,1	155 297 938,5	165 744 184,4	1 250 596,4	1 111 952,5	1 126 191,5	
Puit pidevprofiiliga	130 449 675,8	141 542 555,3	156 564 884,6				m3
Ümarpuit	129 030 378,2	199 557 708,0	151 298 205,4	2 556 752,6	2 927 492,9	2 396 266,9	t
Vineer	65 323 398,0	84 773 813,0	111 384 275,1	95 943,0	120 388,3	150 065,9	m3
Kemi-termo-mehaaniline puitmass	72 901 321,5	83 928 181,9	68 819 182,2	152 459,8	154 460,6	145 490,6	t
Jagamata 44	71 163 905,0	54 048 159,9	53 891 599,1				
Pleegitamata paber	55 946 397,0	64 219 932,9	45 736 615,5	77 536,2	77 147,7	55 419,4	t
Puitlaastud ja pilpad	31 262 896,8	38 197 358,6	44 700 186,3	477 195,9	493 744,4	737 141,3	t
Puitpakendid	38 346 839,6	39 594 225,1	40 226 938,9				
Muu44	34 761 397,6	42 852 852,0	39 253 033,8				
Spoon	41 832 998,9	46 488 571,1	39 067 723,4	68 338,8	78 181,4	56 924,0	m3
Puitlaastplaadid	23 286 832,0	24 443 229,1	23 817 553,3	98 216,8	94 989,5	86 608,8	m3
Küttepuit	17 614 054,8	26 974 781,5	23 684 710,6	266 701,9	297 613,8	262 972,4	m3
Tselluloos	17 037 441,7	13 554 086,3	22 501 603,1	30 485,5	22 562,5	40 835,6	t
Puitkiudplaadid	17 715 922,0	17 681 324,6	19 103 130,1	89 937,1	83 220,0	90 118,8	m3

Paberi- või papijäätmetest mass ja paberi- või papijäätmed	13 649 890,7	13 362 669,9	13 688 058,9	74 631,5	75 619,7	72 246,2	t
Muu paber ja papp	10 589 831,4	11 524 047,0	10 129 499,5	10 554,0	9 903,7	9 220,6	t
Vitsapuit, lõhestatud teibad, vaiaid jne	9 859 340,0	7 145 438,8	7 408 381,2	37 725,4	23 303,5	26 008,6	t
Presspuit	6 895 392,5	6 044 342,1	5 597 525,1	19 593,2	19 153,0	13 287,9	m3
Puitraamid maalidele, fotodele, peeglitele jms	5 360 117,8	6 995 216,7	5 256 344,8	1 248,5	1 647,7	1 366,2	t
Puidujäätmed	574 495,2	458 825,2	1 895 677,2	12 165,5	8 498,0	36 527,7	t
Puidust püttsepatooted ja nende puitosad	1 253 799,0	1 525 098,7	1 353 044,3	418,4	501,7	369,6	t
Puitlaekad, kastikesed, puidust dekoratiivesemed	925 775,4	832 426,1	1 221 474,2				t
Puusüsi	1 005 611,4	854 391,6	954 030,8	1 977,5	1 651,9	1 601,8	t
Puidust lauanõud ja köögitarbed	815 873,7	789 221,7	856 816,5	130,9	171,4	114,0	t
Puidust tööriistad	727 211,1	903 436,4	785 849,4	387,9	436,3	374,8	t
Brikett	565 011,9	502 152,9	669 639,2	12 484,8	6 881,8	9 826,2	t
Puitvill, puidujahu	74 906,3	95 264,8	117 721,4	11,8	13,8	15,5	t
Raudteede ja trammiteede puitliiprid			36 190,0			732,0	t
Saepuru	108 256,9	13 989,2	27 907,2	459,5	61,1	161,5	t

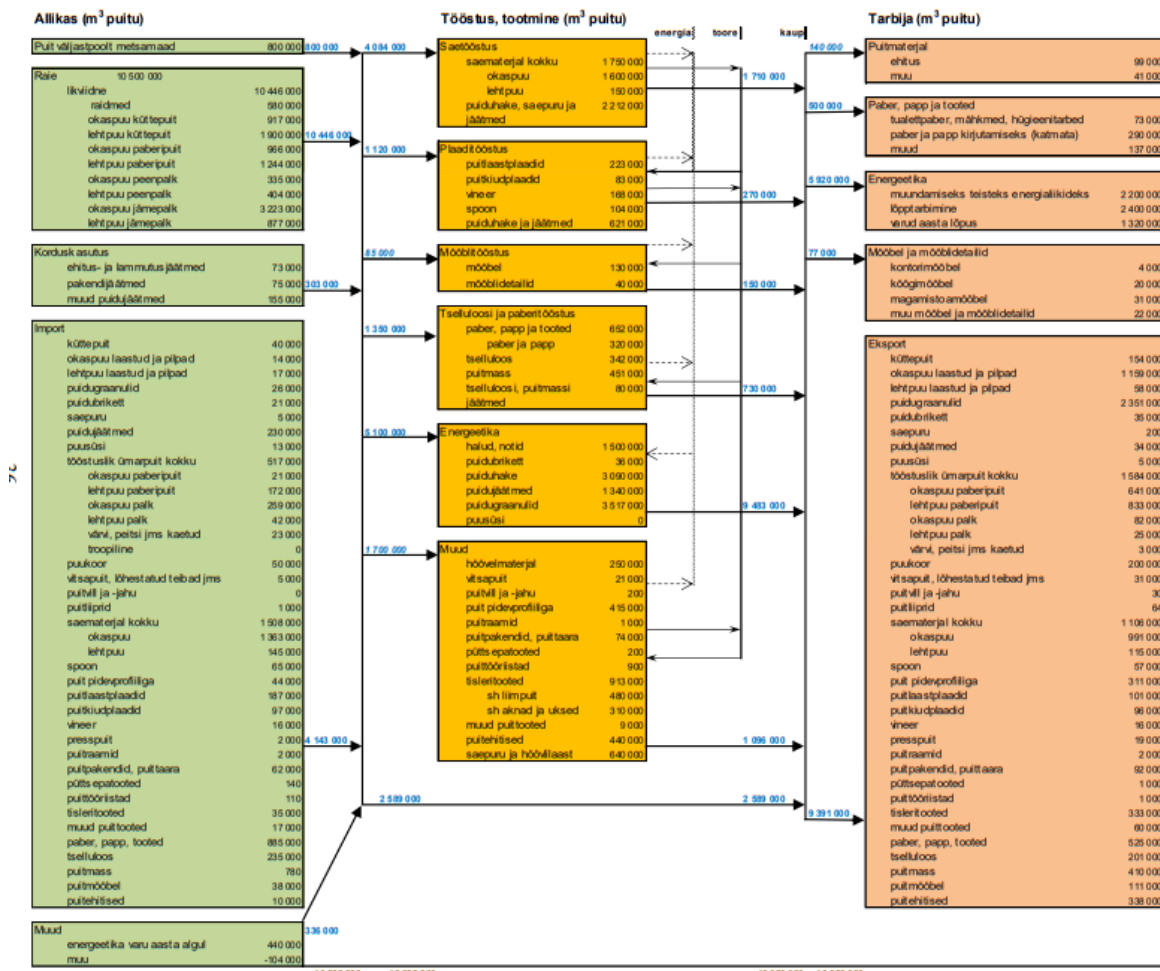


Figure A1. Detailed timber balance for 2020 (source Puidubilanss 2020)

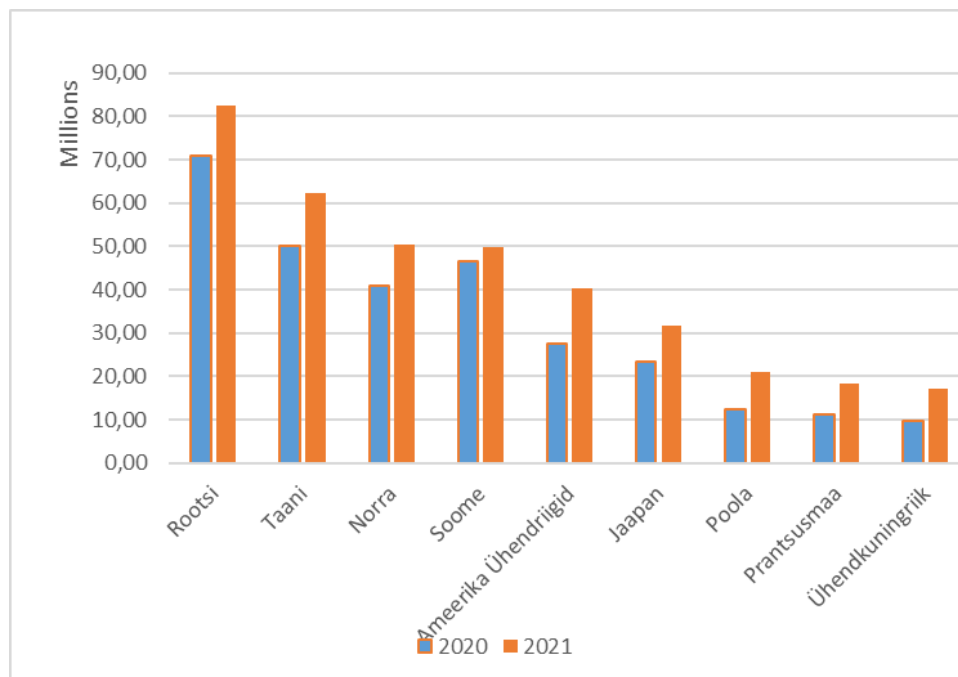


Figure A2. Exported Wood products summarized in biggest countries by value (€) (Estonian Foreign trade statistics)

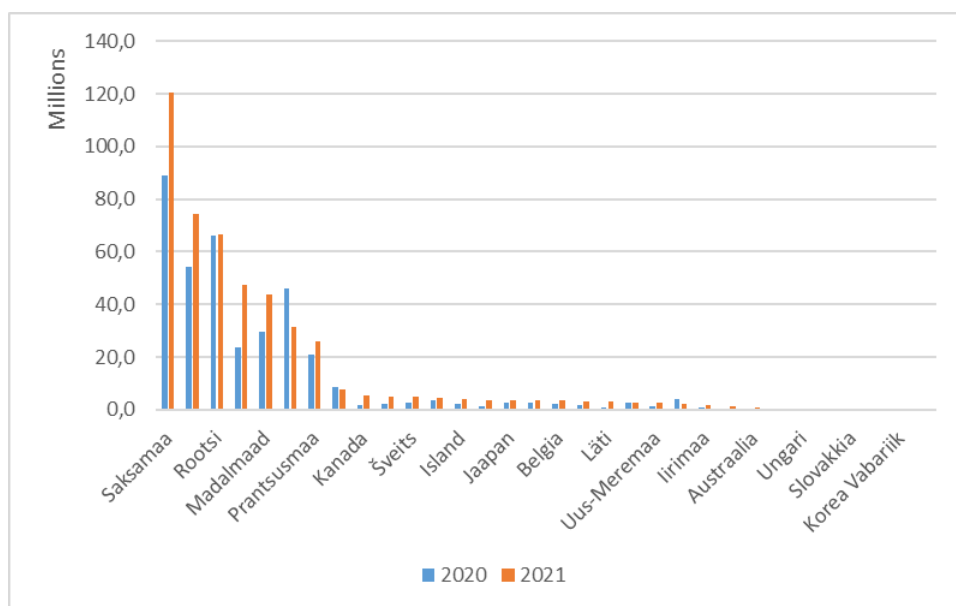


Figure A3. Exported Detachable Wooden buildings summarized in biggest countries by value (€) (Estonian Foreign trade statistics)

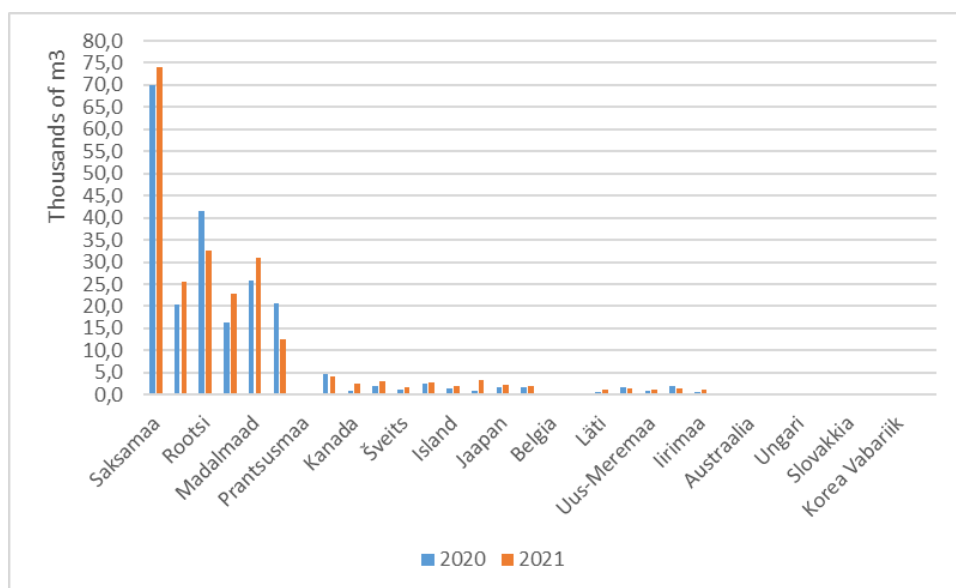


Figure A4. Exported Detachable Wooden buildings summarized in biggest countries by quantity (m³) (Estonian Foreign trade statistics)