Appendix B Attribution of end of life procedures for products to modules C1–C4 and D

Abbreviations

Indicators

C content	Amount of CO_2 absorbed from the atmosphere during the growth of biomass and bound over the lifetime of the material
GWP	Global warming potential
GWP biogenic	Global warming potential - biogenic
EEE	Exported electrical energy
EET	Exported thermal energy
MER	Materials for energy recovery
MFR	Materials for recycling
PERE	Renewable primary energy - as an energy source
PERM	Renewable primary energy - as a raw material
PERT	Renewable primary energy - total (sum of PERE and PERM)
PENRE	Non-renewable primary energy - as energy source
PENRM	Non-renewable primary energy - as a raw material
PENRT	Non-renewable primary energy - total

Processes

→	The arrow means that a conversion process of a material inherent property takes place in the respective module.
- PERM→ + PERE - PENRM→ + PENRE	During combustion, the primary energy used as raw material (PERM, PENRM) is converted into primary energy used for energy generation (PERE, PENRE). PERM, PENRM are therefore written off as a negative value and the same value is entered as a positive value in PERE, PENRE.
+ GWP biogenic (C content→ CO_2)	The carbon stored in the product ("C content") is converted into CO_2 emissions during combustion processes, which are expressed as a positive value in the GWP biogenic.
+ GWP biogenic (- C content)	The carbon stored in the product leaves the product without being converted. It is cancelled out in the GWP biogenic ("-C content (+ GWP biogenic)").
- GWP biogenic (+ C content)	Inputs of biogenic CO_2 into the product system ("C content") are characterised as a negative value in the GWP biogenic.

B1 General information on specific material properties ("material inherent properties")

B1.1 General rule for specific material properties

- Material inherent properties of substances such as calorific value or composition (e.g. carbon content) must always be passed on reflecting the physical flows when crossing the system boundary between product systems (see EN 15804+A2, 6.4.3.1 and 6.4.3.2).

B1.2 Biogenic carbon content and biogenic GWP

- Inputs of biogenic CO_2 into the product system (from the air or from a previous product system) are characterised as LCIA as -1 kg CO_2 eq./kg CO_2. Emissions of biogenic CO_2 from biomass and outputs of biomass from the product system shall be characterised as a positive value, i.e. +1 kg CO_2 eq./kg CO_2 of biogenic carbon (EN 15804+A2, Annex C2.4).

B1.3 Material-bound energy content (indicators PERM and PENRM Use of primary energy sources used as raw materials)

- The material-bound energy content is measured using the PERM and PENRM indicators (use of primary energy sources used as raw materials). Outputs of material-bound energy content from the product system must be characterised as a negative value of PERM (renewable energy) or PENRM (non-renewable energy).
- The material-bound energy content is released during combustion processes. PERM and PENRM are characterised as negative values in MJ and the same amount as positive values in MJ for PERE and PENRE.

B2 Thermal disposal or energy recovery

B2.1 Attribution according to EN 15804 in conjunction with EN 16485

- For the attribution of the thermal disposal or recovery of combustible materials, it is recommended that the specifications in accordance with EN 15804 in conjunction with EN 16485, 6.2.4.5 Table 1 be taken into account (see Table 1).

  Explanations to the table:

  Criterion 2: "Materials for energy recovery are identified based on the efficiency of energy recovery with a rate higher than 60 % without prejudice to existing legislation. Materials from which energy is recovered with an efficiency rate below 60 % are not considered materials for energy recovery." (EN 15804, 6.3.5.5).

  Note: Criterion 2 of EN 15804 contains a contradiction in terms of content. In the first sentence, the efficiency of the energy generation plant (future, corresponding to the selected scenario, but actually unknown at the time of EPD creation) is used as a criterion, while the second sentence refers to "materials … with an efficiency rate ...". From the logic of the environmental product declaration, the actual material properties such as calorific value, bulk density and absence of pollutants should be the basis for categorisation as energy recovery or thermal disposal (see also the Circularity-Index according to BNB 4.1.4).

In the "thermal waste treatment" disposal process, the waste flow does not reach the "end-of-waste" status before incineration and the plant has an R1 value ≤ 0.6. The environmental impact of the waste treatment and incineration processes is declared as a disposal process in C4.

When applying the "energy recovery" scenario, the waste flow does not reach the "end-of-waste" status before incineration, but the plant has an R1 value > 0.6. The environmental impact of the waste treatment and incineration processes is declared in C3.

When applying the "Use of secondary fuel" scenario, the waste flow reaches the "end-of-waste" status before incineration or energy recovery. This qualifies the material flow at the system boundary as a secondary fuel and the R1 value criterion is not applicable. The environmental impacts of waste processing to secondary fuel are declared in C3, the environmental impact of the incineration processes in D.

Table 1: Attribution of thermal recovery or disposal processes to modules C1 - C4 and D depending on whether a flow is considered as waste and on the R1 value of the incineration plant (if applicable). Source: EN 16485, 6.2.4.5 Table 1

Criteria	Thermal waste treatment	Energy recovery	Use of secondary fuel
Criterion 1	Flow is considered waste (flow does not reach end-of-waste status)	Flow is considered waste (flow does not reach end-of-waste status)	Flow is not considered waste (flow reaches end-of-waste status)
Criterion 2	R1 value of incinerator facility ≤ 0.6	R1 value of the incinerator facility > 0.6	Not applicable
Module	**Resulting attribution of processes to information modules**		
C1	Dismantling / Demolition	Dismantling / Demolition	Dismantling / Demolition
C2	Transport to the incineration site	Transport to the incineration site	Transport to the sorting platform
C3		Processing and incineration	Sorting and processing
C4	Processing and incineration		
D	Avoided impacts of electricity production and heat/energy recovery	Avoided impacts of electricity production and heat/energy recovery	Incineration and avoided impacts of electricity production and heat/energy recovery

B2.2 Declaration of environmental information describing the output flows

- In accordance with the modelling of the disposal processes, the environmental information for describing the output flows must be declared as shown in Table 2.

Table 2: Declaration of the environmental information describing the output flows**.** All indicators have positive values.

Module	Thermal waste treatment	Energy recovery	Use of secondary fuel
C3		Exported electrical energy (EEE) Exported thermal energy (EET)	Materials for energy recovery (MER)
C4	Exported electrical energy (EEE) Exported thermal energy (EET)		

B2.3 Attribution of material inherent properties

- In accordance with the modelling of the disposal processes, the material inherent properties must be attributed as shown in Table 3.

Table 3: Attribution of material inherent properties

Module	Thermal waste treatment	Energy recovery	Use of secondary fuel
C3		Incineration process: - PERM→ + PERE - PENRM→ + PENRE + GWP biogenic (C content→ CO_2)	Output of secondary fuel: - PERM - PENRM + GWP biogenic (- C content)
C4	Incineration process: - PERM→ + PERE - PENRM→ + PENRE + GWP biogenic (C content→ CO_2)		
D	PERM = 0 PENRM = 0 GWP biogenic (C content) = 0	PERM = 0 PENRM = 0 GWP biogenic (C content) = 0	Input of secondary fuel: + PERM + PENRM - GWP biogenic (+ C content) Incineration process: - PERM→ + PERE - PENRM→ + PENRE + GWP biogenic (C content→ CO_2)

Explanation:
The arrow ("→ ") means that a conversion process of a material inherent property takes place in the respective module. Example:

> "+ GWP biogenic (C content→ CO_2)" means that the carbon stored in the product ("C content") is converted into CO_2 emissions during combustion processes, which are expressed as a positive value in the GWP biogenic.
> In the "Use of secondary fuel" scenario, the carbon stored in the secondary fuel leaves the product system as well, but without conversion. It is written off as GWP biogenic ("+ GWP biogenic (- C content)").

In the end of life processes "**thermal waste treatment**" and "**energy recovery**", the primary energy used as raw material (PERM, PENRM) is converted into primary energy used for energy generation (PERE, PENRE). PERM, PENRM are therefore written off as a negative value and the same value is entered as a positive value in PERE, PENRE.
The biogenic carbon content in the material is released during incineration and is to be declared as a positive value in the global warming potential biogenic (GWP biogenic).
For the "thermal waste treatment" disposal method, this information must be provided in module C4, and for the "energy recovery" disposal method in module C3.

In the end of life process "**Use as secondary fuel**", the primary energy used as raw material (PERM, PENRM) is transferred from module C3 to module D as a material inherent property. It must therefore be specified as a negative value in C3. The energy used as raw material (PERM, PENRM) is transferred with the net flow of the secondary fuel to Module D and is then converted to used energy (PERE, PENRE) in the course of thermal recovery.
The global warming potential of the CO_2 stored in the biogenic material must be specified in module C3 as a

positive value of +1 kg CO_2 eq./kg CO_2 in GWP biogenic (EN 15804, C2 " transfers of biomass into subsequent product systems" and EN 16485). Accordingly, the biogenic CO_2 stored in the net flow of the secondary fuel has a negative value of -1 kg CO_2 eq./kg CO_2 on the GWP biogenic when it enters Module D ("Transfers from previous product systems"). When the secondary fuel is incinerated, the biogenic CO_2 is ultimately released and indicated as a positive value in the GWP biogenic. In the case of complete incineration (only CO_2 and no other greenhouse gas is formed), the sum of these two calculation steps in Module D is zero.

The procedure is illustrated in **Figure 1** using a fictitious example.

Figure 1:
Example: Declaration of material inherent properties for thermal recovery and disposal processes

Scenario 1 Thermal waste treatment	A1-A3	C4	D
PERE [MJ]	4500	11008	-1650
PERM [MJ]	**11000**	**-11000**	**0**
PERT [MJ]	15500	8	-1650
PENRE [MJ]	3485	658	-5960
PENRM [MJ]	**645**	**-645**	**0**
PENRT [MJ]	4130	13	-5960
Biogenic carbon [CO2 eq]	**-1063**	**1063**	**0**
GWP total [CO2 eq]	-812	1155	-650

Note on the values in Module D: Scenario 1 generally involves a poorer efficiency of energy generation than scenario 2. As no corresponding data set was available for the example, the data from scenario 2 was used to demonstrate the principle of the declaration.

Scenario 2 Energy recovery	A1-A3	C3	D
PERE [MJ]	4500	11008	-1650
PERM [MJ]	**11000**	**-11000**	**0**
PERT [MJ]	15500	8	-1650
PENRE [MJ]	3485	658	-5960
PENRM [MJ]	**645**	**-645**	**0**
PENRT [MJ]	4130	13	-5960
Biogenic carbon [CO2 eq]	**-1063**	**1063**	**0**
GWP total [CO2 eq]	-812	1155	-650

Scenario 3 Use of secondary fuel	A1-A3	C3	D	Breakdown to sub-processes *)		
				D 1	D 2	D 3
PERE [MJ]	4500	8	9350	0	11000	-1650
PERM [MJ]	**11000**	**-11000**	**0**	11000	-11000	0
PERT [MJ]	15500	-10992	9350	11000	0	-1650
PENRE [MJ]	3485	13	-5315	0	645	-5960
PENRM [MJ]	**645**	**-645**	**0**	645	-645	0
PENRT [MJ]	4130	-632	-5315	645	0	-5960
Biogenic carbon [CO2 eq]	**-1063**	**1063**	**0**	-1063	1063	
GWP total [CO2 eq]	-812	1065	-560	0	90	-650

*) For explanatory purposes only: D1 Material is transferred, D2 Material is burnt, D3 Energy is substituted.

Basic data for the calculation	Unit	Value
PERT (C Effort for sorting and processing up to the end of waste properties)	MJ	8
PENRT (C Effort for sorting and processing up to the end of waste properties)	MJ	13
PERT (D Avoided impacts)	MJ	-1650
PENRT (D Avoided impacts)	MJ	-5960
PERM (wood content)	MJ	11000
PENRM (binder content)	MJ	645
Biogenic carbon content	in CO_2-eq	-1063
GWP-fossil (A1-A3)	in CO_2-eq	251
GWP-fossil (C Effort for sorting and processing until the end of waste properties)	in CO_2-eq	1.5
GWP-fossil (emissions from combustion process)	in CO_2-eq	90
GWP-fossil (D Avoided impacts)	in CO_2-eq	-650

B3 Recycling

B3.1 Modelling the recycling process

- In accordance with EN 15804, the recycling processes are generally modelled as follows:
  C1 Dismantling / Demolition
  C2 Transport to the processing plant
  C3 Waste treatment
  C4 not applicable
  D Avoided impacts through recycling

  Which recycling processes are still part of the product system and which are counted as part of the next product system is determined by the time of the "end of waste status" in accordance with EN 15804. An example of a construction product with end-of-waste status after processing into a secondary raw material is shown in Table 4.

  Table 4: Attribution of recycling processes to modules C1 - C4 and D using the example of a construction product with end-of-waste after processing into secondary raw material.

Criterion	Recycling
Criterion 1	Flow is not considered waste (flow reaches end-of-waste status).
Criterion 2	Not applicable
Module	**Resulting attribution of processes to information modules**
C1	Dismantling / Demolition
C2	Transport to the sorting plant
C3	Sorting and processing
C4	
D	Avoided impacts of the provision of the substituted primary material

  Note on wood and wood-based materials: The comparison of Table 4 with Table 1 makes it clear that the "Recycling" and "Use of secondary fuel" scenarios only differ in Module D. The environmental indicator values for modules C1 to C3 therefore generally hardly differ between the two scenarios.

B3.2 End of waste properties

- The end-of-waste properties are described in EN 15804+A2, 6.3.5.5 End-of-life stage as follows:

  " This output however reaches the end-of-waste state when it complies with all the following criteria:
  - the recovered material, product or construction element is commonly used for specific purposes;
  - a market or demand, identified e.g. by a positive economic value, exists for such a recovered material, product or construction element;
  - the recovered material, product or construction element fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products;
  - the use of the recovered material, product or construction element will not lead to overall adverse environmental or human health impacts.

  The end-of-life system boundary of the construction product system to module D is set **where outputs, i.e. secondary materials or fuels, have reached the "end-of-waste" state.**"

"NOTE 3 In principle waste processing is part of the product system under study. In the case of materials leaving the system as secondary materials or fuels, such processes as collection and transport before the end-of-waste state are, as a rule, part of the waste processing of the system under study. However after having reached the “end-of-waste” state further processing may also be necessary in order to replace primary material or fuel input in another product system. Such processes are considered to be beyond the system boundary and are assigned to module D."

B3.3 Attribution of material inherent properties and environmental information describing the output flows

- According to the modelling of the disposal processes, the material inherent properties and the environmental information describing the output flows have to be declared as shown in Table 5:

Table 5: Attribution of material inherent properties and environmental information describing the output flows

Module	Recycling
C1, C2 or C3	- PERM - PENRM + GWP biogenic (-C content) + MFR (materials for recycling)
D	+ PERM = 0 + PENRM = 0 + C content (- GWP biogenic) = 0

Explanation:

The primary energy used as raw material (PERM, PENRM) is transferred from module C to module D as a material inherent property. It must therefore be specified as a negative value in Module C. Similarly, the global warming potential of the CO_2 stored in the biogenic material must be specified in Module C as a positive value with +1 kg CO_2 eq./kg CO_2 in the GWP biogenic (EN 15804, C2 " transfers of biomass into subsequent product systems"). Whether this is done in module C1, C2 or C3 depends on the assumptions used to determine the end of the waste property.

Both the energy used as raw material (PERM, PENRM) transferred with the net flow of the secondary material to Module D and the biogenic CO_2 stored in the biogenic material and fed into Module D are inevitably also removed from the downstream system at the theoretical end of its life cycle. In total, the effects of the material inherent properties on PERM, PENRM and GWP are therefore also zero over the completed Module D.
The potential of using secondary materials therefore does not lie in the material inherent properties, but results from the substituted provision of the corresponding primary resource.

B4 Landfill

B4.1 Modelling of the end-of-life process

- Landfill is modelled as follows in accordance with EN 15804:
  C1 Dismantling / Demolition
  C2 Transport to landfill
  C3 not applicable
  C4 Landfill
  D Avoided impacts from electricity generation and heat/energy recovery

B4.2 Avoided impacts / landfill gas

- Potential benefits of energy generation from landfill gas can be considered in the next product system (Module D) in accordance with EN 15804+A2, 6.3.5.5:

  "Loads, (e.g. emissions) from waste disposal in module C4 are considered part of the product system under study, according to the "polluter pays principle". If however this process generates energy such as heat and power from waste incineration or landfill the potential benefits from utilisation of such energy in the next product system are assigned to module D and are calculated using current average substitution processes."

  Since the landfilling of organic substances is an undesirable process and the generation of energy from landfill gas is the most inefficient form of energy recovery from organic materials, it is not recommended to offset a utilisation potential in Module D.

B4.3 Attribution of material inherent properties

- In accordance with the modelling of the disposal processes, the material inherent properties must be declared as follows:

Table 6: Attribution of material inherent properties

Module	No conversion of the material-bound energy	100 % conversion of material-bound energy
C4	PERM = 0 PENRM = 0 + GWP biogenic (C content→ CO_2)	- PERM→ + PERE - PENRM→ + PENRE + GWP biogenic (C content→ CO_2)
D		If applicable, benefits and loads from landfill gas utilisation (not recommended)

Explanation:

The global warming potential of the CO_2 stored in the biogenic material (GWP biogenic) must be stated in module C4 as CO_2 emissions and thus as a positive value in +1 kg CO_2 eq./kg CO_2, see EN 15804+A2, 6.3.5.5:
"The degradation of a product's biogenic carbon content in a solid waste disposal site, declared as GWP-biogenic, shall be calculated without time limit. Any remaining biogenic carbon is treated as an emission of biogenic CO_2 from the technosphere to nature."

If energy used as raw material (PENRM, PERM) is converted over a period of 100 years (e.g. into heat during decomposition processes), the equivalent quantity of PERM or PENRM is converted into PERE or PENRE.
If no energy conversion takes place (e.g. this could be the case for wood wool lightweight building boards under landfill conditions), the product-related PERM and PENRM in Module C must be set to 0. The energy bound in the raw material (PENRM, PERM) from modules A and B remains in the material and no longer provides any benefit.
If only a proportionate conversion takes place, the corresponding proportion of the PERM/PENRM must be declared as energy.

B5 Inputs of secondary raw materials or secondary fuels into the product system under consideration

- The material inherent properties of secondary raw materials or secondary fuels that enter the product system under consideration as input (usually in A1-A3) are treated analogously to the preceding rules.

Table 7: Attribution of the material inherent properties of secondary raw materials and secondary fuels:

Input / Output (module)	Indicator
Output from the previous product system (C1, C2 or C3)	- PERM - PENRM + GWP biogenic (- C content)
Input into the product system under consideration (A1-A3)	+ PERM + PENRM - GWP biogenic (+ C content)

Note:

The indicators for describing the use of resources

- Renewable secondary fuels (RSF) (MJ),
- Non-renewable secondary fuels (NRSF) (MJ)

are to be regarded as additional information to the PERM or PENRM.
They provide information on what proportion of the PERM or PENRM comes from secondary materials.
The difference (PERM - RSF or PENRM - NRSF) gives the proportion of primary materials used.