Research Fund for Coal & Steel

Large Valorisation on Sustainability of Steel Structures

Design Guide

Université de Liège

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Introduction

- The design guide aims at providing information on the different steps to be crossed for the environmental assessment of steel and composite buildings in AMECO 3 software

- The design guide focuses on:

  - The description of the calculation process
  - A guidance on how to use AMECO 3 tool
  - Application of AMECO 3 on case studies

Introduction

- The design guide includes 8 chapters:
  - Chapter 1 – Introduction and aim
  - Chapter 2 – Computer code and environment
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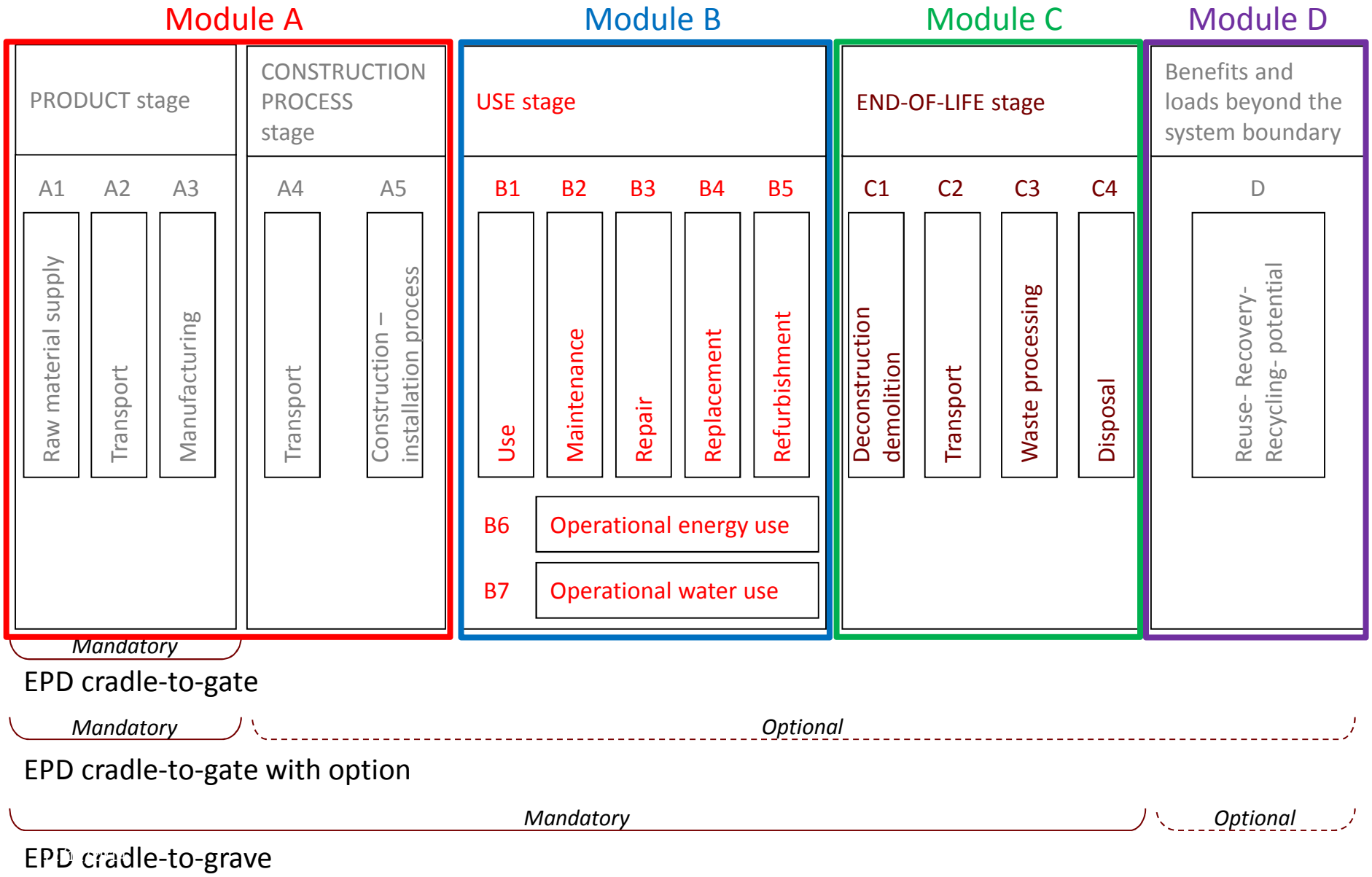
General features of AMECO 3

- AMECO 3 deals with either buildings or bridges made of steel and concrete
- It takes into account 24 environmental impact indicators included in the following groups:
  - Quantities describing environmental impacts
  - Quantities describing resources use, secondary materials and fuels and use of water
  - Other environmental information describing waste categories
  - Other environmental information describing output flows

General features of AMECO 3

- Further more, each indicator is included into one of the following 4 modules as previously presented:
  - Module A: Product and construction process stage
  - Module B: Use stage
  - Module C: End of life
  - Module D: Benefits and loads beyond the system boundaries


Module A
Module B
Module C
Module D
PRODUCT stage
CONSTRUCTION PROCESS stage
USE stage
END-OF-LIFE stage
Benefits and loads beyond the system boundary
A1
A2
A3
A4
A5
B1
B2
B3
B4
B5
C1
C2
C3
C4
D
Raw material supply
Transport
Manufacturing
Transport
Construction – installation process
Use
Maintenance
Repair
Replacement
Refurbishment
Deconstruction demolition
Transport
Waste processing
Disposal
Reuse- Recovery- Recycling- potential
B6
Operational energy use
B7
Operational water use
Mandatory
EPD cradle-to-gate
Mandatory
Optional
EPD cradle-to-gate with option
Mandatory
Optional
EPD cradle-to-grave

General features of AMECO 3

- Considered impact indicators

Environmental impacts				
Index	Data available	Abbreviation	Designation	Unit
1	Yes	GWP	Global Warming Potential	tCO_2eq
2	Yes	ODP	Ozone Depletion Potential	t_{CFCeq}
3	Yes	AP	Acidification Potential	t_{SO2eq}
4	Yes	EP	Eutrophication Potential	t_{PO4eq}
5	Yes	POCP	Photochemical Ozone Creation Potential	$t_{Etheneeq}$
6	Yes	ADP-e	Abiotic Depletion Potential – elements	t_{Sbeq}
7	Yes	ADP-ff	Abiotic Depletion Potential – fossil fuels	GJ NCV

General features of AMECO 3

- Considered impact indicators

Resource use, secondary material and fuels				
Index	Data available	Abbreviation	Designation	Unit
8	No	RPE	Use of renewable primary energy excluding renewable primary energy resources used as raw materials	GJ NCV
9	No	RER	Use of renewable energy resources used as raw materials	GJ NCV
10	Yes	RPE-total	Total use of renewable primary energy (primary energy and primary energy resources used as raw materials)	GJ NCV
11	No	Non-RPE	Use of non renewable primary energy excluding non renewable primary energy resources used as raw materials	GJ NCV
12	No	Non-RER	Use of non renewable energy resources used as raw materials	GJ NCV
13	Yes	Non-RPE-total	Total use of non renewable primary energy (primary energy and primary energy resources used as raw materials)	GJ NCV
14	No	SM	Use of secondary material	t
15	No	RSF	Use of renewable secondary fuels	GJ NCV
16	No	Non-RSF	Use of non renewable secondary fuels	GJ NCV
17	Yes	NFW	Use of net fresh water	10^3m^3

General features of AMECO 3

- Considered impact indicators

Other environmental information describing waste categories				
Index	Data available	Abbreviation	Designation	Unit
18	Yes	HWD	Hazardous waste disposed	t
19	Yes	Non-HWD	Non hazardous waste disposed	t
20	Yes	RWD	Radioactive waste disposed	t

Other environmental information describing output flows				
Index	Data available	Abbreviation	Designation	Unit
21	No	CR	Components for reuse	t
22	No	MR	Materials for recycling	t
23	No	MER	Materials for energy recovery	t
24	No	EE	Exported energy	t

General features of AMECO 3

- The main additional feature of AMECO 3 in comparison to the previous version is the introduction of the use phase on the calculation of the environmental impact
- It allows the estimation of energy needs for a variety of building systems
- Their calculation is based on several international norms such as ISO-13370, ISO-13789 and ISO-13790 as well as European norm (EN 15316)
- The extension of the use phase is only available for buildings!

Definition of a project in AMECO 3

- The calculation of impacts needs several quantities describing:
  - The structure
  - The way elements are transported to the site
  - Information on how the elements will be used after demolition of the structure

- Steps to be crossed for the definition of a building structure:
  - Definition of general parameters (main geometry of the building, location of the building, use of the building…)
  - Definition of the floor slabs
  - Definition of the bearing structure
  - Building envelope (façades and roof)
  - Building occupancy (divided in three periods per day and distinction made between business and weekend days))
  - Building systems (heating system, cooling system, ventilation…)
  - Transport assumptions
  - End of life

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Calculation process

- As previously mentioned, AMECO 3 uses 24 environmental impact indicators in its calculation process which are shared between four modules:
  - Module A: Product and construction process stage
  - Module B: Use stage
  - Module C: End of life
  - Module D: Benefits and loads beyond the system boundaries
- These 24 indicators follow the same equations
- Only coefficients used within the equations, called 'impact coefficients', are changed
- These coefficients are predefined in AMECO 3 and cannot be modified by the user

Calculation process

- Considered impact coefficients

Impact coefficient considered	Denomination
RER: Steel plate worldsteel	$k_{RERStPl}$
RER: Steel sections worldsteel	$k_{RERStSec}$
GLO: Steel rebar worldsteel	k_{GLOSt}
RER: Steel hot dip galvanized worldsteel	$K_{RERStHDG}$
DE: Concrete C20/25 PE	$k_{DEConC20}$
DE: Concrete C30/37 PE	$k_{DEConC30}$
DE: Glued laminated timber PE [for 1kg]	k_{DEW}
GLO: Value of scrap worldsteel	k_{GLO}
Steel building demolition - impact for 1kg treated	$k_{StBldgDem}$
CH: disposal, building, concrete, not reinforced, to final disposal	k_{CHCon}
CH: disposal, building, reinforcement steel, to final disposal	k_{CHSt}
CH: disposal, building, concrete, not reinforced, to sorting plant [incl. 40% to sanitary landfill]	$k_{CHConPit}$
CH: disposal, building, reinforcement steel, to sorting plant	$k_{CHStPit}$
CH: disposal, concrete, 5% water, to inert material landfill	$k_{CHConLof}$
CH: gravel, unspecified, at mine	k_{CHGr}
RER: Landfill for inert matter (Steel) PE	$k_{RERStLof}$
EU-27: Waste incineration of wood products (OSB, particle board) ELCD/CEWEP <p-agg> [1kg wood]	k_{EUWWa}
Credit for waste incineration (agg minus p-agg)	k_{Wa}
EU-27: Landfill of wood products (OSB, particle board) PE <p-agg>	k_{EUWLof}
CH: disposal, inert material, 0% water, to sanitary landfill	k_{CHLof}
RER: Articulated lorry transport PE [for 1tkm]	k_{RERALT}
Transport by train [for 1tkm]	k_{Tr}
Transport by concrete truck [for 100kgkm]	k_{Cont}
Average European transportation for steel [for 1t on average European distance]	k_{StAvg}
EU-27: Electricity grid mix PE [1kWh]	k_{EUElec}
Electricity Output Recovery	k_{EOR}
RER: Steel plate worldsteel (scrap input)	$k_{RERStPl0}$
RER: Steel sections worldsteel (scrap input)	$k_{RERStSec0}$
RER: Steel hot dip galvanized worldsteel (scrap input)	$k_{RERStHDG0}$
GLO: Steel rebar worldsteel (scrap input)	k_{GLOSt0}

In AMECO 3, impact coefficients will be defined for 10 indicators. For the remaining 14 indicators, they are set to zero due to a lack of information, except for the 5 last coefficients which have the same constant values for all the impact indicators

k_{EOR}	8.865E-01
$k_{RERStPl0}$	1.125E-01
$k_{RERStSec0}$	8.492E-01
$k_{RERStHDG0}$	9.162E-02
k_{GLOSt0}	6.983E-01

Calculation process

- Equations for Module A (Product and construction process stage)

Module A			
Product stage	A1 Raw material supply	Concrete of floors	$m_{consl}\ k_{DECon}$
		Steel sheets	$m_{tss}\ k_{RERStHDG}$
		Concrete of structure	$(m_{tcb} + m_{tcc})\ k_{DECon}$
		Steel reinforcement	$(m_{conrs} + m_{trs})\ k_{GLOSt}$
		Steel beams	$m_{tsb}\ (1 + S_{plos})\ k_{RERStSec}$
		Steel columns	$m_{tsc}\ (1 + S_{plos})\ k_{RERStSec}$
		Wood beams	$m_{twb}\ k_{DEW}$
		Wood columns	$m_{twc}\ k_{DEW}$
	A3 Manufacturing	Production losses	$(m_{tsb} + m_{tsc})\ S_{plos}\ k_{RERALT} / 10$
		Steel studs and bolts	$(m_{tst} + m_{tbo})\ k_{GLOSt}$
		Plate connections	$m_{tpl}\ k_{RERStPl}$
	A1-A3	Macro-component	
Construction process stage	A4 Transport	Concrete - mixer truck	$m_{conmix}\ d_{conmix}\ k_{Cont} / 100$
		Concrete - regular truck	$m_{conreg}\ d_{conreg}\ k_{RERALT} / 1000$
		Steel - regular truck	$m_{sreg}\ d_{sreg}\ k_{RERALT} / 1000$
		Steel - train	$m_{str}\ d_{str}\ k_{Tr} / 1000$
		Steel - average transport	$m_{tstrtot}\ k_{StAvg}$
		Wood - train	$m_{wtr}\ d_{wtr}\ k_{Tr} / 1000$
		Wood - regular truck	$m_{wreg}\ d_{wreg}\ k_{RERALT} / 1000$
		Macro-component	
Total Module A			Sum of all quantities in module A

Calculation process

- For Module B (Use phase), its calculation involves several steps:
  - Computation of characteristics of the ground floor
  - Evaluation of the energy need for the space heating and the associated solar heat gains
  - Evaluation of the energy need for the space cooling and the associated solar heat gains
  - Evaluation of the energy need for the domestic hot water system
- All the equations associated to these different steps are reported in the design guide

Calculation process

- Equations for Module C (end of life)

Module C			
End of life	C1 Deconstruction	Steel sheets	$m_{tss}\ k_{StBldgDem}$
		Steel beams	$m_{tsb}\ k_{StBldgDem}$
		Steel columns	$m_{tsc}\ k_{StBldgDem}$
		Steel studs and bolts	$(m_{tst} + m_{tbo})\ k_{StBldgDem}$
		Plate connections	$m_{tpl}\ k_{StBldgDem}$
	C2 Transport	Steel sheets	$m_{tss}\ k_{RERALT} / 10$
		Steel beams	$m_{tsb}\ k_{RERALT} / 10$
		Steel columns	$m_{tsc}\ k_{RERALT} / 10$
		Steel studs and bolts	$(m_{tst} + m_{tbo})\ k_{RERALT} / 10$
		Plate connections	$m_{tpl}\ k_{RERALT} / 10$
		Wood beams	$m_{twb}\ k_{RERALT} / 10$
		Wood columns	$m_{twc}\ k_{RERALT} / 10$
		Macro-component	
	C3 Waste processing	Concrete of floors to sorting plant	$m_{consl}\ eol_{srs}\ k_{Corr}$
		Concrete of structure to sorting plant	$(m_{tcb} + m_{tcc})\ eol_{srs}\ k_{Corr}$
		Rebars to sorting plant	$(m_{conrs} + m_{trs})\ eol_{srs}\ k_{CHStPit}$
	C4 Disposal	Steel sheets	$m_{tss}\ (1 - eol_{sa})\ k_{RERStLaf}$
		Steel beams	$m_{tsb}\ (1 - eol_{sbc})\ k_{RERStLaf}$
		Steel columns	$m_{tsc}\ (1 - eol_{sbc})\ k_{RERStLaf}$
		Steel studs and bolts	$(m_{tst} + m_{tbo})\ (1 - eol_{stbo})\ k_{RERStLaf}$
		Plate connections	$m_{tpl}\ (1 - eol_{spl})\ k_{RERStLaf}$
		Concrete of floors landfilled	$m_{consl}\ [\ (1 - eol_{srs})\ k_{CHCon} + (eol_{srs} - val_{conf})\ k_{CHConLaf}\ ]$
		Concrete of structure landfilled	$(m_{tcb} + m_{tcc})\ [\ (1 - eol_{srs})\ k_{CHCon} + (eol_{srs} - val_{const})\ k_{CHConLaf}\ ]$
		Rebars landfilled	$(m_{conrs} + m_{trs})\ (1 - eol_{srs})\ k_{CHSt}$
		Wood beams	$m_{twb}\ (inc_w\ k_{EUWWa} + (1 - inc_w)\ k_{EUWLaf})$
		Wood columns	$m_{twc}\ (inc_w\ k_{EUWWa} + (1 - inc_w)\ k_{EUWLaf})$
		Macro-component	
Total Module C			Sum of all quantities in module C

Calculation process

- Equations for Module D (Benefits and loads beyond the system boundaries)

Module D			
Benefits and loads beyond the system boundaries	D Benefits	Concrete of floors	$- m_{consl}\ val_{confl}\ k_{CHGr}$
		Steel sheets	$- m_{tss}\ (eol_{sd} - k_{RERStHDG0})\ k_{GLO}$
		Concrete of structure	$- (m_{tcb} + m_{tcc})\ val_{const}\ k_{CHGr}$
		Steel reinforcement	$- (m_{conrs} + m_{trs})\ (eol_{srs} - k_{GLOSt0})$
		Steel beams	$- m_{tsb}\ [\ (eol_{sbc} - k_{RERStSec0})\ k_{GLO} + re_{sbc}\ (k_{RERStSec} - k_{StAvg} / 1000)\ ]$
		Steel columns	$- m_{tsc}\ [\ (eol_{sbc} - k_{RERStHDG0})\ k_{GLO} + re_{sbc}\ (k_{RERStSec} - k_{StAvg} / 1000)\ ]$
		Steel studs and bolts	$- (m_{tst} + m_{tbo})\ (eol_{stbo} - k_{GLOSt0})\ k_{GLO}$
		Plate connections	$- m_{tpl}\ (eol_{spl} - k_{RERStPl0})\ k_{GLO}$
		Wood beams	$- m_{twb}\ (inc_w\ k_{Wa} + (1 - inc_w)\ k_{EOR}\ k_{EUElec} / 3.6)$
		Wood columns	$- m_{twc}\ (inc_w\ k_{Wa} + (1 - inc_w)\ k_{EOR}\ k_{EUElec} / 3.6)$
		Macro-component	
Total Module D			Sum of all quantities in module D

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Software output

- The results of AMECO 3 are displayed through result tabs, depending on the chosen option:
  - Calculation sheet
  - Histogram for the selected impact (with the possibility of distinguishing the module(s) to be considered)
  - Radial graph summarizing the total from Module A to Module C or from Module A to Module D for all impacts
- The different possibilities will be demonstrated during the next presentation

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Guidance on the use of AMECO 3 software

- Within the Design Guide, Chapter 6 is dedicated to guidance on the use of AMECO 3

- For a complete study of a building, parameters will have to be provided for each of the following modules:
  - Project
  - Building
  - Envelope
  - Base floor
  - Roof
  - Occupancy
  - Systems
  - Floors
  - Structure
  - Transport
  - Results

Guidance on the use of AMECO 3 software

- To investigate the environment impact of the structure only, the following modules have to be considered:
  - Project
  - Building
  - Floors
  - Structure
  - Transport

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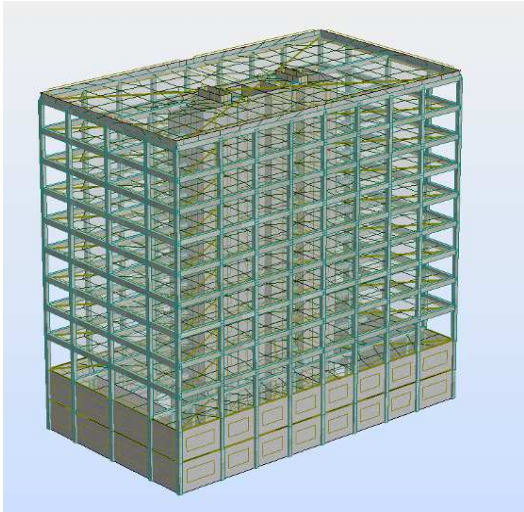
Case studies

- Chapter 7 is dedicated to the investigation of case studies
- The objective is to present the calculation of the environmental impact of different types of buildings
- Three types of buildings are considered as case studies:
  - Office building
  - Residential building
  - Industrial hall
- The considered case studies are briefly introduced within this presentation
- They will be presented in details later on during this workshop

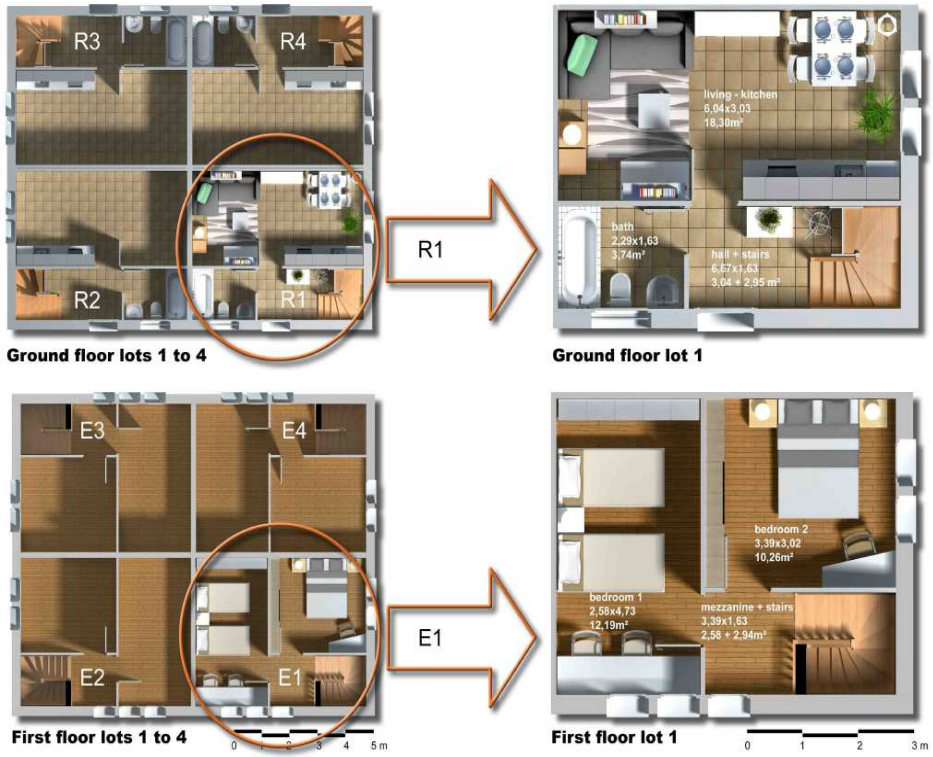
Case studies – Office building

- Three types of structural systems, which are the more common ones in Europe, are analysed:
  - Steel-concrete composite structure
  - Concrete structure
  - Optimized steel-concrete composite structure (optimization based on an ECO-Design)
- The design was done by an external Engineering office and reviewed by a group of independent experts



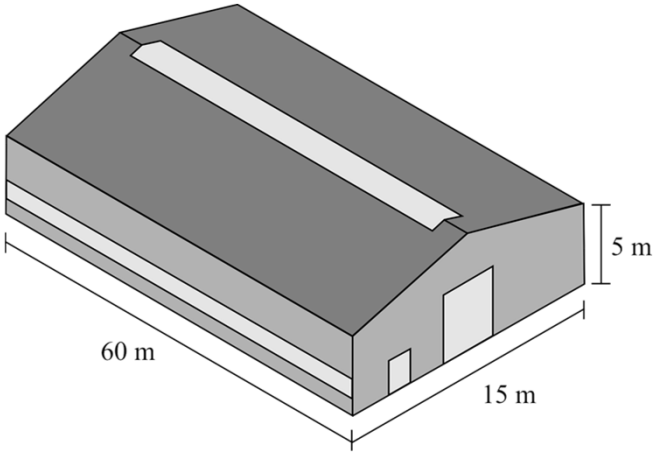
Case studies – Residential building

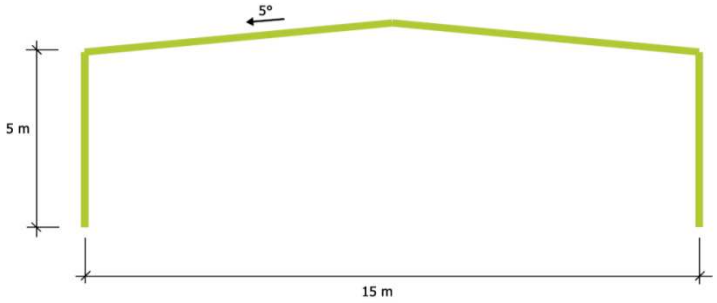
- For this case study, a 4-family house built in Romania has been selected
- This building is divided in 4 apartments of 55 m² net floor area equally arranged over two floors



Case studies – Industrial hall

- A single storey industrial building with an area of 900 m² is considered
- Two different structural systems are investigated:
  - Pinned-base portal frame, composed of hot rolled profiles
  - Rigid column bases, pinned ended girder, composed of reinforced concrete members





The next presentation will address the description of AMECO 3 software and IPad application

Thank you for your attention…