2023-2025

ADVANCE

ACCOMPANYING MEASURE FOR DISSEMINATION, VALORISATION AND COLLABORATIVE EXPLOITATION OF CIRCULARITY OF CONSTRUCTIONAL STEEL PRODUCTS

Circular construction through reuse of steel structures and components

Helena Gervásio, Universidade de Coimbra

Petr Hradil, VTT

Brussels, 17th of June 2025

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Reuse of steel buildings

- The CAB luxury apartments – Former Civic Administration Building

6,150
TONNES CARBON SAVED

98%
DEMOLITION WASTE REPURPOSED

Source: https://www.beca.com/what-we-do/projects/buildings/the-cab-former-civic-administration-building

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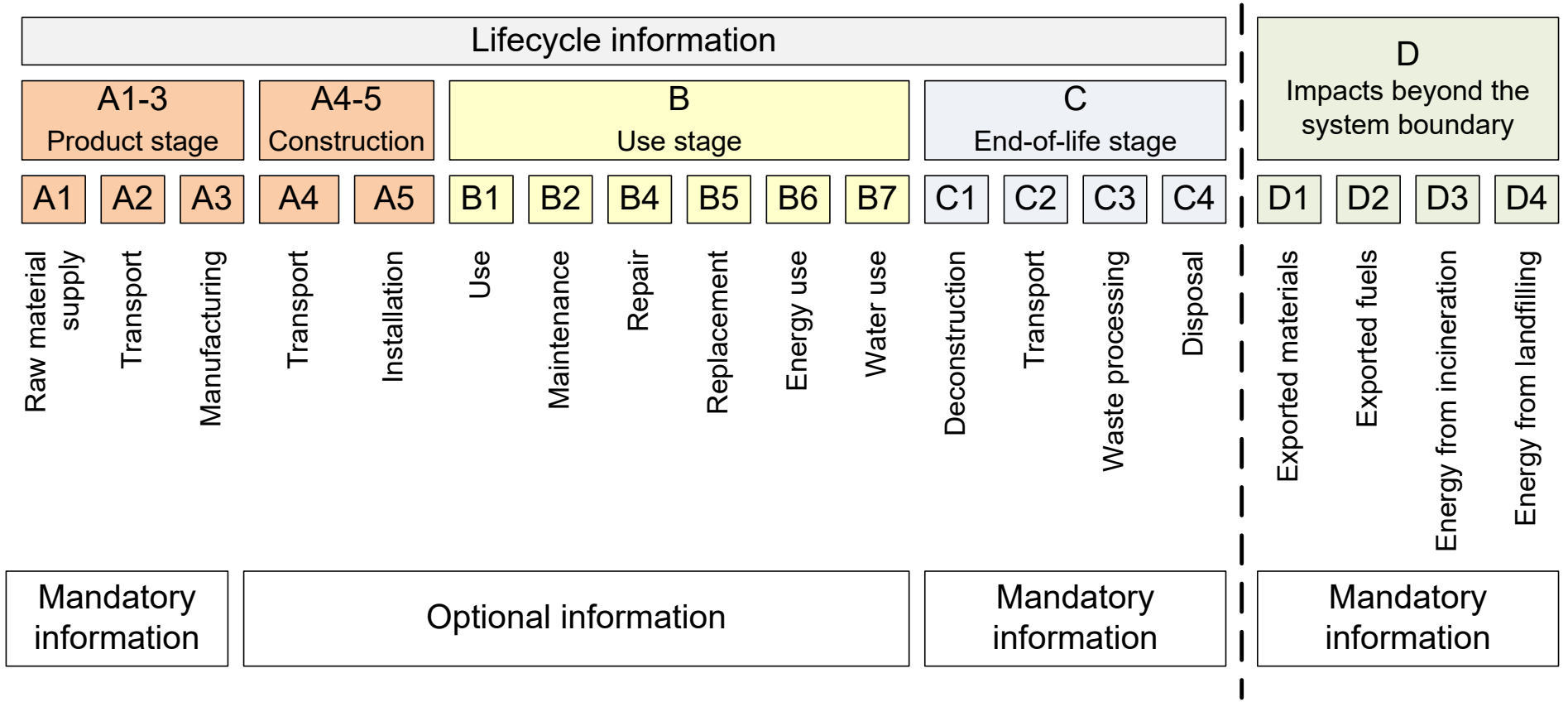
LCA and Module D

END-OF-LIFE STAGE: MODULE D (CEN/TC350)



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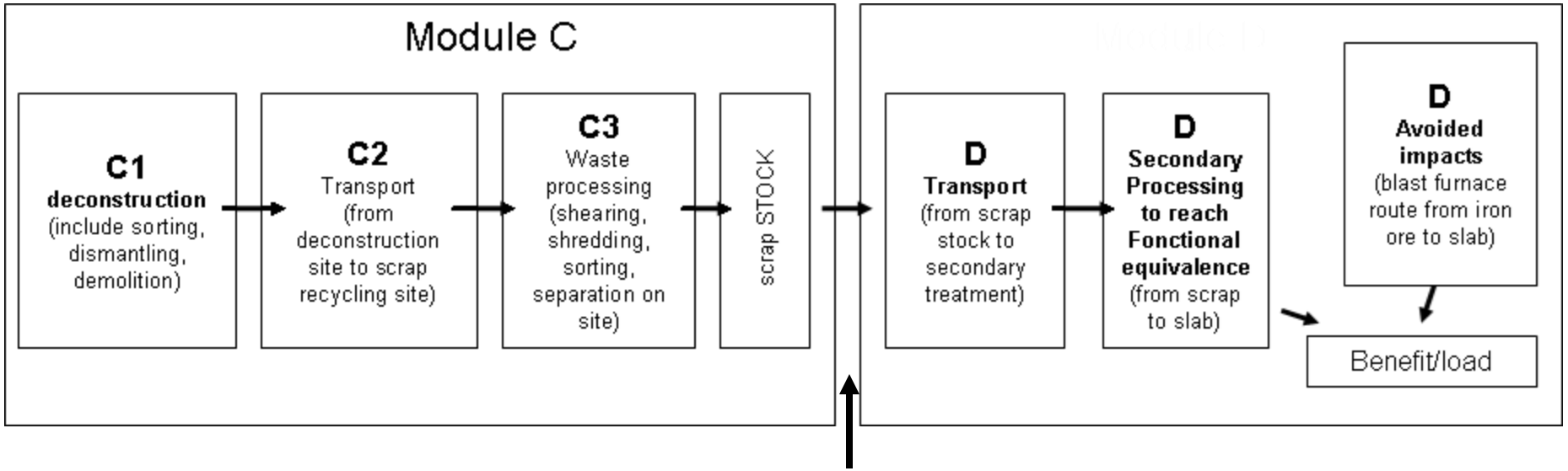



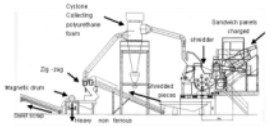
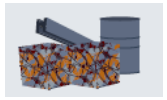

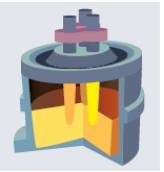


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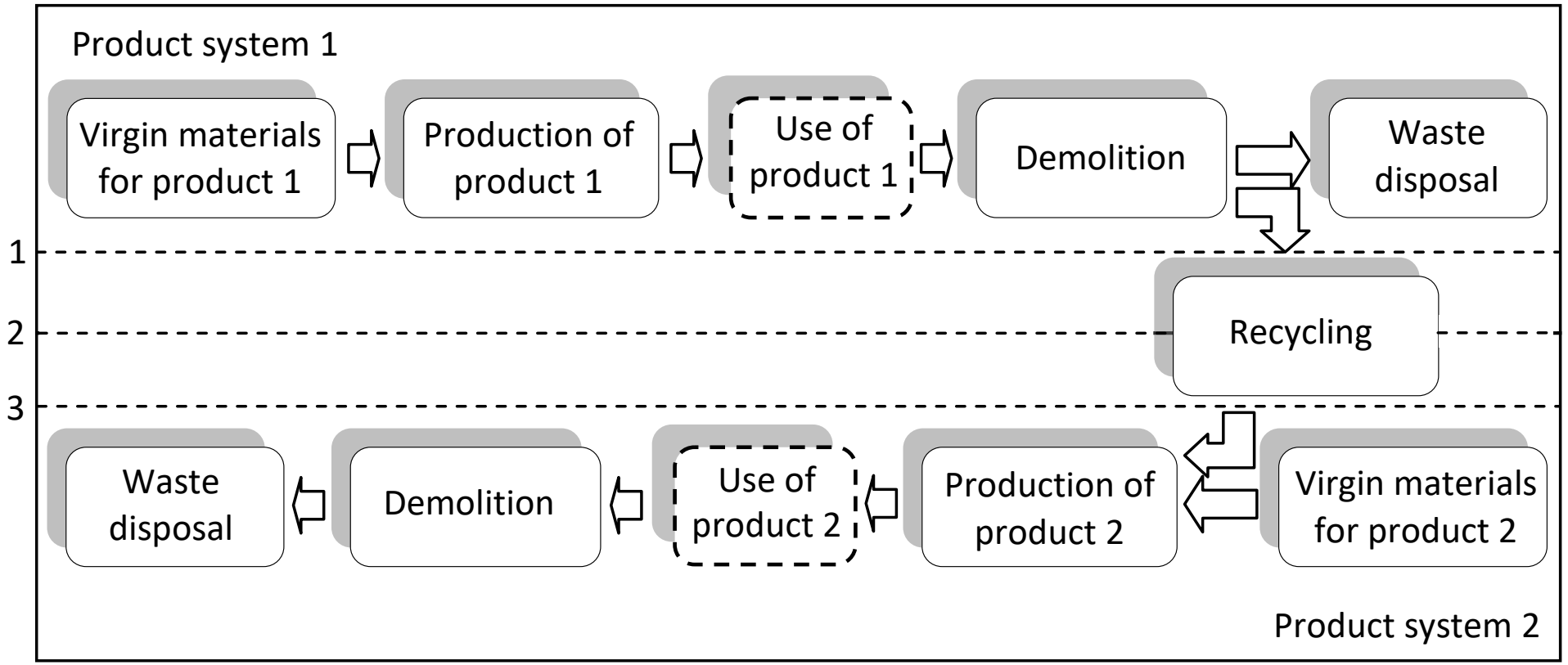
LCA and Module D

END-OF-LIFE STAGE: ALLOCATION OF IMPACTS



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LCA and Module D

Module D (EN 15804:2012 + A2:2019)

loads and benefits related to the export of secondary materials

loads and benefits related to the export of energy as a result of waste incineration

$$e_{module\ D} = e_{module\ D1} + e_{module\ D2} + e_{module\ D3} + e_{module\ D4}$$

loads and benefits related to the export of secondary fuels

loads and benefits related to the export of energy as a result of landfilling

$$e_{module\ D1} = \sum_i \left(M_{MR\ out}\big|_i - M_{MR\ in}\big|_i\right) \cdot \left(E_{MR\ after\ EoW\ out}\big|_i - E_{VMSub\ out}\big|_i \cdot \frac{Q_{R\ out}}{Q_{Sub}}\Big|_i\right)$$

$M_{MR\ out}$ amount of material exiting the system that will be recovered (recycled and reused) in a subsequent system. This amount is determined at end-of-waste point

$M_{MR\ in}$ amount of input material to the product system that has been recovered (recycled or reused) from a previous system (determined at the system boundary)

$Q_{R\ out}$ quality of the outgoing recovered material (recycled and reused), i.e. quality of the recycled material at the point of substitution;

Q_{Sub} quality of the substituted material, i.e. quality of primary material or quality of the average input material if primary material is not used;

$Q_{R\ out} / Q_{Sub}$ quality ratio between outgoing recovered material (recycled and reused) and the substituted material.

$E_{MR\ after\ EoW\ out}$ specific emissions and resources consumed per unit of analysis arising from material recovery (recycling and reusing) processes of a subsequent system after the end-of-waste state

$E_{VMSub\ out}$ specific emissions and resources consumed per unit of analysis arising from acquisition and pre-processing of the primary material, or average input material if primary material is not used, from the cradle to the point of functional equivalence where it would substitute secondary material that would be used in a subsequent system

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LCA and Module D – Case study

Multideck Car Park

Project Value: $39.1 million

Contractor: Kane Constructions

Steel fabricator: Apex Welding & Steel Fabrication

Galvanizer: GB Galvanizing

Completion date: 22 July 2024

Size: 4 decks, 428 car parking spaces for train commuters and 265 for other users

Sustainability: 8 EV chargers

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LCA and Module D – Case study

Multideck Car Park

BoM

- ✓ Columns (UC profiles) and crash barriers (SHS profiles) – 247 tonnes;
- ✓ Floor beams (UB profiles) – 432 tonnes

TOTAL – 679 tonnes of galvanized steel

Life span: 120 years

EoL scenarios

- ✓ 1st scenario: 100% recycling of the structure after 120 years;
- ✓ 2nd scenario: 100% reuse of the structure after 120 years, with regalvanization;
- ✓ 3rd scenario: 100% reuse of the structure after 60 years, without regalvanization + 100% reuse after 120 years, with regalvanization.

Functional unit

- ✓ A galvanized steel structure for a car park with a service life of 120 years.

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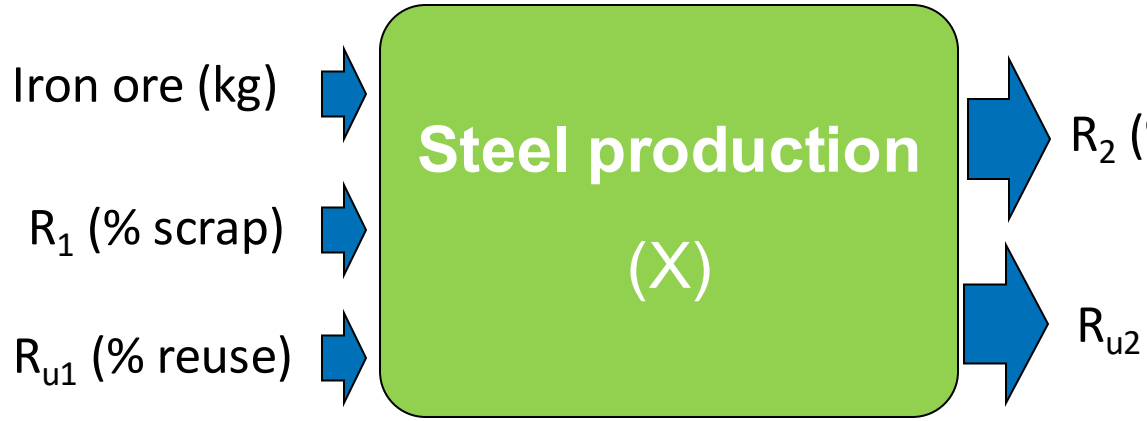
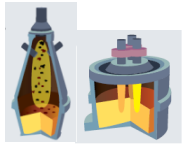
LCA and Module D – Case study

Steel Recycling & Reusing

General case of steel production including recycling and reuse:



Net benefit of EoL Recycling



$$\text{LCI for 1 kg of steel}^{(*)} = X - [(R_2 - R_1).(X_{pr} - X_{re})\ Y + (R_{u2} - R_{u1}).(X_m - X_{refurb})\ Z]$$

Net benefit of EoL reuse

(*) assuming the quality factor as 1

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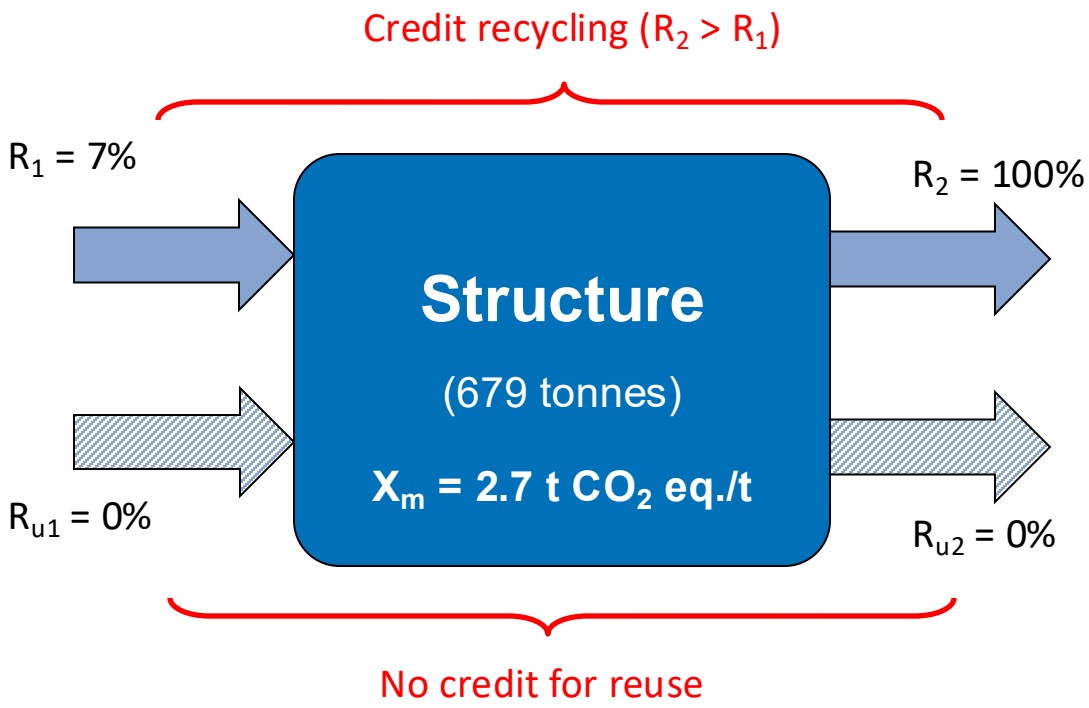
LCA and Module D – Case study

1st scenario : 100% recycling of the structure after 120 years



Production stage (A1-A3):

X_{A1-A3} = 1833 t CO_2 eq.

Benefits/burdens recycling & reuse (D):

X_{D1} = - 1023 + 0 = - 1023 t CO_2 eq.

X_{TOTAL} = 810 t CO_2 eq./t

LCA Period – 120 years

X_m = 2.7 t CO_2 eq./t (1)
X_{SC} = 1.62 t CO_2 eq./t (1)
$X_{refurb} = X_{HDG}$ = 50 kg CO_2 eq./t (2)

(1) Worldsteel (https://worldsteel.org/wp-content/uploads/Guidance-on-methodologies-for-modelling-reuse-and-remanufacture-in-LCA-Studies.pdf)
(2) Arguillarena et al.. Carbon footprint of the hot-dip galvanisation process using a life cycle assessment approach, Cleaner Engineering and Technology 2 (2021) 100041

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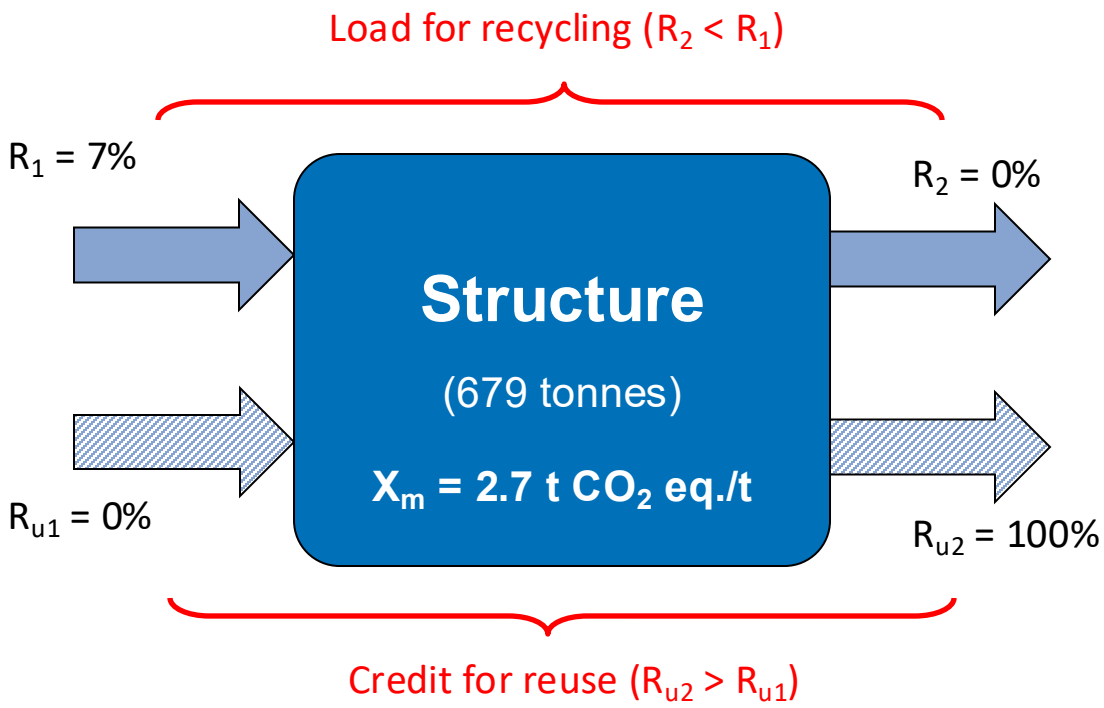
LCA and Module D – Case study

2nd scenario: 100% reuse of the structure after 120 years (with regalvanization)



Production stage (A1-A3):

X_{A1-A3} = 1833 t CO_2 eq.

Benefits/burdens recycling & reuse (D):

X_{D1} = 77 - 1799 = - 1722 t CO_2 eq.

X_{TOTAL} = 111 t CO_2 eq./t

LCA Period – 120 years

X_m = 2.7 t CO_2 eq./t (1)
X_{SC} = 1.62 t CO_2 eq./t (1)
$X_{refurb} = X_{HDG}$ = 50 kg CO_2 eq./t (2)

(1) Worldsteel (https://worldsteel.org/wp-content/uploads/Guidance-on-methodologies-for-modelling-reuse-and-remanufacture-in-LCA-Studies.pdf)
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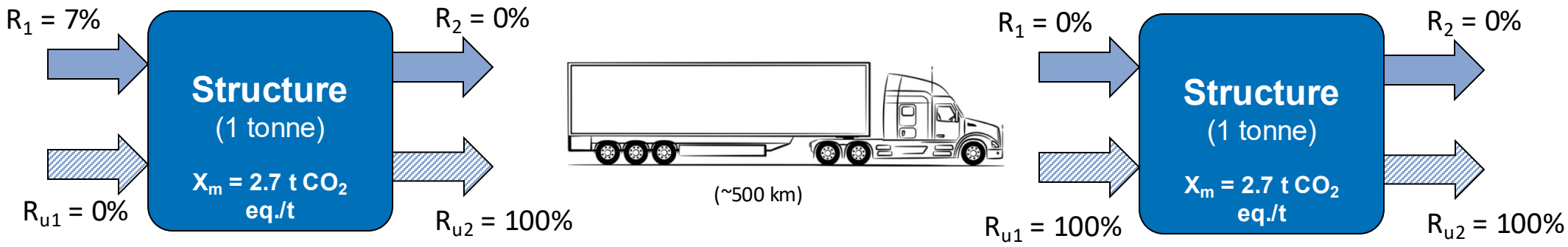
LCA and Module D – Case study

3rd scenario: 100% reuse of the structure after 60 years (without regalvanization) + 100% reuse after 120 years



$X^1_{A1\text{-}A3}$ = 1833 t CO_2 eq.

X^1_D = 77 – 1833 = – 1756 t CO_2 eq.

X_{transp} = 34 t CO_2 eq.

(98 g CO_2 eq./t.km)

$X^2_{A1\text{-}A3}$ = 0

X^2_D = 0 + 34 = = 34 t CO_2 eq.

LCA Period – 120 years

X_m = 2.7 t CO_2 eq./t (1)
X_{SC} = 1.62 t CO_2 eq./t (1)
$X_{refurb} = X_{HDG}$ = 50 kg CO_2 eq./t (2)

$X_{TOTAL)}$ = 145 t CO_2 eq./t

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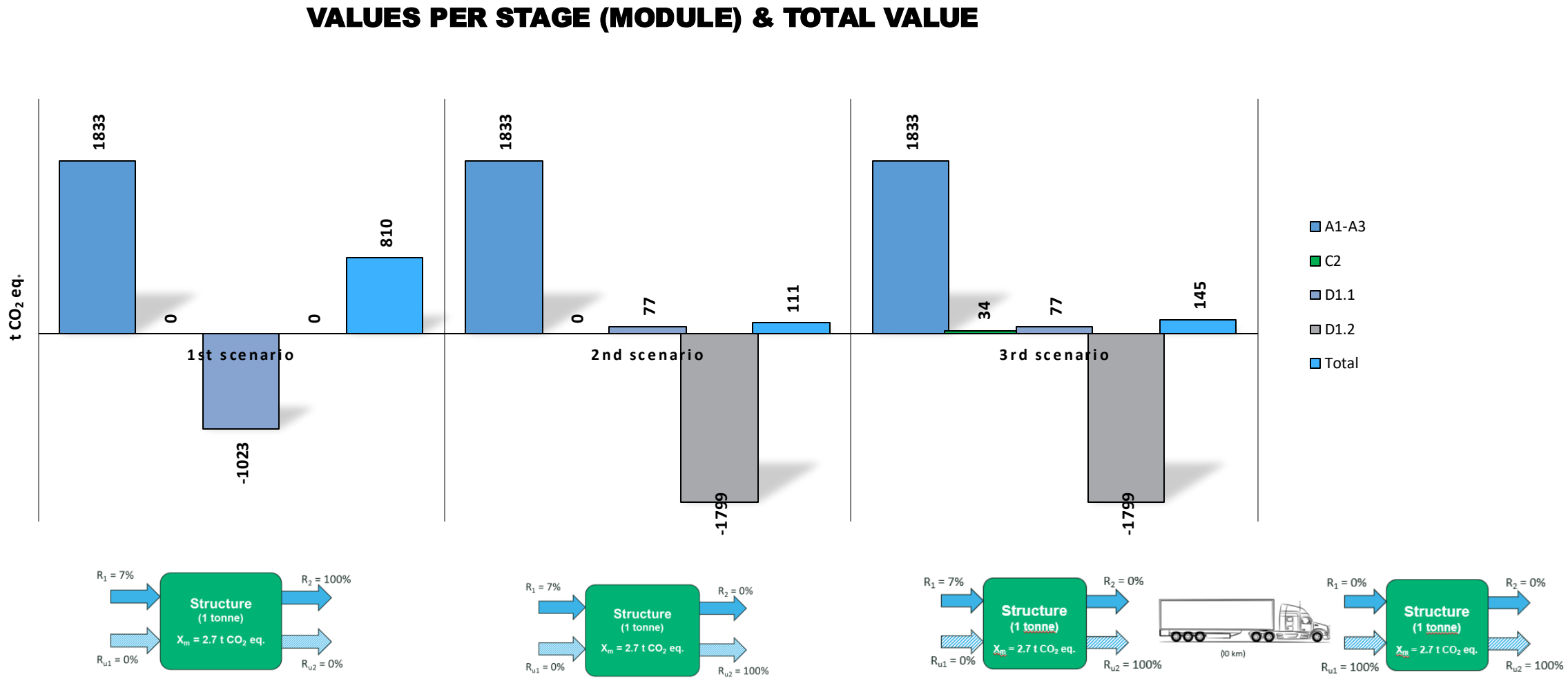

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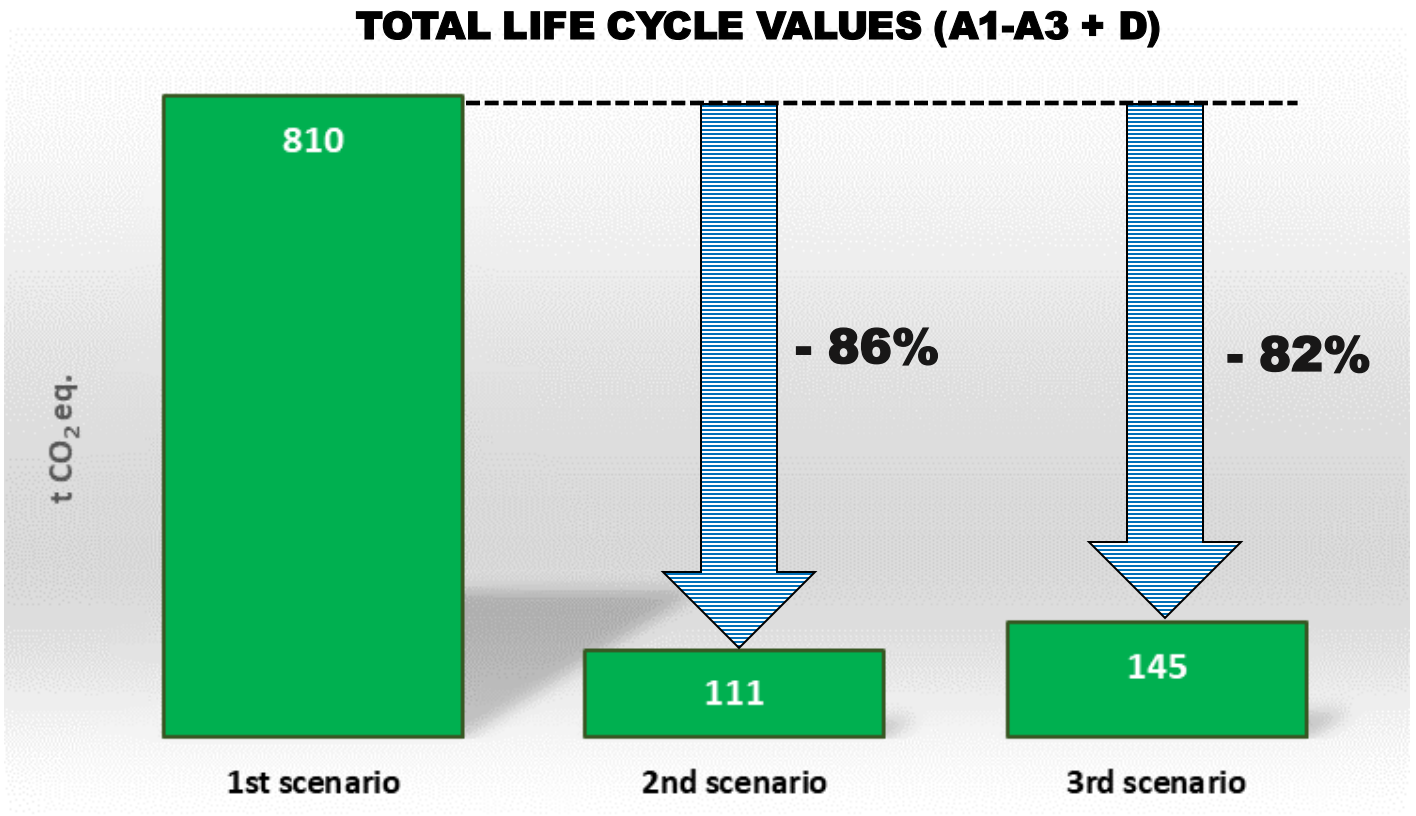

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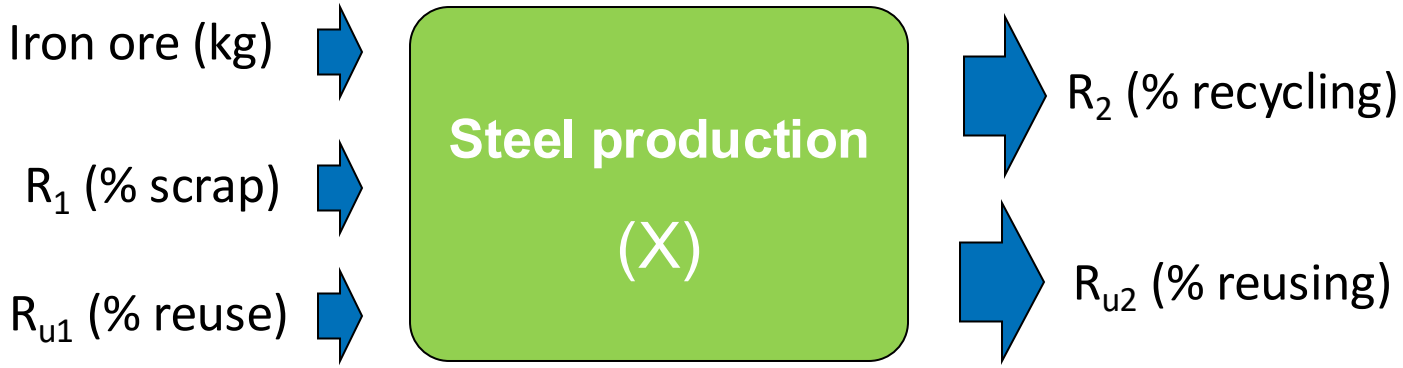
Other allocation approaches (Module D)



Research Project PROGRESS/ADVANCE:

$$X_{D1} = -\left[(R_2 - R_1).(X_{pr} - X_{re}) + (R_{u2} - R_{u1}).(X_{pr} - X_{refurb})\right]$$

Approach in some EPDs for steel:

$$X_{D1} = -\left\{\left[(R_2 + R_{u2} \times R_1) - R_1\right].(X_{pr} - X_{re}) + (R_{u2} - R_{u1}).(X_m - X_{refurb})\right\}$$

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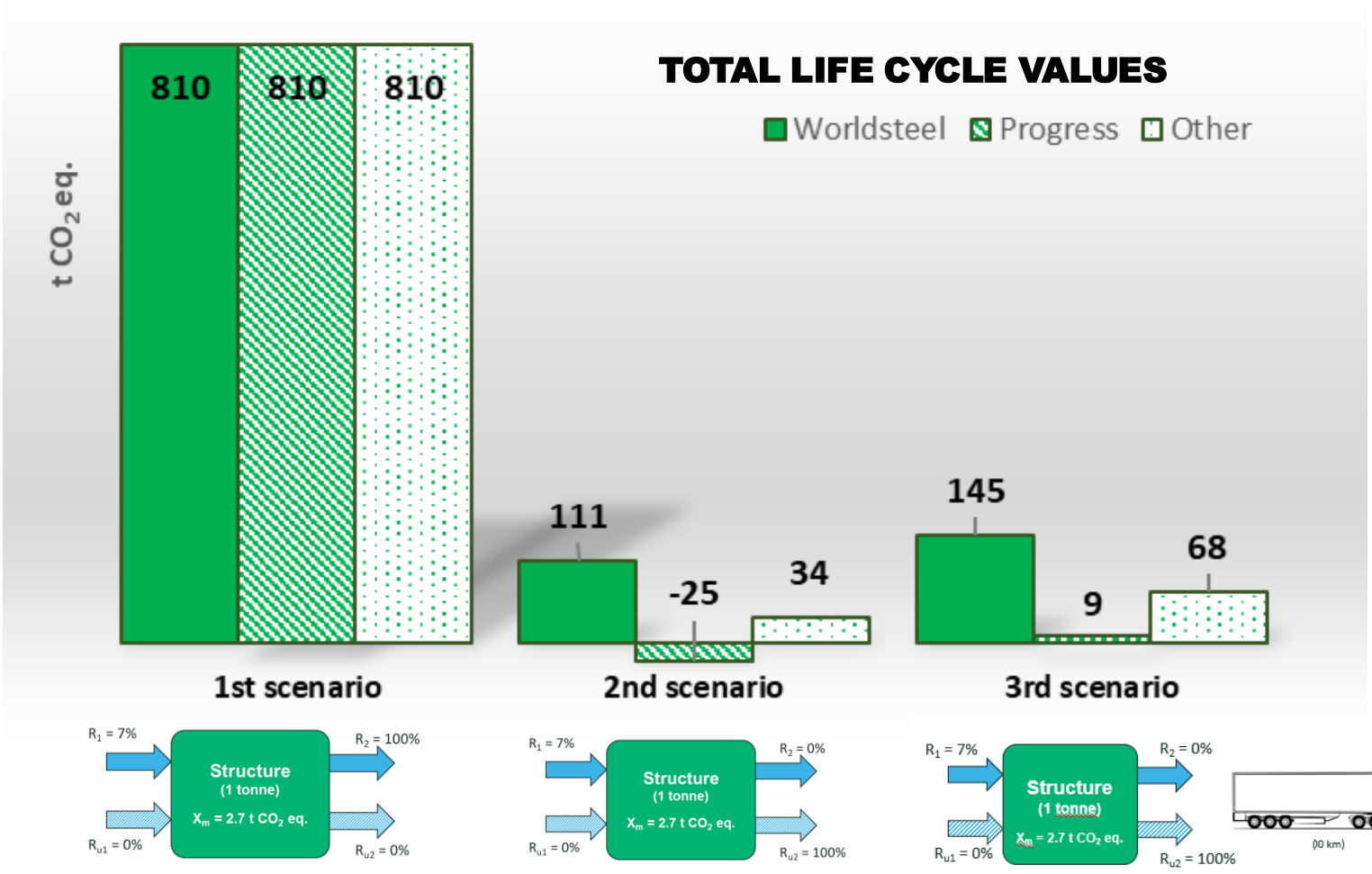

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PRELIMINARY NOTES

- ✓ Circular Economy can cut CO_2 emissions from heavy industry by **56% by 2050** – **Opportunities for steel**!
- ✓ The **reuse of steel** can offer substantial environmental benefits on the life cycle performance of buildings (potential reductions in carbon emissions from **70% to 95%**);
- ✓ There is a need for transparent communication of sustainability credits (avoiding greenwash) – **Use of Module D**;
- ✓ Module D allows to reduce the embodied carbon of an existing project but also reduces the embodied carbon of future projects (Module A);
- ✓ Module D is crucial for the construction sector to deliver on global net zero targets and create a future-proof circular economy.

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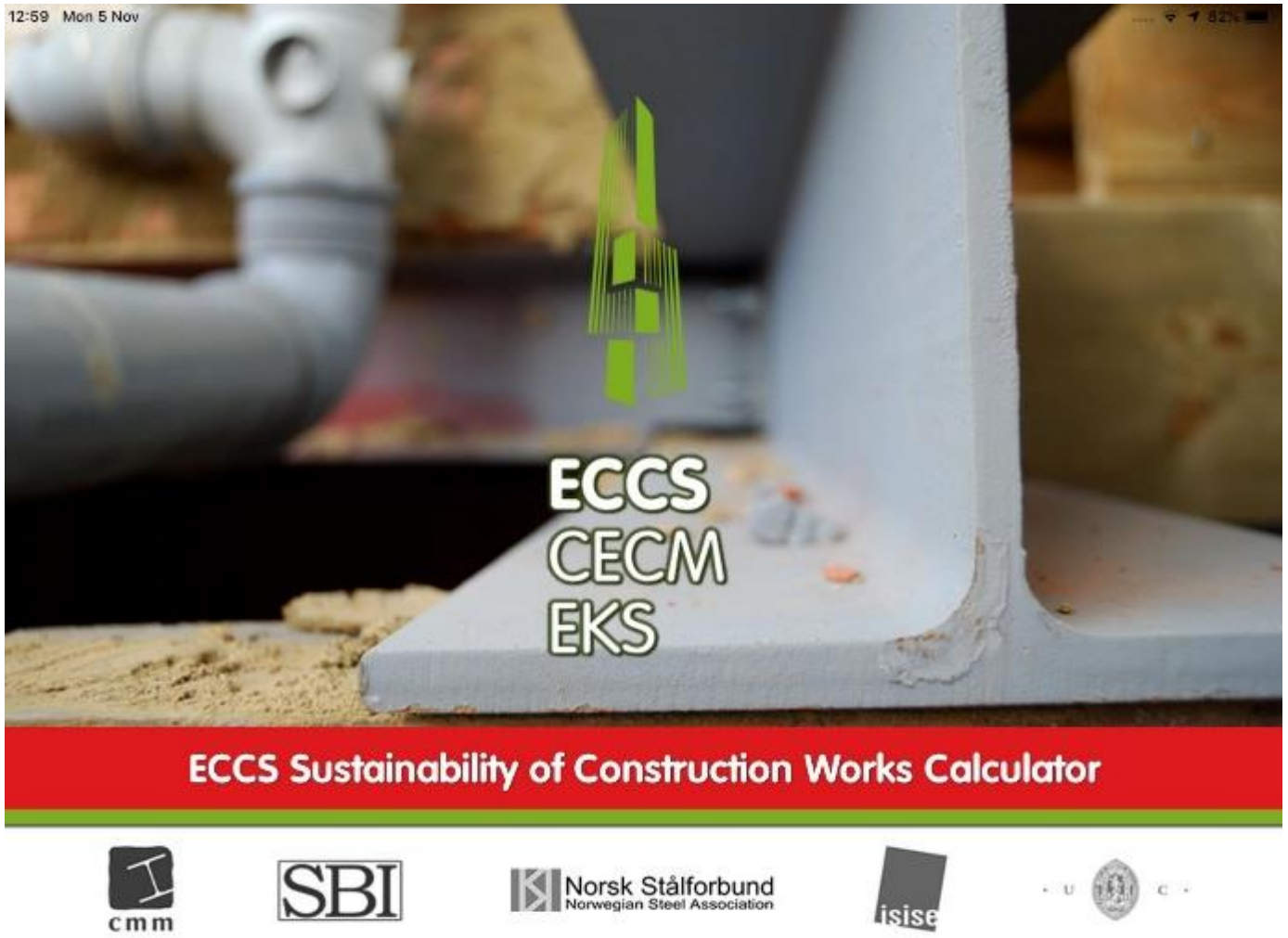
BUILDINGS LCA



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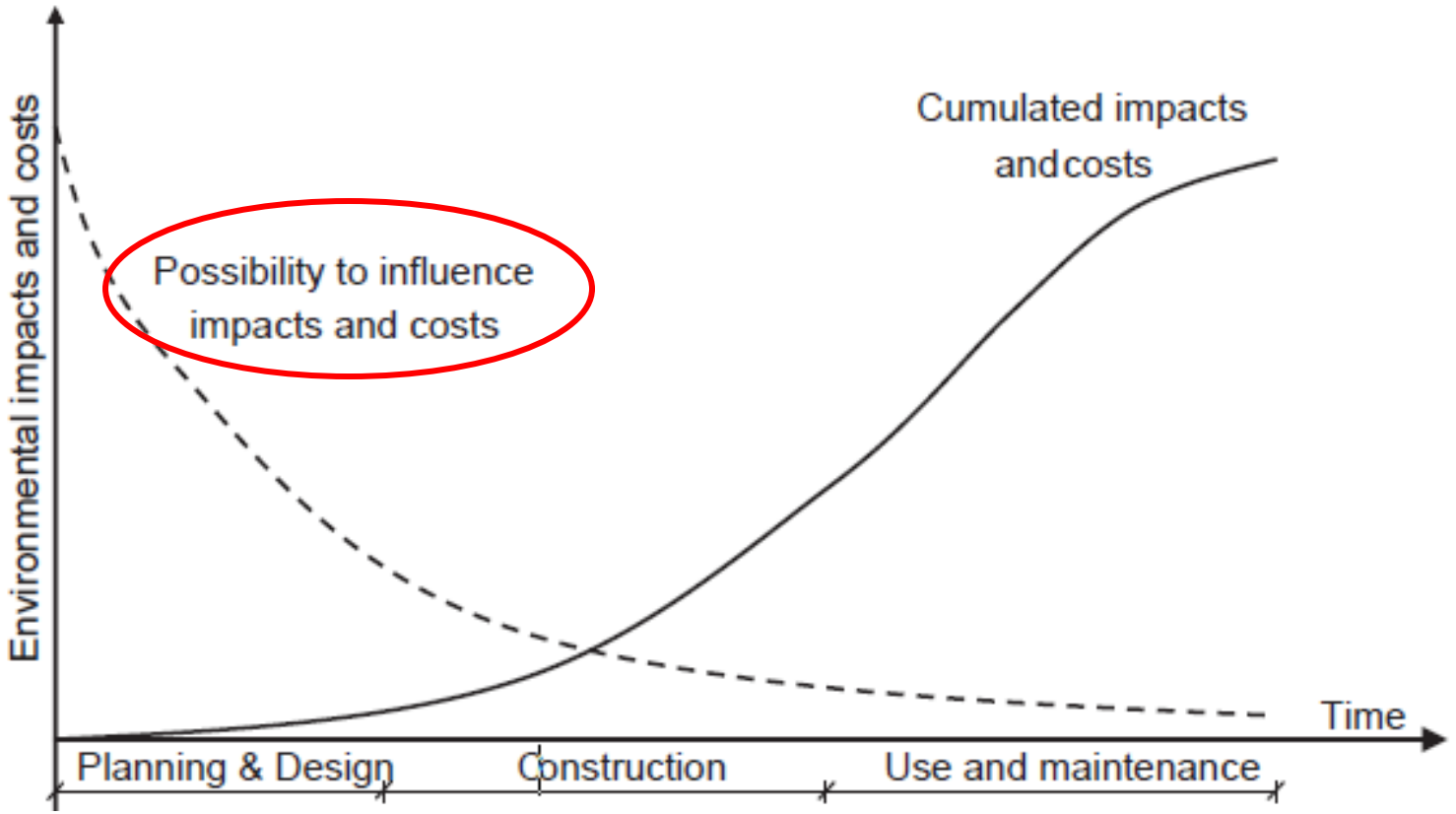

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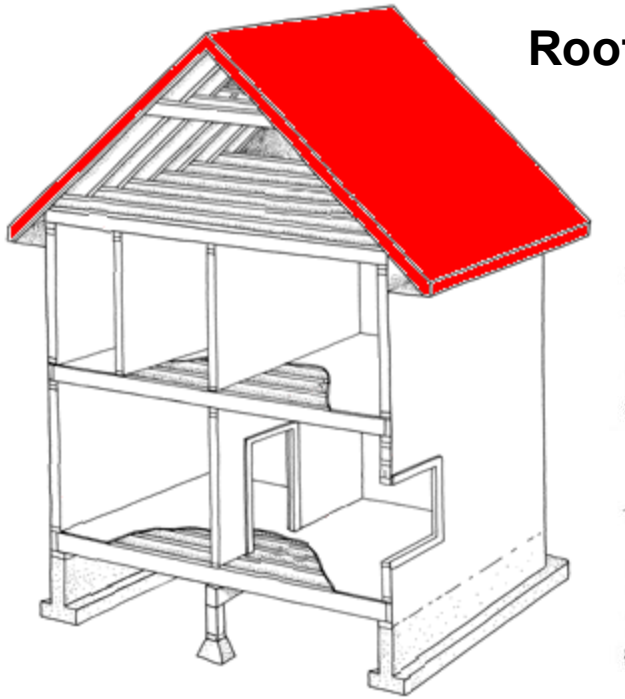
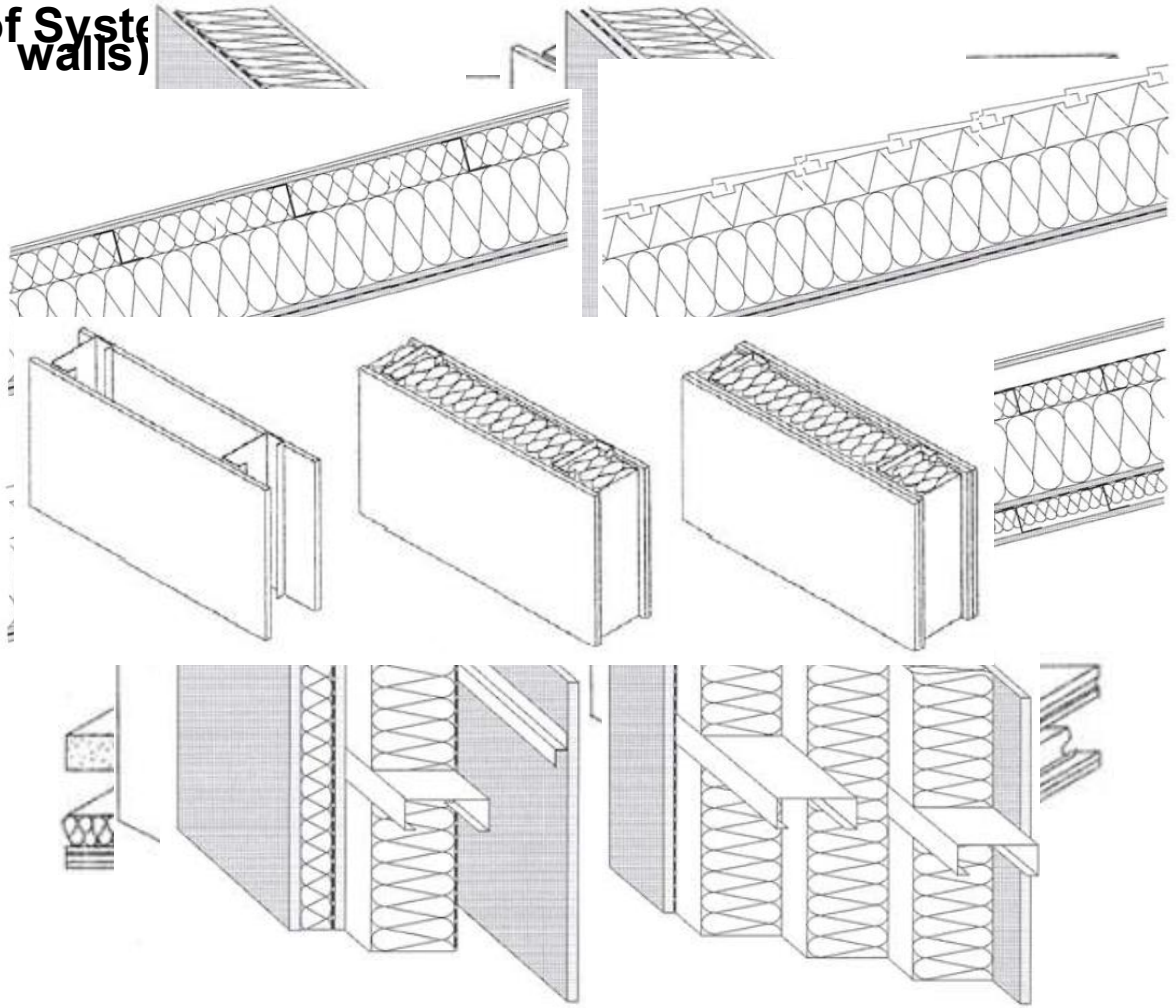


Roof Syste

Internal wall system (load-bearing walls)



External wall system (load-bearing walls)

Floor system

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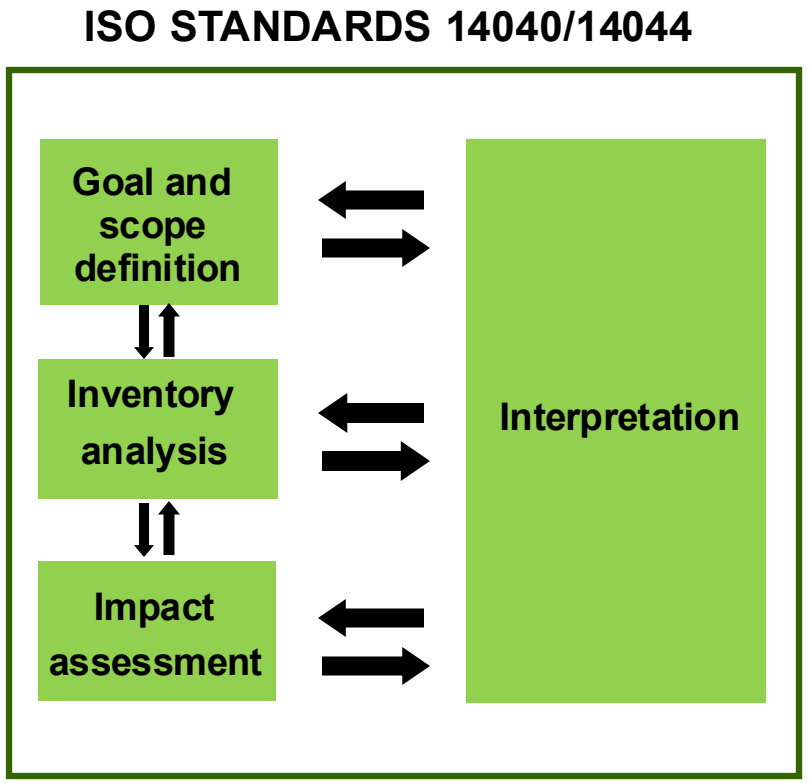

Other relevant standards (CEN TC350): prEN15643 – Sustainability of construction works

Mandatory elements

- Selection of indicators
- Classification
- Characterization

$$IA_{jk} = \sum_{i=1}^{n} I_{ij} \times IAfactor_i$$

Optional elements

- Normalization
- Weighting

$$IAScore_{jk} = \frac{IA_{jk} \times IVwt_k}{Norm_k}$$

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BUILDINGS LCA

Steel-framed buildings classification

Single family house in Category 1 (steel intensive building)

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Building component classification scheme (UniFormat)

(A) Substructure	(A40) Slabs-on-grade	(A4010) Standard slabs-on-grade	
(B) Shell	(B10) Superstructure	(B1010) Floor construction	(B1010.10) Floor structural frame
			(B1010.20) Floor decks, slabs and toppings
		(B1020) Roof construction	(B1020.10) Roof structural frame
			(B1020.20) Roof decks, slabs and sheathing
	(B20) Exterior vertical enclosures	(B2010) Exterior walls	(B2010.10) Ext. wall veneer
			(B2010.20) Ext. wall construction
		(B2020) Exterior windows	
		(B2050) Exterior doors	
	(B30) Exterior horizontal enclosures	(B3010) Roofing	
		(B3060) Horizontal openings	
(C) Interiors	(C10) Interior construction	(C1010) Interior partitions	
	(C20) Interior finishes	(C2010) Wall finishes	
		(C2030) Flooring	
		(C2050) Ceiling finishes	

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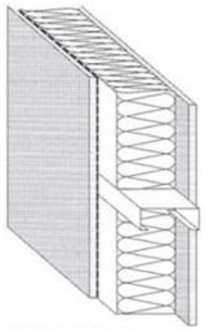
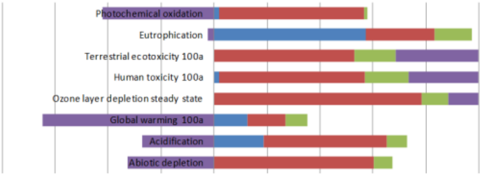
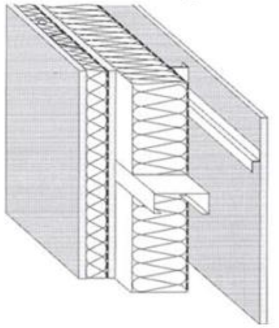
BUILDINGS LCA

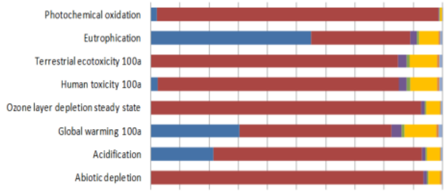
MACRO-COMPONENT DATABASE

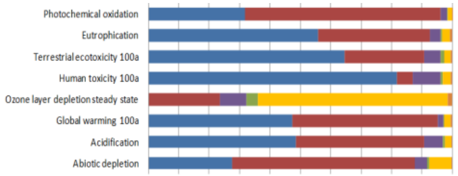
External wall type	Environmental profile	Floor system type	Environmental profile

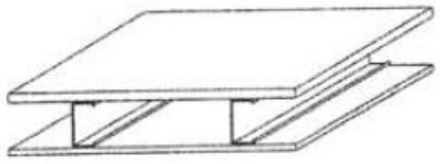


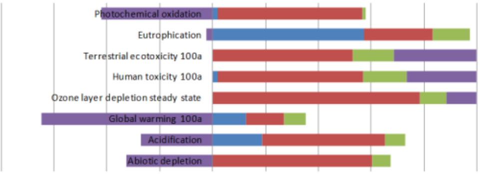


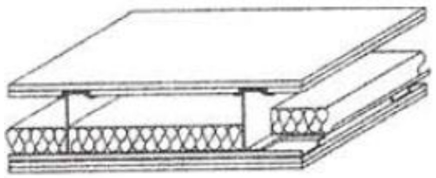


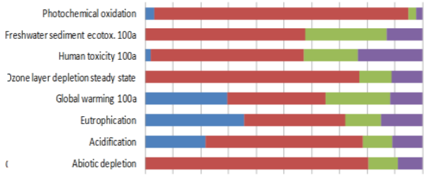


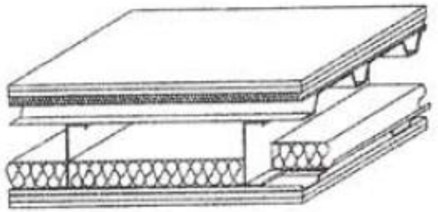


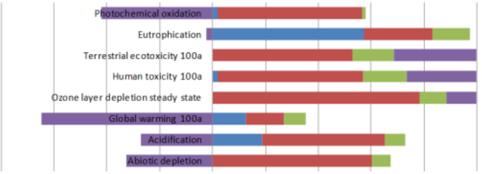


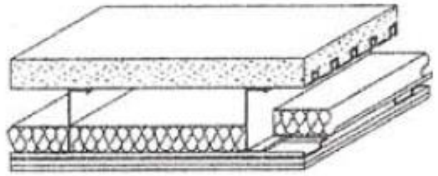


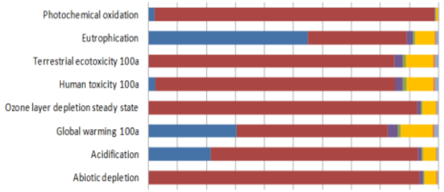












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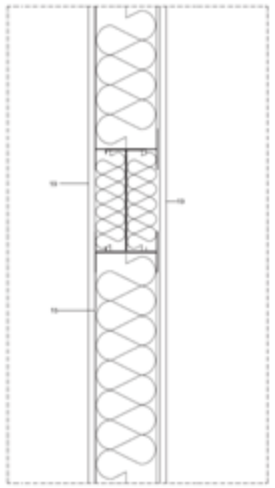
BUILDINGS LCA

MACRO-COMPONENT DATABASE

Internal wall type

Macrocomponent: *Internal wall* **Ref. No.:** *MC_5*

Functional unit – 1 m²



Components

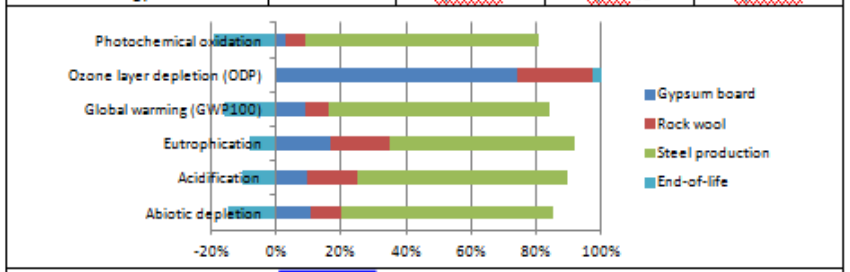
Ref.no.	Material	Thickness (mm)
15	Rock wool	60
19	Gypsum board	15
-	Steel	20 kg/m²

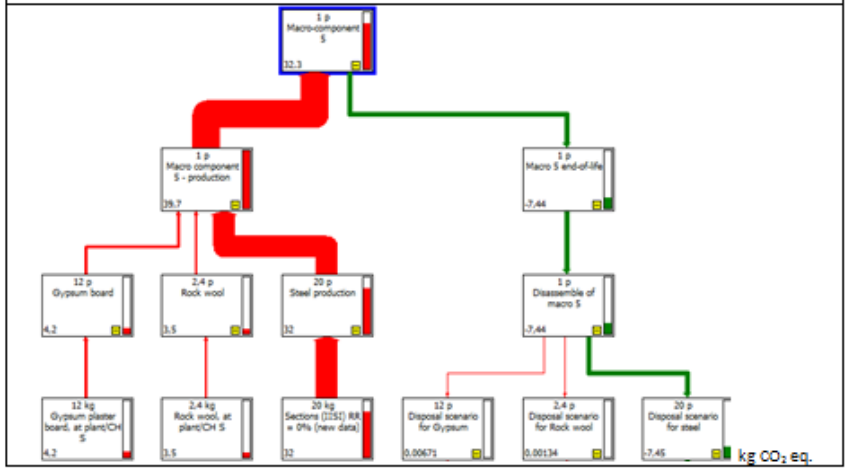
Thermal transmittances

U (W/m2. °C)	U bridging (W/m2. °C)
0.515	0.810

Life Cycle Analysis: cradle-to-gate + end-of-life stage

	Unit	Production stage	End-of-life stage	Total
Environmental categories				
Abiotic depletion	Kg Sb eq.	2,34E-01	-4,11E-02	1,92E-01
Acidification	Kg SO_2 eq.	1,19E-01	-1,35E-02	1,06E-01
Eutrophication	Kg $(PO_4)^{3-}$ eq.	1,13E-02	-8,90E-04	1,03E-02
Global warming	Kg CO_2 eq.	3,97E+01	-7,44E+00	3,23E+01
Ozone layer depletion	Kg CFC 11 eq.	6,13E-07	1,70E-08	6,30E-07
Photochemical oxidation	Kg Ethene eq.	1,47E-02	-3,49E-03	1,12E-02
Energy categories				
Non renewable energy	MJ	4,20E+02	-4,55E+01	3,74E+02
Renewable energy	MJ	6,21E+00	4,85E-03	6,21E+00





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BUILDINGS LCA

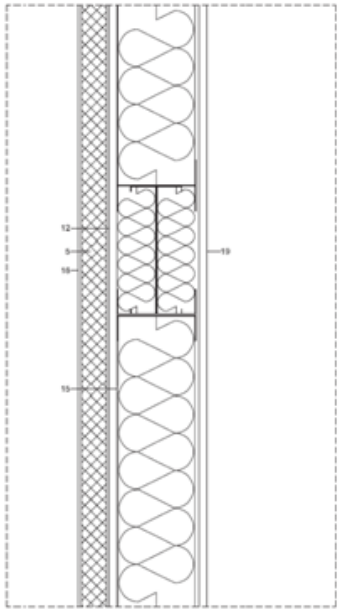
MACRO-COMPONENT DATABASE

External wall type

Macrocomponent: *External wall*

Ref. No.: *MC_4*

Functional unit – 1 m^2



Components

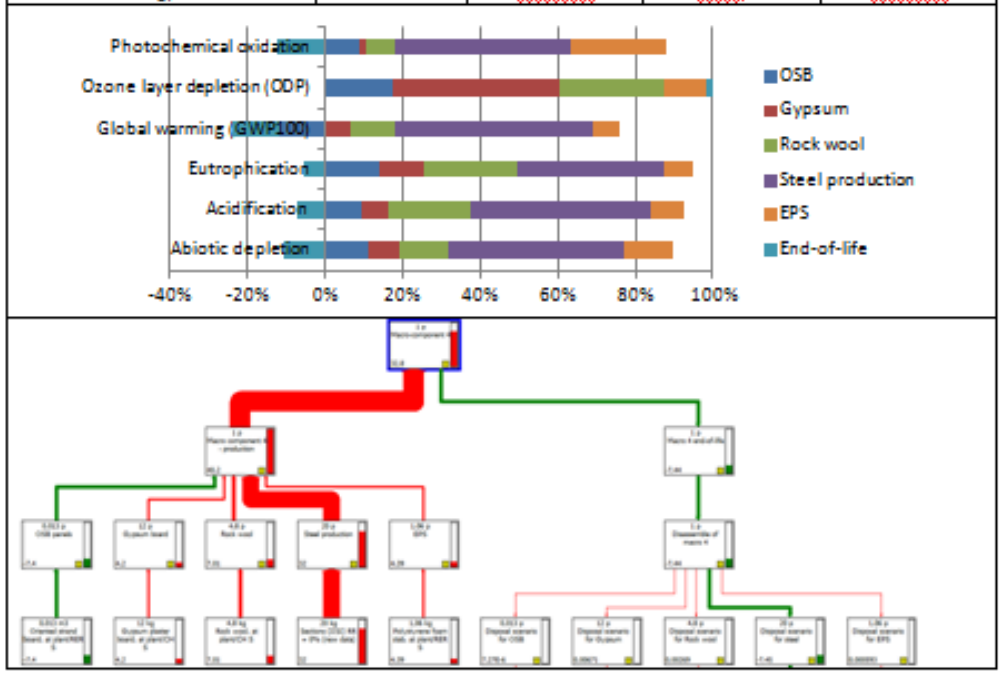
Ref.no.	Material	Thickness (mm)
16_5	ETICS	53
12	OSB	13
15	Rock wool	120
19	Gypsum board	15
-	Steel	20 kg/m^3

Thermal transmittances

U (W/m2. °C)	$U_{bridging}$ (W/m2. °C)
0.210	0.269

Life Cycle Analysis: cradle-to-gate + end-of-life stage

	Unit	Production stage	End-of-life stage	Total
Environmental categories				
Abiotic depletion	Kg Sb eq.	3.53E-01	-4.11E-02	3.12E-01
Acidification	Kg SO_2 eq.	1.72E-01	-1.35E-02	1.59E-01
Eutrophication	Kg $(PO_4)^{3-}$ eq.	1.74E-02	-9.87E-04	1.65E-02
Global warming	Kg CO_2 eq.	4.02E+01	-7.44E+00	3.28E+01
Ozone layer depletion	Kg CFC 11 eq.	1.06E-06	1.96E-08	1.08E-06
Photochemical oxidation	Kg Ethene eq.	2.55E-02	-3.49E-03	2.20E-02
Energy categories				
Non renewable energy	MJ	6.89E+02	-4.55E+01	6.44E+02
Renewable energy	MJ	1.84E+02	4.92E-03	1.84E+02



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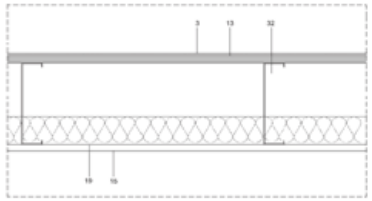
BUILDINGS LCA

MACRO-COMPONENT DATABASE

Internal slab type

Macrocomponent: *Internal slab* **Ref. No.:** *MC_1*

Functional unit – 1 m²



Components

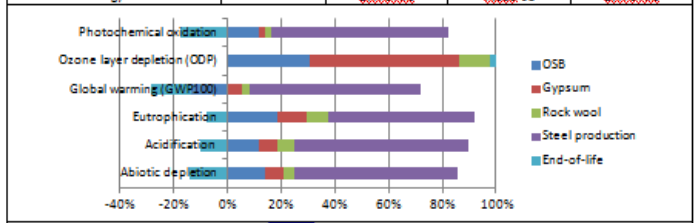
Ref.no.	Material	Thickness (mm)
13	OSB	18
32	Air cavity	390
19	Rock wool	40
15	Gypsum board	15
-	Steel	30 kN/m²

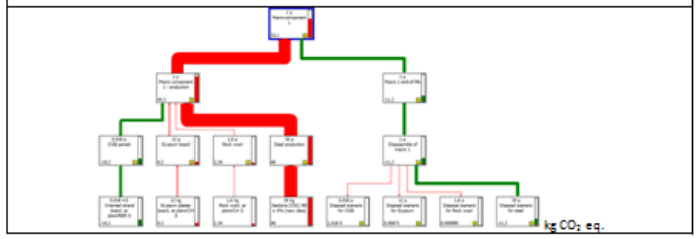
Thermal transmittances

U (W/m2. °C)	U bridging (W/m2. °C)
0.596	0.597

Life Cycle Analysis: cradle-to-gate + end-of-life stage

	Unit	Production stage	End-of-life stage	Total
Environmental categories				
Abiotic depletion	Kg Sb eq.	3,77E-01	-6,17E-02	3,15E-01
Acidification	Kg SO_2 eq.	1,80E-01	-2,03E-02	1,60E-01
Eutrophication	Kg $(PO_4)^{3-}$ eq.	1,77E-02	-1,49E-03	1,62E-02
Global warming	Kg CO_2 eq.	4,43E+01	-1,12E+01	3,31E+01
Ozone layer depletion	Kg CFC 11 eq.	8,25E-07	1,96E-08	8,45E-07
Photochemical oxidation	Kg C_2H_4 eq.	2,44E-02	-5,24E-03	1,92E-02
Energy categories				
Non renewable energy	MJ	6,99E+02	-6,84E+01	6,30E+02
Renewable energy	MJ	2,47E+02	7,10E-03	2,47E+02

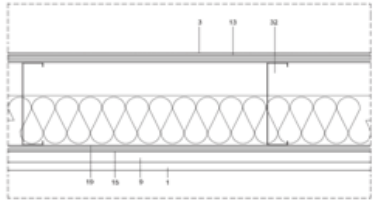




External slab type

Macrocomponent: *External slab* **Ref. No.:** *MC_2*

Functional unit – 1 m²



Components

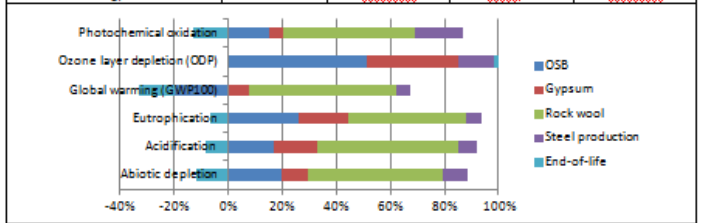
Ref.no.	Material	Thickness (mm)
13	OSB	18
32	Air cavity	80
19	Rock wool	120
15	OSB	13
9_1	ETICS	53
-	Steel	30 kN/m2

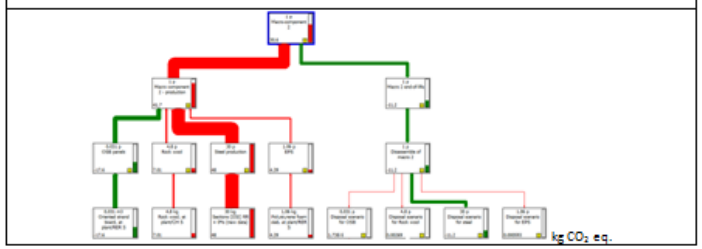
Thermal transmittances

U (W/m2. °C)	U bridging (W/m2. °C)
0.184	0.342

Life Cycle Analysis: cradle-to-gate + end-of-life stage

	Unit	Production stage	End-of-life stage	Total
Environmental categories				
Abiotic depletion	Kg Sb eq.	4,75E-01	-6,17E-02	4,13E-01
Acidification	Kg SO_2 eq.	2,26E-01	-2,03E-02	2,06E-01
Eutrophication	Kg $(PO_4)^{3-}$ eq.	2,25E-02	-1,50E-03	2,10E-02
Global warming	Kg CO_2 eq.	4,17E+01	-1,12E+01	3,06E+01
Ozone layer depletion	Kg CFC 11 eq.	8,59E-07	1,39E-08	8,73E-07
Photochemical oxidation	Kg Ethene eq.	3,50E-02	-5,24E-03	2,98E-02
Energy categories				
Non renewable energy	MJ	9,17E+02	-6,84E+01	8,48E+02
Renewable energy	MJ	4,22E+02	6,94E-03	4,22E+02





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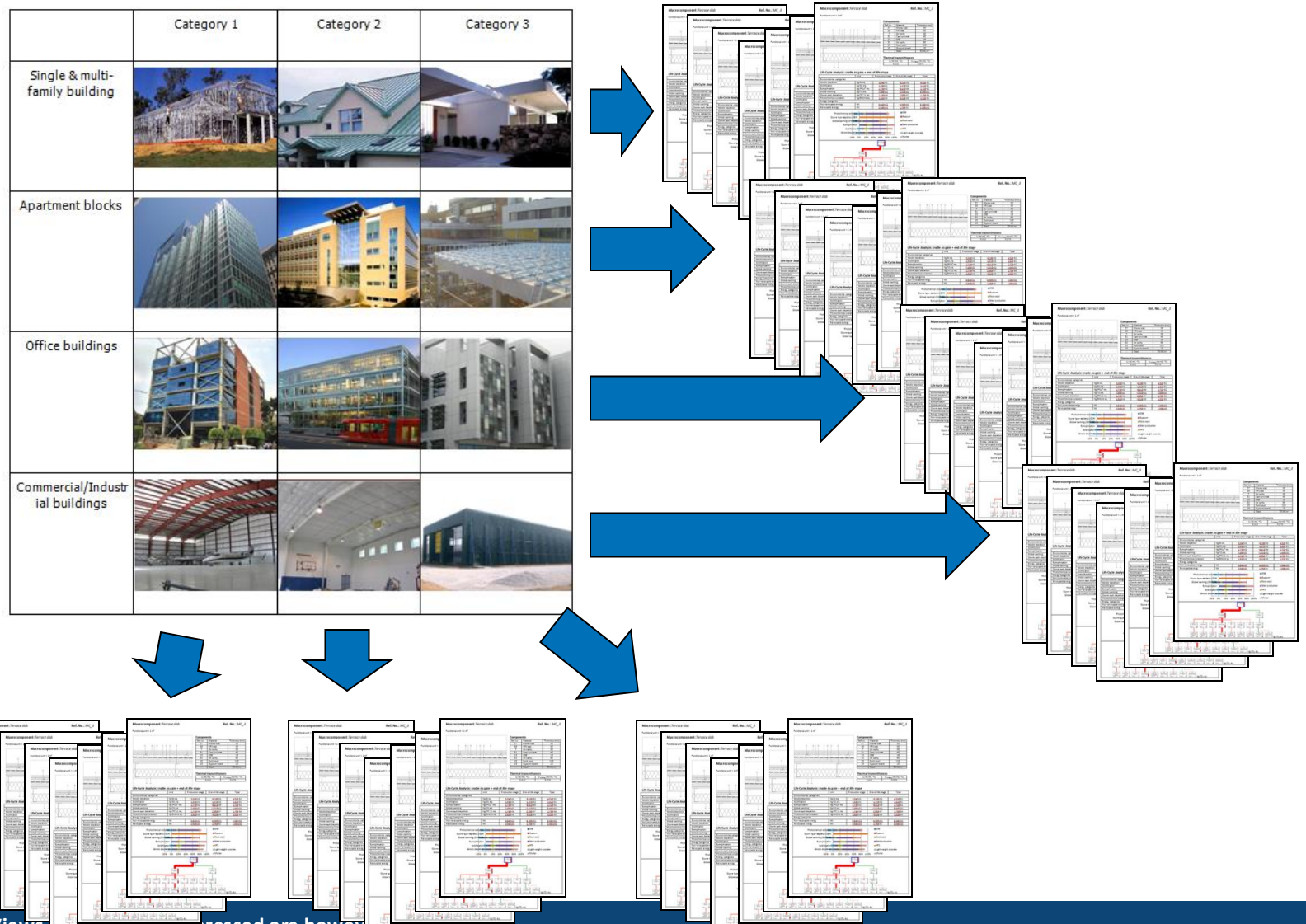
BUILDINGS LCA

MACRO-COMPONENT DATABASE



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BUILDINGS LCA

EXAMPLE

Case study: low-rise residential house

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BUILDINGS LCA

EXAMPLE

Steel-framed buildings classification

	Category 1	Category 2	Category 3
Single & multi-family building			
Apartment blocks			
Office buildings			
Commercial/Industrial buildings			

Single family house in Category 1 (steel intensive building)

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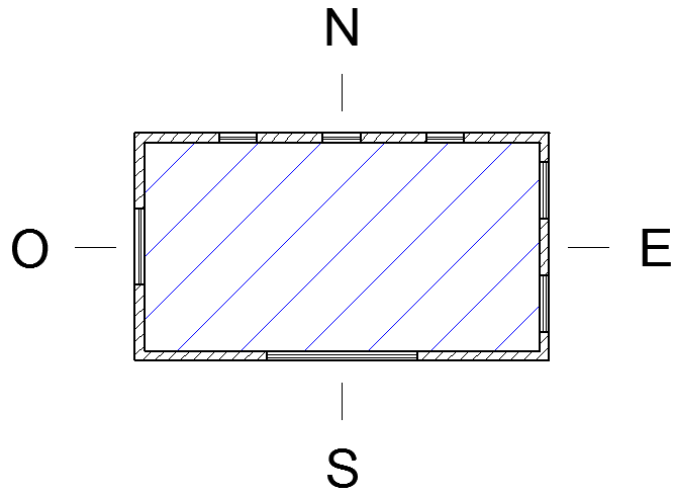
CONCEPTUAL STAGE OF DESIGN – INPUT DATA

TABLE OF AREAS:

Area of floors	Area (m^2)
Ground floor	100.8
1st floor	100.8
2nd floor	80.64
Terrace	20.16
External walls	266.40
Internal partitions	110.00



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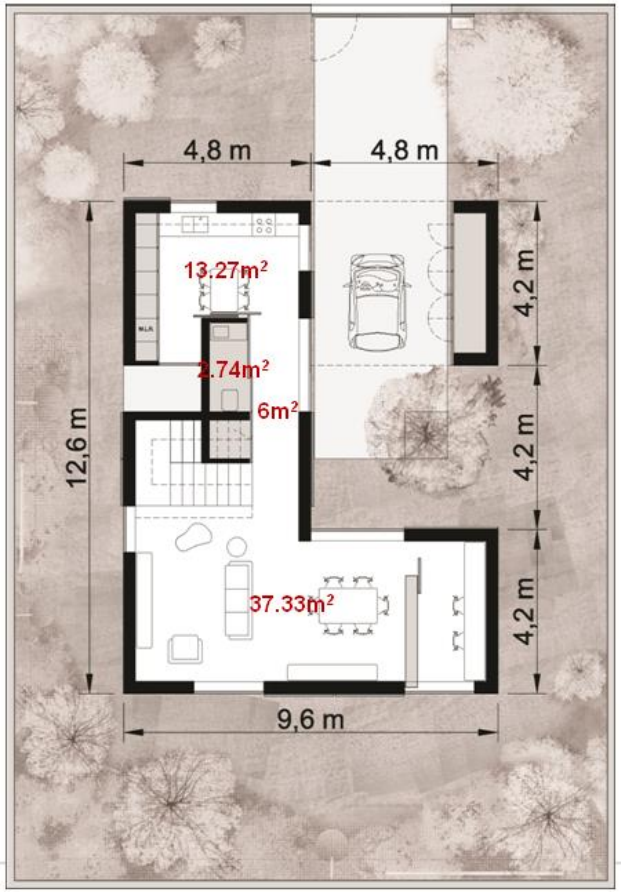
BUILDINGS LCA

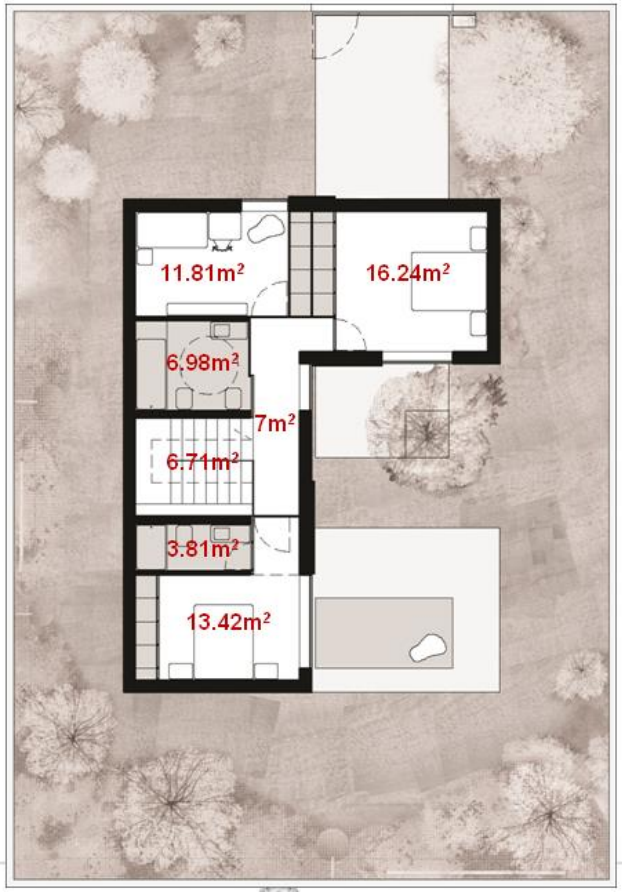
EXAMPLE

PRE-DESIGN STAGE – INPUT DATA

Groundfloor level



First floor level



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PRE-DESIGN STAGE – INPUT DATA

Elevations

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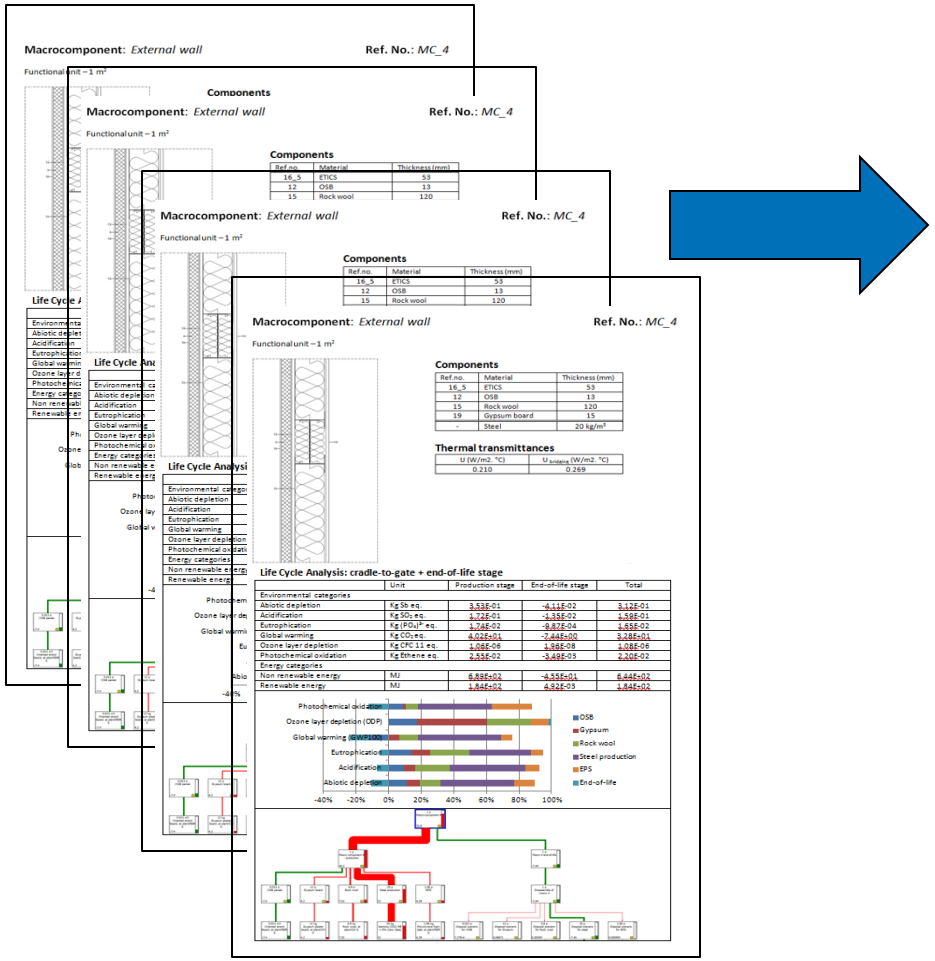
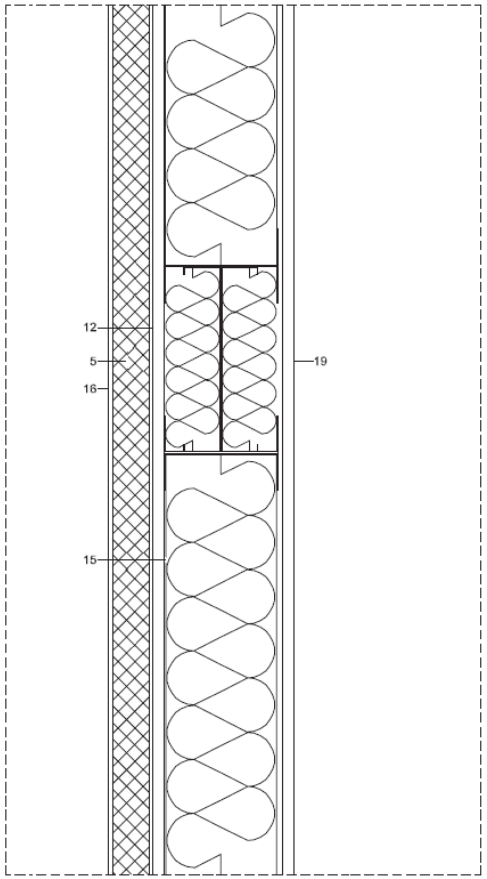
BUILDINGS LCA

EXAMPLE

Macro-component type: external wall





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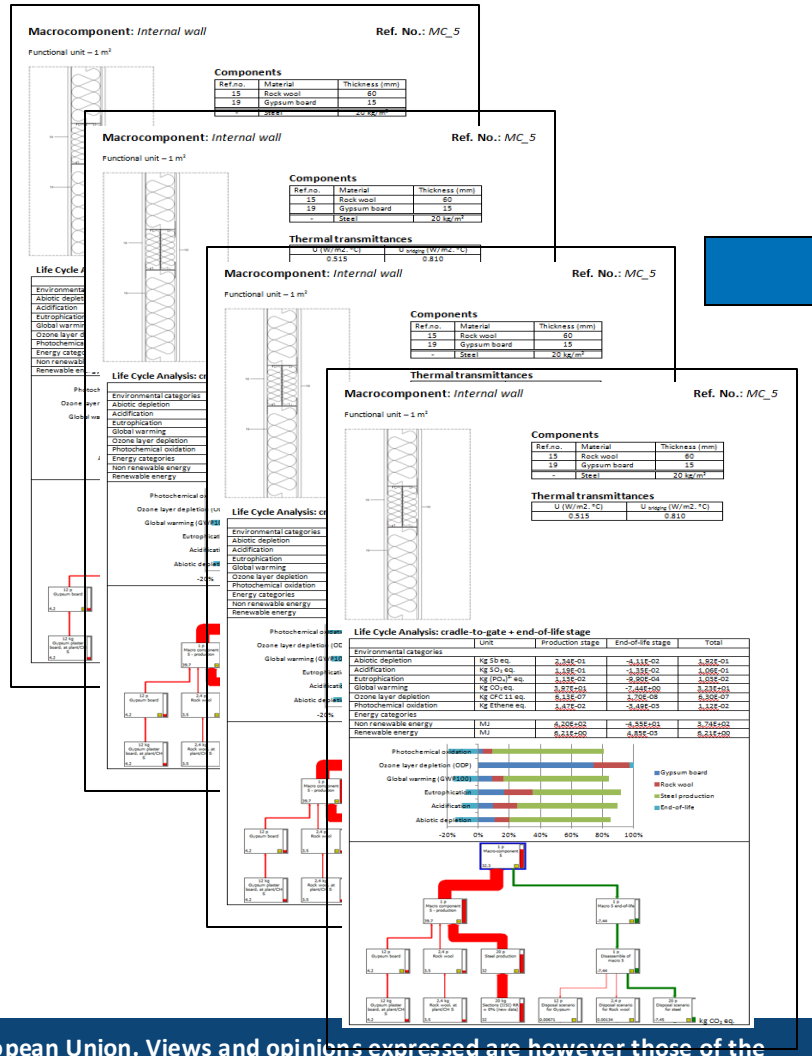
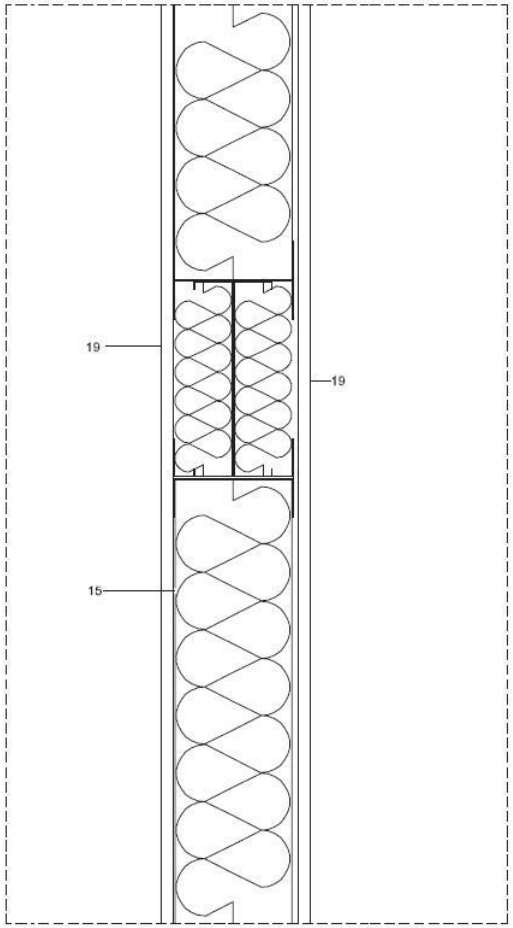
BUILDINGS LCA

EXAMPLE

Macro-component type: internal wall





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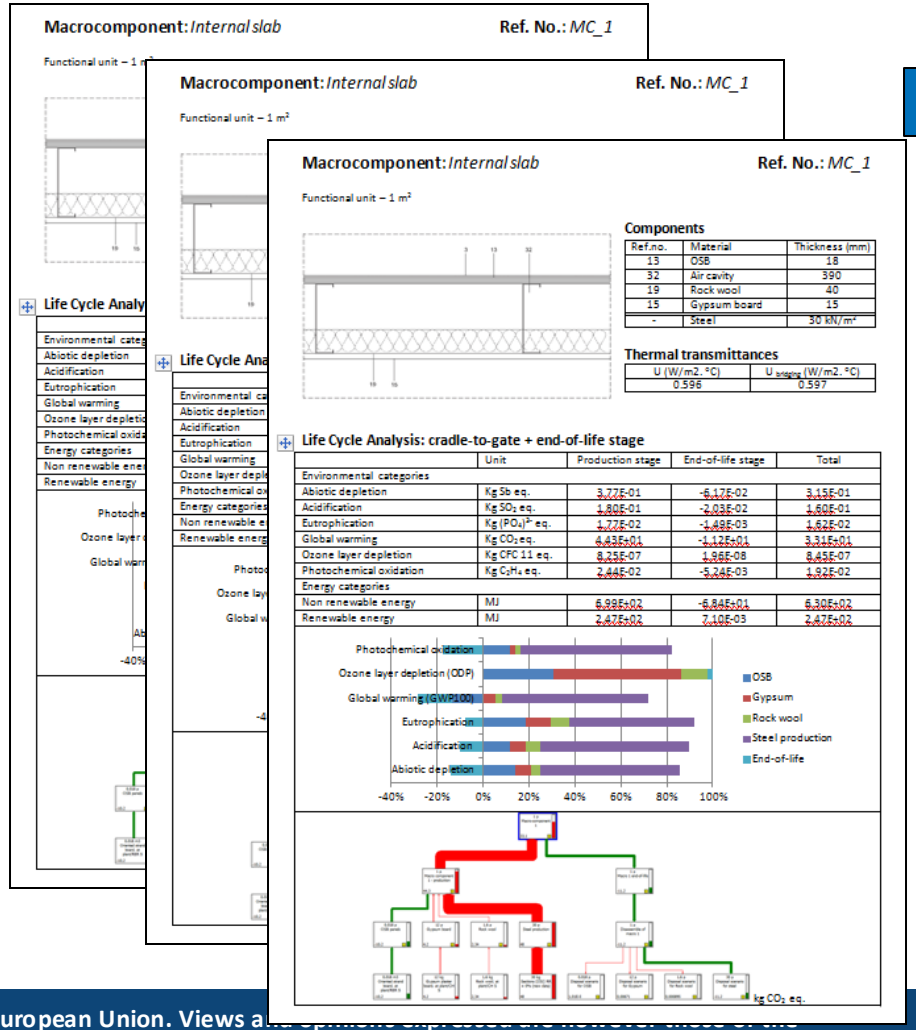
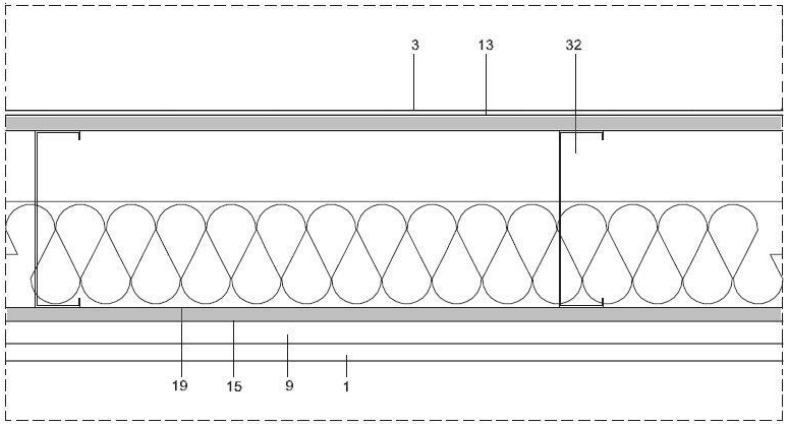
BUILDINGS LCA

EXAMPLE

Macro-component type: internal slab





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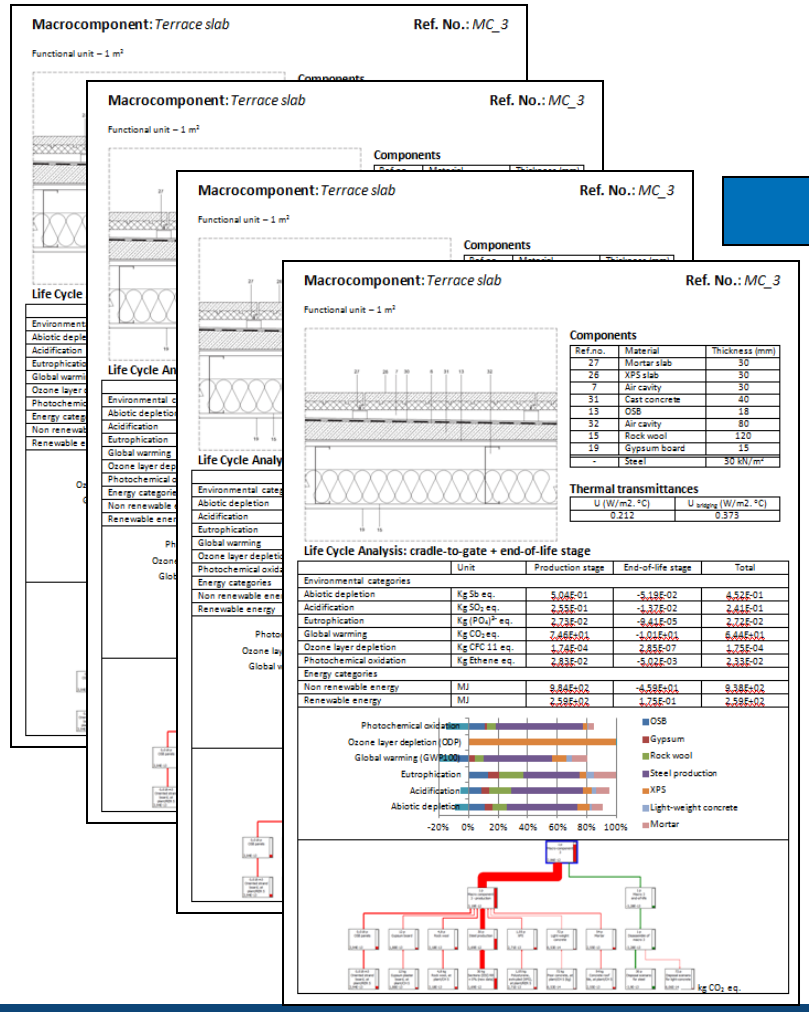
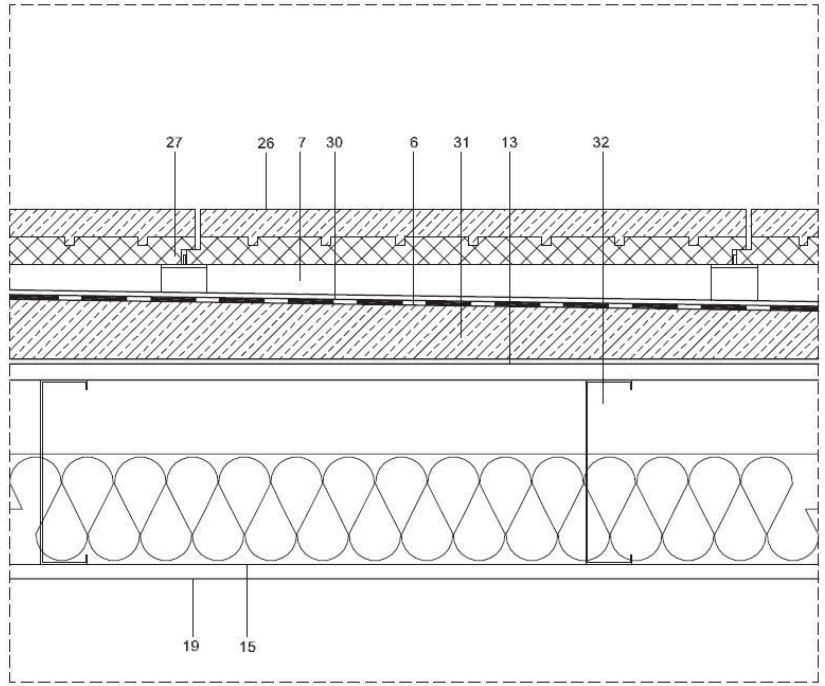
BUILDINGS LCA

EXAMPLE

Macro-component type: external slab





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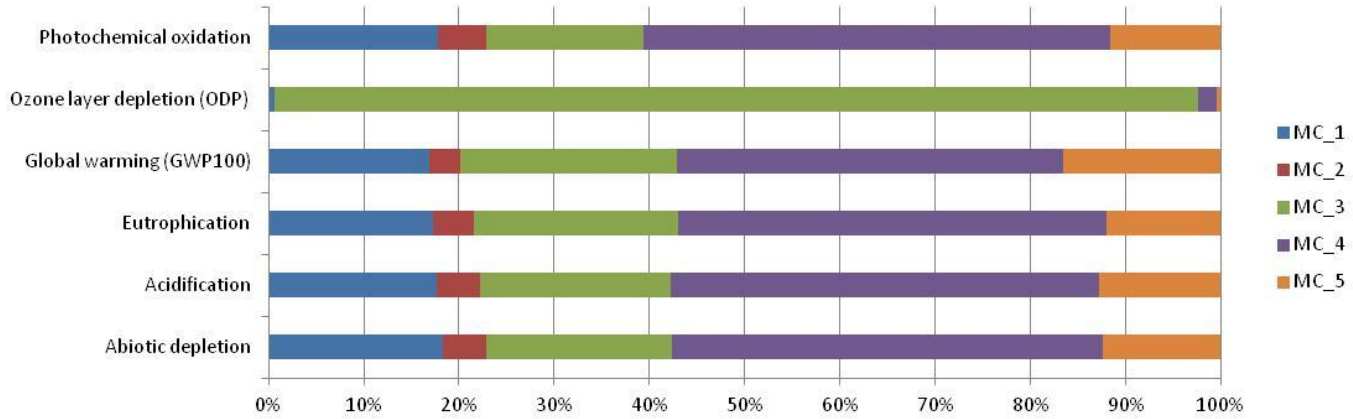
BUILDINGS LCA

EXAMPLE

TABLE OF AREAS:

Area of floors	Area (m^2)
Ground floor	100.8
1st floor	100.8
2nd floor	80.64
Terrace	20.16
External walls	266.40
Internal partitions	110.00

Impact category	Unit	**Total**	MC_1	MC_2	MC_3	MC_4	MC_5
Abiotic depletion	kg Sb eq	**2,08E+02**	3,80E+01	9,57E+00	4,06E+01	9,40E+01	2,57E+01
Acidification	kg SO2 eq	**1,02E+02**	1,81E+01	4,56E+00	2,05E+01	4,59E+01	1,31E+01
Eutrophication	kg PO4--- eq	**1,03E+01**	1,78E+00	4,53E-01	2,20E+00	4,65E+00	1,24E+00
Global warming (GWP100)	kg CO2 eq	**2,64E+04**	4,46E+03	8,42E+02	6,01E+03	1,07E+04	4,37E+03
Ozone layer depletion (ODP)	kg CFC-11 eq	**1,45E-02**	8,32E-05	1,73E-05	1,41E-02	2,84E-04	6,74E-05
Photochemical oxidation	kg C2H4	**1,39E+01**	2,46E+00	7,06E-01	2,29E+00	6,80E+00	1,62E+00



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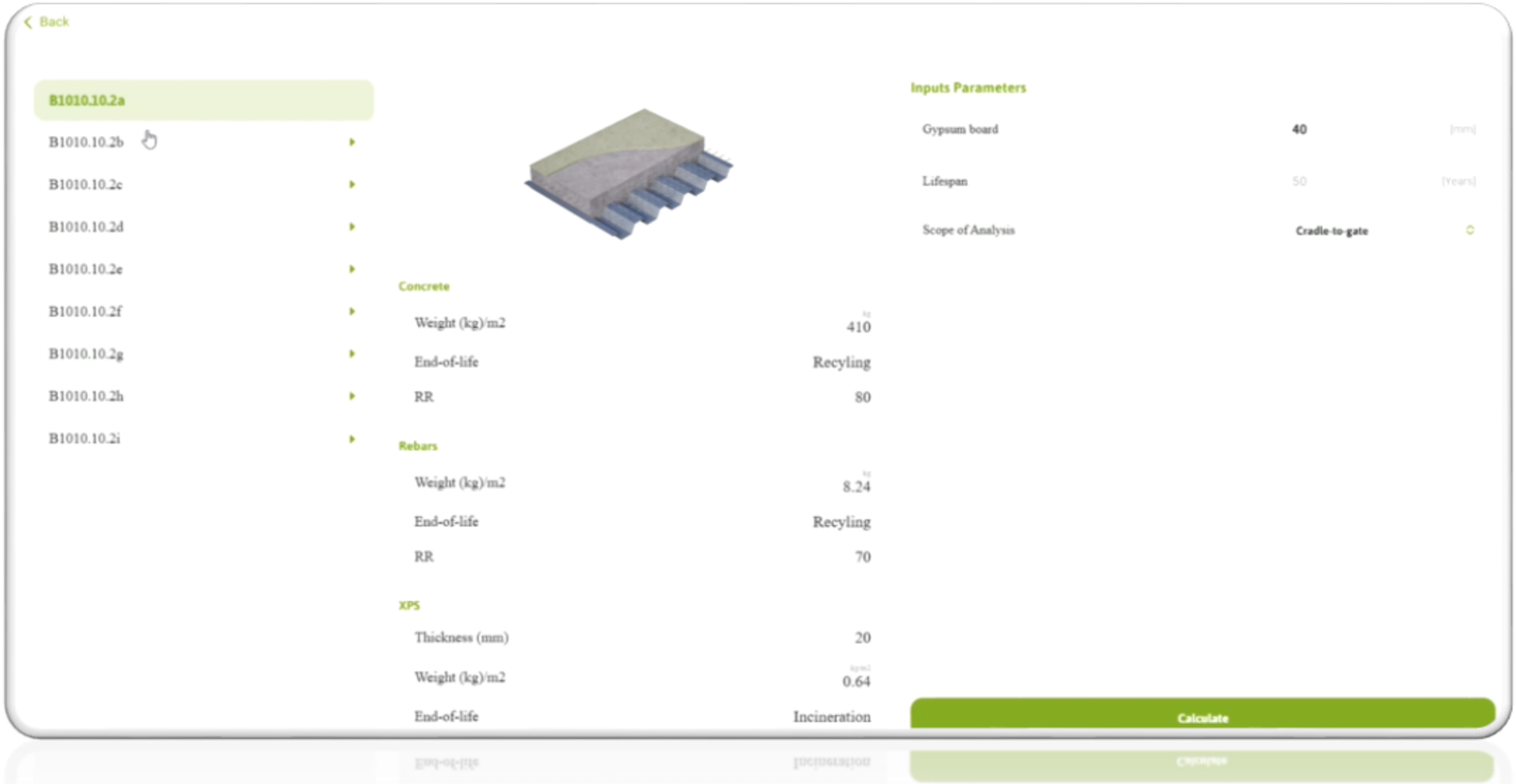
BUILDINGS LCA

VIDEO



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2023-2025

ADVANCE

ACCOMPANYING MEASURE FOR DISSEMINATION, VALORISATION AND COLLABORATIVE EXPLOITATION OF CIRCULARITY OF CONSTRUCTIONAL STEEL PRODUCTS

Thank you for the attention!

CONTACT US:

https://www.steelconstruct.com/eu-projects/advance/

Helena Gervasio - hger@dec.uc.pt

Petr Hradil - petr.hradil@vtt.fi

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