Bio-based building products in the Dutch Environmental Database (NMD)

Part 2: Proposal for updated end-of-life lump-sum values for wood based products

Martien van den Oever (WFBR), Helmer Weterings, Eric de Munck (Centrum Hout)

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This study was carried out by Wageningen Food & Biobased Research, subsidised and commissioned by the Dutch Ministry of Agriculture, Nature and Food Quality and funded by TKI.

Wageningen Food & Biobased Research
Wageningen, September 2024

Public

Report 2582
DOI: 10.18174/672247

WAGENINGEN
UNIVERSITY & RESEARCH

WFBR Project number: 6224122800/ BO-59-006-003
Version: Final
Reviewer: Harriëtte Bos
Approved by: Jan Jetten
Carried out by: Wageningen Food & Biobased Research, Centrum Hout
Subsidised by: the Dutch Ministry of Agriculture, Nature and Food Quality
Funded by: TKI
This report is: Public

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Samenvatting

Om hergebruik en recycling van bouwproducten te stimuleren, kunnen verwachte milieueffecten van toekomstig hergebruik en recycling worden gecrediteerd in de zogenaamde module D van de Bepalingsmethode Milieuprestatie Bouwwerken (Bepalingsmethode). Dit betekent dat de milieu-besparingen die samenhangen met de toekomstige vermeden productie van nieuwe grondstoffen kunnen worden afgetrokken van de milieu-impact van momenteel toegepaste bouwproducten. Indien er geen speciaal inzamelings- en recyclingsysteem bestaat, kent de Bepalingsmethode forfaitaire waarden voor verwerking-scenario's bij einde leven voor een breed scala aan (groepen van) producten: x% wordt hergebruikt, y% wordt gerecycled, z% wordt verbrand, v% wordt gestort, w% wordt in de grond achtergelaten.

De huidige forfaitaire waarden voor hergebruik en recycling van schoon hout zoals balken en planken zijn respectievelijk 5% en 10% en zijn al vele jaren onveranderd van kracht. Met toenemende aandacht en inspanningen op het gebied van duurzaamheid en circulair gebruik van materialen, wordt echter verwacht dat hergebruik-/recyclingpercentages voor hout en houtproducten die vrijkomen uit gebouwen en constructies hoger zijn dan deze huidige forfaitaire waarden, en de komende jaren nog verder zullen toenemen.

Het doel van deze studie is om actuelere onderbouwde forfaitaire waarden voor verwerking-scenario's bij einde leven vast te stellen voor een aantal houtachtige bouwproducten.

Op basis van gedetailleerde gegevens van een recent onderzoek en input van een breed scala aan experts, zijn twee sets einde-levensduurscenario's voor een selectie van hout en houtproducten opgesteld: één set voor huidige gemiddelde sloopprактijken (tabel 3) en één set voor huidige circulaire sloopprактijken (tabel 4).

Op basis van input van een beperkt aantal aannemers van civiele werken, is een vergelijkbare en conservatieve set einde-levensduurscenario's opgesteld voor specifieke typen producten uit de Grond, Weg en Waterbouw (tabel 6). De resultaten geven aan dat de scenario's grotendeels verschillen voor verschillende typen houtafvalstromen uit civiele werken, die momenteel worden gecombineerd als één afvalstroom in de NMD-lijst met einde-leven-scenario's.

Er wordt voorgesteld om deze drie datasets (tabellen 3, 4 en 6) in plaats van de twee huidige te gebruiken als forfaitaire waarden voor de verwerking-scenario's bij einde leven van de aangegeven houtproducten en toepassingen bij de aangegeven sloop- (gebouwen) en winningspraktijken (civiele werken).

Summary

In order to stimulate reuse and recycling of building products, expected environmental impact benefits of future reuse and recycling can be credited in the so called module D of the Dutch Environmental Performance of Buildings and civil engineering works Determination Method (Determination Method). This means that the environmental impact savings associated with the future avoided sourcing and production of virgin materials may be subtracted from the impact of presently applied building products. If no actual collection and recycling system is in place, the Determination Method presents lump-sum values for end-of-life (EoL) scenarios for a wide range (of groups) of products: x% is reused, y% is recycled, z% is incinerated, v% is landfilled, w% is left in the ground.

The current lump-sum values for reuse and recycling of clean wood like beams and planks are 5% and 10%, respectively, and have been in place unchanged for many years. With increasing attention and efforts on sustainability and circular use of materials, however, it is expected that reuse/recycling rates for wood based materials released from buildings and constructions are higher than these current lump-sum values, and may increase further during the coming years.

The objective of this study is to establish updated underpinned lump-sum values for end-of-life scenarios for a number of wood-based building products.

Based on detailed data of a recent study as well as on input from a broad range of experts, two sets of end-of-life scenarios for a selection of wood-based building products have been established: One for current average demolition practices (table 3), and one for current circular demolition practices (table 4).

Based on input from a limited number of civil works contractors, a similar and conservative set of end-of-life scenarios has been established for specific types of civil works products (table 6). The results indicate that the scenarios largely differ for different types of civil works wood waste streams, which are currently combined as one waste stream in the NMD end-of-life scenario scheme.

These 3 datasets (tables 3, 4 and 6) have been proposed to be used as lump-sum end-of-life scenarios for the indicated wood-based products for mentioned applications and indicated demolition (buildings) and extraction (civil works) practices.

1 Introduction

The value of reuse & recycling of building materials

The building and construction sector consumes large amounts of primary materials. By far the largest share of these building materials is based on finite feedstock, or their production causes large environmental impacts. To make the construction sector more sustainable, it is important to reduce the use of primary abiotic raw materials and create sustainable and circular value chains.[1] Renewable, circular and sustainable bio-based alternatives therefore are of large interest. However, even if the applied materials are renewable and circular, extending the lifetime of bio-based building products by reducing raw material usage and waste generation through reuse and recycling is important. However, reuse and recycling do not automatically result in a large reduction of environmental impact.[2] Reuse and recycling of building products at the end-of-life is beneficial if the environmental impacts related to preparing the 'waste streams' as feedstock for new products is compensated by avoided impacts of the production of virgin feedstock.[3] Moreover, reuse and recycling of bio-based materials reduces pressure on land use. Further, reuse and recycling of bio-based into building products keeps the biogenic carbon out of the atmosphere for a longer period of time, thus also contributing to retarding climate change.[4]

Even if bio-based materials are renewable, recycling of these materials is relevant to reduce impacts of feedstock production and to optimally utilise available land in order to produce the required volume of bio-based feedstock to replace fossil feedstock.

Crediting future reuse & recycling benefits – Lump-sum values

In order to stimulate reuse and recycling of building products, expected environmental impact benefits of future reuse and recycling can be credited in module D (Figure 1) of the Environmental Performance of Buildings and civil engineering works Determination Method (Determination Method):[5] the environmental impact savings associated with the future avoided sourcing and production of virgin materials may be subtracted from the impact of presently applied building products if an actual collection and recycling system is in place.[6] This is the case for specific products for which a dedicated collection and recycling system exists. If reuse/recycling can only be shown at a higher aggregation level, the Determination Method presents lump-sum values for end-of-life (EoL) scenarios for a wide range (of groups) of products: x% is reused, y% is recycled, z% is incinerated, v% is landfilled, w% is left in the ground.[7]

[1] National Circular Economy Programme 2023-2030, https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/beleidsnotas/2023/02/03/nationaal-programma-circulaire-economie-2023-2030/NPCE+Circulaire+Economie+rapport+Engels.pdf

[2] JRC, 'Techno-economic and environmental assessment of construction and demolition waste management in the European Union' (2024), https://circulareconomy.europa.eu/platform/sites/default/files/2024-01/JRC135470_01_1.pdf

[3] The environmental impact of A1-A3 in the total impact for phases A1 – C4 for a timber frame construction for a pitched roofing element (same example as in section 6.4.6 of report under footnote nr. 4), excluding the biogenic carbon extraction in A1 and the biogenic carbon emission in C3, and expressed as environmental cost indicator (MKI) is 76% and 77% for set A1 and set A2 weighing sets, respectively.

[4] WUR, 'Bio-based building products in the Dutch Environmental Database (NMD) – Part 1: Proposal for crediting biogenic carbon storage' (2024), https://edepot.wur.nl/647711

[5] In Dutch 'Bepalingsmethode Milieuprestatie Bouwwerken', 'Bepalingsmethode' in short. https://milieudatabase.nl/media/filer_public/89/42/8942d5dd-8d37-4867-859a-0bbd6d9fb574/bepalingsmethode_milieuprestatie_bouwwerken_maart_2022_engels.pdf

[6] Determination Method, section 2.6.3.9, p.20.

[7] https://milieudatabase.nl/nl/milieudata-lca/informatie-voor-lca-opstellers/verwerkingsscenarios-einde-leven/

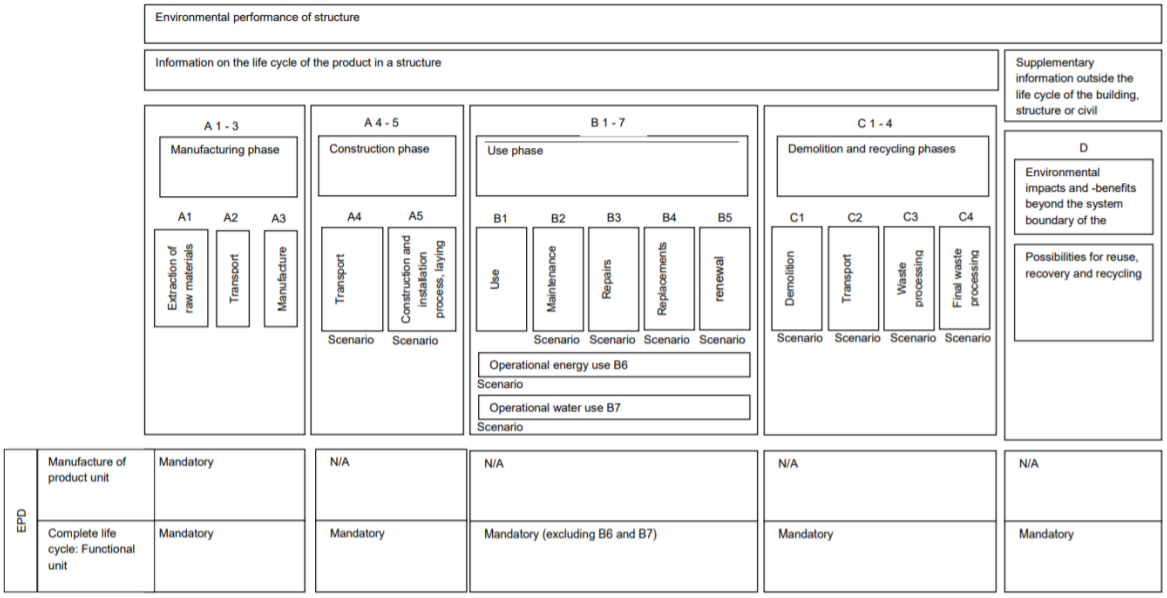

Figure 1 Life cycle phases addressed in life cycle assessment (LCA) and environmental product declaration (EPD)

Construction sector becoming more sustainable – Updated values for wood based material EoL scenarios

The current lump-sum values for reuse and recycling of clean wood like beams and planks are 5% and 10%, respectively,[8] and have been in place unchanged for many years. With increasing attention and efforts on sustainability and circular use of materials, however, it may be reasonably expected that reuse/recycling rates for wood based materials released from buildings and constructions are higher than these current lump-sum values.

Objective of this study

This study aims to establish updated underpinned lump-sum values for end-of-life scenarios for a number of wood-based building products.

Approach

First, a review of data on recycling stream volumes and recycling rates of wood based products in public literature has been performed (chapter 2). Next, detailed data of a recent study have been elaborated further according to the scenarios so far considered in the NMD lump-sum end-of-life table, and sent to stakeholders for feedback (sections 3.1 & 3.2). Feedback and input from stakeholders has been translated into two proposals for updated end-of-life scenarios for wood based building demolition streams (sections 3.3 & 3.4).

For wood waste streams from civil works, an enquiry has been sent to stakeholders and their input has been translated to a proposal for updated end-of-life scenarios for civil works types of products (section 3.5).

Conclusions are presented in chapter 4.

[8] https://milieudatabase.nl/media/filer_public/06/41/0641bd8a-caf8-479f-8172-32a3fa494fc0/forfaitaire_waarden_mei_2024.pdf

2 Review of recycling rates in public literature

Optimal use of waste streams starts with knowledge about their availability. CBS reports on wood waste streams, however, at a high aggregation level: A, B and C wood. No distinction is made regarding the origin of the waste wood, which would be a prerequisite for analysing reuse and recycling of e.g. wood 'waste' from construction demolition.

- Side note: As a consequence, demolition companies generally do not collect data for wood 'waste' volumes from construction demolition separately, and therefore such data are not generally available. Even less so, data per type of 'waste' streams and per type of application where the wood 'waste' streams are going to (e.g. construction, wood based panels, doors, window and door frames, timber frame construction (TFC) material) are recorded. It may be considered to include such detailed data in CBS reporting as they could serve as a measure for the level and quality of reuse and recycling, thus facilitating stimulation of reuse and recycling, next to setting a reference for establishing lump sum values for end-of-life scenarios.

On the other hand, several studies have reported on wood waste and recycling stream volumes. This literature has been reviewed in order to find first estimates for reuse and recycling rates of wood based products.

For reference, first the present lump-sum values for end-of-life scenarios for wood based building products as defined in the Determination Method are presented in Table 1.

Table 1 Lump-sum values for end-of-life scenarios belonging to the Determination Method.[8]

Material	Left in place	Landfill	Incineration	Recycling	Reuse
Clean wood (formwork)			10	10	80
Clean wood (beams, planks)		5	85	10	5
Clean wood (via 'residual material')		10	85	5	
Clean board material (via 'residual material')		5	85	10	
Contaminated wood (painted, impregnated)		5	95		
Contaminated wood (via 'residual material')		10	90		
Waterworks wood (brushwood mats)	50	25	25		
Waterworks wood (sheet piles, decking, jetty, sheeting)	10		90		
(Wood) polymer composites (profiles)			100		
'Volkern' (Trespa)		5	75	20	
Other organic (e.g. insulation): Flax, hemp, cellulose, cork, sheep wool		5	95		
Shells		10		90	

The wood waste and recycling stream volumes and recycling rates of wood at end-of-life reported in public literature during the past decade have been summarized in Table 2. The following observations can be derived:

- From the 8 studies reviewed, one presents estimates for the reuse percentage of construction and demolition waste, ranging from about 5 to 40% for various types of wood waste streams (line 8 in the table 2). This one study refers for the percentage of wood streams going to recycling to the study summarized in line 5.
- The majority of the studies report consolidated volumes for wood waste streams from all sources (lines 4 to 7).

- Reports focussing on Civil and Utility Construction (in Dutch 'Burgerlijke en Utiliteitsbouw', B&U) or Construction and demolition waste (C&DW) either do not specify where the recycled wood is going (lines 2 and 3), or do not specify what is the origin of the recycled wood which is applied in the B&U sector (line 1).
- Demarcation of data is not always clear. E.g. one organisation reports 2 different values for A/B wood waste stream volume for the same year in 2 different reports (lines 4 and 5). In another report data presented in a table do not match data presented in a flow chart (line 2).
- Most recent material recycling data for wood date from 2018, while majority of the data refers to the period 2012 – 2015.
- Overall, derived wood recycling percentages show large variation.
- The reported wood reuse and recycling percentages are in the range 5 – 40% versus lump-sum values of 5 – 15% for clean wood and board materials.

Considering the above, it is concluded that:

- Based on the studies found, the estimated reuse percentage varies per type of C&DW wood stream, ranging from about 5 – 40%. No clear conclusions regarding wood recycling rates for building and construction sector can be drawn from this literature.

Table 2 Wood waste and recycling stream volumes and rates for recycling to material use reported in public literature.

#	Type of material	Reference year	Sector	Brought on market (tonnes DM)	Waste stream (tonnes DM)	Reuse/ Recycling as material (tonnes DM)	% Recycling	Recycling in
1	All wood[9]	2014	B&U	610,000	360,000	91,900 Origin not clear	25.5	B&U
2	A/B wood[10]	2012	C&DW		1,322,000	463,000	35.0	Not specified
3	All wood[11]	2018 situation	C&DW in MRA *1	201,861	140,549	64,652	46.0	Not specified
4	A/B wood[12]	2015	All sources		1,250,000	180,000	14.4	Not specified
5	A/B wood[13]	2015	All sources		1,378,000	120,445 180,000	8.7 13.1 (total of 21.8%)	Particle board in Germany and Belgium; Not further specified in NL
6	Waste wood[14]	2015	All sources		1,300,000	208,000 156,000	16.0 12.0 (total of 28.0%)	Particle board in Germany and Belgium; Pallets in NL
7	A + A/B wood[15]	2015	All sources		1,502,000	325,000 *2 260,000	21.6 17.3 (total of 38.9%)	Particle board in Germany and Belgium; Pallets in NL
8	A + A/B wood[16]	2017	C&DW		435,000		20 Reuse (Recycling % unknown)	Indication per type of stream, e.g.: 40% reuse for beams, 15% for planks, 4% for window frames

*1 Metropolitan Region Amsterdam.

*2 EVOA data indicate 121,000 tonnes export to Germany and Belgium, however, stakeholders in the sector claim that about an additional 200,000 tonnes of A wood is exported without reporting, because it is not mandatory to report transport of A wood.

[9] EIB, Metabolic, SGS, 'Materiaalstromen, milieu-impact in de woning- en utiliteitsbouw' (2020), https://www.eib.nl/publicaties/materiaalstromen-milieu-impact-en-energieverbruik-in-de-woning-en-utiliteitsbouw/

[10] USI, 'Circulaire keten hout: Studie naar de houtafvalketen in de regio Utrecht' (2016), https://www.cirkelregio-utrecht.nl/wp-content/uploads/2021/03/Circulair-bouwen_Hout_Onderzoek-naar-houtafval-in-de-regio-utrecht_USI_2016.pdf

[11] Dr2 New Economy, Metabolic, 'De MRA als een circulaire grondstoffen hub' (2018), https://www.allesovercirculairslopen.nl/kennisbank/-604-de-mra-als-een-circulaire-grondstoffen-hub-10-cases/

[12] Probos, 'Kerngegevens bos en hout in Nederland' (2019), https://www.bosenhoutcijfers.nl/de-houtmarkt/houtproducten/gebruikt-hout/

[13] Probos, 'De markt voor afvalhout in 2015' (2017), https://www.probos.nl/rapporten-2017/1464-de-markt-voor-afvalhout-in-2015

[14] Nabuurs et al., 'Nederlands bosbeheer en bos- en houtsector in de bio-economie' (2016), https://edepot.wur.nl/390425

[15] Tauw, 'Knelpuntenanalyse houtrecycling' (2017), https://www.nedvang.nl/wp-content/uploads/2019/02/knelpuntenanalyse-houtrecycling1.pdf

[16] SloopCheck, 'De herfabricage van sloophout in Zuid-Holland' (2023), https://circulair.zuid-holland.nl/wp-content/uploads/2022/12/Rapport-de-herfabricage-van-sloophout-in-Zuid-Holland.pdf

3 Recycling rates from construction demolition sector

Next to increased attention for efficient use of virgin raw materials, also the reuse and recycling of (building) products at the end-of-life is important to meet sustainability and climate goals. Therefore, reuse and recycling of 'waste' streams is getting considerable attention, both in policy as well as in the building and construction demolition sector. This also holds for wood based materials.

Whereas in the previous chapter data for reuse and recycling rates of wood based material streams recovered from the demolition of buildings as presented in public literature have been analysed, this chapter focusses on data as indicated by the demolition sector itself. The approach comprises the steps as indicated in Figure 2 and further elaborated below.

Note 1: It may be considered that end-of-life scenarios depend on a range of aspects:[17]

- Construction practices during the construction of buildings. This relates to the year of construction.[18]
- Requirements by the demolition commissioner: To which extent is circularity rewarded.
- Time available for demolition and sales of recovered material streams: To which extent does planning and storage capacity allow demolition practices which enable recovery of useful materials and products and bring them to the market.
- Demand and price level for recovered materials.

Note 2: It appears that the initially provided expert estimates are averages considering all conditions. This means that they are conservative when compared to what is potentially possible today and what is actual practice for a couple of demolition companies already.

Note 3: Contrary to the data in the NMD table with lump-sum values for end-of-life scenarios, the data in the tables below and in Annex 1 have been displayed starting with reuse at the left hand side, in order to focus attention on this highest value end-of-life option.

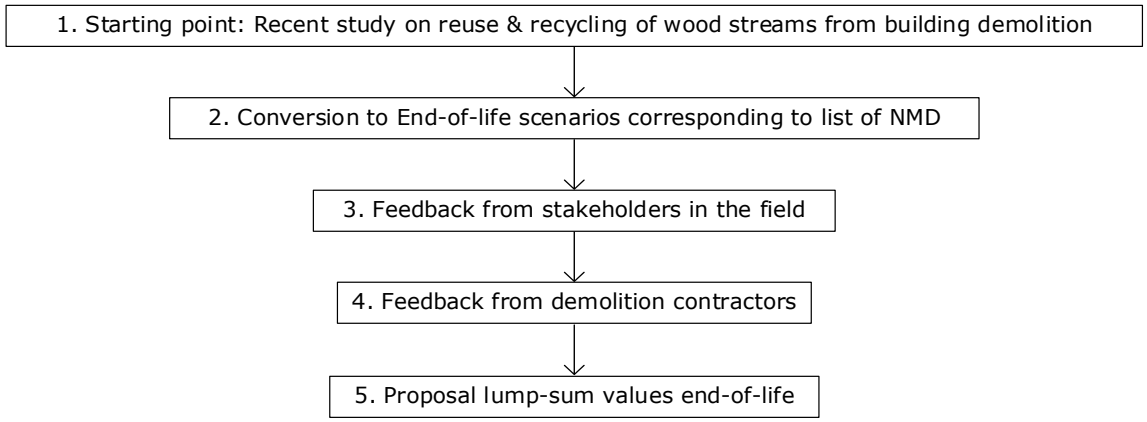

Figure 2 Steps taken to derive underpinned data for reuse and recycling of wood based material streams recovered from the demolition of buildings.

[17] Erik Hoven (Veras), personal communications.

[18] During the past decades construction practices have changed towards increased production speed and higher requirements for a.o. heat insulation. As a result, the number of different building materials has increased and the detachability has decreased due to the use of staples, glue, foils, etc. Both trends complicate demolishing for reuse and recycling.

3.1 Starting point: A recent analysis

The present volumes of reuse and recycling set a minimum benchmark for lump-sum values for end-of-life scenarios. With continued and emerging attention for efficient reuse and recycling of raw materials, however, the additional potential for reuse and recycling as estimated by experts may be considered to become the actual reuse and recycling practice by the time that the building products which are installed today will be released at their end-of-life. All of this under the condition that sufficient attention is paid to 'releasable' design and construction.

Sloopcheck has recently analysed the present status as well as potential of reuse/recycling of most common wood based streams from construction demolitions waste streams.[16] That study has been performed for the Province of Zuid-Holland, however the basic data refer to the Netherlands. Based on existing wood 'waste' stream data and interviews with demolition contractors, Sloopcheck has derived actual reuse as well as potential reuse and remanufacturing shares for a range of wood based 'waste' streams from building demolition. These data are listed in Table A1.1 in Annex 1.

3.2 Conversion to scenarios corresponding to the list of NMD

The categorisation of end-of-life scenarios in the Sloopcheck study[16] is not exactly corresponding to the default end-of-life scenarios of the Determination Method governed by NMD. The scenario of remanufacturing has been introduced because it appears prominent within organizations involved in circular wood based products business. Remanufacturing is one of the 9 R-strategies of circular economy,[19] and the value of material suitable for remanufacturing is typically in between those of materials suitable for reuse and recycling, which are default scenarios included in the NMD end-of-life scenarios list. Whereas NMD considers remanufacturing as fitting under 'reuse',[20] next to repair, refurbish and repurpose, the demolition contractors consider remanufacturing as a separate scenario, and therefore this scenario has been distinguished in the present study as well in order to keep the detailing (relevant for the sector).
The conversion of the Sloopcheck data to match the NMD scenarios, with the addition of remanufacturing as a scenario, has been elaborated as follows:

- The meaning of wood in the category 'being reused' (Table A1.1 in Annex 1) has been checked with Sloopcheck and appears to be either actually reused or remanufactured. Remanufacturing is a process in between reuse and recycling; it slightly modifies the form of a product while keeping the structure of the material itself intact. For wood building products it includes shaving, removing 'iron', sawing to different sizes, etc.[21] The distribution over the two scenarios of reuse and remanufacturing has been estimated via interviews by Centrum Hout with demolition contractors, reviewing 2nd hand materials offered on online marketplaces, and demolition projects communicated on social media in the period 2022-2023. The data are presented in Table A1.2 in Annex 1. The distribution is based on: demand for recollected materials, ease of removing materials intact, number of nails, etc., and volumes offered at online marketplaces.
- The wood in the category 'potential for remanufacturing' comprises A/B-wood, and therefore this fraction is considered to roughly follow the usual end-of-life scenarios according to Probos (2017),[22] which reports values of 20% for recycling and 80% for BEC/AVI.[23] Nevertheless, small fractions might be suitable for reuse, while despite the ban on landfilling wood, small fractions

[19] PBL, 'Circular Economy: Measuring innovation in the product chain' (2017). https://www.pbl.nl/uploads/default/downloads/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf
[20] https://milieudatabase.nl/nl/milieudata-lca/informatie-voor-lca-opstellers/verwerkingsscenarios-einde-leven/
[21] Similar operations could be applied to e.g. iron or concrete beams.
[22] https://www.probos.nl/images/pdf/rapporten/Rap2017_De_Markt_voor_afvalhout_in_2015.pdf#page=9
[23] It may be noted that most waste wood from building and construction demolition is incinerated in a biomass energy plant (in Dutch 'Biomassa-energiecentrale', BEC) to recover energy. The NMD list of lump-sum values for end-of-life scenarios refers to waste incineration (in Dutch 'Afvalverbrandingsinstallatie', AVI) which typically has low energy recovery rate.

are considered to end up in landfill. The following considerations have resulted in the distribution as presented in Table A1.3:

- The flow chart of wood waste streams in 2015 in the Netherlands (Sloopcheck[16] page 13) includes a line for 'high-quality reuse'. This reuse is not quantified nor substantiated by official sources, however, checking with Sloopcheck reveals that demolition contractors indicated to be actively looking for options to increase the volume of demolition wood back on the market; i.e. even small wooden products such as slats can be collected and resold. For this reason, in the present study it is considered plausible that a reuse share of 1% may be taken as a conservative value.
- Values for landfill have been estimated based on the ease/difficulty to reach (and clean) the products. Wooden framework is easy to recycle, because there is no paint or sealant. Windows that can be opened and doors are easy to remove from a building via the hinges. Fixed window frames are more difficult to recover, however these frames are often interesting because they are made of thick and valuable (tropical) wood. Door frames are also more difficult to reach while wood dimensions are smaller. For 'other wood streams' it is estimated that more will go to landfill; e.g. products composed of several smaller products which are difficult to sort out in the demolition and recycling sorting processes, and which (partly) cannot be incinerated.

- The fraction 'less suitable for remanufacturing' also ends in the A/B-wood fraction, and therefore also here the usual end-of-life scenarios according to Probos (2017) are considered as a starting point. The following considerations have resulted in the distribution presented in Table A1.4:
  - Wood can be processed relatively easily. Therefore, individuals may find opportunities to use parts of wood based products which are not generally recognized. As the attention for utilizing 'waste' materials increases, in the present study it is considered plausible that a remanufacturing share of 1% may be taken as a conservative value.
  - Values for landfill are considered to be slightly higher than for 'potential for remanufacturing'.
- Considering the volumes in tonnes per type of wood waste product (Table A1.5) and the percentages in Tables A1.1 – A1.4, the distribution of end-of-life scenarios for the different type of wood 'waste' products can be calculated as indicated in Table A1.6. Rounding these data to 5%, as is being done in the NMD lump-sum table, and combining the data for window frames and door frames into 1 category, results in Table 3 below.
  - Values for reuse and recycling of planks have been rounded up by 5%, as it may be expected that planks can be more easily reused compared to board materials, and more easily recycled compared to doors.
  - On average both reused and remanufacturing are rounded down. Recycling and BEC are rounded up on average, BEC being rounded up most.

If remanufacturing would have to be positioned in the current NMD default end-of-life scenarios, it would count under 'reuse' according to the NMD end-of-life scenario scheme.[20]

Table 3 End-of-life scenarios for various waste wood products; distribution based on interviews with a broad range of demolition contractors and second hand building material traders in 2022 by Sloopcheck,[16] completed by data in studies by Probos[13] and Tauw[24] for reference year 2015.[25]

Type of waste product	Reuse	Remanufacturing	Recycling	BEC incineration	Landfill
Beams	30%	15%	10%	45%	0%
Planks	15%	5%	20%	60%	0%
Window & door frames	0%	5%	20%	70%	5%
Doors	5%	10%	15%	65%	5%
Wooden framework	0%	5%	20%	70%	5%
Board materials	10%	35%	10%	40%	5%
Other	0%	25%	15%	55%	10%

[24] Tauw, 'Knelpuntenanalyse houtrecycling – Inzicht in de afvalhoutmarkt in Nederland' (2017), https://www.nedvang.nl/wp-content/uploads/2019/02/knelpuntenanalyse-houtrecycling1.pdf

[25] For reason of recognition, the data have been presented to the stakeholders from the sector in the order as presently done in the NMD lump-sum value table.

3.3 Feedback from stakeholders in the field

Table 3 has been sent to over 30 stakeholders in the C&DW sector early 2024, asking them to provide feedback on these values as estimates of current end-of-life scenario distributions. 13 Parties have responded:

- 7 Independent experts and (entrepreneurial) consultants involved in the wood sector
- 3 LCA experts involved in the wood sector
- 2 Recyclers
- 1 Representative of a governmental organisation

The obtained feedback can be described and concluded as follows:

- 5 Respondents have provided feedback to specific scenario data, one of which addressing all data and 4 respondents giving modified data for 2 or 3 individual data points only. Another 5 respondents have provided qualitative feedback; further 2 have given other feedback like suggestions for references; 1 respondent has indicated not having the knowledge to provide feedback.
- 3 Respondents have indicated that (some) reuse and/or recycling data are higher, 3 that the data are reasonably correct, and 4 that values for specific product streams are lower.[26] Remarkably, some experts have indicated that reuse values for specific product streams should be lower, whereas an actual recycler has indicated that the values are higher.[27]
- As far as the feedback can be averaged, the tenor is that the data in Table 3 present reasonably well the actual end-of-life scenarios according to the respondents.
- If remanufacturing will become a new scenario, then also new 'standard profiles' will have to be added to the processes database.
- Two respondents have mentioned that landfill of wood based products is not allowed (anymore), except in case of contamination with asbestos.
- One group of key stakeholder has been missing in the responses: the demolition contractors. Therefore, they have been approached again (see next paragraph).

In conclusion: The reuse, remanufacturing and recycling rates as indicated in Table 3 have been confirmed by a broad range of stakeholders in the field: independent experts, LCA experts, recyclers. However, feedback from the key group of demolition contractors is missing.

3.4 Feedback from demolition contractors

During the first round, the building demolition contractors, being key stakeholders for the topic of investigation, have not provided feedback. Therefore, a dedicated meeting has been organized with Veras, the Dutch association for demolition contractors. During this meeting, it has turned out that scoring end-of-life scenarios for wood based C&DW streams would be easier when splitting up some categories of waste streams: 1) Larger and smaller dimensions for beams/framework; 2) A-wood and B-wood for large beams; 3) Distinction between 'regular wood' and tropical hardwood for window and door frames. Accordingly, Table 3 has been translated into a new table (Table A1.7 in Annex 1), where values for B-wood and smaller dimension framework wood have been given lower values compared to Table 3, and tropical hardwood frames have been given higher values compared to Table 3. The data as presented in Table A1.7 have been distributed to Veras members. Three demolition companies have responded, for several categories claiming significantly higher values for reuse at the expense of incineration , see Table 4.

[26] One of the stakeholders is a recycler which 'gets' the wood stream that the demolition contractors do not collect for reuse themselves. Accordingly, they only see the part of the wood stream that is not suitable for reuse (and recycling?).

[27] Recyclers typically receive fractions of wood waste streams which have already been plundered in terms of the most reusable fraction, and therefore may tend to underestimate the reuse rates of the overall volume of wood streams released from the demolition of buildings.

The huge difference between Table 3 and 4 may be explained by considering the following:

- Data in Table 3 reflect average demolition practices in the Netherlands, including the significant share of non-circular demolition, whereas Table 4 reflects the data for circular demolition only.
- Stakeholders other than the demolition contractors (Table 3) do not have day-to-day direct insight into demolition practices and results. E.g. recyclers only obtain the wood waste stream which has been deprived already from the fraction considered reusable by the demolition contractor. Other stakeholders have an even more distant view and may also be influenced by reports about wood/biomass incineration and that wood is always burned, and may therefore paint a relatively negative picture. The demolition contractors are the only parties having direct insight into actual demolition practices.

Note: It may be mentioned that circular demolition contractors observe that an increasing share of demolition contractors is developing towards more circular practices.

In conclusion: The reuse, remanufacturing and recycling rates as indicated in Table 4 can be considered the scenarios for current circular demolition practices.[28]

Table 4 End-of-life scenarios for various waste wood categories; average of current practice data indicated by 3 circular demolition contractors.

Type of waste product	Reuse	Remanufacturing	Recycling	BEC incineration	Landfill
Beams A-wood, > 45x145	80%	10%	5%	5%	0%
Beams B-wood, > 45x145	75%	10%	5%	10%	0%
Planks A-wood	75%	5%	10%	10%	0%
Planks B-wood	70%	5%	15%	10%	0%
Window & door frames (softwood)	10%	5%	65%	20%	0%
Window & door frames (hardwood)	20%	35%	35%	10%	0%
Doors	55%	10%	15%	20%	0%
Wooden framework, > 45x70	50%	5%	40%	5%	0%
Wooden framework, < 45x70	25%	10%	35%	30%	0%
Board materials	35%	25%	30%	10%	0%
Other	15%	15%	10%	55%	5%

Scenarios for future demolition

The data in Table 4 are for buildings which are currently demolished, viz. mainly buildings from the period 1945 – 1970, involving relatively small number of different materials and a fair detachability. Starting around 1990, construction practices have changed towards increased production speed and higher requirements for a.o. heat insulation. As a result, the number of different building materials has increased and the detachability has decreased due to the use of staples, glue, foils, etc. Both trends complicate demolishing for reuse and recycling. However, even then, a circular demolition contractor indicates percentages for the scenarios reuse, remanufacturing and recycling which are higher than considered in Table 3, see Table 5.

Note 5: Considering:

- The upcoming 'Circular Materials Plan' pays specific attention to wood;[29]
- Less wood residues will go to BEC/AVI, more to material;
- The generally increasing attention for circularity;

It may be reasonably expected that the values for reuse, remanufacturing and recycling can increase again when buildings and constructions are being designed for reuse of materials. The level of detachability may benefit from dedicated regulations and development programs like Circulaire Geveleconomie,[30] and concrete projects like: removal of metal from waste wood streams,[31] using

[28] Table 3 indicates data for average demolition practices.
[29] https://open.overheid.nl/documenten/ronl-19af9657291766e943e09d74899fb340e0f6d378/pdf
[30] https://www.circulairegeveleconomie.nl/
[31] https://www.tno.nl/nl/newsroom/insights/2022/11/in2innovation-hergebruik-afvalhout/

computational design to draft products based on the recognition of type and form of actually available wood 'waste',[32] setting up retour systems of hardwood frames.[33]

Table 5 End-of-life scenarios for various waste wood categories; indication of circular demolition practices for buildings constructed since about 1990.

Type of waste product	Reuse	Remanufacturing	Recycling	Waste incinerator	Landfill
Beams A-wood, > 45x145	45%	10%	35%	10%	0%
Beams B-wood, > 45x145	45%	10%	35%	10%	0%
Planks A-wood	50%	5%	30%	5%	0%
Planks B-wood	25%	5%	50%	20%	0%
Window & door frames (softwood)	25%	10%	20%	45%	0%
Window & door frames (hardwood)	25%	35%	20%	20%	0%
Doors	25%	5%	25%	45%	0%
Wooden framework, > 45x70	25%	5%	50%	15%	0%
Wooden framework, < 45x70	5%		50%	45%	0%
Board materials	30%	20%	30%	20%	0%
Other	0%	20%	15%	55%	0%

Timber frame construction (TFC)

Demolition of TFC elements does not seem to be complex. Also shortening or extending such elements (remanufacturing) can be done relatively easily. This way, the value of the element is retained as much as possible. Detachability of individual components from the TFC elements may be difficult; moreover, the resulting beams, etc. will have lower value than the original building element such as floor, wall or roof elements. Both reusability of elements as well as eventual detachability into components can be addressed by design for reuse/remanufacturing.

Cross Laminated Timber (CLT)

CLT is a wood based material gaining interest in the construction sector with increasing application volumes. The demolition of CLT based constructions does virtually not apply so far. A first indication for reusability of CLT is the take-back guarantee by Derix which is based on an LCA for which 60% reuse is considered, while claiming that this value is a conservative estimation.[34]

3.5 Civil Works

Civil works have been part of Dutch heritage dating back to the Romans, who already used wood for sheet piling, lock gates and road construction during their stay in the Netherlands. Due to the large number of waterways, lakes and other water entities, the Dutch have been using large quantities of wood in civil works up to today. According to research by Tauw[35] about a total of 156.160 m^3 of wood is currently used in civil works yearly, which over time will be extracted for renewal or replacement and be partly available for reuse and or recycling. According to Dutch law, the entity that executes a civil works project automatically becomes owner of the materials extracted from the project, while at the same time all these materials need to be reported before any activity or reuse is due. Yet, data on reuse and recycling of wood extracted from civil works are scarce. The Tauw report mentions 25% reuse for sheet piles, and suggesting higher percentages for mooring-posts and fenders, whereas Royal HaskoningDHV reports[36] that 77% of extracted wood from civil works at RWS was dedicated for energy purposes, 16% reuse, 7% recycling and 1% Landfill. These data for reuse and recycling are higher than

[32] https://www.hva.nl/kc-techniek/gedeelde-content/projecten/circular-transition/digital-production-research-group/circular-wood-4.0.html
[33] https://toekomstbestendigeleefomgeving.nl/gebouwen/ & https://www.linkedin.com/feed/update/urn:li:activity:7202232387089444864/
[34] https://www.hethoutblad.nl/houtbouwnieuws/x-lam-als-eerste-met-circulaire-epd-in-nmd/76451/
[35] https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/@92211/verkenning-introductie-retoursysteem/
[36] https://open.rijkswaterstaat.nl/@269588/casestudie-vrijkomende-materialen/

indicated in the lump-sum values for end-of-life scenarios presented by the NMD,[37] viz. 90% incineration and 10% left in place, i.e. 0% reuse and recycling. At the same time, the scenario data are not very specific for type of application and related conditions, whereas the EoL scenarios may be expected to relate to dimensions (thickness) and application conditions such as mostly dry, at water surface, in soil. From experience and the increasing number of projects designed and executed with recycled wood, Centrum Hout expects that the volume of recovered wood reused or recycled is much higher in practice than the Royal HaskoningDHV report declares. Therefore Centrum Hout has sent an enquiry to 20 contractors in civil works, ranging from small operators tot large size companies for further analyses. In this enquiry, several main types of construction products with different dimensions and application conditions have been distinguished, as indicated and explained in Annex 2.

Three civil works contractors, 1 medium and 2 small size companies, have provided estimates of the end-of-life scenarios of different waste wood streams from civil works based on their business practice. The range of estimated end-of-life scenarios and estimated service life per type of construction product is presented in table A3.1 in Annex 3, the average estimated end-of-life scenarios are presented in table A3.2. The results indicate that there is a great difference between entrepreneurs and the way they operate with a view to circularity, recycling and reuse (frontrunners vs generic operations). The results also indicate a significant difference between the type of construction and the possibilities to recycle and reuse wood extracted from civil works. Sheet piles and Mooring-posts, being wood of large dimension have good opportunity to be recycled or reused. Products with slimmer dimensions as used in e.g. revetments, have considerable shorter lifespan and higher chance of deterioration and therefore are prone to be left in place, landfilled or end up in a furnace for energy recovery. Further, compared to waste wood streams from building demolition, the share of landfill and 'left in place' is considerably high due to partial degradation and adhering/trapped sand. It is therefore recommended to closely look at the type of applications and make separate categories when establishing lump-sum end-of life scenarios.

The average values in Annex 3 have been rounded to 5%, as is being done in the NMD lump-sum table, and presented in Table 6. The values for reuse and recycling have all been rounded down to obtain conservative values, also to account for the considerable variation in scenarios among respondents. The values for landfill and 'left in place' have been rounded to the nearest 5%. The value for incineration has been adapted to match a total of 100%, meaning an increase compared to the average values as estimated by the civil works contractors (Table A3.2).

As circularity in civil works will advance over the coming years, it is advised to continuously monitor developments in this part of the construction market.

In conclusion: The end-of-life scenarios per type of construction products as presented in Table 6 can be considered the current reasonably possible average end-of-life scenarios for civil works in 2024. The results indicate that the scenarios largely differ for different types of civil works wood waste streams, which are currently combined in one set of scenarios in the NMD list of lump-sum scenarios.

Table 6. End-of-life scenarios for various waste wood streams from civil works, conservatively derived from estimates by civil works contractors in 2024.

Type of waste product	Reuse	Recycling	Incineration	Landfill	Left in place
Sheet piles	30%	30%	35%	0%	5%
Revetments	0%	10%	50%	25%	15%
Jetty/Decking	15%	25%	50%	10%	0%
Bridge construction	15%	30%	50%	5%	0%
Fenders	30%	35%	35%	0%	0%
Mooring-posts	40%	35%	20%	0%	0%
Beams	20%	25%	50%	5%	0%

[37] https://milieudatabase.nl/media/filer_public/06/41/0641bd8a-caf8-479f-8172-32a3fa494fc0/forfaitaire_waarden_mei_2024.pdf

4 Conclusions

Remanufacturing has been distinguished as a scenario in between reuse and recycling, comprising materials extracted from buildings and constructions which e.g. have been reduced in size by sawing or extended by making finger joints. It is proposed to add remanufacturing of wood as scenario in the lump-sum value list.
Alternatively, it will count under 'reuse', according to the NMD end-of-life scenario scheme.

The data in Table 3 can be considered the reuse, remanufacturing, recycling and incineration percentages for various waste wood products for current average demolition practices for buildings in 2024, as confirmed by a wide range of stakeholders in the field. When demolition practices will be left to the market as they are today, it is proposed to use these data as the lump-sum end-of-life scenarios for the indicated waste wood products.

The data in Table 4 can be considered the reuse, remanufacturing, recycling and incineration percentages for various waste wood categories for circular demolition practices for buildings in 2024. When circular demolition practices will be adequately and effectively promoted, these data will become the standard practice and can be taken as the lump-sum end-of-life scenarios.

Buildings constructed since about 1990 contain more gluing and stapling, etc., which hinders proper recovery of construction materials during demolition for adequate reuse, remanufacturing and recycling. The data in Table 5 present first estimates for the end-of-life scenarios for various waste wood products when using circular demolition practices for buildings constructed using indicated (gluing and stapling) manufacturing concepts built after about 1990. To improve detachability in order to increase the share reuse, remanufacturing and recycling, buildings and constructions will have to be designed for reuse of materials. Dedicated regulations may boost such design for reuse.

The data in Table 6 can be considered as the current averages for the scenarios leave, landfill, incineration, recycling and reuse by civil works entrepreneurs and contractors. The results indicate that the scenarios largely differ for different types of civil works wood waste streams, which are currently combined as one waste stream in the NMD end-of-life scenario scheme. It is proposed to use these data as the lump-sum end-of-life scenarios for the indicated civil works wood waste streams, and to monitor scenario developments.

Abbreviations

A wood	Wood that has not been painted or treated, such as floor beams
B wood	Wood that has been painted, varnished and/or glued, such as window frames
C wood	Impregnated wood, such as Wolmanized fencing
AVI	'Afvalverbrandinginstallatie' (Waste incinerator)
BEC	'Biomassa Energie Centrale' (Biomass power plant)
B&U	'Burgerlijke en Utiliteitsbouw' (Civil and Utility Construction)
C&DW	Construction and demolition waste
CBS	'Centraal buro voor de statistiek' (Statistics Netherlands)
CLT	Cross laminated timber
DM	Dry matter
EoL	End of life
EPD	Environmental product declaration
LCA	Life cycle analysis
NMD	'Nationale Milieudatabase' (National Environmental Database)
TFC	Timber frame construction ('Houtskeletbouw' (HSB) in Dutch)

Annex 1 End-of-life scenarios of wood streams collected from building demolition

Table A1.1. Potential reuse and recycling of wood collected from average building demolition practices in base year 2022, copied from Figure 20 in Sloopcheck (2023).[16]

Type of waste product	Being 'Reused'	Potential for 'remanufacturing'	Less suitable for 'remanufacturing'
Beams	41%	51%	8%
Planks	15%	57%	28%
Window frames	4%	55%	41%
Doors	14%	86%	0%
Door frames	4%	81%	15%
Wooden framework	5%	30%	65%
Board materials	45%	0%	55%
Other	23%	0%	77%

Definitions of terms used in this table:

- Being reused: Demolition companies have found applications for wood and deliver to these markets directly/themselves.
- Potential for remanufacturing: Wood of good quality, however, which is not yet utilised by the demolition companies themselves and sold to recyclers.
- Less suitable for remanufacturing: Wood of poor quality, sold to recyclers.

Table A1.2. Breakdown of 'being reused' in Table A1.1 into 'reuse' and 'remanufacturing', derived from interviews with demolition contractors and other experts in the sector in 2023.

Type of waste product	Reuse	remanufacturing
Beams	70%	30%
Planks	60%	40%
Window frames	10%	90%
Doors	15%	85%
Door frames	5%	95%
Wooden framework	40%	60%
Board materials	20%	80%
Other	5%	95%

Table A1.3. Breakdown of 'potential for remanufacturing' in Table A1.1 into more specific end-of-life scenarios, following the scenarios presented by Probos (2017) and Tauw (2017) for base year 2015, and additional info as described in section 3.2.[38]

Type of waste product	Reuse	Recycling	BEC incineration	Landfill
Beams	1%	20%	78%	1%
Planks	1%	20%	78%	1%
Window frames	1%	20%	75%	4%
Doors	1%	20%	75%	4%
Door frames	1%	20%	73%	6%
Wooden framework	1%	20%	77%	2%
Board materials	1%	20%	75%	4%
Other	1%	20%	71%	8%

[38] The data in this table and the following tables have been displayed starting with reuse at the left, in order to focus attention on this highest value end-of-life option.

Table A1.4 Breakdown of 'less suitable for remanufacturing' in Table A1.1 into more specific end-of-life scenarios, following the scenarios presented by Probos (2017) and Tauw (2017) for base year 2015, and additional info as described in section 3.2.

Type of waste product	Remanufacturing	Recycling	BEC incineration	Landfill
Beams	1%	20%	78%	1%
Planks	1%	20%	78%	1%
Window frames	1%	20%	74%	5%
Doors	1%	20%	74%	5%
Door frames	1%	20%	71%	8%
Wooden framework	1%	20%	77%	2%
Board materials	1%	20%	74%	5%
Other	1%	20%	69%	10%

Table A1.5 Volumes of waste wood streams considered by Sloopcheck (2023).[16]

Type of waste product	Amount (tonnes)
Beams	41,400
Planks	27,600
Window frames	27,600
Doors	6,900
Door frames	13,800
Wooden framework	48,300
Board materials	18,400
Other	46,000

Table A1.6. End-of-life scenarios for various waste wood streams derived from Tables A1.1 – A1.5.

Type of waste product	Reuse	Remanufacturing	Recycling	BEC incineration	Landfill
Beams	29%	12%	12%	46%	1%
Planks	10%	6%	17%	66%	1%
Window frames	1%	4%	19%	72%	4%
Doors	3%	12%	17%	65%	3%
Door frames	1%	4%	19%	70%	6%
Wooden framework	2%	4%	19%	73%	2%
Board materials	9%	37%	11%	41%	3%
Other	1%	23%	15%	53%	8%

Table A1.7. End-of-life scenarios for various waste wood streams, after updating the stream categories according to demolition contractors' input. These data have been presented to Veras members for their feedback.

Type of waste product	Reuse	Remanufacturing	Recycling	BEC incineration	Landfill
Beams A-wood, > 45x145	30%	15%	10%	45%	0%
Beams B-wood, > 45x145	20%	15%	15%	50%	0%
Planks A-wood	15%	5%	20%	60%	0%
Planks B-wood	5%	5%	25%	65%	0%
Window & door frames (softwood)	0%	5%	20%	70%	5%
Window & door frames (hardwood)	0%	25%	20%	50%	5%
Doors	5%	10%	15%	65%	5%
Wooden framework, > 45x70	0%	5%	20%	70%	5%
Wooden framework, < 45x70	0%	0%	20%	75%	5%
Board materials	10%	35%	10%	40%	5%
Other	0%	25%	15%	55%	10%

Annex 2 Product groups of civil works applications

Revetments: consist of wooden poles and horizontal wooden planks, sometimes backed by geotextiles to prevent soil entering the water. Due to the small dimensions, the lifespan can be short and extraction may be difficult, renewal often involves letting the old revetment be and placing a new construction in front.

Figure 3 Revetment in Stolwijk (NL). (Photo www.houtindegww.nl)

Sheet Piles: vertical profiles wooden planks ranging from 3 to 10 cm in thickness, up to 6 meters in length, which are pushed into the waterbed to stabilise the soil behind it. Only steel ankers and bolts are used and make it easy to detach and reuse. Due to the heavy dimension, wooden sheet piles are valuable when extracted and often reused as sheet piles in other or even the same project, just by using the intact wood again.

Girdle: horizontal beam used on pile sheeting with heavy loads to distribute the forces evenly over the vertical planks.

Figure 4 Double girdle mounted on sheet pile planks. (Photo Eric de Munck, CentrumHout)

Bridges: wood construction composed of heavy and smaller dimensions. Only bolts are use and therefore easy to dismount. Almost all parts can be reused. The decking is usually covered by asphaltic material and therefore more difficult to recycle.

Figure 5 Pedestrian bridge Dirkshorn (NL). (Photo www.houtindegww.nl)

Mooring-posts: large dimension poles (200 x 200 mm up to 300 x 300 mm) with lengths up to 13 m used to anchor ships.

Figure 6 Mooring-posts in the harbour of Oude Schilt, Texel. (Photo Eric de Munck, CentrumHout)

Jetty: a wooden construction composed of poles, beams and decking bringing water and waterfront together that can be used for docking (harbours), fishing or other ways of leisure.

Figure 7 Jetty in 'De grote Wielen' (NL). (Photo www.houtindegww.nl)

Fender: Wooden construction of heavy sized beams and columns mounted on a wood, steel or concrete construction situated in the 'funnel mouth' of lock gates ('sluizen' in Dutch) used to guide boats in the right direction, prevent damage to boats while docking while waiting for passage.

Figure 8 Fender in Rotterdam (NL). (Photo www.houtindegww.nl)

Beams: wood of heavy dimensions, usually applied horizontally in different wood constructions, for example bridge constructions, often not in direct contact with soil.
Decking: (profiled) plank used as deck.

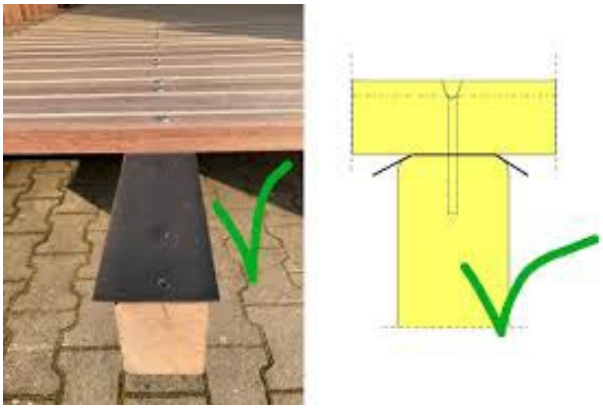

Figure 9 Beam in bridge construction, with decking on top. (Photo+image www.crow.nl)

Annex 3 End-of-life scenarios of wood streams collected from civil works

Table A3.1. Ranges of end-of-life scenarios and service live for various waste wood streams from civil works, according to contractors in 2024.

Type of waste product	Service life	Reuse	Recycling	Incineration	Landfill	Left in place
Sheet piles	30 - 40	25 - 45	10 - 60	15 - 45	0	0 - 20
Revetments	20 - 25	0 - 5	5 - 30	25 - 80	0 - 75	0 - 40
Jetty/Decking	30 - 40	10 - 25	15 - 60	25 - 75	0 - 35	0
Bridge construction	30 - 35	10 - 35	20 - 50	15 - 70	0 - 25	0
Fenders	35 - 40	10 - 65	25 - 55	5 - 60	0 - 5	0
Mooring-posts	20* - 45	15 - 65	20 - 70	5 - 20	0 - 5	0
Beams	35 - 40	15 - 40	15 - 40	10 - 70	0 - 10	0 - 5

* 20 years when naval shipworms are deteriorating the posts in e.g. the Province of Zeeland, else 40 years.

Table A3.2. Average end-of-life scenarios for various waste wood streams from civil works, according to contractors in 2024.

Type of waste product	Reuse	Recycling	Incineration	Landfill	Left in place
Sheet piles	32%	33%	28%	0%	7%
Revetments	2%	11%	45%	25%	17%
Jetty/Decking	17%	30%	41%	12%	0%
Bridge construction	20%	32%	40%	8%	0%
Fenders	35%	37%	26%	2%	0%
Mooring-posts	47%	38%	13%	2%	0%
Beams	23%	27%	45%	3%	2%

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