Economic and environmental assessment of reusing reclaimed steel: A European case study

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Objective

The study describes the **environmental impact assessment** and **life cycle cost** of a single storey industrial building in Romania, with the main goal to compare the impacts of steel reuse, by comparing new construction using new steel components and new construction using reused steel components.

Reuse potential

Documented case studies

https://www.steelconstruct.com/eu-projects /progress/case-studies/

Examples

Photo credits: SCI

SEGRO warehouse, Slough, UK

Relocation with the help of original designers

Warehouse building in 2000 relocated in a different layout in 2015 to enable construction of a new road bridge.

Photo credits: Ruukki

S-Market, Urjala, Finland

Deconstruction and reassembly of a steel structure in a new location

The owner of the retail stores chain decided to replace a building in Tampere with a larger one. At the same time, the need for a new grocery store emerged only 60 km away creating the opportunity for relocated reuse.

Examples

Photo credits: SCI

NTS building, Thirsk, UK

The structure that was never built

The original building order was cancelled in 2008 after the fabrication of steelwork, divided in four parts and sold in auction. New building was erected in 2017 by using one of the lots.

Photo credits: UPT

MEXX DAY hall, Timisoara, Romania

The design of a relocated steel industrial hall

The structure was designed in 2008 as a standard kit to be adapted for different locations and applications. It was erected in 2009 and relocated for reuse in 2017.

Examples

Photo credits: BestHall

YIT warehouse, UK
The warehouse follows its owner

The building frame has been erected several times in Finland and in the UK. As YIT's sites changed, Best-Hall relocated the building, which is used as a warehouse.

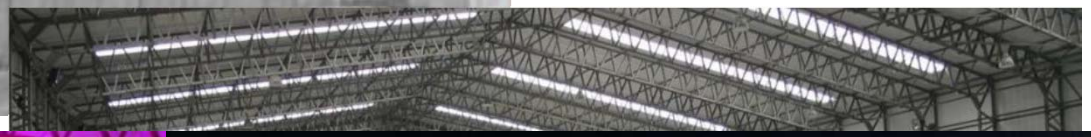
Photo credits: SCI

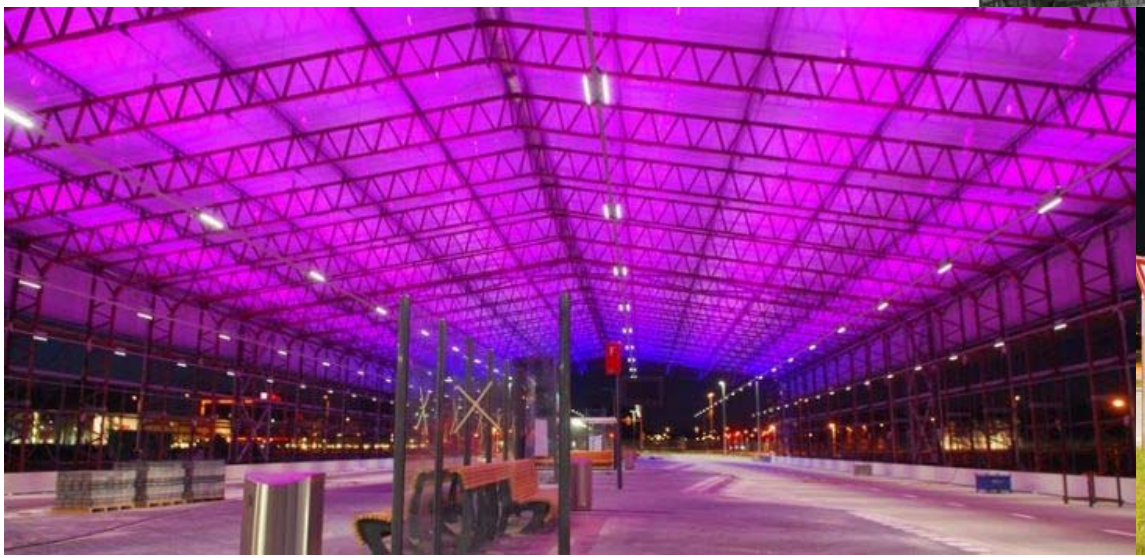
Blue Steel Building, Leeds, UK
Warehouse refurbishment with columns extension

The existing warehouse was refurbished. Its portal frame was raised by 3 m, existing purlins, bracing and rafters were reused and a new office block was added with composite metal decking.

Bus station Schiphol - Nord

1942 London





Reuse scenarios

	In-situ	Same site		Different site	
		Same configuration	Different configuration	Same configuration	Different configuration
Entire primary structure	A	B	C	D	E
Elements of the primary structure	N/A	N/A	F	N/A	G
Individual elements	N/A	N/A	H	N/A	I

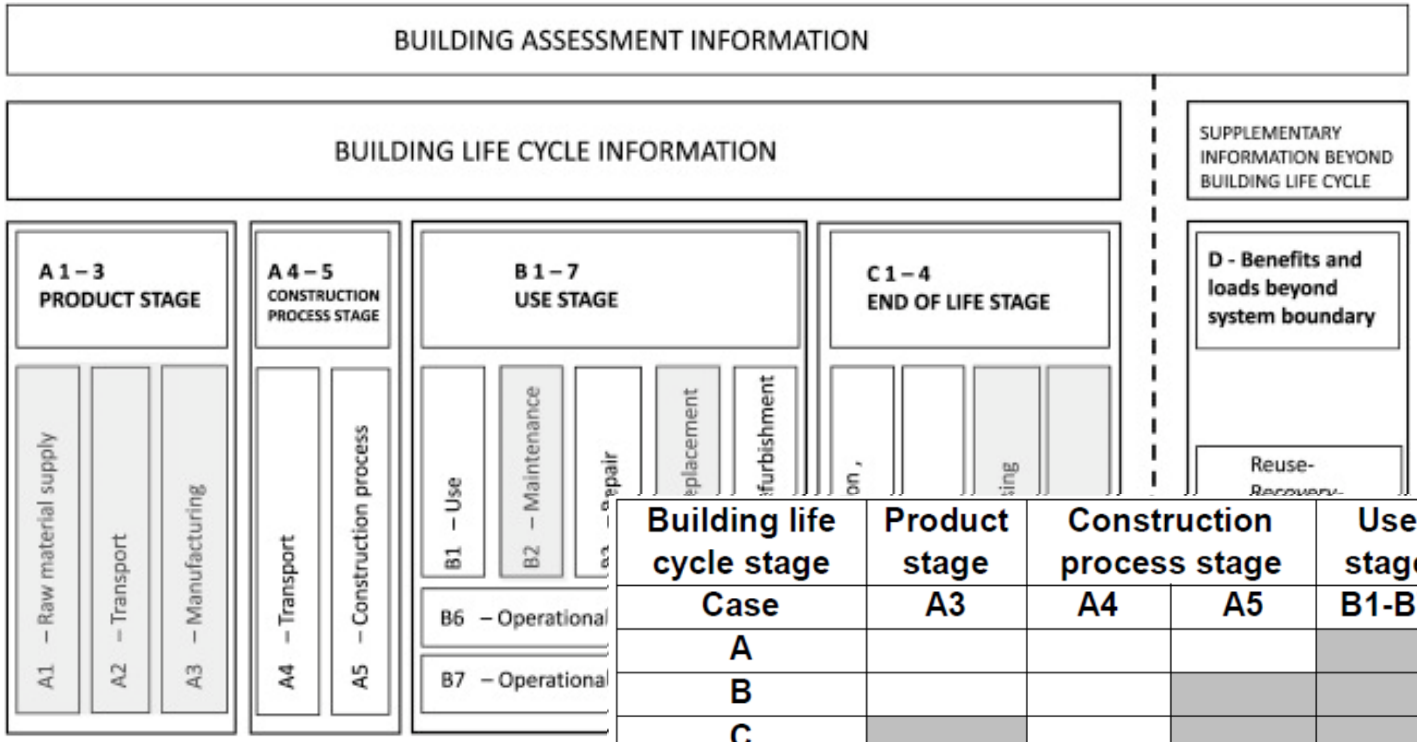
Type of product:

- The entire primary structure;
- Elements of the primary structure, e.g. trusses or 2D portal frames;
- Individual structural elements, e.g. the column or rafter.

Location:

- Reuse in-situ, i.e. the primary structure is retained and not deconstructed;
- Reuse on the same site, i.e. the primary structure is deconstructed and re-erected either in the same configuration and/or same or different location;
- Reuse on a different site.

Reuse scenarios



Modules of the building life

EN 15804: *Sustainability of construc*
declarations. Core rules for the proa

Building life cycle stage	Product stage	Construction process stage		Use stage	End of life stage			
Case	A3	A4	A5	B1-B7	C1	C2	C3	C4
A								
B								
C								
D								
E								
F								
G								
H								
I								

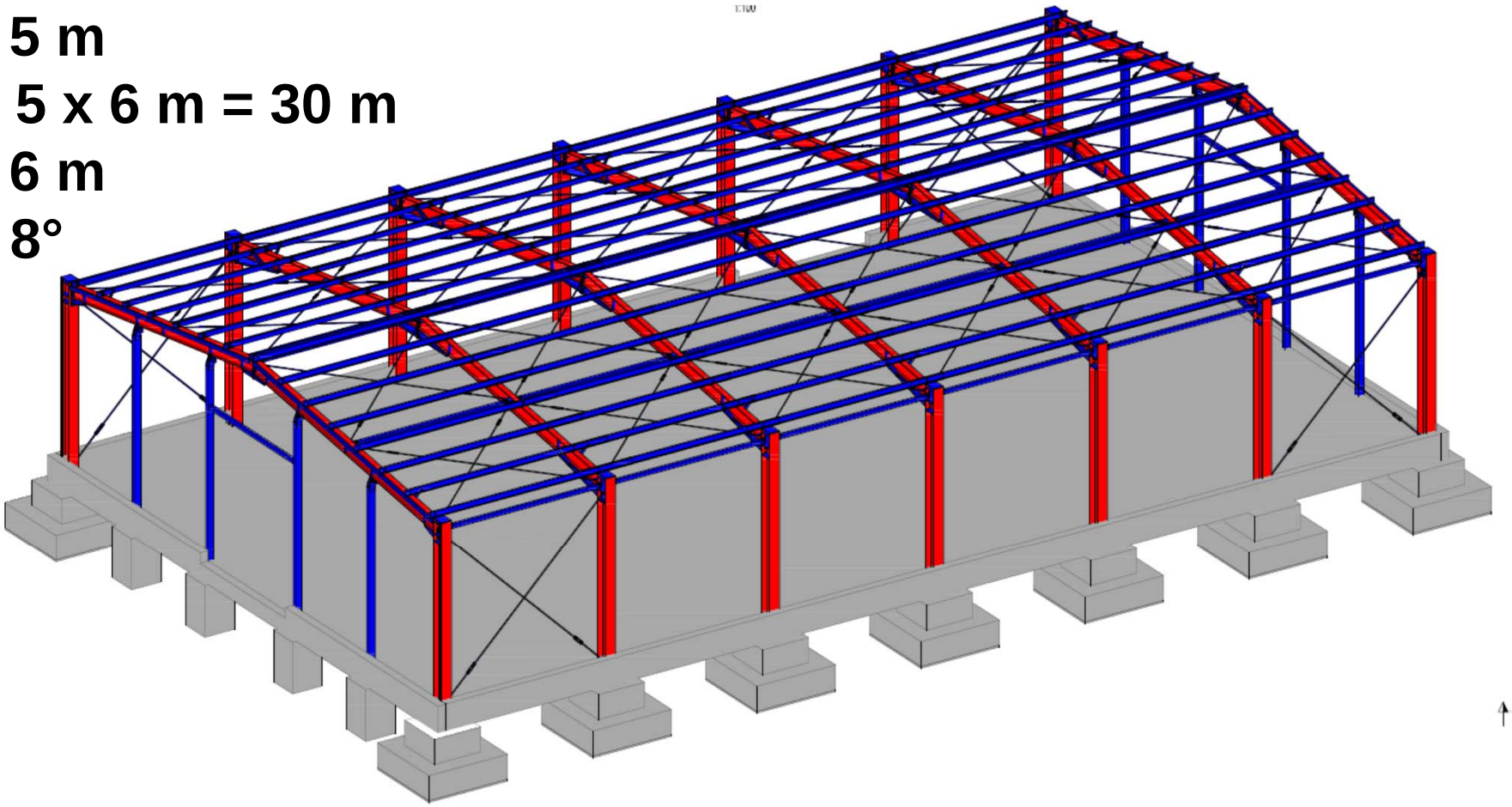
Active modules of a building life cycle in case of reused building scenarios A-I

Remarks

- The case studies proved the reuse of existing steel structure is feasible;
- In most of the case studies the entire primary structure was reused (degree of reutilization 80-100%);
- The dismantling process is easier in the case of structures using bolted connections;
- The reused steel structures need to be strengthened by the addition or change of some structural components;
- The reuse process is easier when the original project and material certificates are available.

Case study

SSSB L = 17,5 m
T = 5 m
B = 5 x 6 m = 30 m
h = 6 m
α = 8°



CASE 1: Design considering the reuse of an existing steel structure. The structure is originated in Germany and will be reassembly in Romania (distance on road 1200 km).

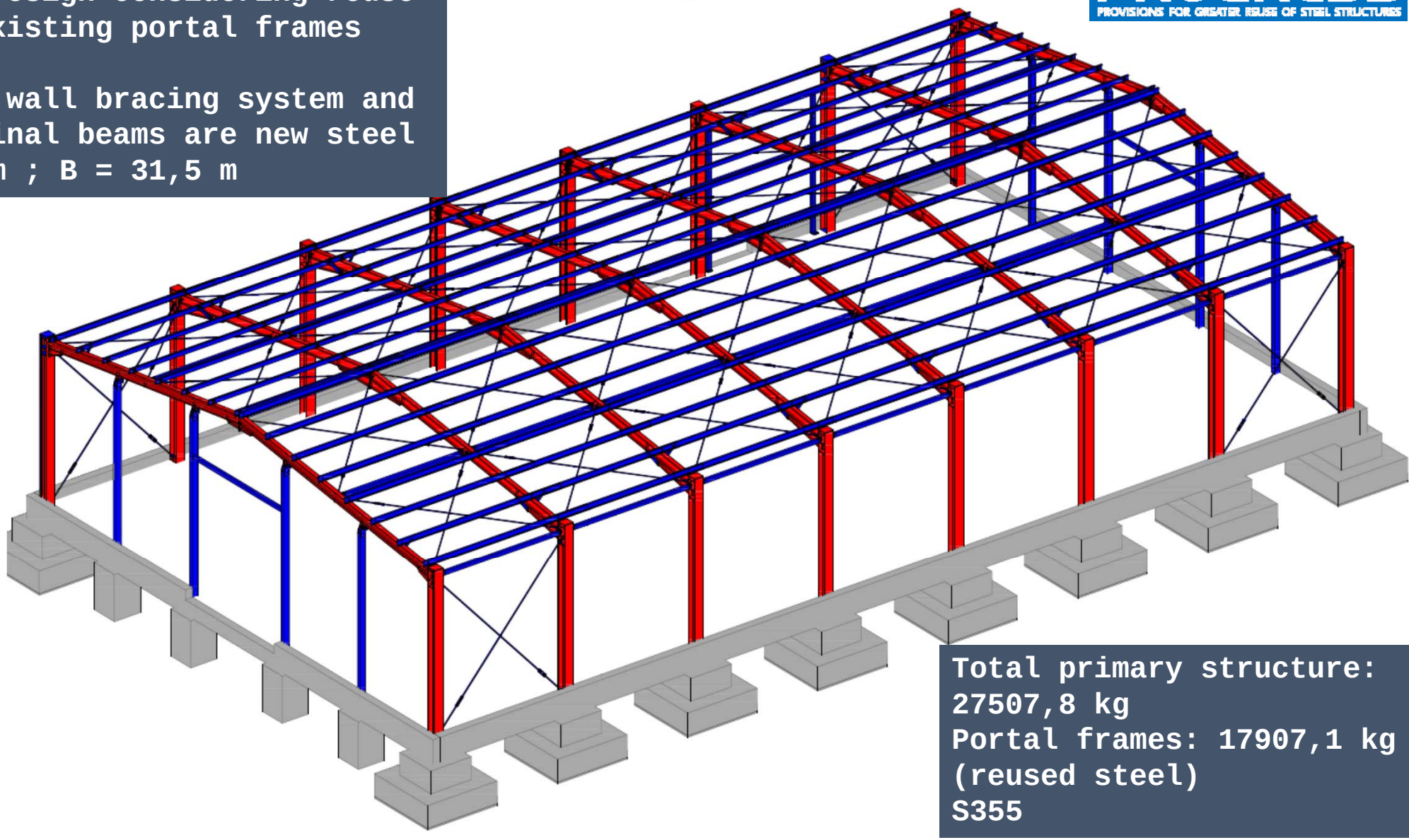
CASE 2: Design considering reclaim steel elements. Existing profiles for columns and beams were identified in a storage yard in Germany, coming from the deconstruction of other buildings. All other components used represent new steel.

CASE 3: Design considering reclaim elements. The same as CASE 2 plus end plates for beams and columns coming from the deconstruction of other buildings. All other components used represent new steel.

CASE 0: Structure is designed as a new structure with new steel - optimal design (20% recycled content).

CASE 1: Design considering reuse of the existing portal frames

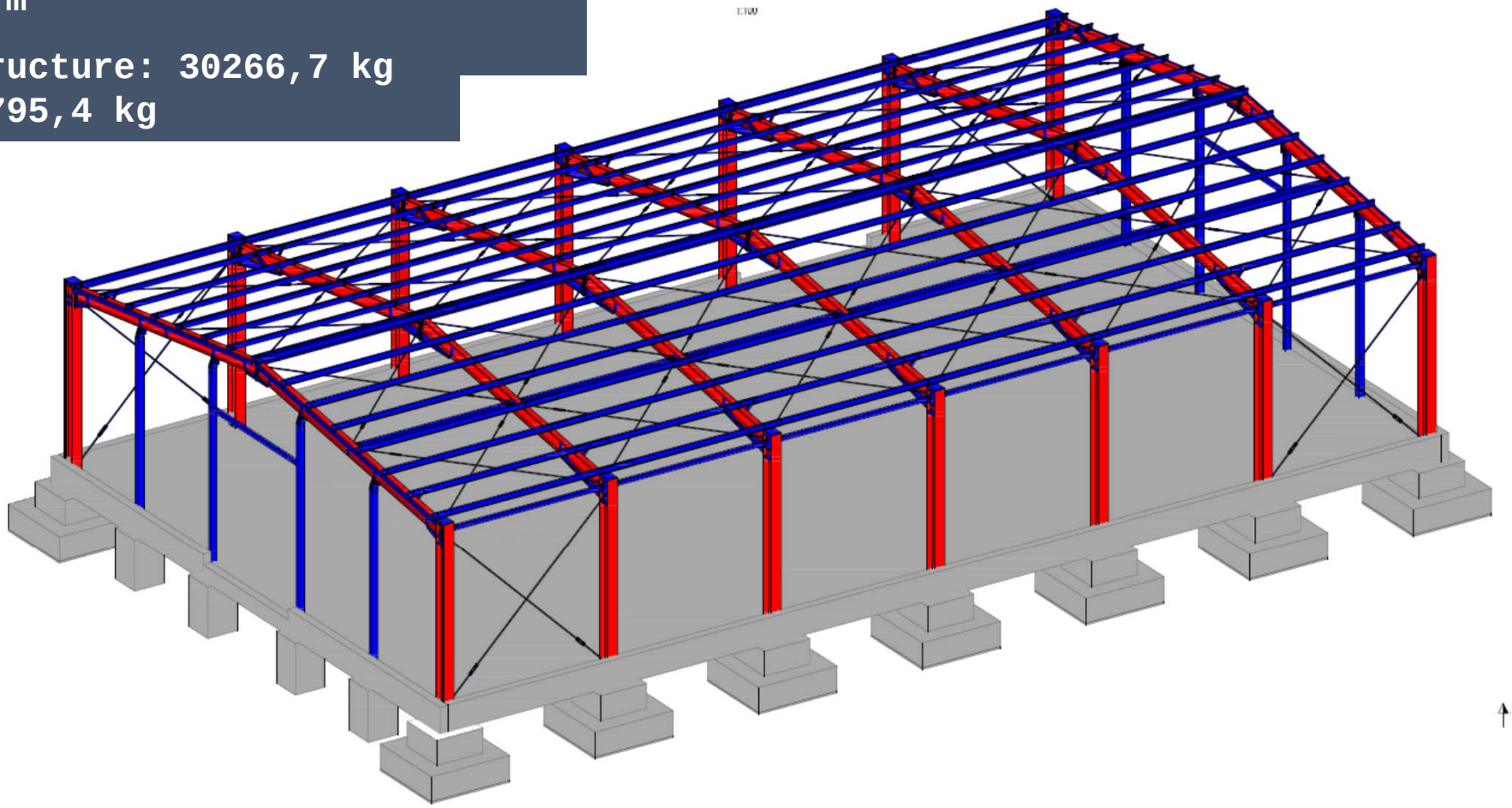
Roof and wall bracing system and longitudinal beams are new steel
T = 4,5 m ; B = 31,5 m



Total primary structure: 27507,8 kg
Portal frames: 17907,1 kg (reused steel)
S355

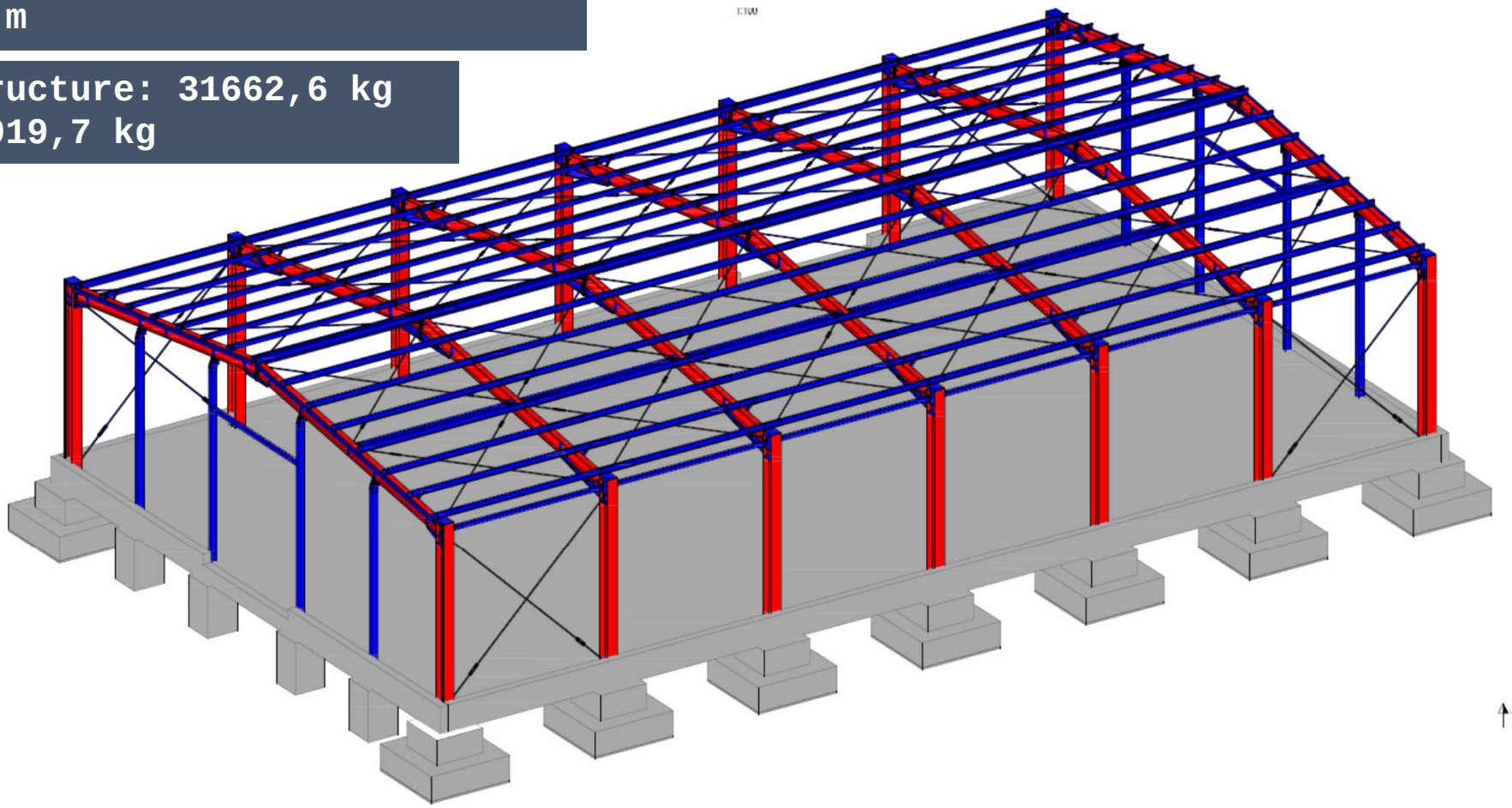
CASE 2: Design considering reclaim elements
Profiles HEA400 for columns and IPE 360 for beams – S275
All other elements are new steel
T = 5 m ; B = 30 m

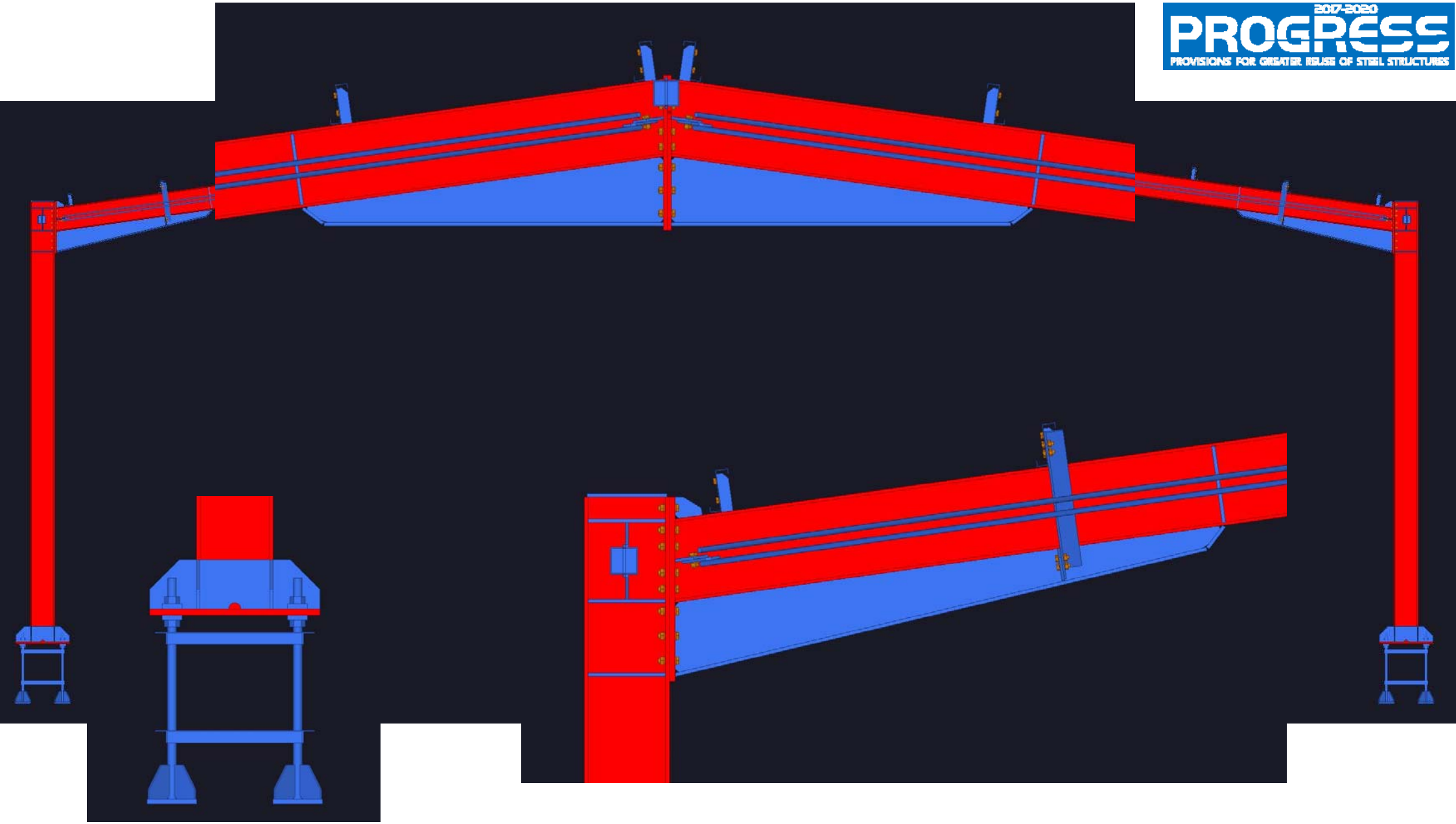
Total primary structure: 30266,7 kg
Reused steel: 16795,4 kg



CASE 3: Design considering reclaim elements
Profiles HEA400 for columns and IPE 360 for beams – S275
End plates for beams and columns – S275
All other elements are new steel
T = 5 m ; B = 30 m

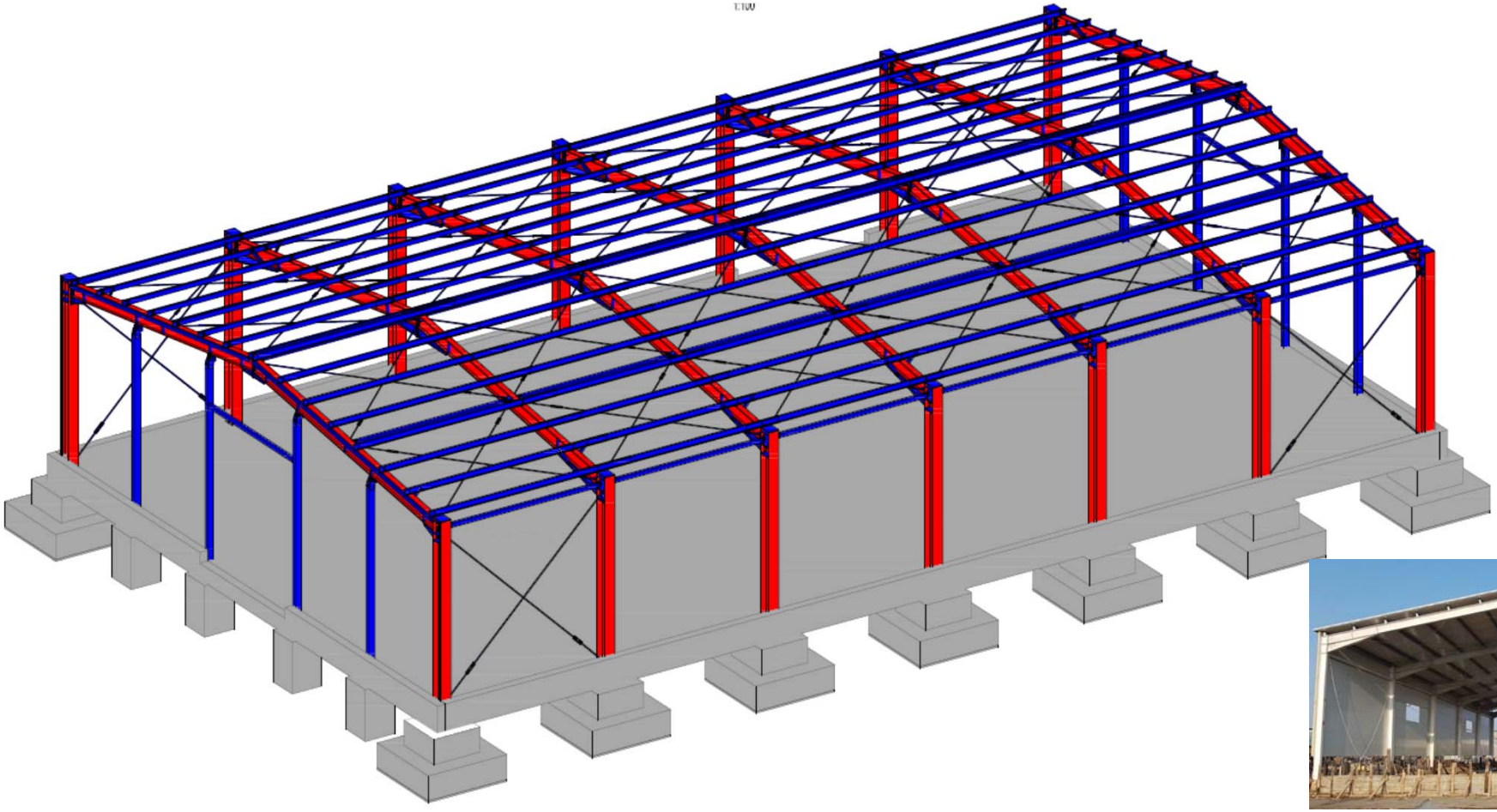
Total primary structure: 31662,6 kg
Reused steel: 19919,7 kg




2017-2020
PROGRESS
PROVISIONS FOR GREATER REUSE OF STEEL STRUCTURES

CASE 0: New design / new steel (real design)
(Columns HEA320 / Beams IPE 300) – S355

Total primary structure: 23682,8 kg



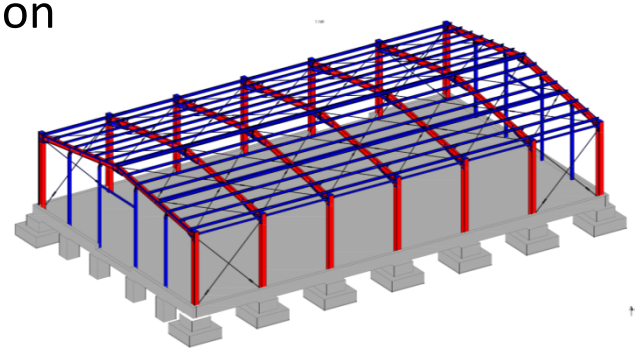
Steel consumption total steel vs. reused steel

Case no.	Total weight [kg]	Reused steel [kg]	%	Purlins [kg]
CASE 1	24812,7	17907,1	72,2	2695,1
CASE 2	27716,3	16795,4	60,6	2550,4
CASE 3	29112,2	19919,7	68,4	2550,4
CASE 0	23682.8	-	-	2550,4

Envelope (1110 m^2): steel sandwich panels with mineral wool insulation

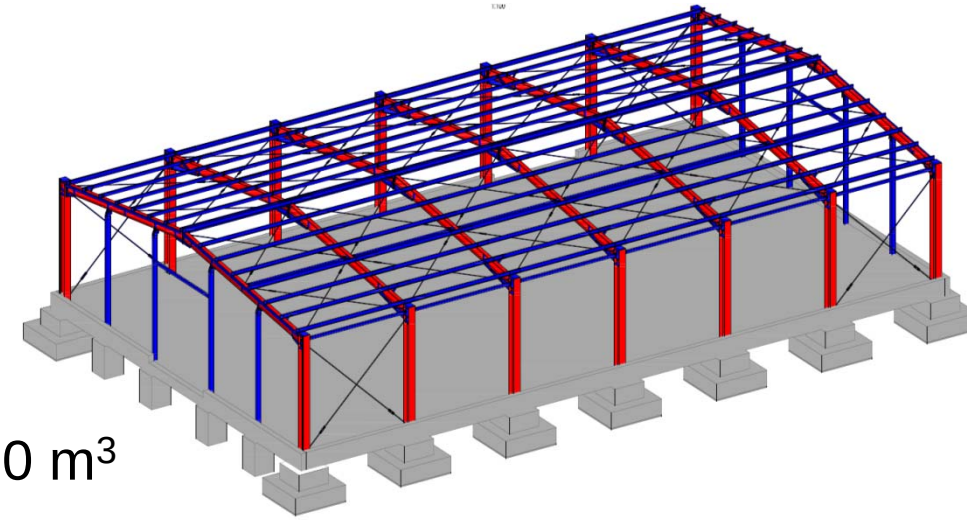
Case 0: 120 mm sandwich panels roof – new elements
80 mm sandwich panels walls – new elements

Case 1-2-3: 80 mm sandwich panels – reused elements
+
60 mm sandwich panels – new elements



The U-values were as follows:

External walls: 0.56 W/m^{2}K
Roof elements: 0.34 W/m^{2}K
Ground floor slab: 0.76 W/m^{2}K.
Windows and entrance-door: 1.3 W/m^{2}K.



Other materials and components:

- concrete foundations and concrete floor: 190 m^3
- triple glazed windows: 22.5 m^2
- sectional sliding gates: 48 m^2.

- for the use phase (module B) only space heating and electricity as operational energy were considered;
- heated floor area: 525 m^2;
- the operational lifetime of the building: 25 years.

Environmental assessment

- LCA and global warming potential (GWP) evaluation are based on the modular building life cycle approach as described in the European standards EN 15978:2011 and EN 15804:2013

Assessed scenarios

- **New steel (Case 0)** – demolition and recycling. It was assumed that the new steel contains 2% scrap and that 90% of the steel is recovered for recycling at end of life.

- **New steel** – deconstruction and reuse. It is assumed that the new steel contains 2% scrap, 90% of the steel is reused, and 90% of the remaining steel (9% of the total mass) is recovered for recycling at end of life.

- **Reused steel (Case 1-2-3)** – demolition and recycling.

- **Reused steel (Case 1-2-3)** – deconstruction and reuse.

Material - case 1	**In**			**Out**		
End-of-life scenario (reuse)	**New steel**	**Reuse**	**Scrap**	**Recycling = Scrap**	**Reuse**	**Waste**
Steel	27.24%	72.20%	0.56%	25%	72%	3%
Material - case 2	**In**			**Out**		
End-of-life scenario (reuse)	**New steel**	**Reuse**	**Scrap**	**Recycling = Scrap**	**Reuse**	**Waste**
Steel	38.61%	60.60%	0.79%	28.4%	68.4%	3.20%
Material - case 3	**In**			**Out**		
End-of-life scenario (reuse)	**New steel**	**Reuse**	**Scrap**	**Recycling = Scrap**	**Reuse**	**Waste**
Steel	30.97%	68.40%	0.63%	28.4%	68.4%	3.20%

Modular assessment considers building life cycle stages from A to C and the stage beyond the system boundary, Module D.

- The product stage **(A1–3)** ⇨ the manufacture of the primary and secondary structure, foundations, floor slab, envelope, doors and windows.

- The construction stage **(A4 and A5)** ⇨ finished products are transported to the building site from the factory and assembled on site.
  - 70 km (average distance between the major cities);
  - 1200 km (distance to transport reused steel and sandwich panels).

Construction work included excavation of soil for the floor slab and foundations, concreting and erection of the primary and secondary steelwork and the envelope using cranes, forklifts and man-lifts, including worker transportation.

- Calculation of the use stage **(Module B6)** ⇨ operational lifetime of the building is 25 years. No maintenance, repair or material replacements or refurbishment are considered. It was assumed that the use stages of new and reused buildings have identical environmental impact.

- In the end-of-life stage (demolition/deconstruction, **Module C1–2**) ⇨ deconstruction of the steel structure follows the reverse process to its erection (1.5 times erection time and costs).

- Transportation (**C2**) of the recovered building elements to the nearest salvage yard is also considered in the model.

- The loads and benefits beyond the system boundary (Module D) are also assessed.

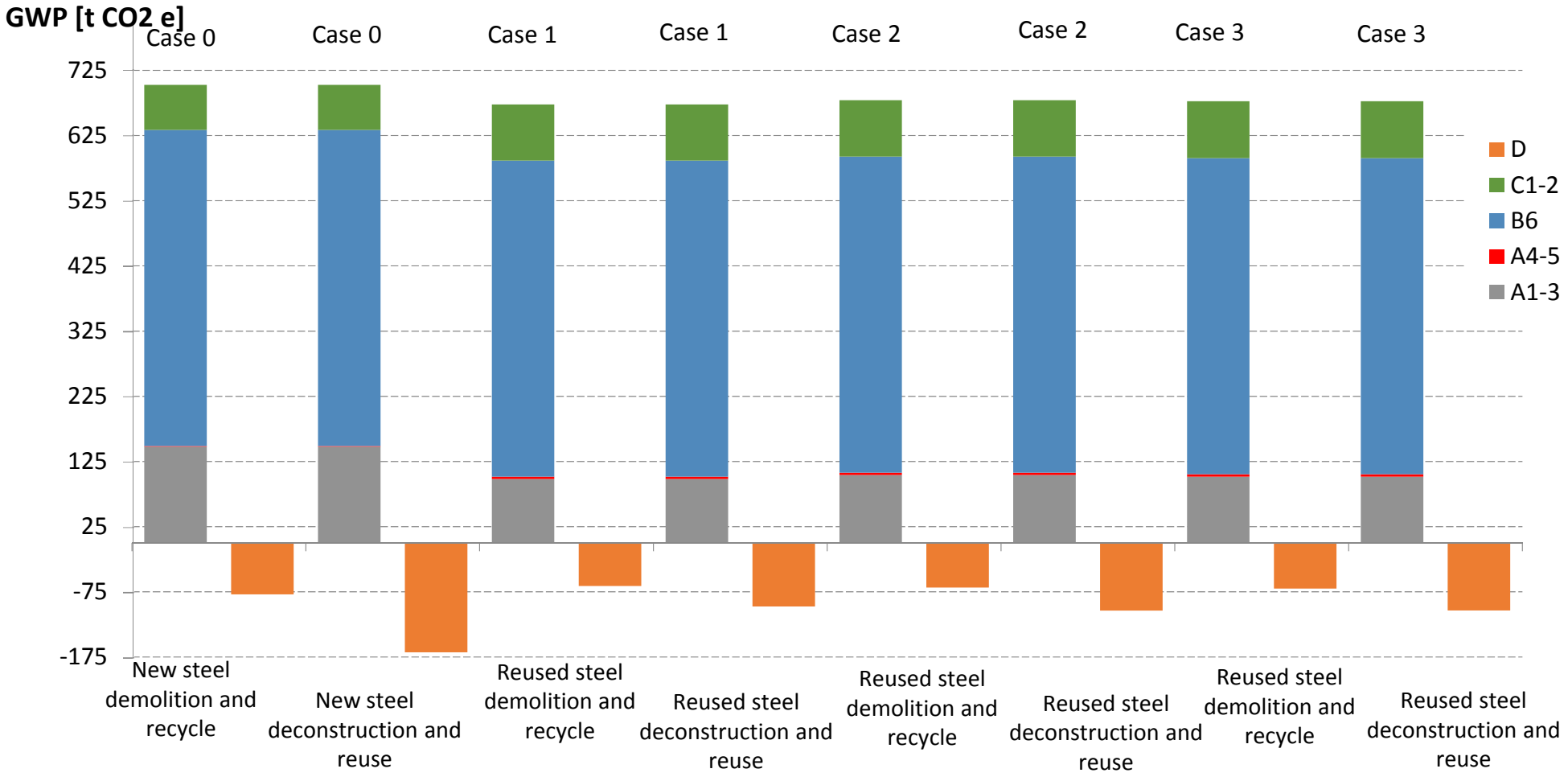
Inventory of the products production costs and GWP impacts (Modules A1–3)

exemplification

Case 0 - Product	Total units	Unit cost	Unit impact
Primary structure	23,68 t	1300 €/t	1,72 tCO2 e/ t
Secondary structure	2,55 t	900 €/t	
Envelope (sandwich panels)	1110 m^2	24 €/m^2	0,036 tCO2 e/ m^2
Concrete floor and foundations	185,47 m^3	59 €/m^3	0,316 tCO2 e/ m^3
Windows and doors	70.5 m^2	144.68 €/m^2	0,049 tCO2 e/ m^2

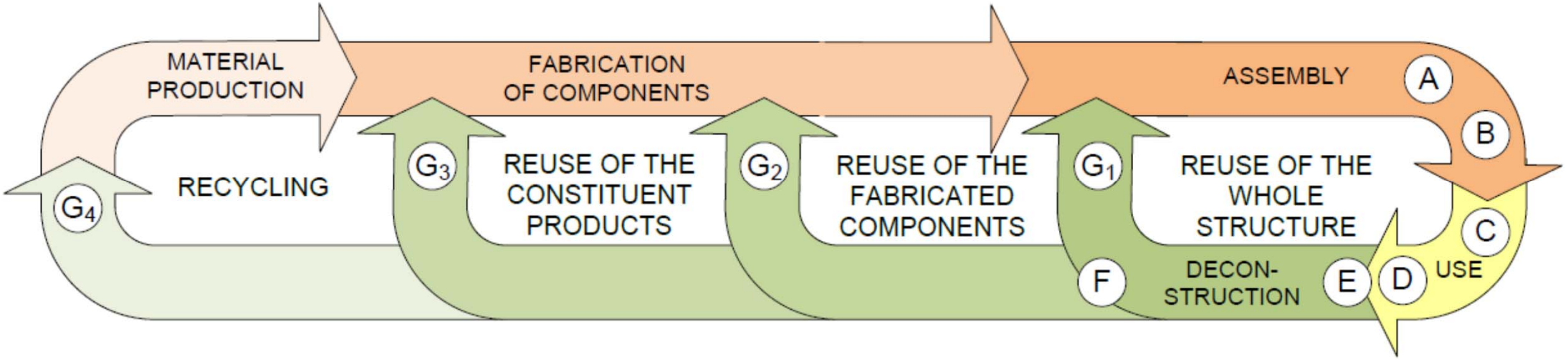
Case2 - Product	Total units	Unit cost	Unit impact
Primary structure (new steel)	10,92 t	1300 €/t	0,847 tCO2 e/ t
Secondary structure (new steel)	2,55 t	900 €/t	
Primary structure (reused steel)	16.8 t	250 €/t	
Envelope (sandwich panels)	1110 m^2	18.5 €/m^2	0,0073 tCO2 e/ m^2
Envelope (sandwich panels) reused	1110 m^2	11.5 €/m^2	
Concrete floor and foundations	185,47 m^3	59 €/m^3	0,316 tCO2 e/ m^3
Windows and doors	70.5 m^2	144.68 €/m^2	0,049 tCO2 e/ m^2

Total LCA results for the four possible scenarios of the studied industrial building



Economic assessment

General description of different reuse flows



In case of demolition or deconstruction, the residual value of the building “G” is calculated as the difference between demolition costs and revenue obtained for the sold of secondary materials (e.g. steel scrap or reusable components),

- The economic assessment results are calculated for the same scenarios/modules with new steel and reused steel as in the LCA analysis.

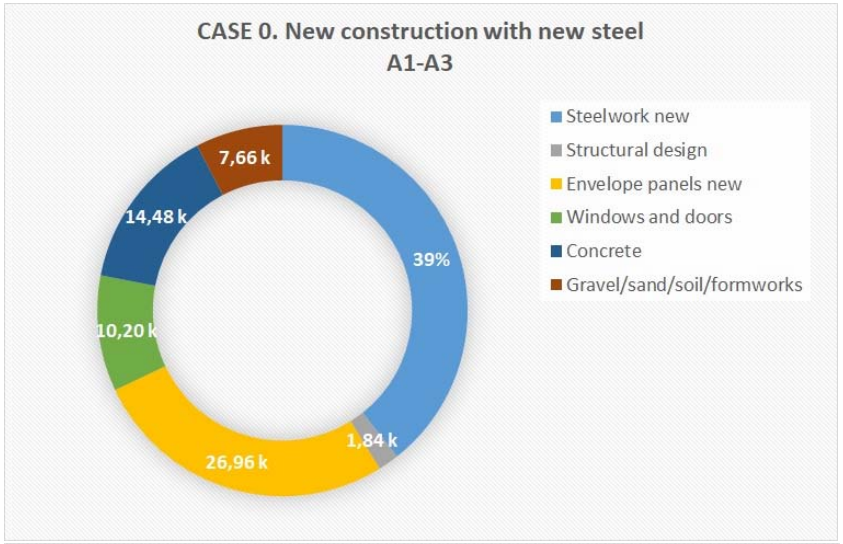
Cost model proposal for Module D

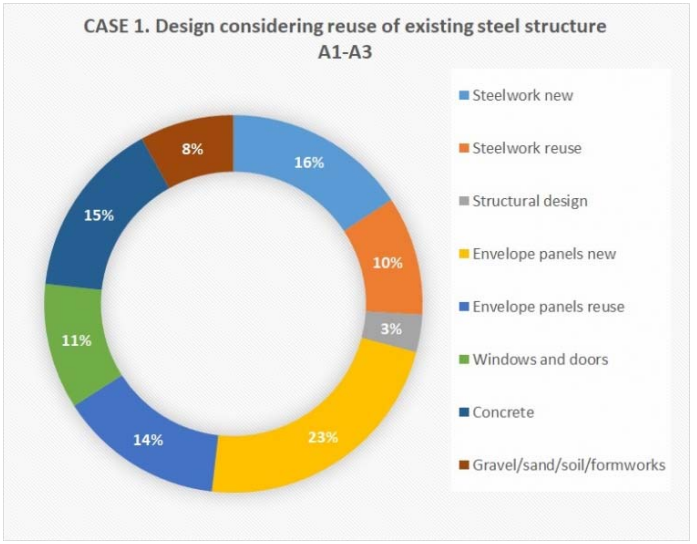
Recycling

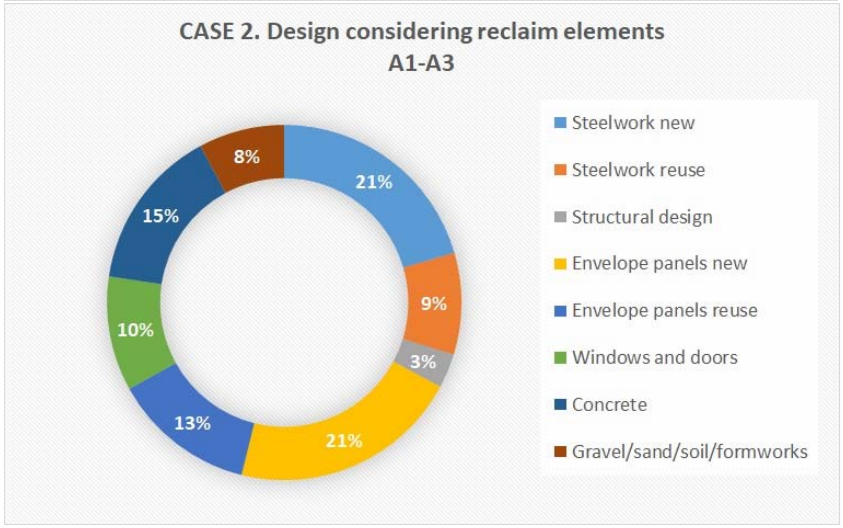
-180 €/t (value represents the revenue from sold steel scrap)

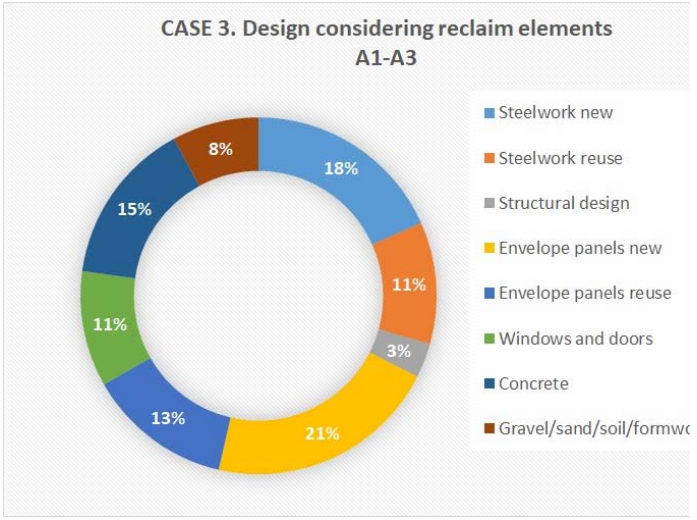
Reuse

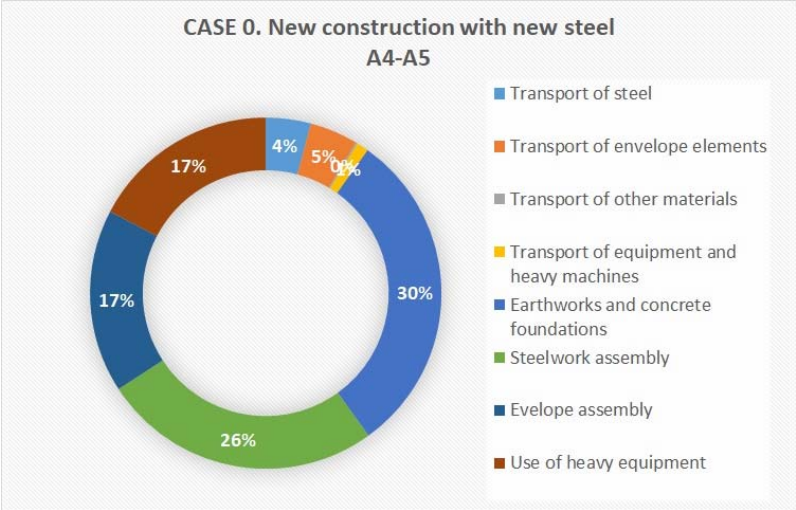
- 639 €/t (value represents revenue from the sold recovered structure)

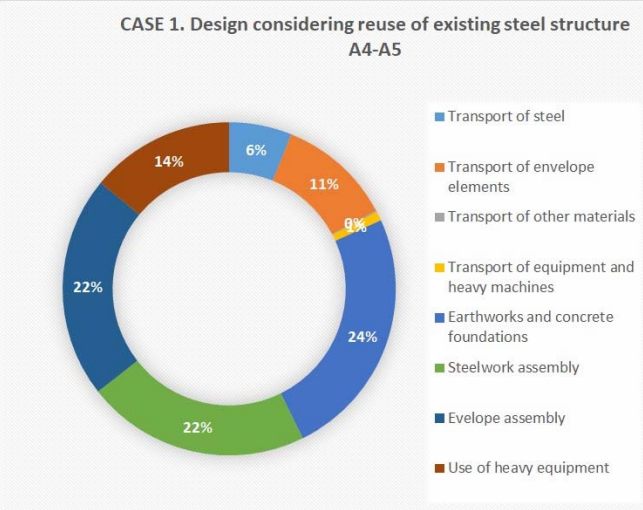

CASE 0. New construction with new steel
A1-A3
7,66 k
14,48 k
10,20 k
26,96 k
1,84 k
39%
Steelwork new
Structural design
Envelope panels new
Windows and doors
Concrete
Gravel/sand/soil/formworks

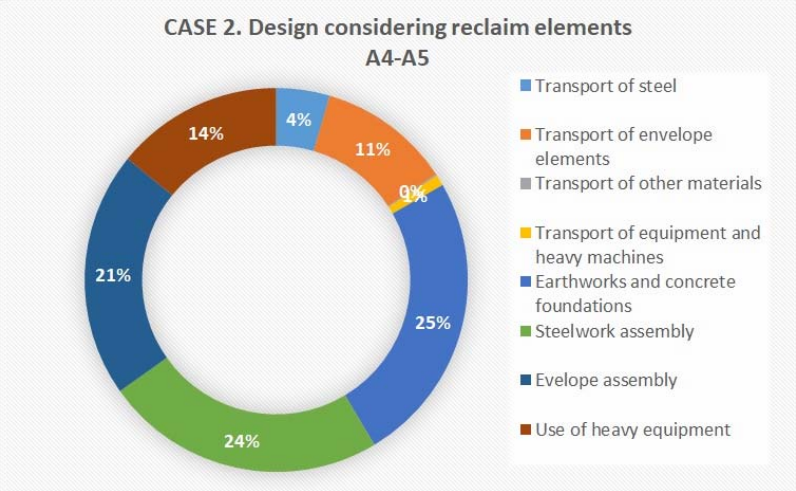

CASE 1. Design considering reuse of existing steel structure
A1-A3
8%
16%
15%
10%
3%
11%
14%
23%
Steelwork new
Steelwork reuse
Structural design
Envelope panels new
Envelope panels reuse
Windows and doors
Concrete
Gravel/sand/soil/formworks

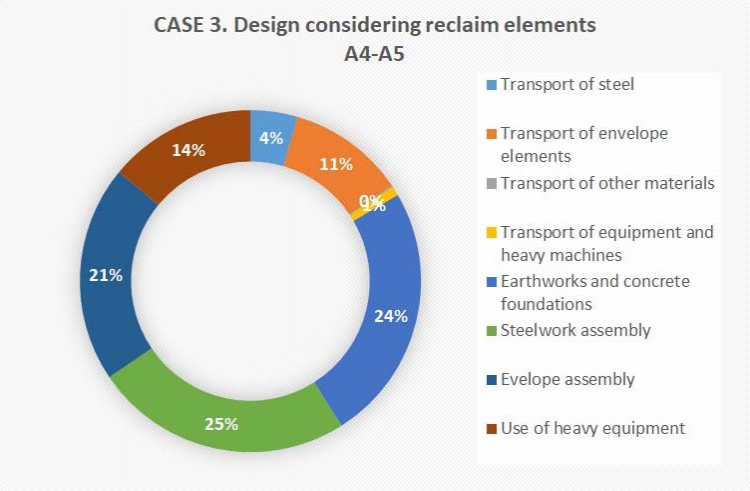

CASE 2. Design considering reclaim elements
A1-A3
8%
21%
15%
9%
10%
3%
13%
21%
Steelwork new
Steelwork reuse
Structural design
Envelope panels new
Envelope panels reuse
Windows and doors
Concrete
Gravel/sand/soil/formworks


CASE 3. Design considering reclaim elements
A1-A3
8%
18%
15%
11%
11%
3%
13%
21%
Steelwork new
Steelwork reuse
Structural design
Envelope panels new
Envelope panels reuse
Windows and doors
Concrete
Gravel/sand/soil/formwo

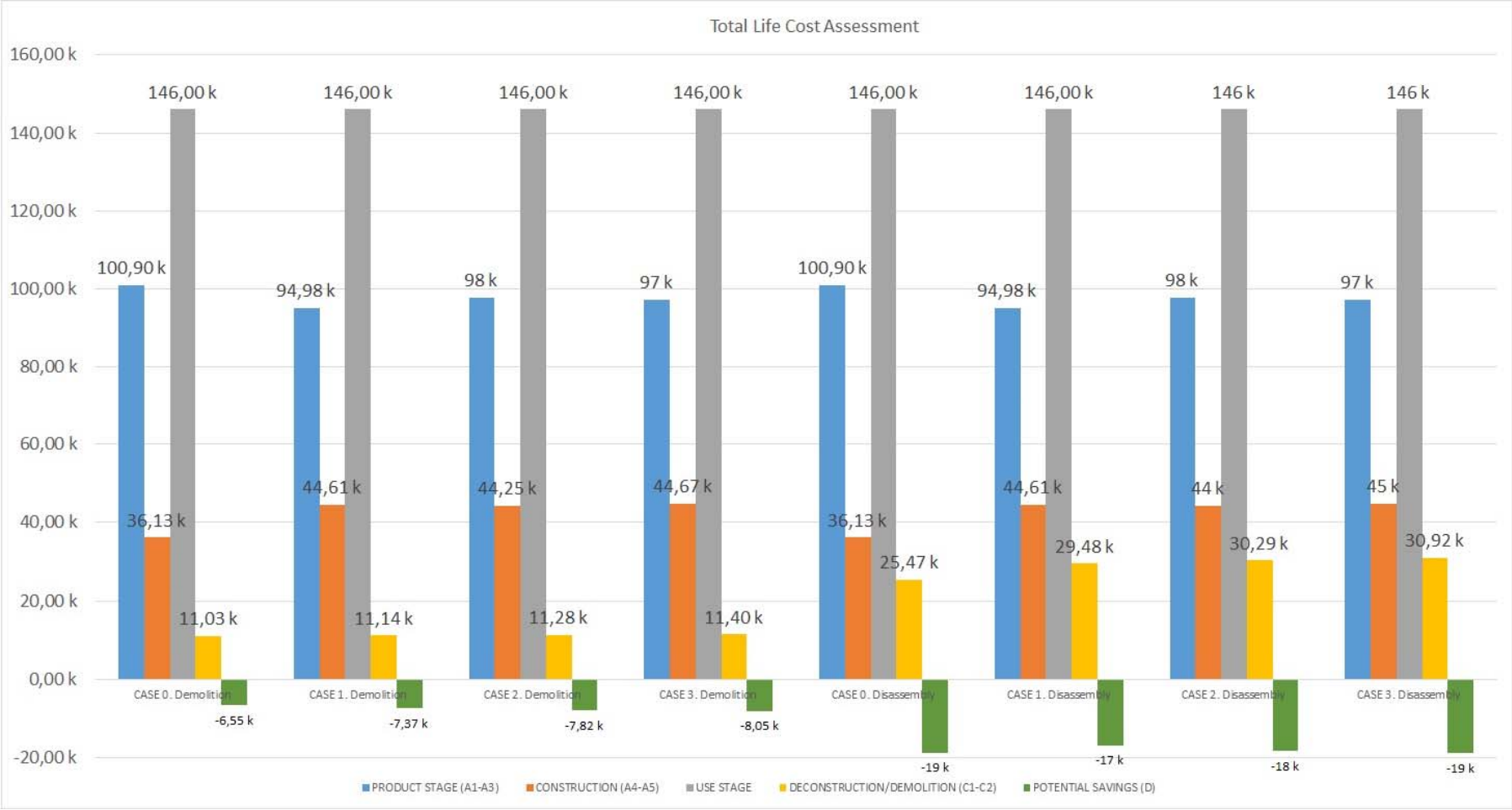

CASE 0. New construction with new steel
A4-A5
4%
5%
0%
30%
26%
17%
17%
Transport of steel
Transport of envelope elements
Transport of other materials
Transport of equipment and heavy machines
Earthworks and concrete foundations
Steelwork assembly
Evelope assembly
Use of heavy equipment


CASE 1. Design considering reuse of existing steel structure
A4-A5
6%
11%
1%
24%
22%
22%
14%
Transport of steel
Transport of envelope elements
Transport of other materials
Transport of equipment and heavy machines
Earthworks and concrete foundations
Steelwork assembly
Evelope assembly
Use of heavy equipment


CASE 2. Design considering reclaim elements
A4-A5
4%
11%
1%
25%
24%
21%
14%
Transport of steel
Transport of envelope elements
Transport of other materials
Transport of equipment and heavy machines
Earthworks and concrete foundations
Steelwork assembly
Evelope assembly
Use of heavy equipment


CASE 3. Design considering reclaim elements
A4-A5
4%
11%
1%
24%
25%
21%
14%
Transport of steel
Transport of envelope elements
Transport of other materials
Transport of equipment and heavy machines
Earthworks and concrete foundations
Steelwork assembly
Evelope assembly
Use of heavy equipment

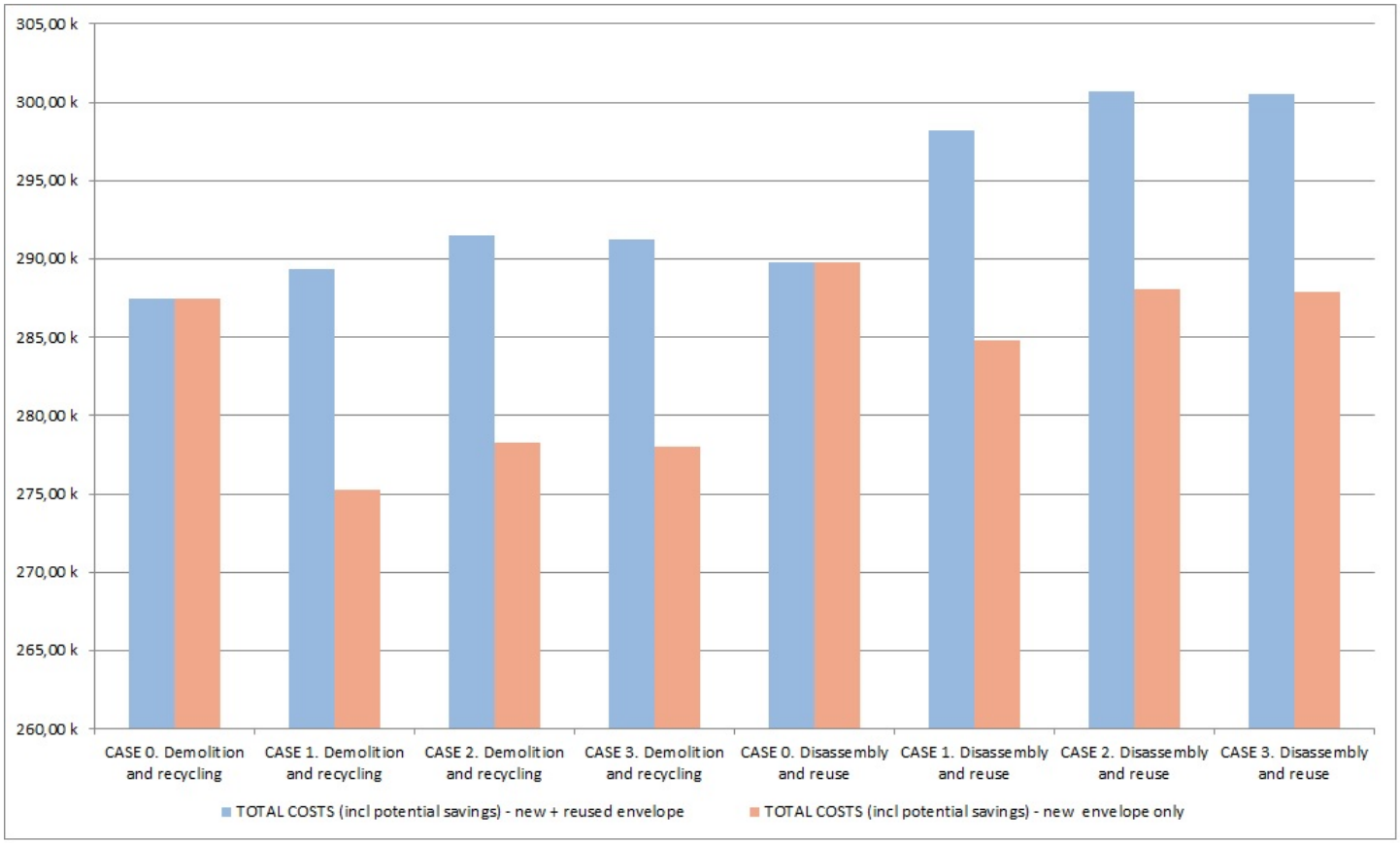
Total costs for the four possible scenarios recycling vs. reuse



Remarks

The envelope for cases 1 – 3 is composed by two layers; i.e. reused envelope + new envelop to fulfill the U-values.

The graph below shows the comparative situation when it is use new envelope only.



Conclusions

- LCA and LCC are commonly used for assessment of the environmental and economic impacts of buildings.
- Constructions use substantial amounts of materials, with significant environmental and economic impacts. To minimise the impact ⇨ replace virgin materials with materials disassembled from demolished buildings.
- The present assessment considered four cases, where the building is constructed from either new or reused components, and where the components will be either reused or recycled in the future.
- If the steel structures are designed for reuse and then reused, then economic and environmental benefits are achievable.

Conclusions

- The overall economic potential of the reuse stages in various reuse scenarios was evaluated and, according to the results, the scenario with reused steel elements resulted in lower cycle costs compared to recycling.

- However, due to the large variation of materials and building practices, LCC and LCA calculations are recommended to be carried out on a case-by-case basis, as the results could differ significantly from the present study.

Conclusions

- Identification of the market needs related to Module D (Benefits and loads beyond the system boundary) or to maximize the efficiency of reuse.
  - to reuse the whole structure as a kit;
  - to design steel structures for complete deconstruction.

Material - case 1	**In**			**Out**		
End-of-life scenario (reuse)	**New steel**	**Reuse**	**Scrap**	**Recycling = Scrap**	**Reuse**	**Waste**
Steel	27.24%	72.20%	0.56%	25%	72%	3%
Material - case 2	**In**			**Out**		
End-of-life scenario (reuse)	**New steel**	**Reuse**	**Scrap**	**Recycling = Scrap**	**Reuse**	**Waste**
Steel	38.61%	60.60%	0.79%	28.4%	68.4%	3.20%
Material - case 3	**In**			**Out**		
End-of-life scenario (reuse)	**New steel**	**Reuse**	**Scrap**	**Recycling = Scrap**	**Reuse**	**Waste**
Steel	30.97%	68.40%	0.63%	28.4%	68.4%	3.20%

Proposal for complete deconstruction …

CASE 4: New design / new material prepared for complete disassembly in individual components.

Total primary structure: 24593.4 kg