Research Fund for Coal & Steel

Large Valorisation on Sustainability of Steel Structures

CASE STUDIES

ArcelorMittal

June 2014

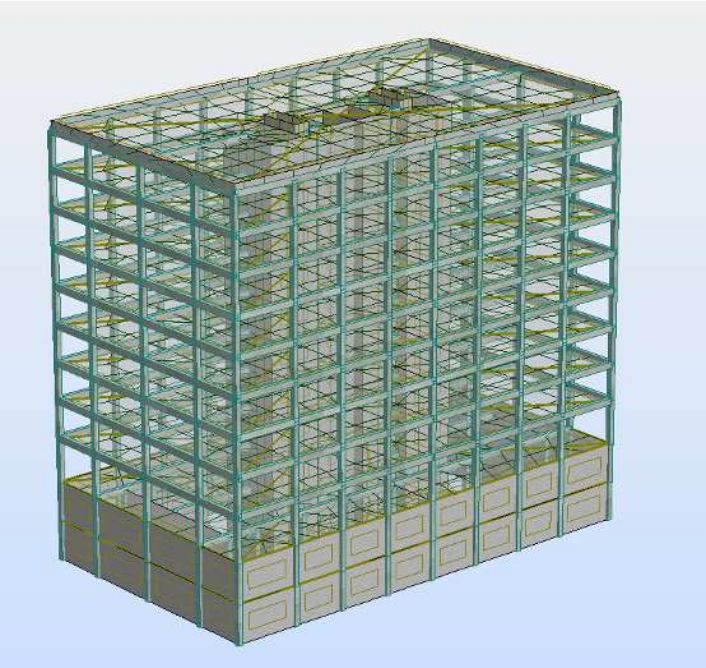
Agenda

1) Office building : typical office building of the French market

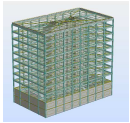
2) Residential building : CasaBuna dwelling in Romania

3) Industrial hall : Steel & concrete portal framing structure in Paris

Office building : typical office building of the French market



Scope of the study

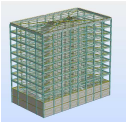


Objective: to compare the environmental quality of the structure of an office building made with different types of structures.

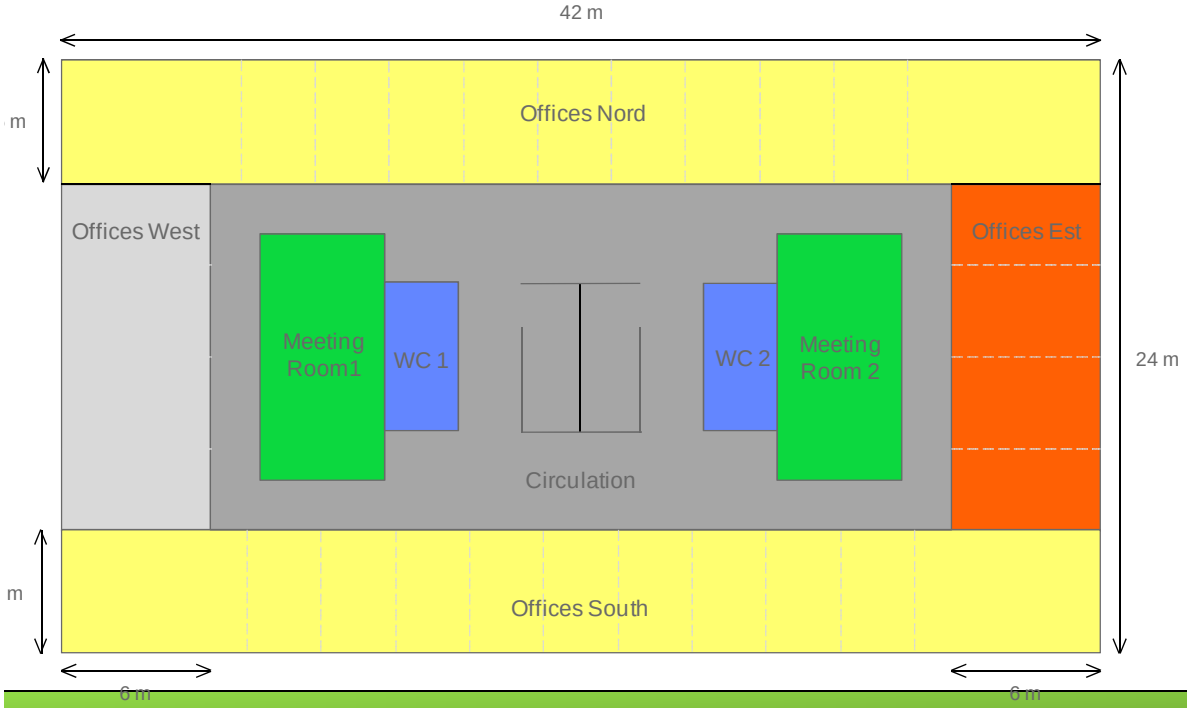
Three types of structural systems are analyzed:

- steel-concrete composite structure
- concrete structure
- optimized steel-concrete composite structure (this optimization has been done on the basis of an ECO-Design)

Definition of the building



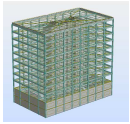
- Surface of the building plan: 42x24 m
- Number of levels in the superstructure (excluding ground floor): 8 levels
- Located in Paris



Project	Building	Envelope	Base Floor	Roof

North - South facade Length	42.4	m
East - West facade length	24.4	m
Floor height	3.4	m
Floor height under ceiling	2.7	m
Number of intermediate floors	8	
Area of intermediate floors	8276.48	m²
Total area of building	9311	m²
Structure only	No	
Building type	Office	

Envelope components

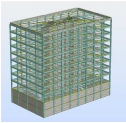


	North/South [m²]	West/East [m2]	Sum [m2]
Walls	908	523	1431
Glazing	389	224	613
Total areas	1297	747	4088

Facade					
Direction	North	East	South	West	
Facade area	1297,44	746,64	1297,44	746,64	m²
Opening area	30	30	30	30	%

- Facade: light steel panels, insulated with 50mm of extruded polystyrene (XPS)
- Windows: double glazing, parts with solar protection
- Roof: insulated with 18 cm of expanded polystyrene (EPS)

Occupancy & Systems



Project | Building | Envelope | Base Floor | Roof | **Occupancy** | Systems | Structure | Floors | Transport

Occupancy related data

Comfort requirements

Office building type →

Heating set-point temperature	20	°C
Cooling set-point temperature	26	°C
Air-flow-rate (heating mode)	0,6	ac/h
Air-flow-rate (cooling mode)	1	ac/h

Project | Building | Envelope | Base Floor | Roof | Occupancy | **Systems** | Structure | Floors | Transport

- Heating & cooling: split system
- Mechanical ventilation with a heat recovery system
- DHW system : electrical boiler

Description of building systems

Heating system

Heating system type	Split (heating)

Cooling system

Cooling type system	Split (cooling)

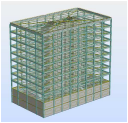
Mechanical ventilation system

Heat recovery system	Yes
Heat recovery percentage	80

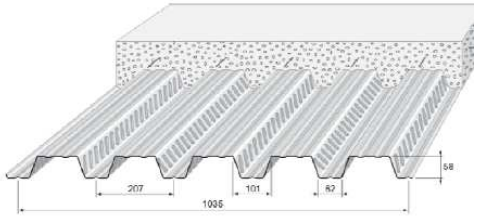
DHW system

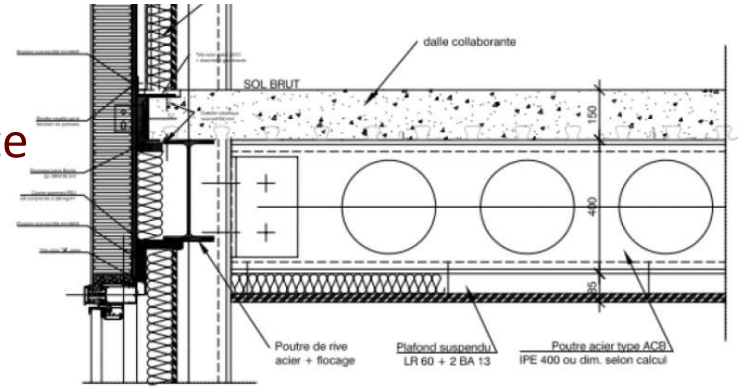
DHW system type	Electric boiler

Structural scenario



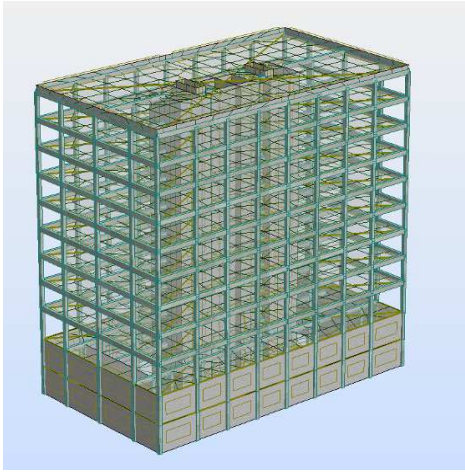
- Steel & concrete Composite structure
  - Composite cellular beams in steel S355
  - Steel Deck COFRA+60 with 15 cm of concrete (C30/37)



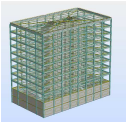


  - Stabilisation by central **concrete core** (C30/37)

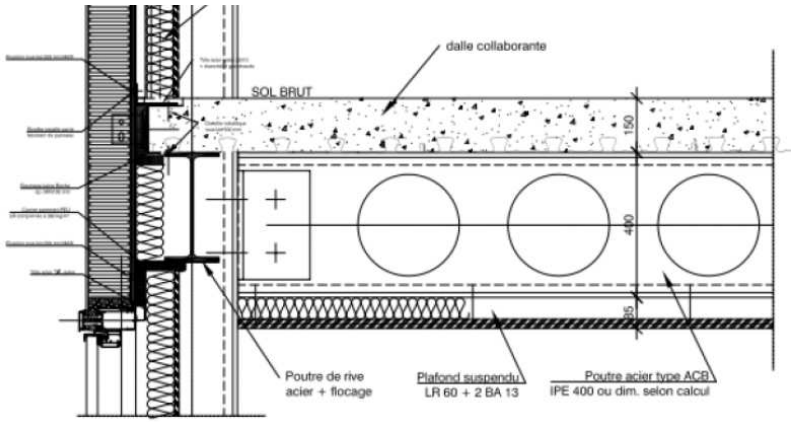
- Concrete structure
  - Steel reinforced concrete for the beams and columns (C30/37)
  - Prefabricated hollow core slab (C30/37)
  - Stabilisation by central **concrete core** (C30/37)

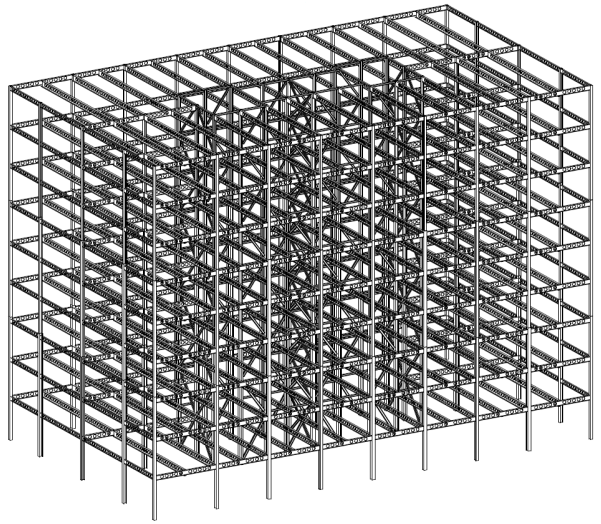


Structural scenario

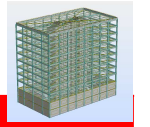


- Eco-optimised Steel & concrete Composite structure
  - Composite cellular beams in steel S460
  - Steel Deck COFRA+60 with 15 cm of concrete (C30/37)
  - Stabilisation by **steel bracing core** (steel S460)





Superstructure of the office building

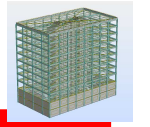


Structural component	Variant 1 Composite structure	Variant 2 Concrete structure	Variant 3 Eco-optimised Composite structure
Main elements	239.9 t of steel sections	1199 t of concrete	197.1 t of steel sections
Steel plate connections	14.994 t	/	11.827 t
Steel reinforcement	/	59.1 t	/
Concrete core	Concrete C30/37 1941 t Steel rebars 44.16 t	Concrete C30/37 1941 t Steel rebars 44.16 t	/
Steel core	/	/	Steel sections 75.46 t Steel plate connections 6.037 t

Bearing structure of the building

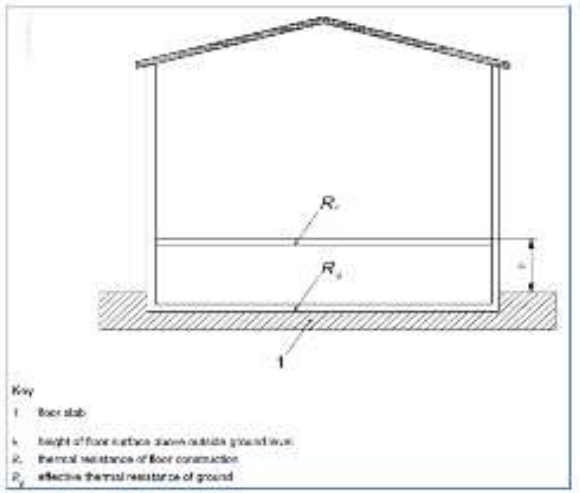
	Steel elements	
Beams (Hot rolled profiles)	239.9	t
Columns (Hot rolled profiles)	0.0	t
Studs	0.0	t
Bolts	0.0	t
Plate Connections	14.99	t

Floor slab of the office building

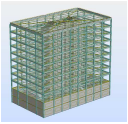


Structural component	Variant 1 Composite structure	Variant 2 Concrete structure	Variant 3 Eco-optimised Composite structure
Steel elements	Cofraplus 60 : 70.6 t	/	Cofraplus 60 : 70.6 t
Total depth	150 mm	240 mm + 70mm of screed	150 mm
Concrete floor	2246 t	4688 t	2246 t
Steel rebars	16.56 t	16.56 t	16.56 t

Steel elements		
Type of slab	Composite slab	
Steel deck	Cofraplus 60	
Thickness of the deck	0.750	mm
Mass of sheeting per m2 of floor	8.53	kg/m²
Mass of sheeting for the building	70.6	t
Minimum depth of the floor	100	mm
Concrete elements		
Total depth of the floor	150.0	mm
Concrete Type	In-situ/Poured	
Concrete Grade	C30/37	
Total mass of the floor concrete (incl. base floor)	2735	t
Steel reinforcement	0.0	t
Total mass of the floor slabs	2805	t



Transport



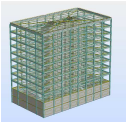
- Transport of Steel :
  - Total weight : 369.6 t
  - Transport : 500 km by regular trucks
- Transport of Concrete :
  - Total weight : 4676 t
  - Transport : 50km by mixer trucks

Roof | Occupancy | Systems | Structure | Floors | Transport | Results

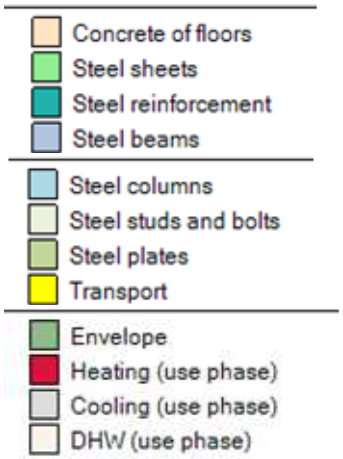
Transport parameters

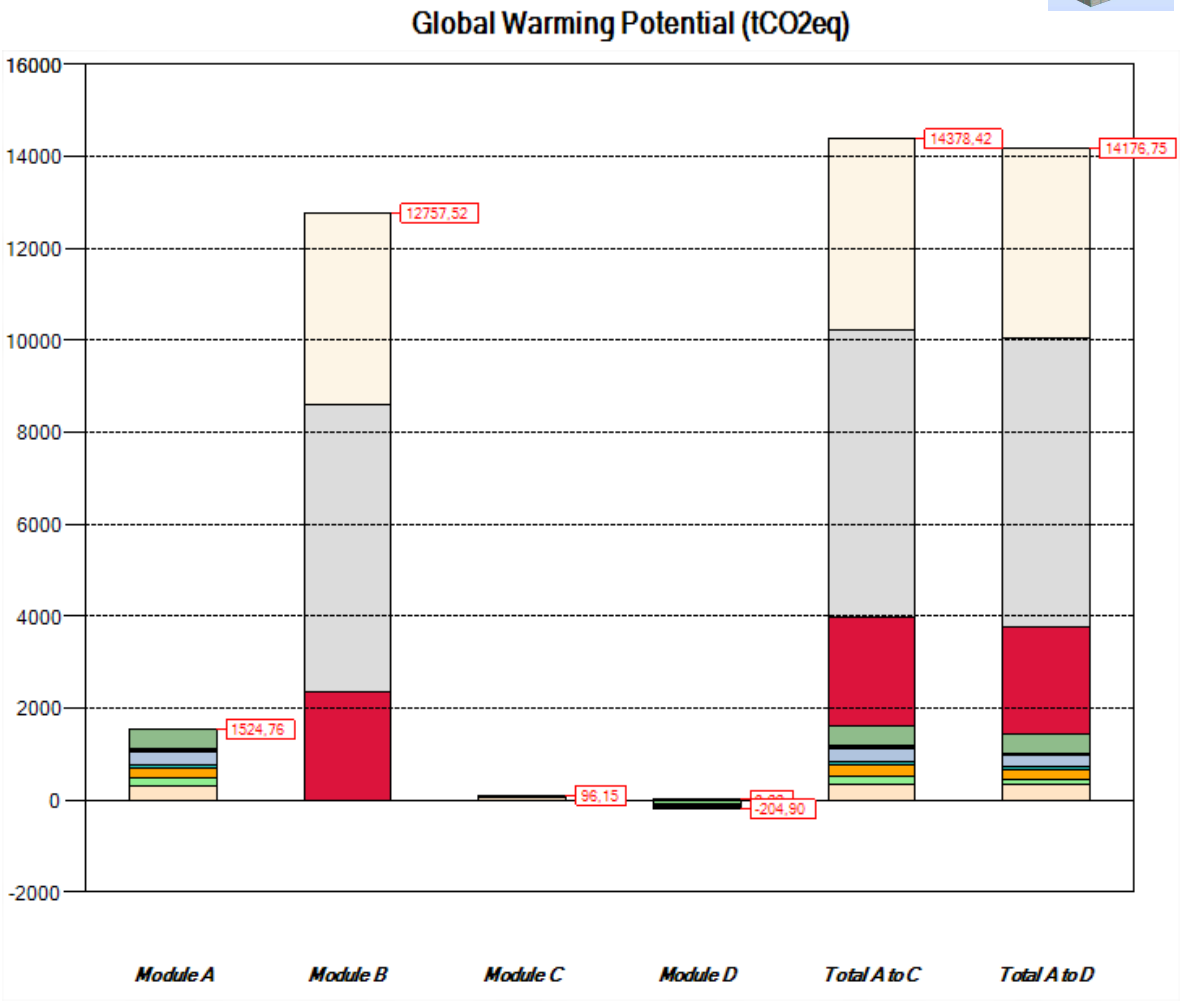
Steel elements		
Total steel transported	369.6	t
Values for the transport impacts	User values	
Mass transported by electric train	0.0	t
Distance	0.0	km
Mass transported by regular trucks	369.6	t
Distance	500	km
Concrete elements		
Total concrete transported	4676	t
Concrete produced on site	4676	t
Distance by mixer trucks	50.0	km
Prefabricated concrete	0.0	t
Distance by regular trucks	0.0	km

Global results of the office building (steel S355)

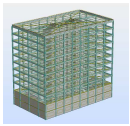


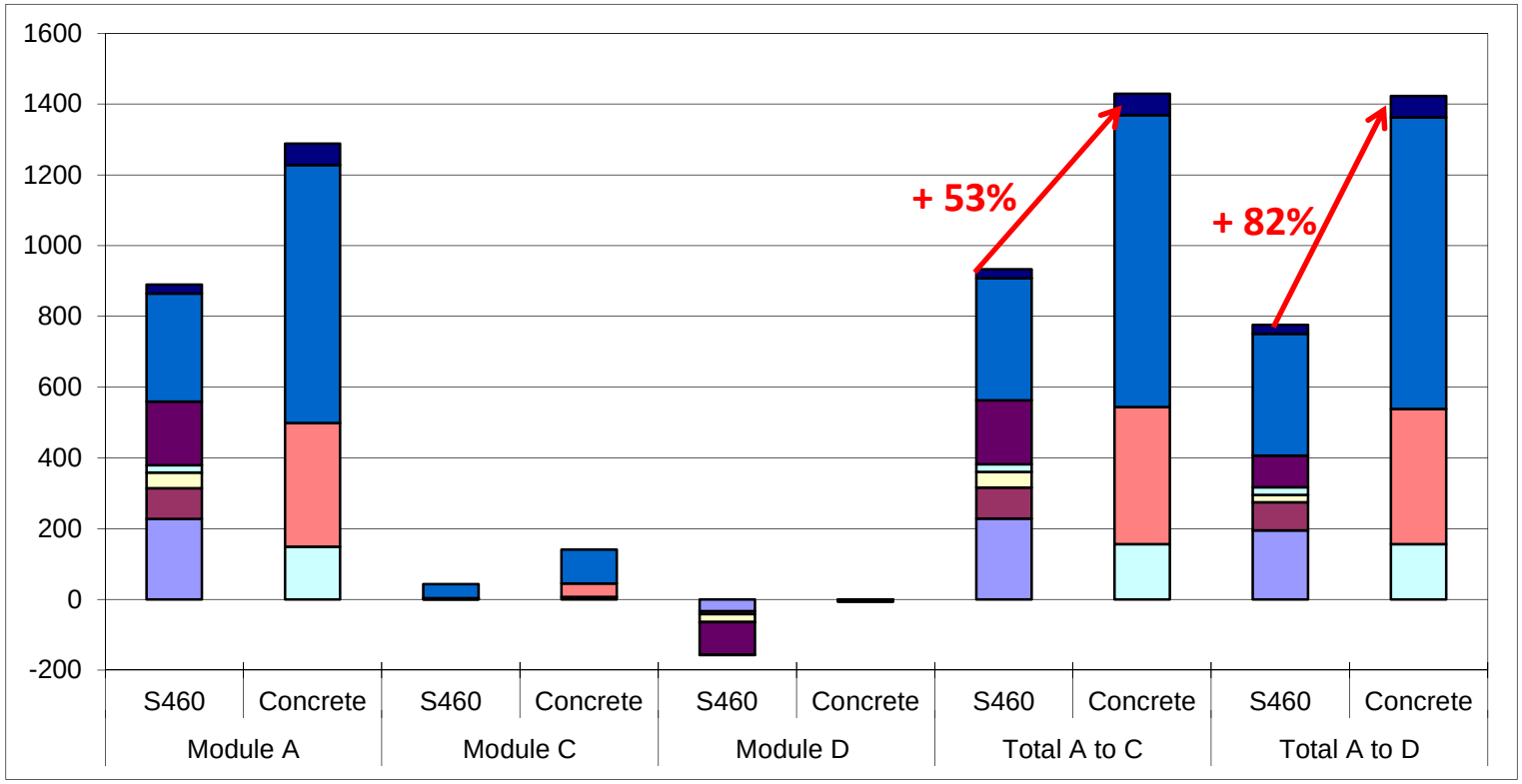
- The use phase (module B) accounts for about 90% of the global GWP impact, for any type of structure



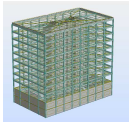


Results : steel S460 vs concrete structure GWP impacts





Results : conclusions



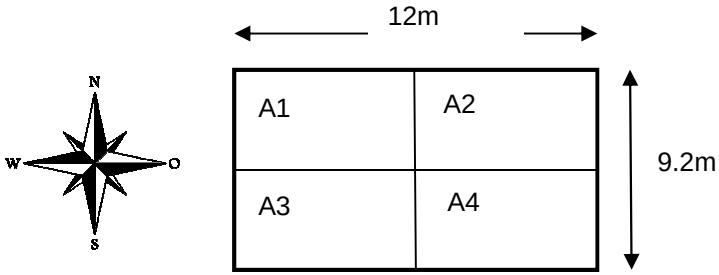
- Exploitation and activity of buildings represent a large part of the environmental footprint. So, ***effective façade systems*** can strongly optimize the LCA of the building. But this is independent of the ***structural system***.

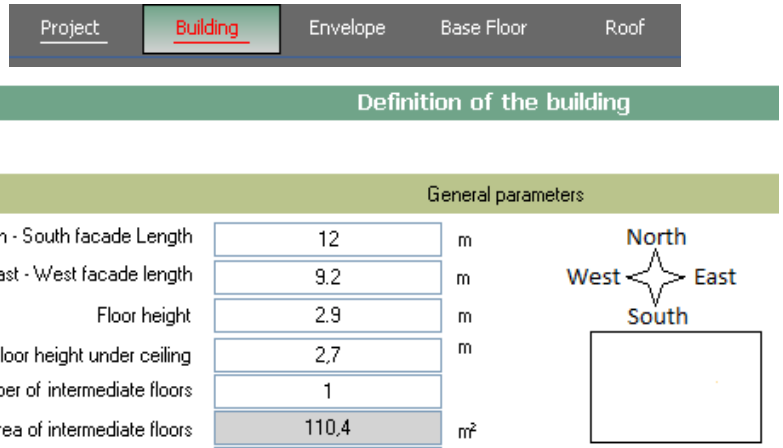
- ***Composite Structures*** made of ***hot rolled sections*** are more sustainable than ***concrete*** one, even without taking into account the recycling. Thanks to the ***recycling*** of material at the ***End of Life***, the difference between steel and concrete solution increases (about 82%)

- Minimizing the use of material by using ***High Strength Steel*** is beneficial for the environment.

Residential building : CasaBuna dwelling in Romania

Definition of the building





- 4 apartments of 55m² net floor area, equally arranged over 2 floors.
- Located in Timisoara

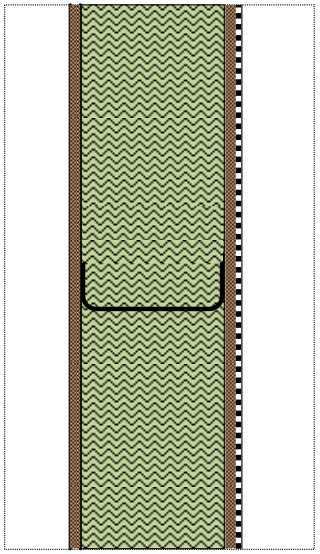
Envelope components

	North/South [m²]	West/East [m²]	Sum [m²]
Walls	47	41	87
Glazing	22	12	34
Total areas	69	53	122

Definition of the building enveloppe

Facade

Direction	North	East	South	West	
Facade area	69.6	53.36	69.6	53.36	m²
Opening area	22	12	22	12	%



- Facade : light steel panels, insulated with 120mm of rockwool
- Windows : double glazing & Aluminium framing
- Roof : insulated with 18 cm of expanded polystyrene

Occupancy & Systems

Project | Building | Envelope | Base Floor | Roof | **Occupancy** | Systems | Structure | Floors | Transport

Residential building type

Occupancy related data

Comfort requirements

Heating set-point temperature	20	°C
Cooling set-point temperature	26	°C
Air-flow-rate (heating mode)	0,6	ac/h
Air-flow-rate (cooling mode)	1	ac/h

Project | Building | Envelope | Base Floor | Roof | Occupancy | **Systems** | Structure | Floors | Transport

- Heating system : a gas fuel heater
- No cooling system
- No mechanical ventilation
- DHW system : electrical boiler

Description of building systems

Heating system

Heating system type: Gas fuel heater

Cooling system

Cooling type system: No cooling

Mechanical ventilation system

Heat recovery system: No

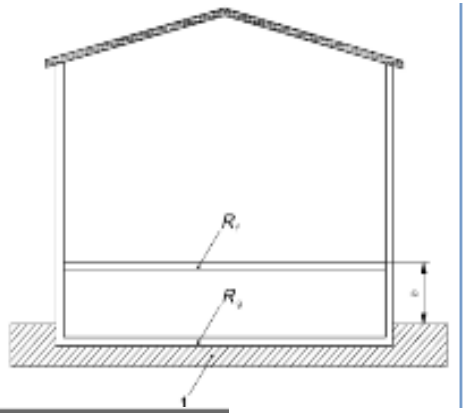
DHW system

DHW system type: Electric boiler

Base floor & Structure of the dwelling

Project | Building | Envelope | **Base Floor** | Roof | Occupancy | Systems | Structure | Floors | Transport | Results

- Suspended base floor, of 0.2m thick made of reinforced concrete (0.7t of rebars)



Project | Building | Envelope | Base Floor | Roof | Occupancy | Systems | **Structure** | Floors | Transport

- Light steel framing included in the facade & roof component
  ➡ no additional steel structural elements

	Steel elements	
Beams (Hot rolled profiles)	0	t
Columns (Hot rolled profiles)	0	t
Studs	0,0	t
Bolts	0	t
Plate Connections	0,0	t
Total mass of structure	0,0	t

Transport

- Transport of Steel :
  - Total weight : 1.6 tons (Rebars)
  - Transport : Average European transportation for steel, for 1 t on average European distance
- Transport of Concrete :
  - Total weight : 52 tons (Base floor)
  - Transport : 30km by mixer trucks

Roof | Occupancy | Systems | Structure | Floors | Transport | Results

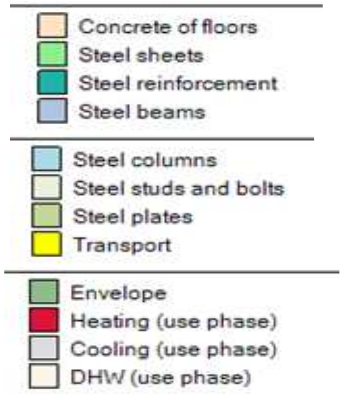
Transport parameters

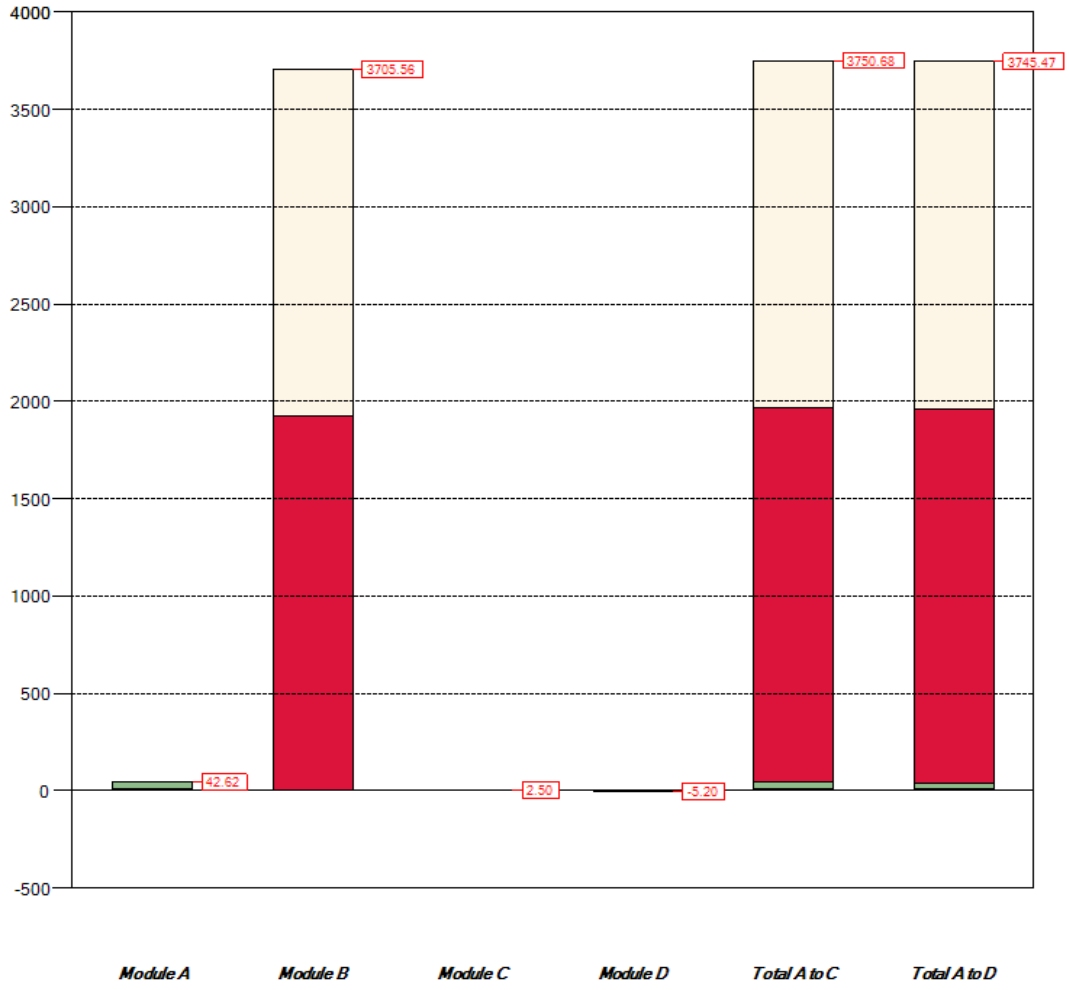
Steel elements		
Total steel transported	1,583	t
Values for the transport impacts	Average values	

Concrete elements		
Total concrete transported	52,11	t
Concrete produced on site	52,11	t
Distance by mixer trucks	30,0	km
Prefabricated concrete	0,0	t
Distance by regular trucks	0,0	km

Global results of the CasaBuna dwelling

- The use phase (module B) accounts for about 99% of the global GWP impact





Heating consumptions

Use phase heating

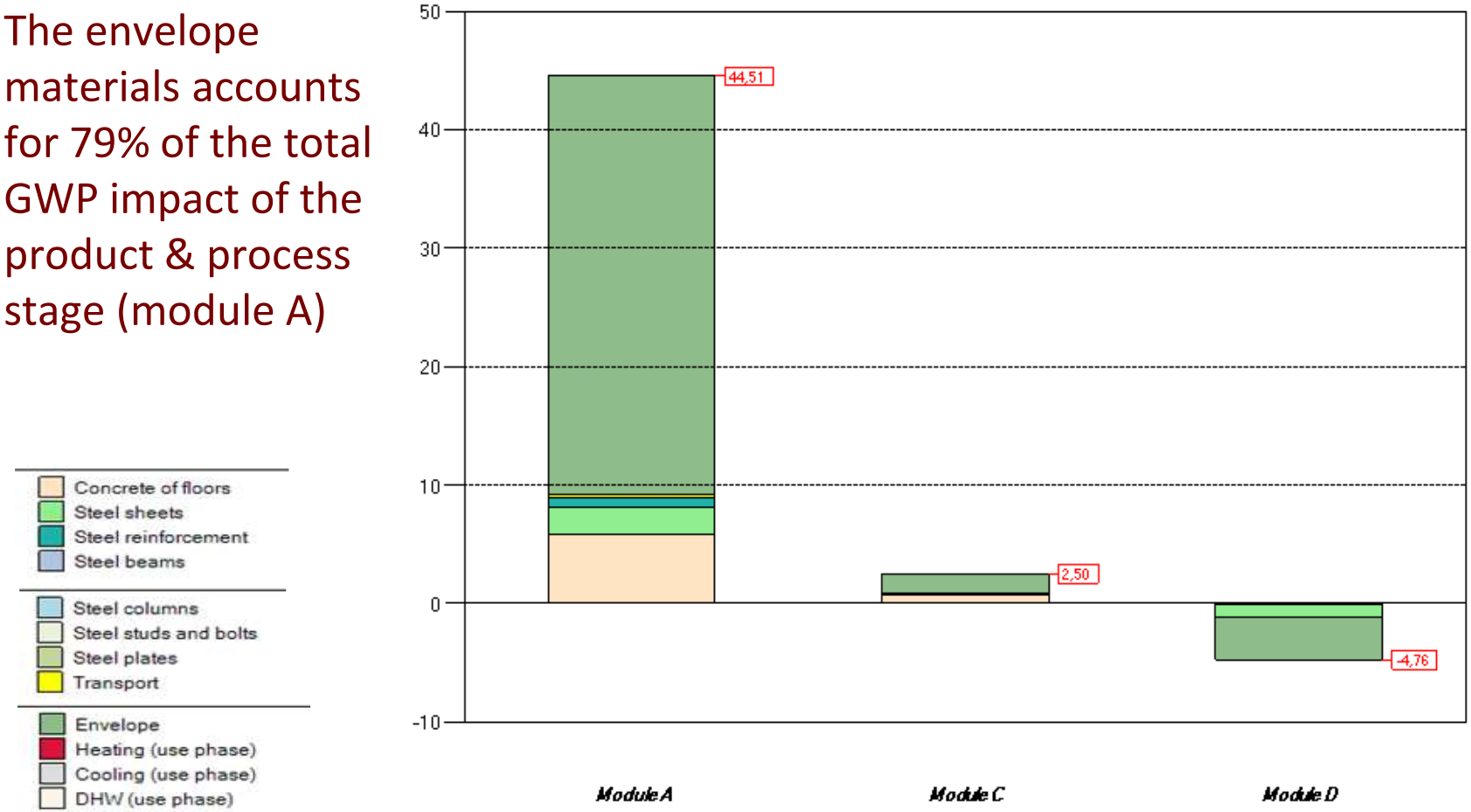
Energy for space heating					
Heat transfer by transmission					
Walls	Glazing	Ext Floor	Roof	Ground	Total
kWh/year	kWh/year	kWh/year	kWh/year	kWh/year	kWh/year
4845.1	5968.3	0.0	3328.8	3008.7	16882.1
Heat Transfer by ventilation			Heat gains		
Ventilation			Glazed	Opaque	Internal
kWh/year			kWh/year	kWh/year	kWh/year
8963.6			14064.4	783.0	10757.0

Energy need for heating												
Qh,nd	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
kWh	911.2	606.4	435.1	129.2	0.0	0.0	0.0	0.0	0.0	100.9	454.8	816.6
kWh/m²	4.1	2.7	2.0	0.6	0.0	0.0	0.0	0.0	0.0	0.5	2.1	3.7

Energy Breakdowns		
Building totals for heating		
Energy need	3454.2	kWh/year
	15.6	kWh/m²/year
Delivered energy	3970.4	kWh/year
COP : 0.87	18.0	kWh/m²/year
Primary	341.5	kgoe/year
fconv : 0.086	1.5	kgoe/m²/year

Results : materials impacts

- The envelope materials accounts for 79% of the total GWP impact of the product & process stage (module A)

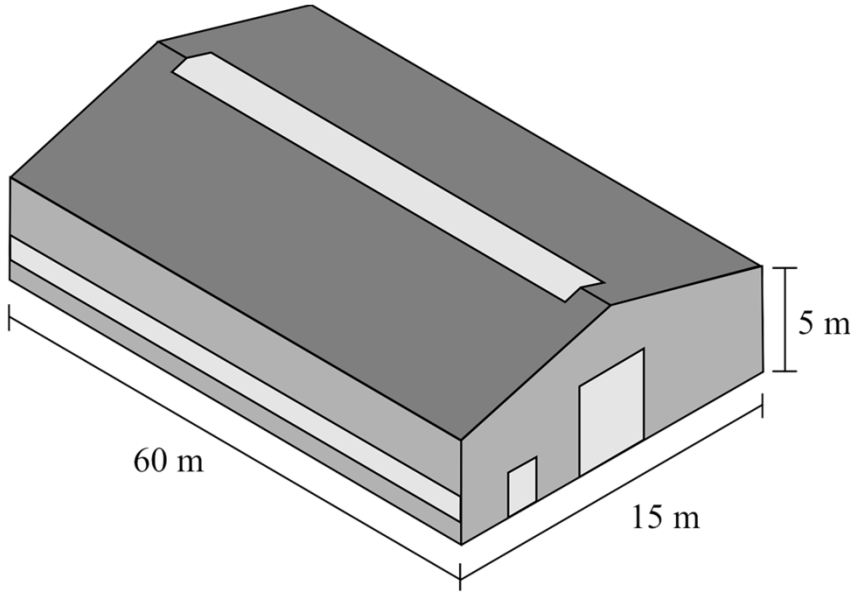


Results : conclusions

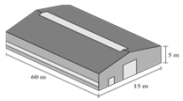
- ***Use phase*** (Module B) of residential buildings represents nearly all the environmental footprint.

  The structural system is nearly neglectable. So, effective façade systems can strongly optimize the Life cycle assessment of the building

Industrial hall : Steel & concrete portal framing structure in Paris



Scope of the study

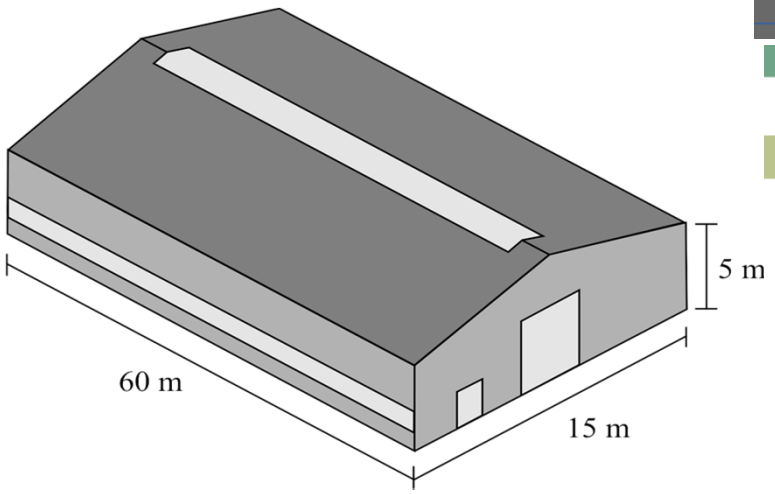


Compare the LCA of an industrial building, based on 2 different structural systems:

- Pinned-base portal frame, composed of hot rolled profiles

- Rigid-base columns, pinned girder, composed of reinforced concrete columns & girder

Definition of the building



Project | Building | Envelope | Base Floor | Roof | Occupancy | Systems | Structure

Definition of the building

General parameters

North - South facade Length	60	m
East - West facade length	15	m
Floor height	5	m
Floor height under ceiling	5	m
Number of intermediate floors	0	
Area of intermediate floors	0	m²
Total area of building	900,0	m²
Structure only	No	
Building type	Industrial	

North
West East
South

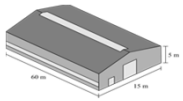
- 900m² industrial hall
- Located in Paris

Location

Country	France
Location	Paris

Display

Envelope components



- Facade : 80mm PUR sandwich panels

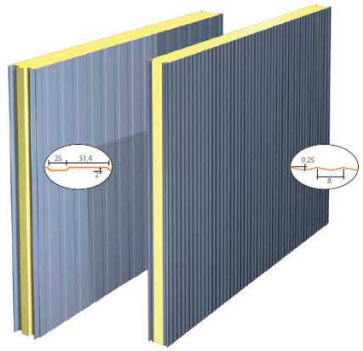
Energetic variant : 200mm PUR sandwich panels

- Windows : double glazing & Aluminium framing

Project | Building | Envelope | Base Floor | Roof | Occupancy | Systems | Structure

Facade properties

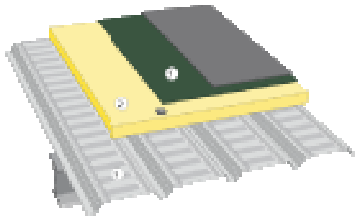
Wall type	Sandwich panel (PUR 80 mm)	
U-value for walls	0,3	W/(m².K)
Opening type	Double glazing	
U-value for openings	2,9	W/(m².K)
Shading device type	No shading device	
Shutter type	No shutter	



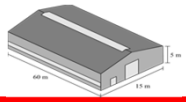
- Roof : Waterproof membranes insulation with 140mm of mineral wool

Roof

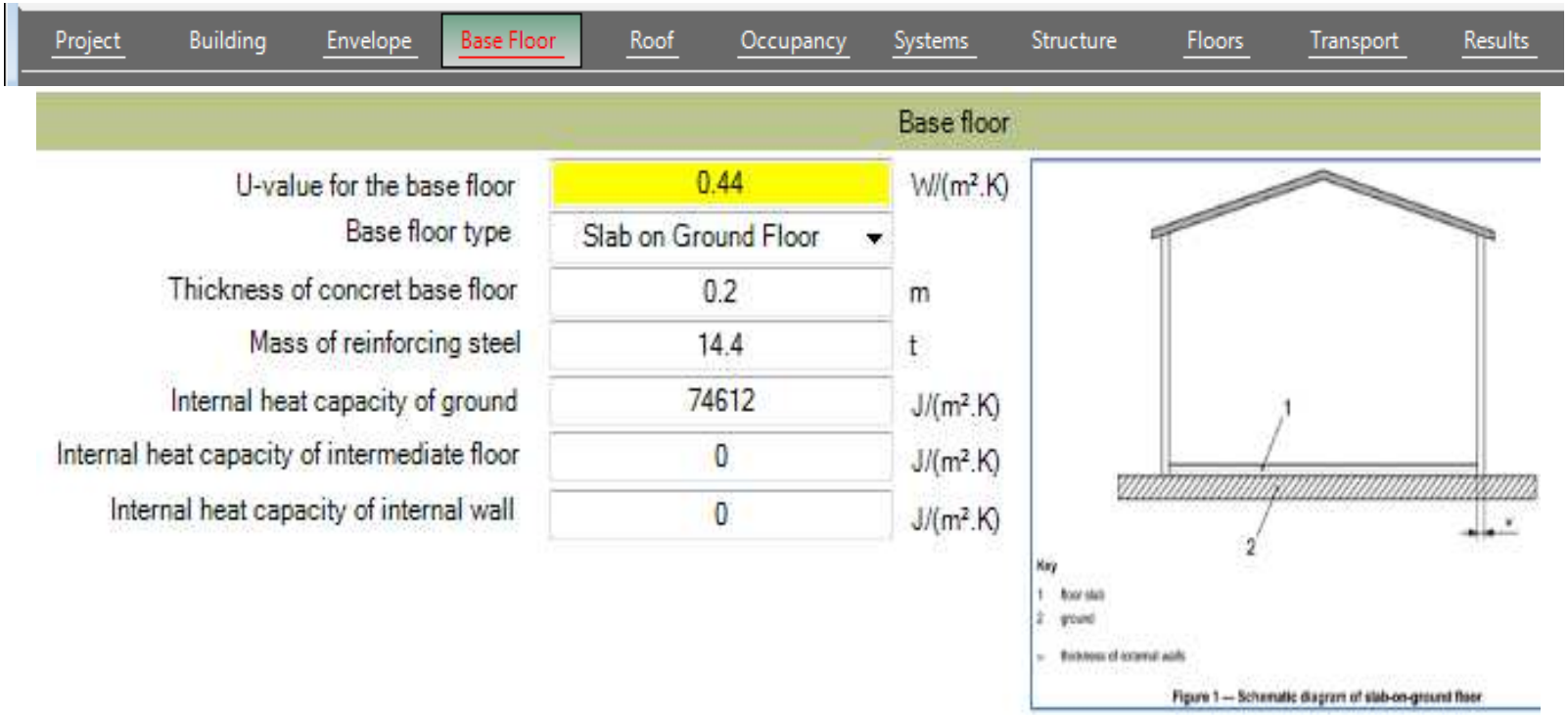
Roof type	Waterproof membrane	
U-value for the roof (flat part)	0,31	W/(m².K)



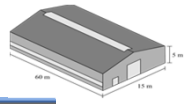
Base floor industrial hall



Structural component	Variant 1 Steel frame S235	Variant 2 Steel frame S460	Variant 3 Concrete frame
Base floor	Concrete : 425.7 kg Rebars : 14.4 t		



Occupancy & Systems



Project | Building | Envelope | Base Floor | Roof | **Occupancy** | Systems | Structure | Floors | Transport

Industrial building type →

Comfort requirements		
Heating set-point temperature	18	°C
Cooling set-point temperature	26	°C
Air-flow-rate (heating mode)	0,6	ac/h
Air-flow-rate (cooling mode)	1	ac/h

Project | Building | Envelope | Base Floor | Roof | Occupancy | **Systems** | Structure | Floors | Transport

- Heating system : a gas fuel heater
- No cooling system
- No mechanical ventilation
- No DHW system

Description of building systems

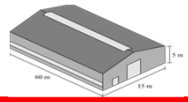
Heating system	
Heating system type	Gas fuel heater

Cooling system	
Cooling type system	No cooling

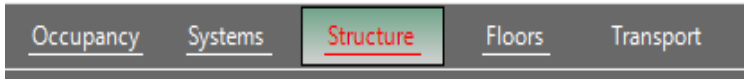
Mechanical ventilation system	
Heat recovery system	No

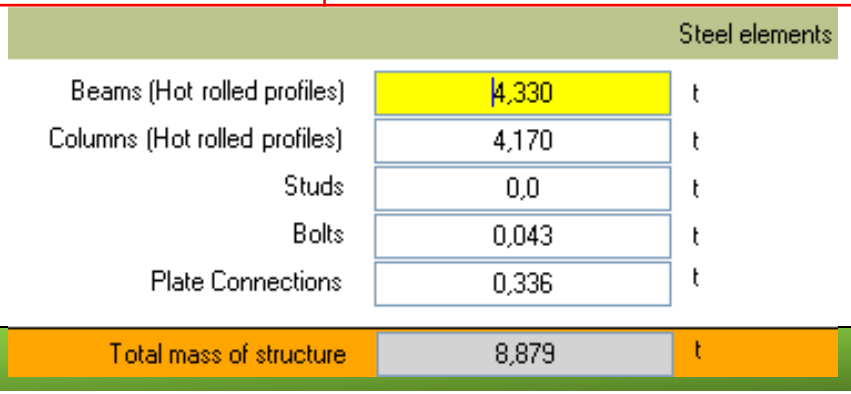
DHW system	
DHW system type	No DHW

Structure industrial hall

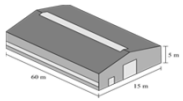


Structural component	Variant 1 Steel frame S235	Variant 2 Steel frame S460	Variant 3 Concrete frame
Girder	IPE 450 (6.88t)	IPE 330 (4.33 t)	Precast concrete unit T80 (34.19 t) Reinforcement BSt500 202.5 kg/m³ (2.93 t)
Columns	Primary : IPE400 Secondary : HEA480 (4.17 t)	Primary : IPE400 Secondary : HEA480 (4.17 t)	Concrete section 0.4x0.4m C30/37 (30.12 t) Reinforcement BSt500 108.1 kg/m³ (1.38 t)
Bolts	43 kg		/
Plate connections	336 kg		/





Transport



- Transport of Steel :
  - Total weight : 26 tons of

    Beams + Columns + Connections elements
  - Transport : Average European transportation for steel, for 1t on average European distance
- Transport of Concrete :
  - Total weight : 425 tons of

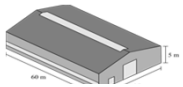
    Beams + Columns
  - Transport : 30 km by mixer trucks

Transport parameters

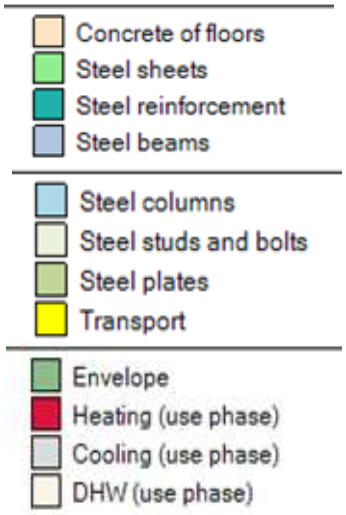
Steel elements		
Total steel transported	25.83	t
Values for the transport impacts	Average values	

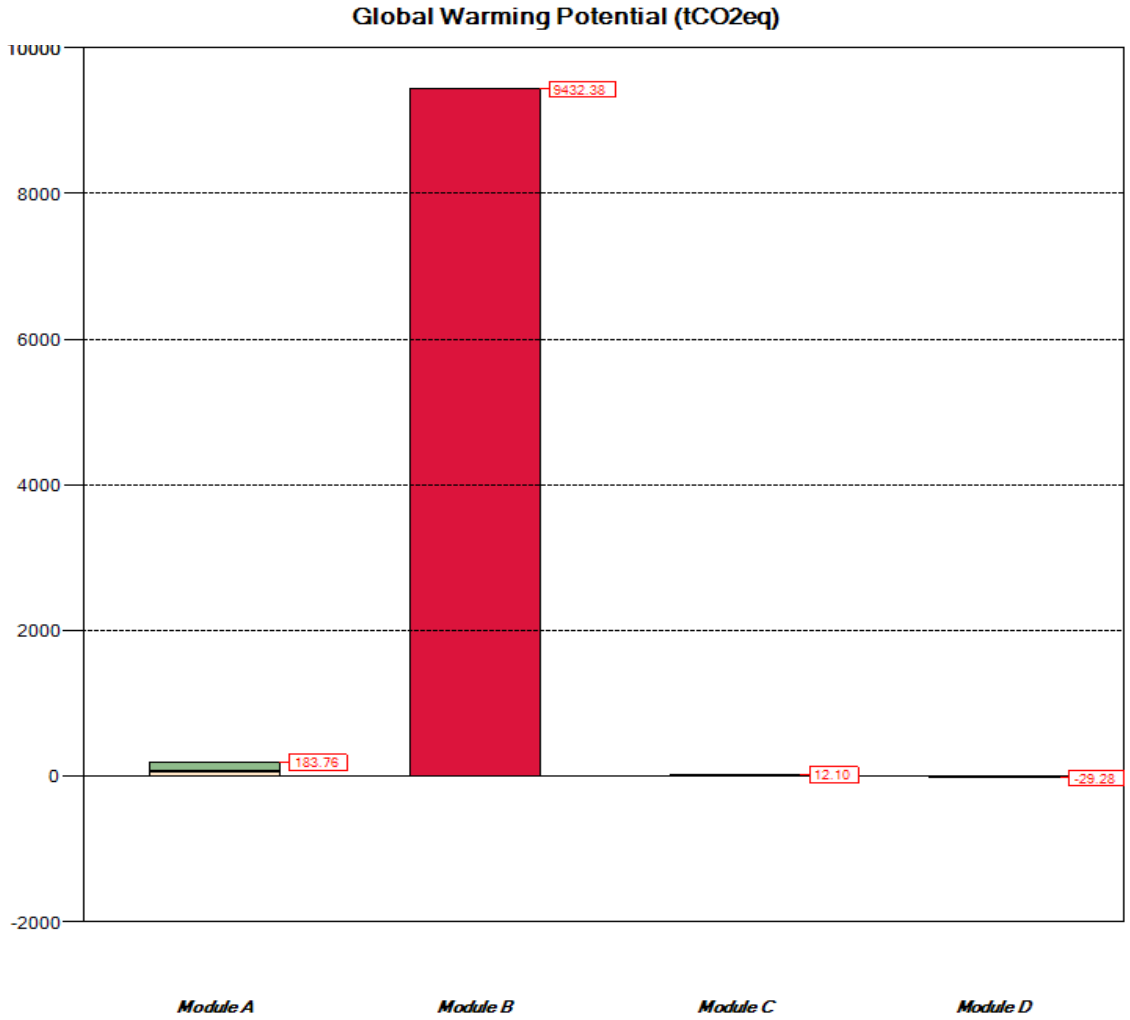
Concrete elements		
Total concrete transported	424.8	t
Concrete produced on site	424.8	t
Distance by mixer trucks	30.0	km
Prefabricated concrete	0.0	t
Distance by regular trucks	0.0	km

Global results of the industrial hall

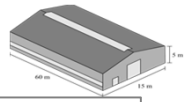


- ***Use phase*** (Module B) accounts for about 99% of the global GWP impact, for any type of structure industrial hall

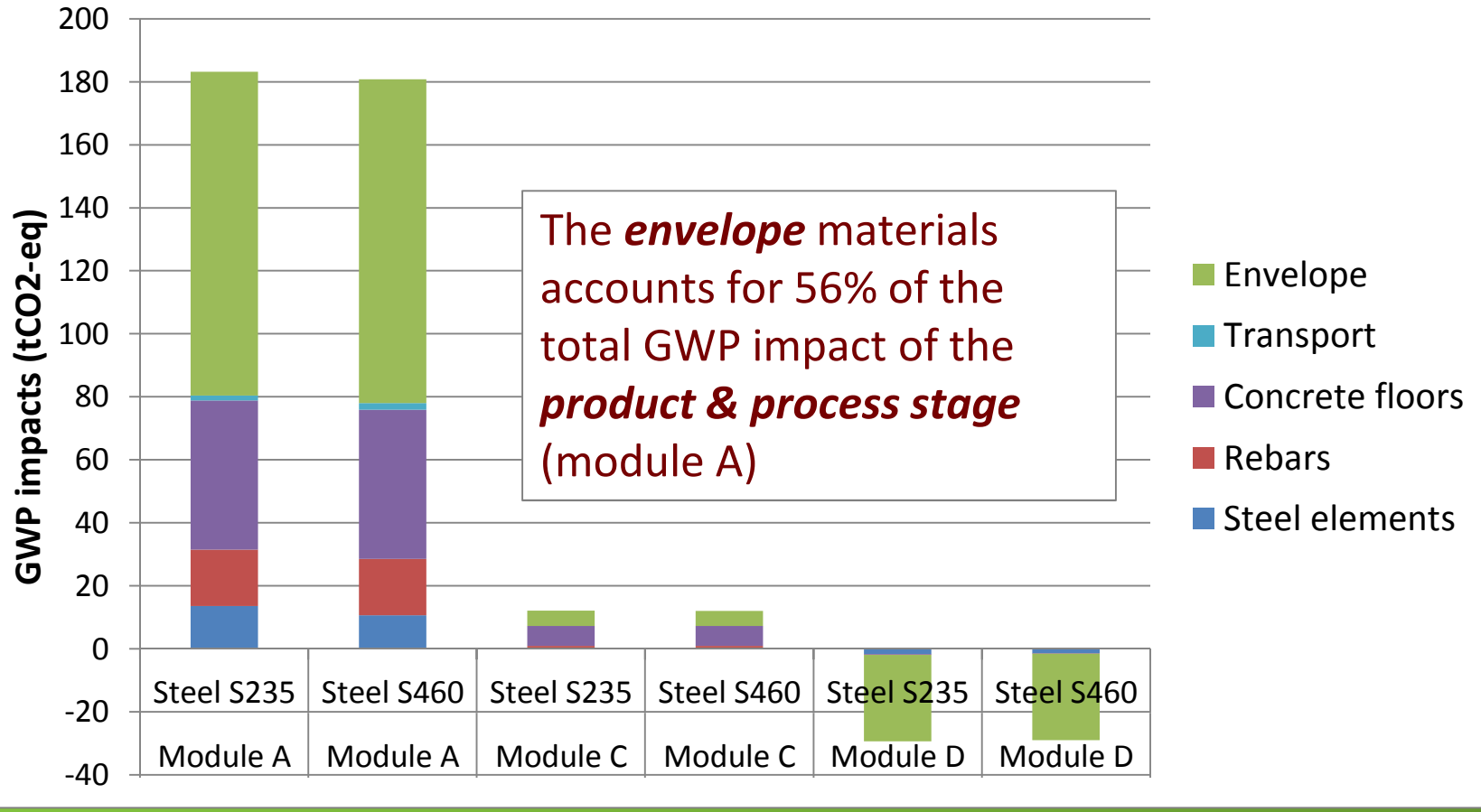




Results : steel structures

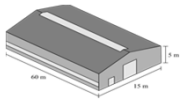


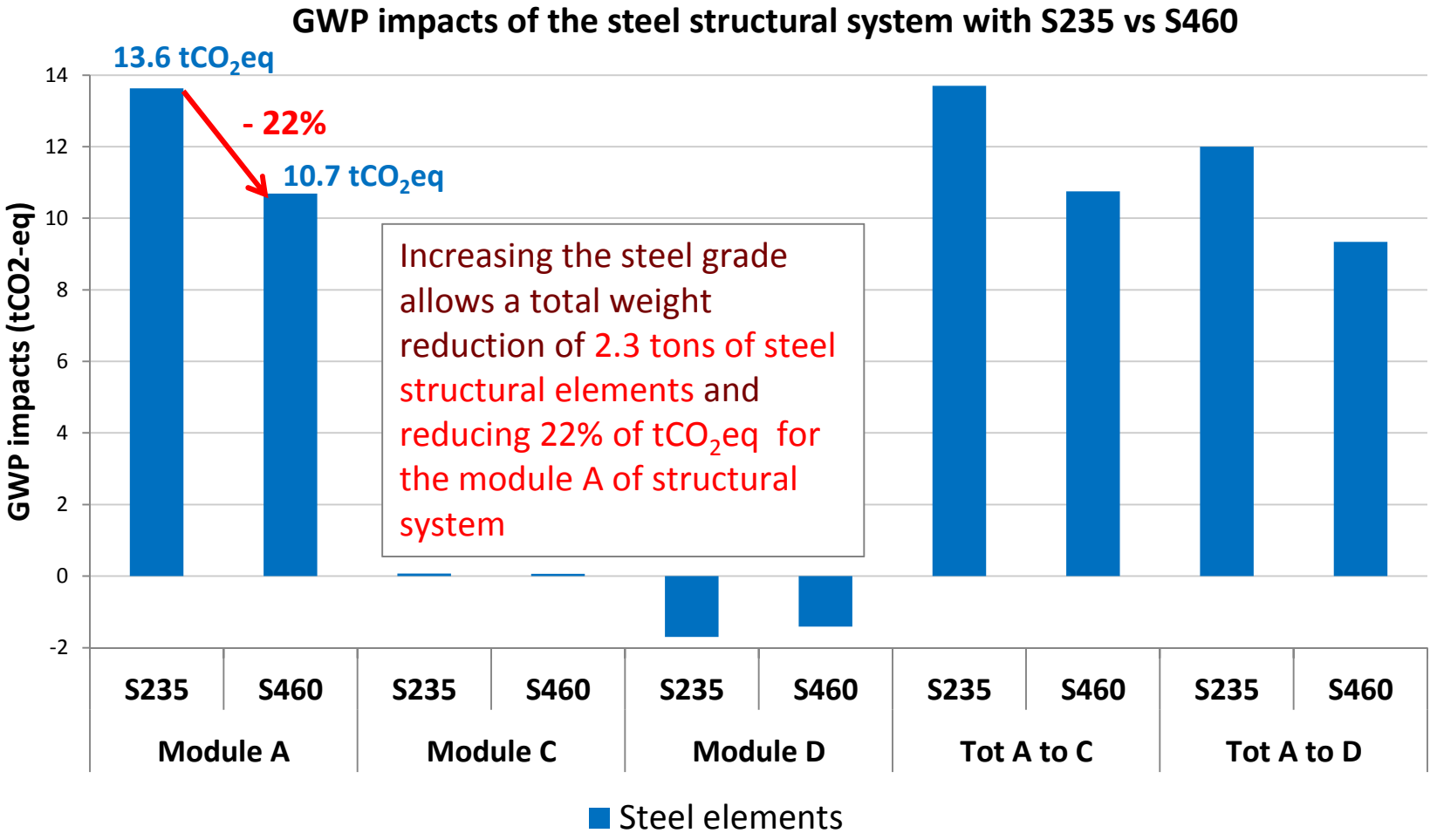
Comparison of the GWP impacts of the steel structural system with S235 vs S460



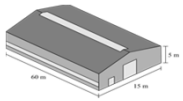
The ***envelope*** materials accounts for 56% of the total GWP impact of the ***product & process stage*** (module A)

Results : steel structures





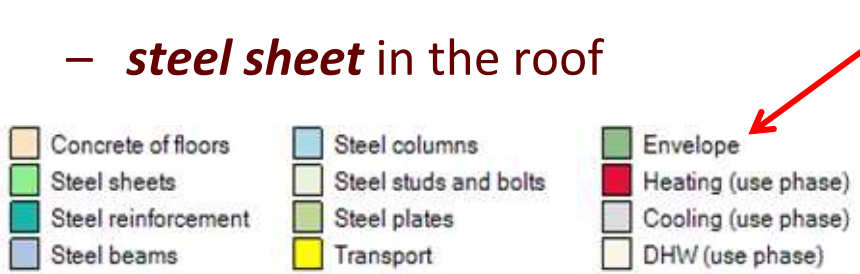
Results : Module D of steel S460 structure



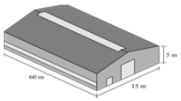
- **Module D** (Benefits and loads beyond the system boundary) of the S460 case study has a total GWP impact of:

  -27.6 t CO_2eq

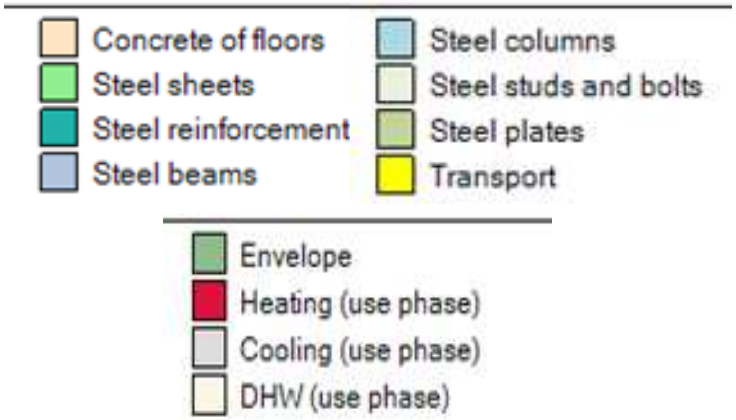
- Highlight of the benefits of the recycled materials within the envelope elements:
  - ***light steel framing*** elements in facade components and
  - ***steel sheet*** in the roof



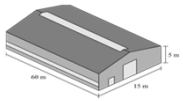
Results : concrete structure

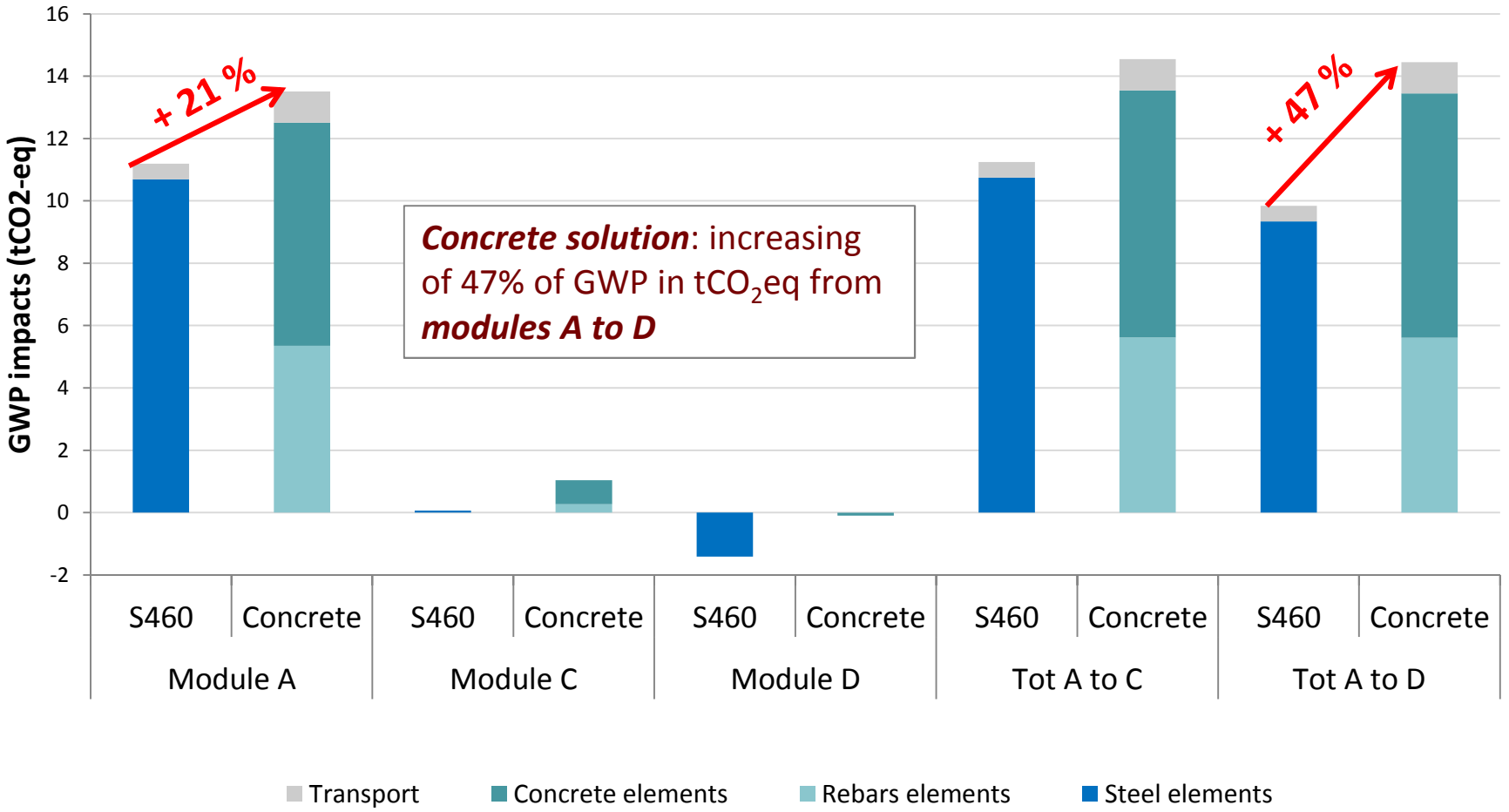


- **Module A:** total GWP impact = 183 tCO_2eq
- Total GWP impacts due to the ***structural system*** = 80 tCO_2eq, with 40% due to the floor concrete.

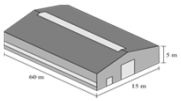


Results : steel vs concrete structure GWP impacts

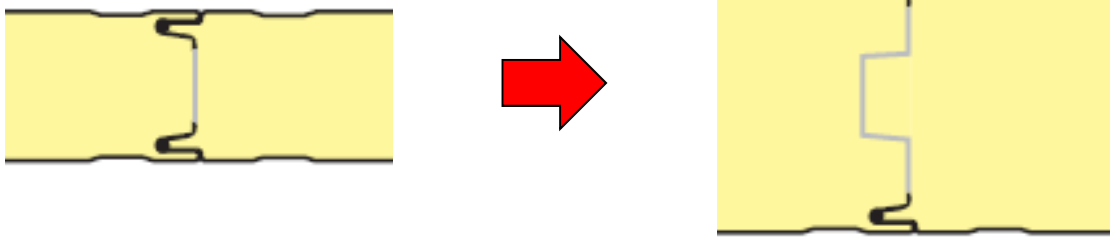




Environmental benefits due to increase of the insulation thickness



80 mm

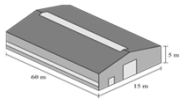


200 mm

- Easy with AMECO3 : user-friendly software
- ***Use phase*** (module B): net saving of 888 tCO_2-eq
- ***Product & process stage*** (module A) : increase of 13 tCO_2eq, due to the extra amount of insulation

➢ Compared to the energy consumption reduction, this is negligible, highlighting the interest of improving the energy efficiency of a building.

Results : conclusions



- ***Exploitation and activity*** of buildings represent a large part of the environmental footprint. So, effective façade systems can strongly optimize the LCA of the building
- ***Steel Structures*** made of ***hot rolled sections*** are more sustainable than **concrete** one, even without taking into account the recycling. Thanks to the ***recycling*** of materials at the ***End of Life*** (infinite recycling of steel and valorization of crushed concrete), the difference between steel and concrete solution increases
- Minimizing the use of material by using ***High Strength Steel*** is beneficial for the environment.