



Eurocodes

Background and Applications

Design of **Steel Buildings** with worked examples



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Organised and supported by

European Commission

DG Enterprise and Industry
Joint Research Centre

European Convention for Constructional Steelwork

European Committee for Standardization

CEN/TC250/SC3

Sustainability aspects, inventory, comparisons

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Joint
Research
Centre

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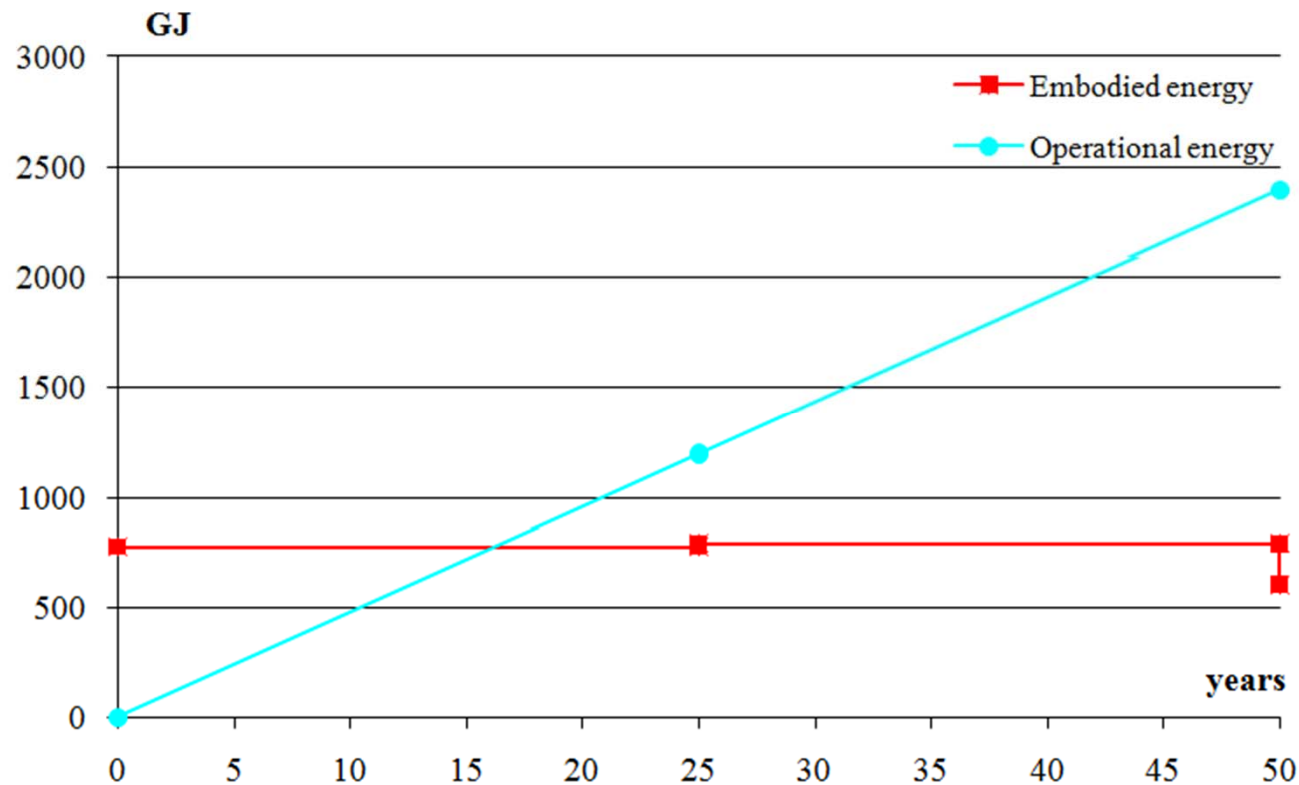
- ✓ Introduction to life cycle thinking
- ✓ Life cycle assessment of construction works
- ✓ Sustainability and LCA of steel structures
- ✓ Case studies
 - LCA of steel products: Examples 1 to 3
 - LCA of a steel building: Example 4

Sustainability of buildings

- ✓ Material selection (structural engineering)
 - important for future, COM 571, after 2020 near zero-energy
 - structural safety and heat transfer
- ✓ Operational costs (other engineering disciplines), present state
 - energy consumption: HVAC and lightening (70%)
 - 37% of total EU energy consumption
 - living environment comfort level, simulation software

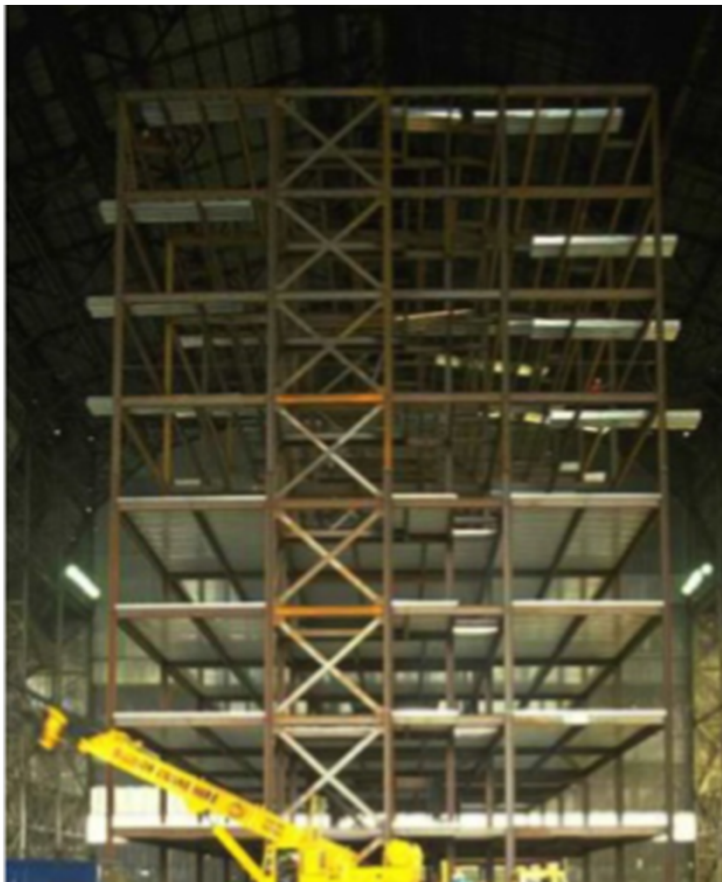
Sustainability of buildings

OPERATIONAL ENERGY vs. EMBODIED ENERGY

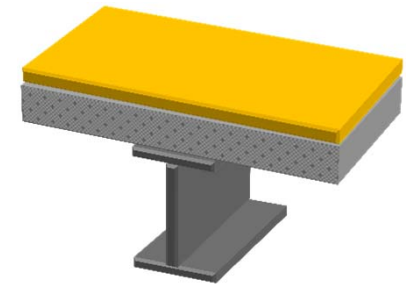
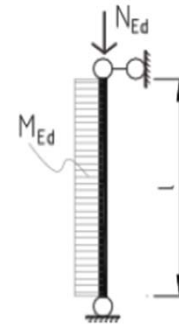


Source: Gervásio *et al.* (2010)

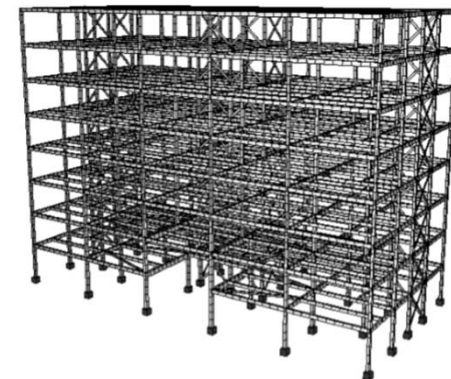
Main goal:



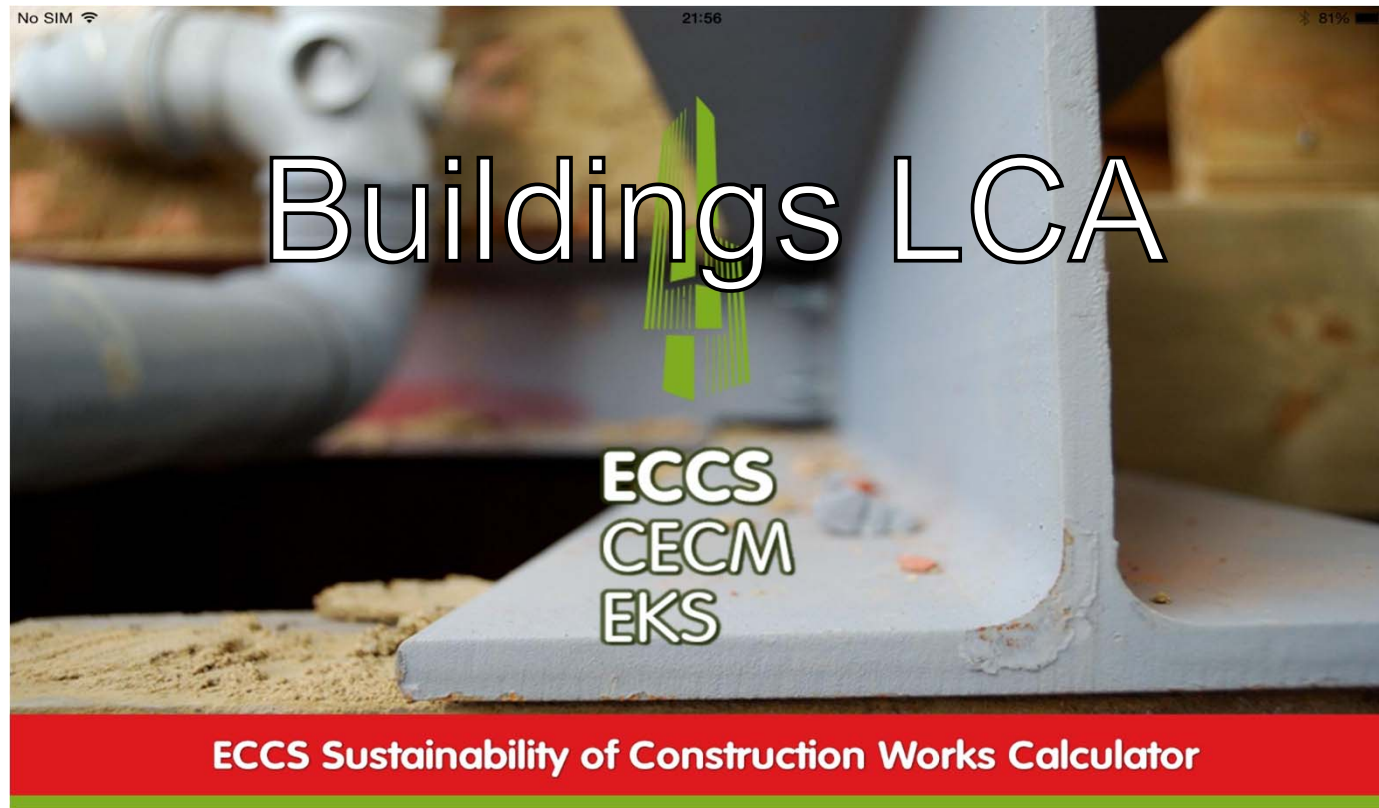
✓ LCA of steel products



✓ LCA of a steel building



Life Cycle Analysis - Tool



Available from AppStore for **iPad** and **iPhone** and GooglePlay for **Androids**

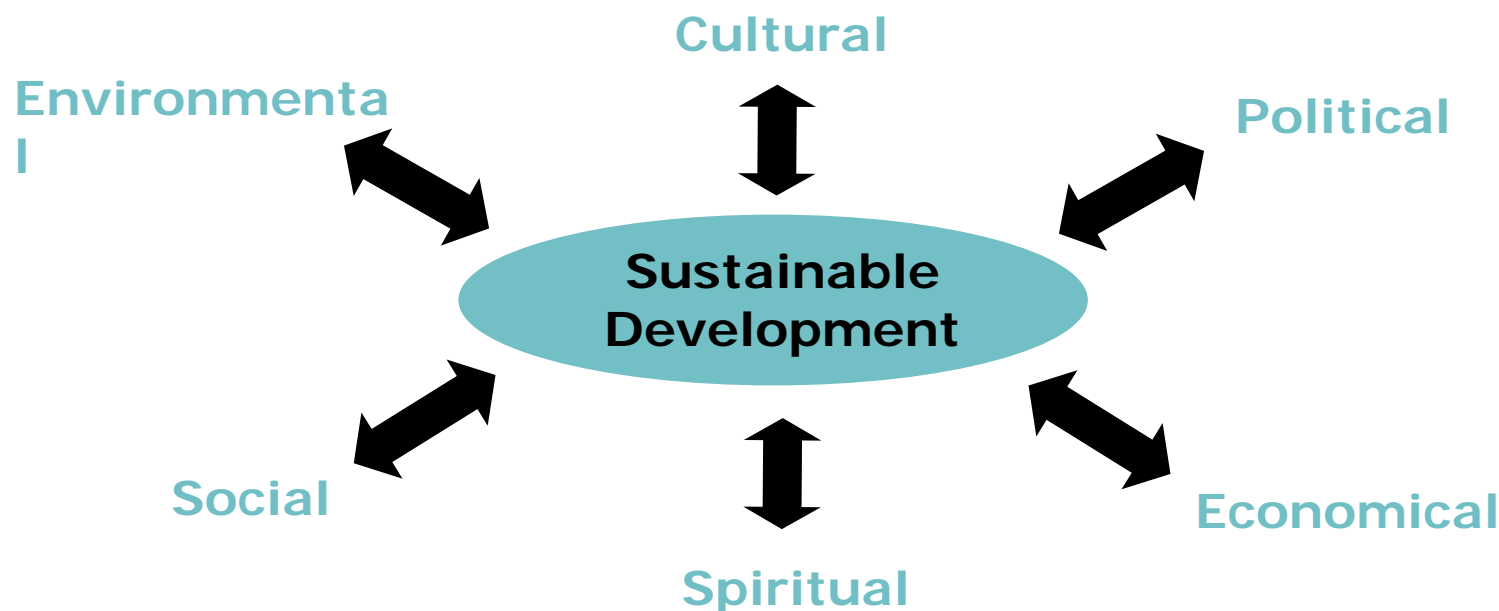


Introduction to life cycle thinking

SUSTAINABLE DEVELOPMENT

“Sustainable Development meets the needs of the present without compromising the ability of future generations to meet their own needs”

In World Commission on Environment - Brundtland Report (1987)



SUSTAINABILITY INDICATORS

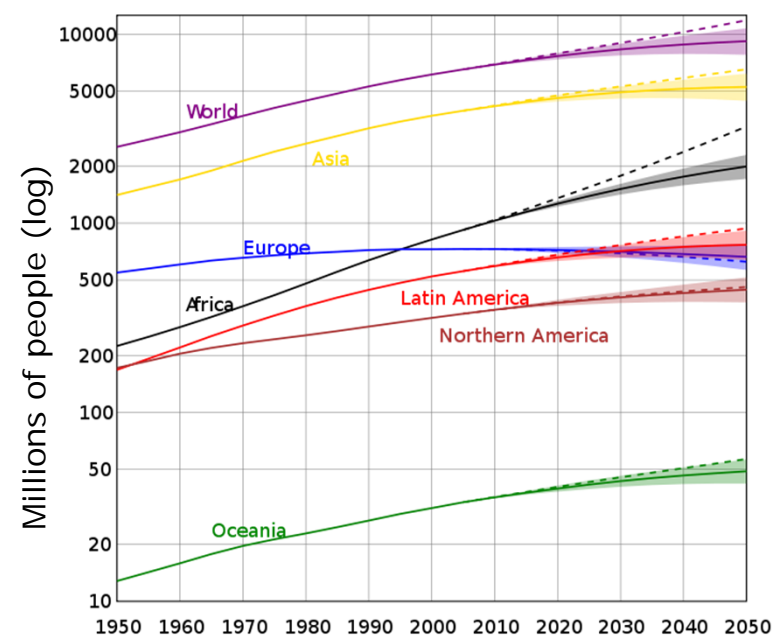
Earth population

➡ Population size fluctuates at differing rates in differing regions.

➡ Nonetheless, population growth is the long-standing trend on all inhabited continents, as well as in most individual states.

➡ During the 20th century, the global population saw its greatest increase in known history, rising from about 1.6 billion in 1900 to over 6 billion in 2000.

Estimates of population evolution between 1950 and 2050, according to the UN.

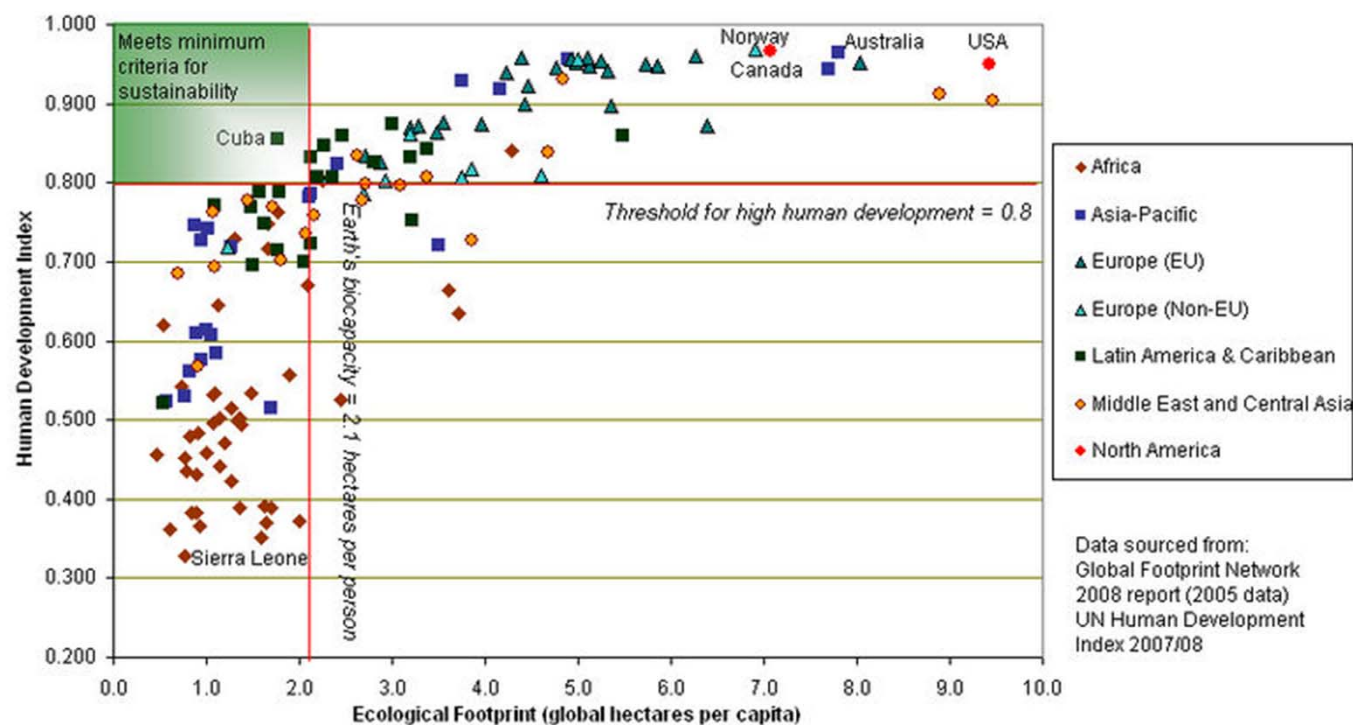


Sources: nationalgeographic.com, www.wikipedia.org

SUSTAINABILITY INDICATORS

Earth carrying capacity

Human Welfare and Ecological Footprints compared



Sources: UN Human Development Index, nationalgeographic.com

SUSTAINABILITY INDICATORS

Earth carrying capacity

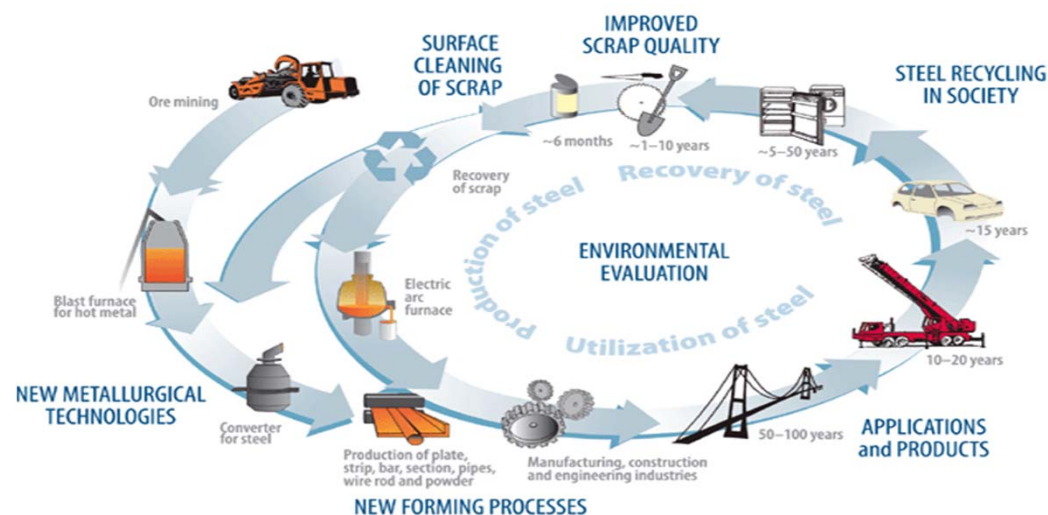
Human Welfare and Ecological Footprints compared



SUSTAINABLE CONSTRUCTION

Sustainable Construction results from the application of the principles of Sustainable Development to the **global cycle of construction**, from raw material acquisition, through planning, design, construction and operation, to final demolition and waste management.

Chrisna du Plessis – *Agenda 21 for Sustainable Construction in Developing Countries*



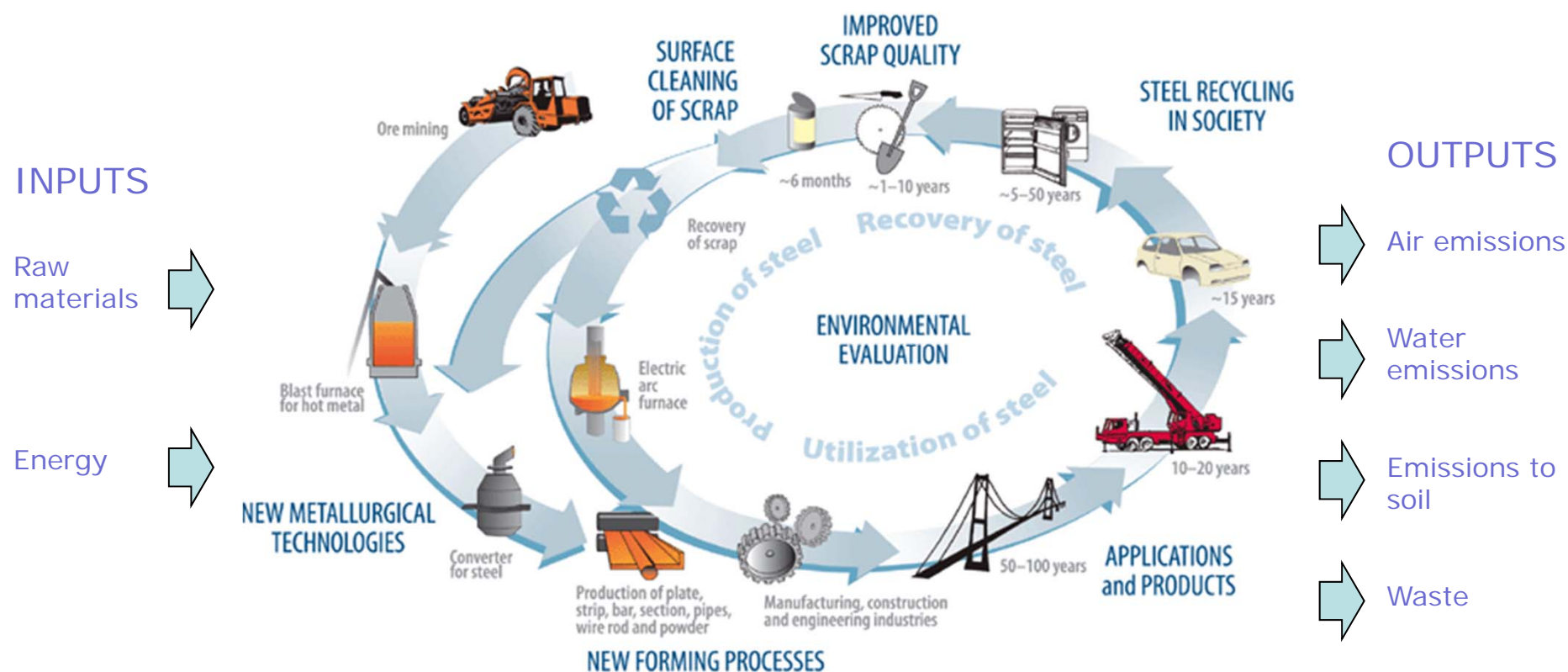
credits to stalkretsloppet.se



Life cycle assessment of construction works

ASSESSMENT OF SUSTAINABILITY IN CONSTRUCTION

Life Cycle Analysis (LCA) – Evaluation of potential environmental impacts of a product, process or activity throughout its entire life



Source: stalkretsloppet.se

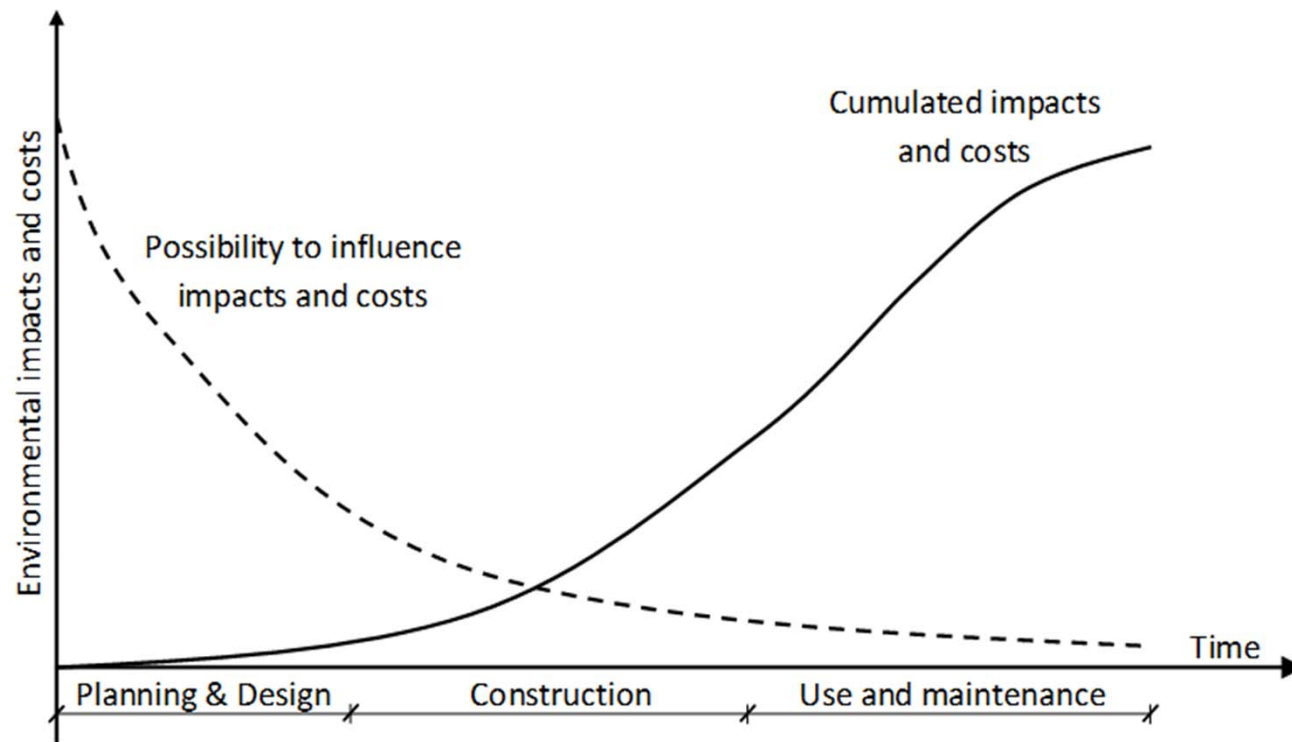
ASSESSMENT OF SUSTAINABILITY IN CONSTRUCTION

LIFE CYCLE ANALYSIS

- ✓ The environmental impacts of buildings occur **throughout all life cycle stages** of a building or other construction;
- ✓ To overcome the **shifting of burdens** from one life cycle stage to another when deciding between options, the life cycle perspective needs to be taken into account;
- ✓ **New international standards** for sustainability assessment of buildings under development follow a **life cycle approach**.

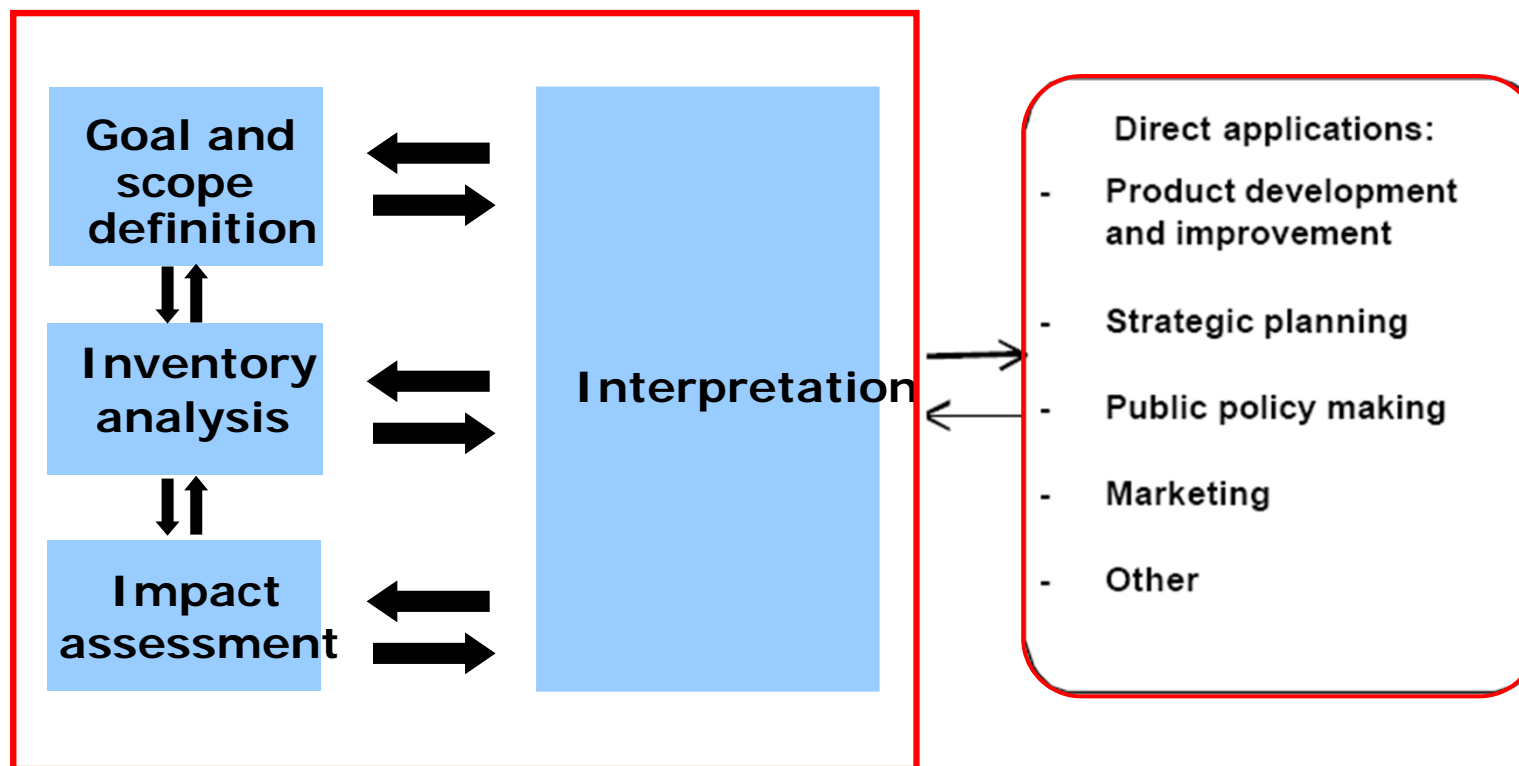
LIFE CYCLE ANALYSIS

INFLUENCE OF DESIGN DECISIONS ON LIFE CYCLE IMPACTS AND COSTS



LIFE CYCLE ANALYSIS

Life cycle environmental analysis according to the general framework
of **ISO 14040:2006** and **ISO 14044:2006**



LIFE CYCLE ANALYSIS

1st stage – Definition of goal and scope of the analysis

- Function(s) of the system
- **Functional unit**
- Definition of the system
- **System boundaries**
- Allocation procedures
- Type of impacts and assessment methodologies
- Data quality requirements
- Assumptions and limitations
- Critical review
- Type and format of report

LIFE CYCLE ANALYSIS

FUNCTIONAL UNIT

A functional unit is a measure of the performance of the functional outputs of the product system.

✓ Product level

e.g.: A simple-supported column, 10 m long, with a load bearing capacity of an axial force of 5000 kN.

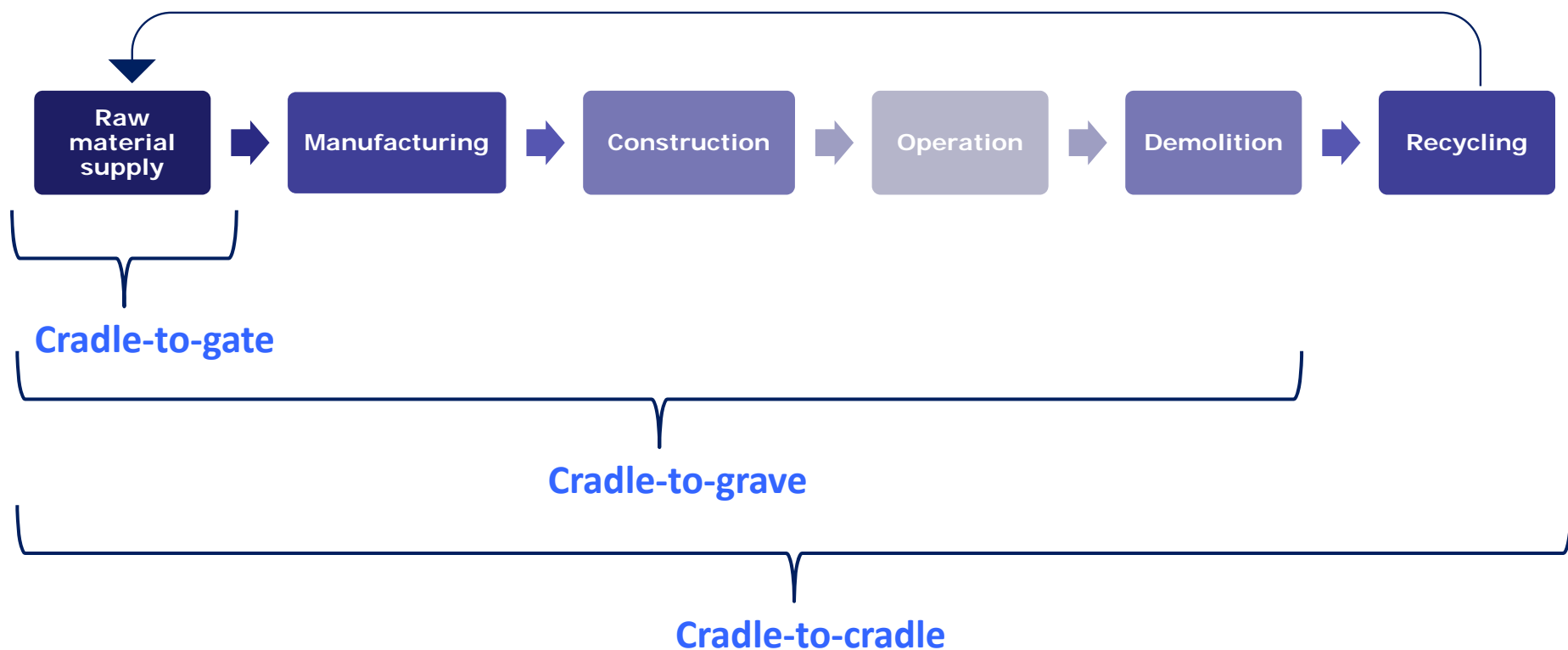
✓ Building level

e.g.: An office building providing a workplace and working environment for 100 workers and designed for a service life of 50 years.

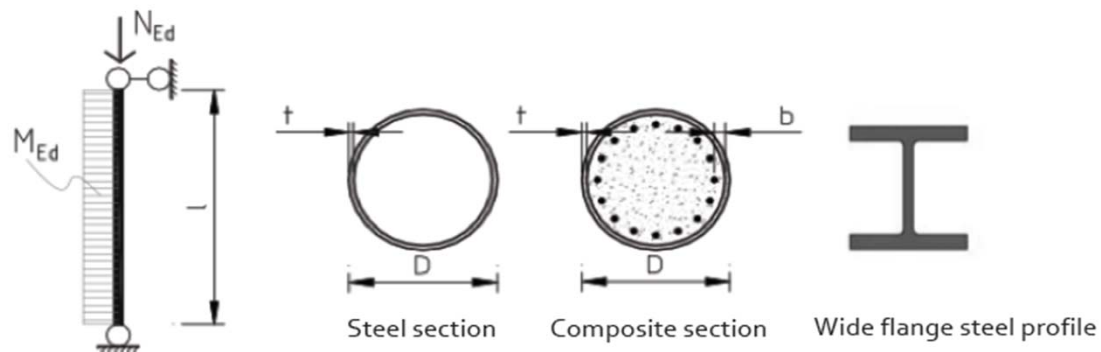
LIFE CYCLE ANALYSIS

SYSTEM BOUNDARY

The system boundaries determine which unit process shall be included within the LCA.



LIFE CYCLE ANALYSIS



Solution	Type	Material(s)	Section
1	Circular hollow section	Steel (S355)	$\phi 35$
2	Circular hollow section	HSS (S690)	$\phi 25$
3	Steel profile	Steel (S355)	HD
4	Steel profile	HSS (S690)	HD
5	Composite circular section	Steel (S355)/Concrete	$\phi 35$
6	Composite circular section	HSS (S690)/Concrete	$\phi 25$

✓ Functional unit:

A simple-supported column, 5 m long, with a load bearing capacity of an axial force of 5000 kN and a bending moment of 100 kNm (around the strong axis for the profile column).

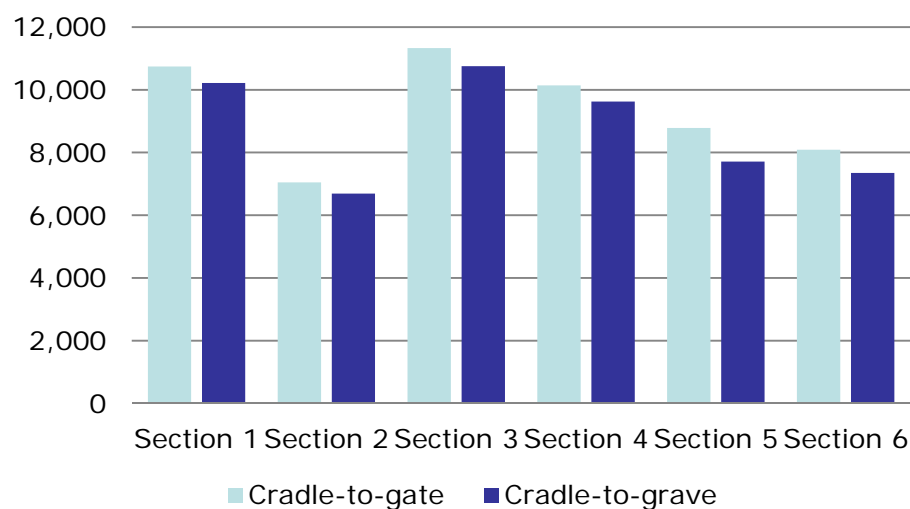
Source: Rossi et al. 2010



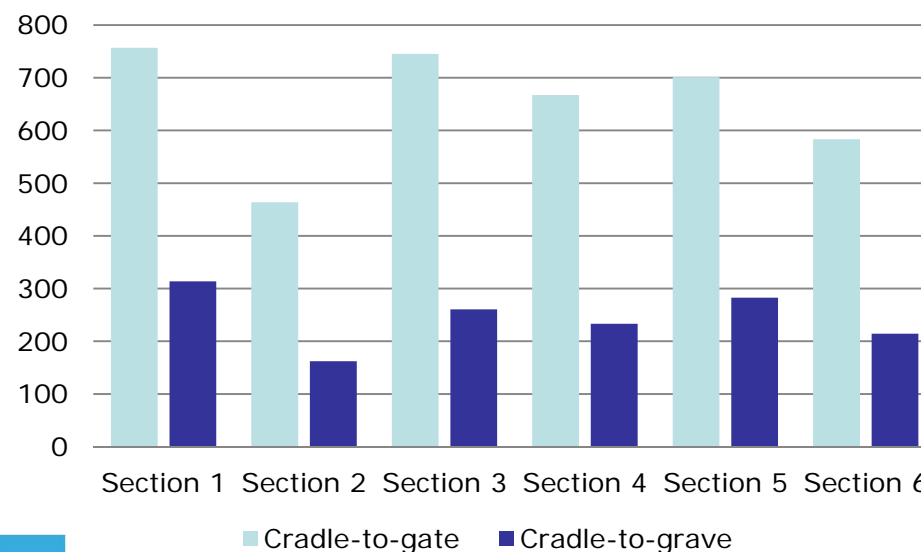
LIFE CYCLE ANALYSIS

Solution	Type	Material(s)	Section	Steel mass
1	Circular hollow section	Steel (S355)	φ35	426.15 kg
2	Circular hollow section	HSS (S690)	φ25	289.15 kg
3	Steel profile	Steel (S355)	HD	464.72 kg
4	Steel profile	HSS (S690)	HD	416.05 kg
5	Composite circular section	Steel (S355)/Concrete	φ35	219.79 kg
6	Composite circular section	HSS (S690)/Concrete	φ25	255.76 kg

Energy consumption (MJ)

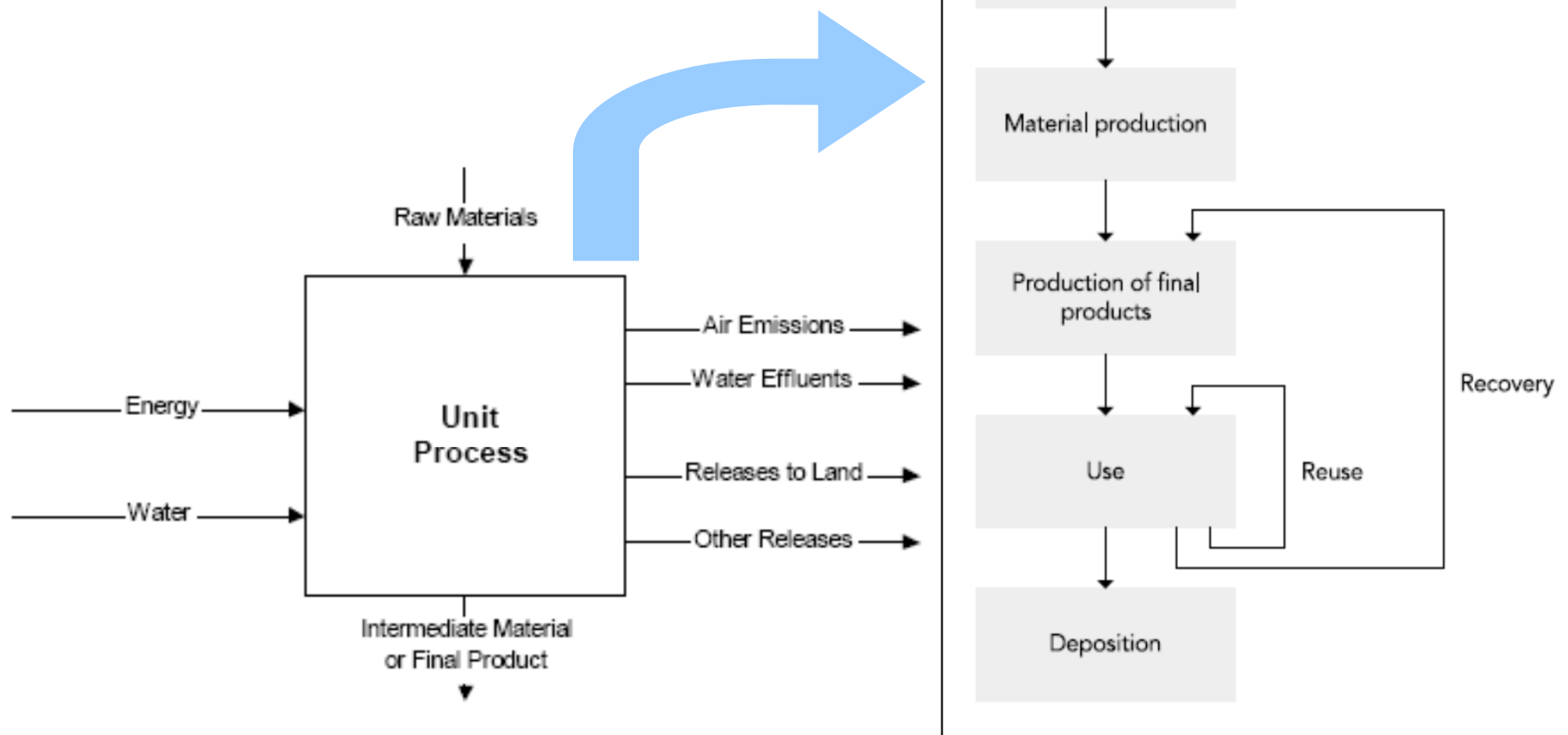


GWP-100 kg CO2 eq.



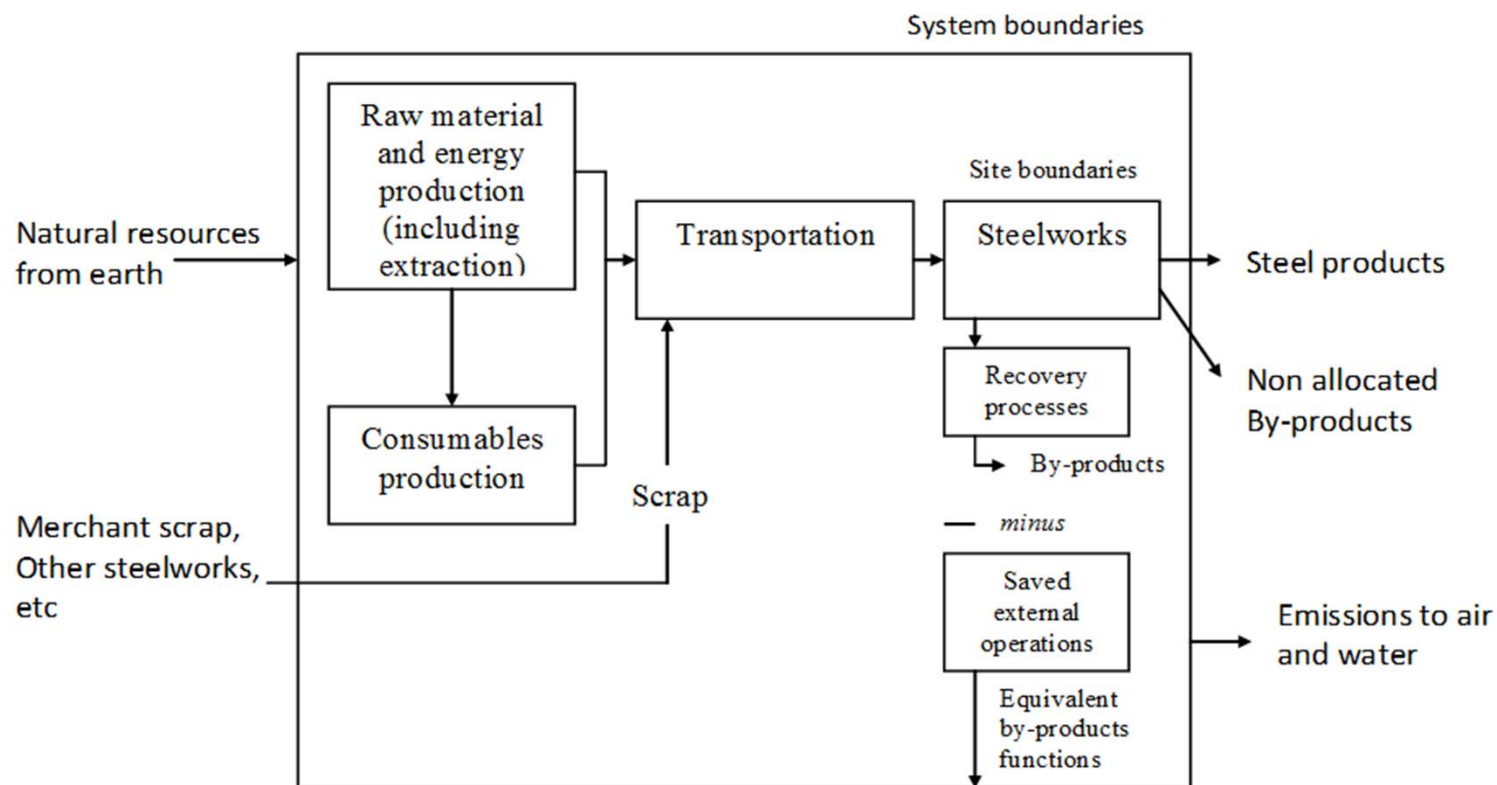
LIFE CYCLE ANALYSIS

2nd stage – Inventory analysis



LIFE CYCLE ANALYSIS

SYSTEM BOUNDARY OF STEEL (worldsteel):



Source: Worldsteel (2011)

LIFE CYCLE ANALYSIS

Life Cycle Inventory Data for Steel Products



Product: Plate BF

EU average, 1kg

Sector: All Sectors, Recovery Rate: 80%

Date of issue : November 2005Date of data : 1999 - 2000

Inputs:

Major Articles*	Units	Plate BF (3 Sites)
(r) Coal (in ground)	kg	0,546629835
(r) Dolomite (CaCO ₃ .MgCO ₃ , in ground)	kg	0,002318261
(r) Iron (Fe)	kg	0,603636348
(r) Limestone (CaCO ₃ , in ground)	kg	0,16912563
(r) Natural Gas (in ground)	kg	0,069112362
(r) Oil (in ground)	kg	0,102852047
(r) Zinc (Zn)	kg	-0,003549737
<u>Water Used (total)</u>	litre	13,55108968

LIFE CYCLE ANALYSIS

Life Cycle Inventory Data for Steel Products



Product: Plate BF

EU average, 1kg

Sector: All Sectors, Recovery Rate: 80%

Date of issue : November 2005Date of data : 1999 - 2000**Outputs:**

Major Articles*	Units	Plate BF (3 Sites)
(a) Cadmium (Cd)	g	3,902E-05
(a) Carbon Dioxide (CO ₂)	g	1418,875516
(a) Carbon Monoxide (CO)	g	10,55869879
(a) Chromium (Total)	g	-0,002015804
(a) Dioxins (unspecified, as TEq)	g	-1,44759E-08
(a) Hydrogen Chloride (HCl)	g	0,049868181
(a) Hydrogen Sulphide (H ₂ S)	g	0,053545397
(a) Lead (Pb)	g	0,001117005
(a) Mercury (Hg)	g	0,000160318
(a) Methane (CH ₄)	g	0,753234393
(a) Nitrogen Oxides (NO _x as NO ₂)	g	2,812515554
(a) Nitrous Oxide (N ₂ O)	g	0,101819626
<u>(a) Particulates (Total)</u>	g	1,672673946
(a) Sulphur Oxides (SO _x as SO ₂)	g	2,808477503
(a) VOC (except methane)	g	0,154643894
(a) Zinc (Zn)	g	0,011189658

Major Articles*	Units	Plate BF (3 Sites)
(w) Ammonia (NH ₄ ⁺ , NH ₃ , as N)	g	0,050782621
(w) Cadmium (Cd ⁺⁺)	g	8,31187E-06
(w) Chromium (Total)	g	6,54706E-05
(w) COD (Chemical Oxygen Demand)	g	0,088007204
(w) Iron (Fe ⁺⁺ , Fe ³⁺)	g	0,041198175
(w) Lead (Pb ⁺⁺ , Pb ⁴⁺)	g	0,000442943
(w) Nickel (Ni ⁺⁺ , Ni ³⁺)	g	2,10445E-05
(w) Nitrogenous Matter (unspecified, as N)	g	0,018854334
(w) Phosphorous Matter (unspecified, as P)	g	0,003236609
(w) Suspended Matter (unspecified)	g	0,001695834
(w) Zinc (Zn ⁺⁺)	g	-0,000202629
<u>Non-allocated byproducts</u>	kg	0,025938684
<u>Waste (total)</u>	kg	0,540490101

LIFE CYCLE ANALYSIS

3rd stage – Life Cycle Impact Assessment (LCIA)

Mandatory elements

Selection

Classification

Characterization

Global warming, Acidification, Eutrophication, Fossil fuel depletion, Criteria air pollutants, Human health, Smog formation, Ecological toxicity, Water intake, Ozone depletion,.....

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

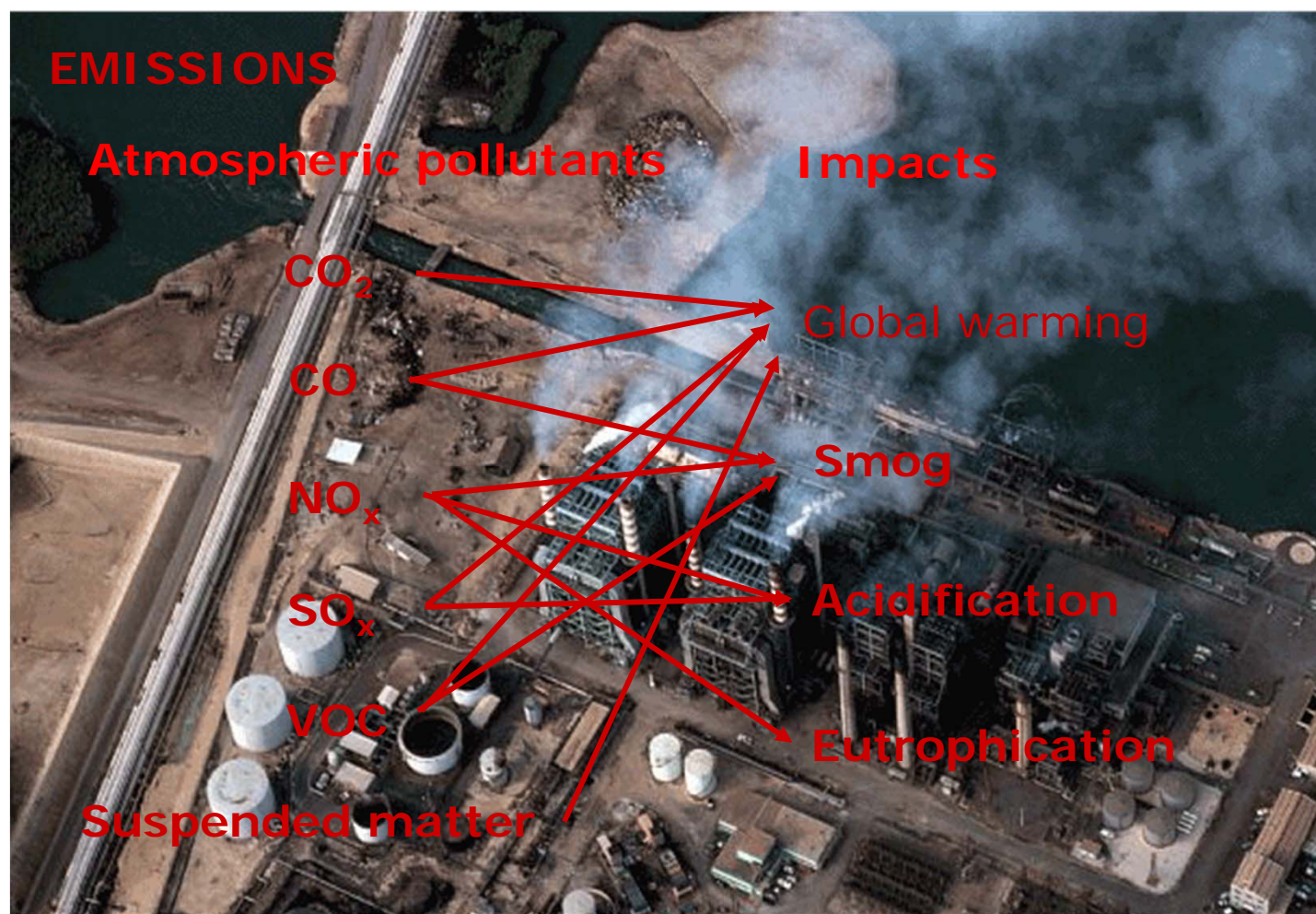
Optional elements

Normalization
Weighting

$$IAScore_{jk} = \frac{IA_{jk} \times IVwt_k}{Norm_k} \times 100$$

$$EnvScore_j = \sum_{k=1}^p IAScore_{jk}$$

LIFE CYCLE ANALYSIS



LIFE CYCLE ANALYSIS

Example: LCA of 1 kg of a generic insulation material

INVENTORY ANALYSIS

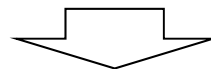
Emissions	Value (in kg)
carbon monoxide (CO)	0.12
carbon dioxide (CO ₂)	0.60
ammonia (NH ₃)	0.01
methane (CH ₄)	0.05
nitrogen oxides (NO _x)	1.02
phosphorus (P)	0.35
sulfur dioxide (SO ₂)	0.10



IMPACT ASSESSMENT

	GWP (kg CO ₂ eq.)	AP (kg SO ₂ eq.)	EP (kg PO ₄ -eq.)
carbon monoxide (CO)	1.53	-	-
carbon dioxide (CO ₂)	1.00	-	-
ammonia (NH ₃)	-	1.60	0.35
methane (CH ₄)	25.00	-	-
nitrogen oxides (NO _x)	-	0.50	0.13
phosphorus (P)	-	-	3.06
sulfur dioxide (SO ₂)	-	1.20	-

e.g.: GWP: $0.12 \times 1.53 + 0.60 \times 1.00 + 0.05 \times 23 = 1.93 \text{ kg CO}_2 \text{ eq}$



ENVIRONMENTAL IMPACTS

GWP (kg CO ₂ eq.)	AP (kg SO ₂ eq.)	EP (kg PO ₄ -eq.)
1.93	0.65	1.21

ENVIRONMENTAL LABELLING

ISO 14020 series



Establishing the general principles of environmental labels and declarations

The ISO 14020 family covers three types of labeling schemes:

Type I – Multi-attribute label developed by a third party

**Environmental Labels and Declarations: Environmental Labeling
Type I, Guiding Principles and Procedures - **ISO 14024:1999****

Type II – Single-attribute label developed by the producer

**Environmental Labels and Declarations: Self-Declaration
Environmental Claims, Terms and Definitions - **ISO 14021:1999****

**Type III – Eco-label whose awarding is based on a full life-cycle
assessment**

**Environmental labels and declarations - Type III environmental
declarations - Principles and procedures – **ISO 14025:2006****

ENVIRONMENTAL LABELLING

ISO 14025: 2006

Examples of EPDs: Cold finished structural hollow sections

ENVIRONMENTAL DECLARATION ISO 14025 and ISO 21930

Cold finished structural hollow sections (CFSHS)

EPD
Foundation for Environmental
Declarations in industry

NEPD no.: 070
Issued, date: 01.04.2007
Valid until, date: 31.03.2010

Independent verification of conformity
We confirm that this environmental declaration has been carried out according to ISO 14044, ISO 14025 and ISO 21930, and Product category rules (PCR) of Steel as construction materials. The documentation has been carried out with the EcoDeco-tool.

The declaration has been prepared by:
SINTEF Byggtorsk SINTEF
Oslo: 01.04.2007
Utan krigsvoll
Independent verifier

Industrial body
Norwegian Steel Association
PO Box 242 NO-1326 Lysaker Norway
Organisation no. 985042897
ISO 14001/EMAS etc.:
Market area: Norway

Background information
Scope (information modules)
Year of study

Declared unit
kg steel

Product description
Cold finished structural hollow sections (CFSHS): Circular, square and rectangular sections are used in building frame structures, made of hot-rolled steel strip by cold-rolling and welding by European manufacturers. Dimensions: Square HS: 25x2 - 300x12.5, Rectangular HS: 50x25x2 - 400x200x12.5 and Circular HS: 21.3x2 - 711x80. The requirements of the EN 10219 standard are applied. The standard steel grade is S355. Density of steel: 7850 kg/m³.

Product specification

	Part 1	Part 2	Part 3	Part 4
Steel	100 %	100 %	100 %	1.00
SUM	100 %	100 %	100 %	1.00

Environmental Indicators

Global warming	0.7	kg CO ₂ equiv.
Energy use	11.3	MJ
Recycled materials	96	%
Indoor air classification (Classification according to CR 1752:1999)	Not relevant	

The Norwegian Steel Association is the sole owner of this document and takes liability and responsibility for the EPD of the steel products. No other is authorised to use the environmental performance of the steel products without an agreement from the Norwegian Steel Association.



“cradle-to-gate” analysis

ENVIRONMENTAL DECLARATION ISO 14025 and ISO 21930

Cold finished structural hollow sections (CFSHS)

EPD
Foundation for Environmental
Declarations in industry

NEPD no.: 079
Issued, date: 01.04.2007
Valid until, date: 31.03.2010

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The declaration has been prepared by:
SINTEF Byggtorsk SINTEF
Oslo: 01.04.2007
Utan krigsvoll
Independent verifier

Manufacturer/Supplier
Contiga AS
Eneveien 31 2216 Røveren Norway
Organisation no.
ISO 14001/EMAS etc.: ISO 14001: 2003-OSL/SYM-8196
Market area: Europe

Background information
Scope
Year of study
Expected service life of building
Service life of product

Functional unit (FU)
kg building frame structure with a service life of 60 years

Product description
Cold finished structural hollow sections (CFSHS): Circular, square and rectangular sections are used in building frame structures, made of hot-rolled steel strip by cold-rolling and welding by European manufacturers. Prefabricated and erected on-site by Norwegian steel entrepreneurs. Dimensions: Square HS: 25x2 - 300x12.5, Rectangular HS: 50x25x2 - 400x200x12.5 and Circular HS: 21.3x2 - 711x80. The requirements of the EN 10219 standard are applied. The standard steel grade is S355. Density of steel: 7850 kg/m³.

Product specification

	Part 1	Part 2	Part 3	Part 4
Steel Hot Rolled Coil	99 %	100 %	100 %	1.00
Oxygen	1 %	100 %	100 %	0.01
Secure 18	1 %	100 %	100 %	0.01
Paint (Alkyde)	1 %	96 %	100 %	0.01
SUM	100 %	100 %	100 %	1.03

Environmental Indicators

Global warming	0.9	kg CO ₂ equiv.
Energy use	21.3	MJ
Recycled materials	94	%
Indoor air classification (Classification according to CR 1752:1999)	No information	

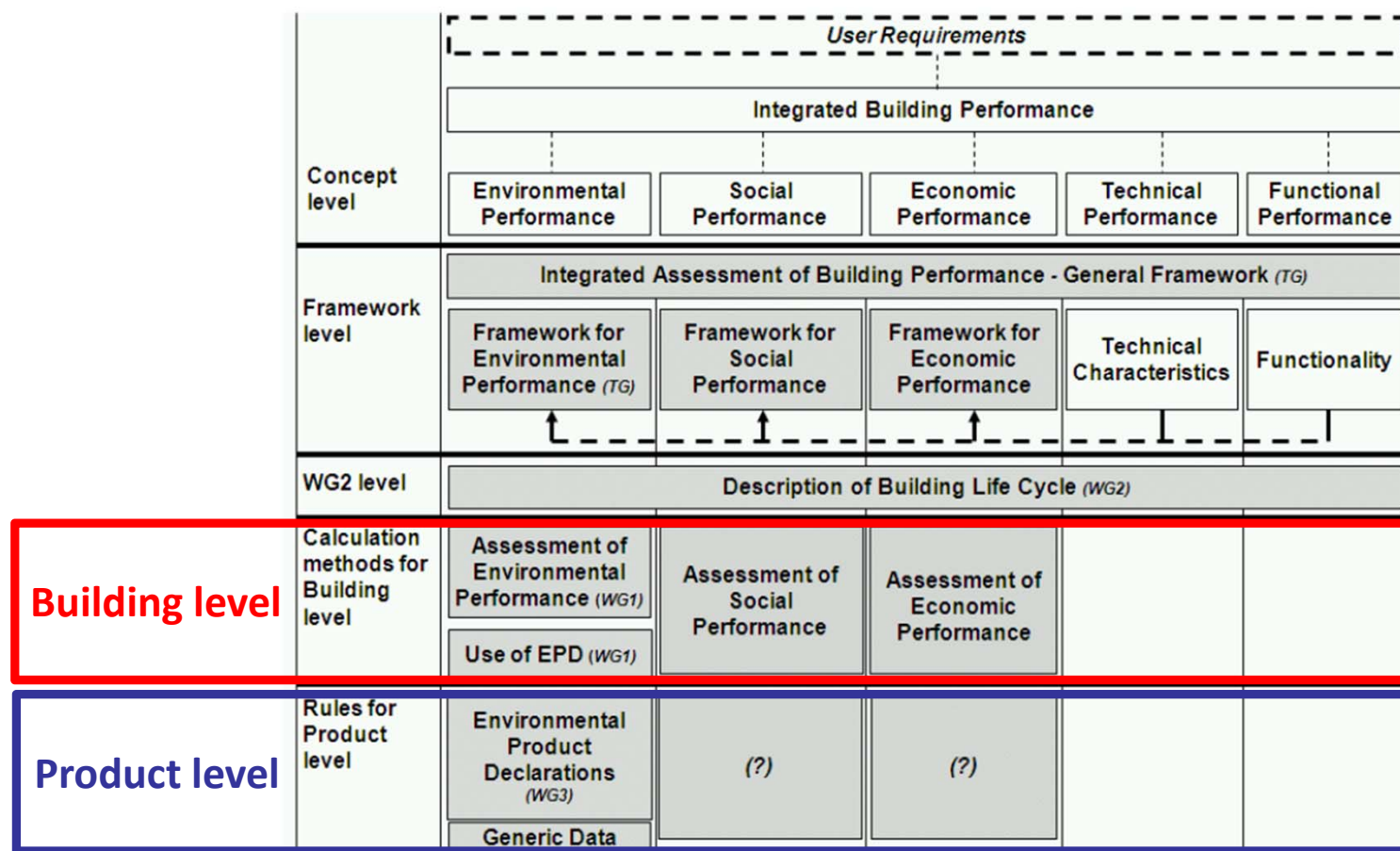


“cradle-to-grave” analysis



LIFE CYCLE ANALYSIS

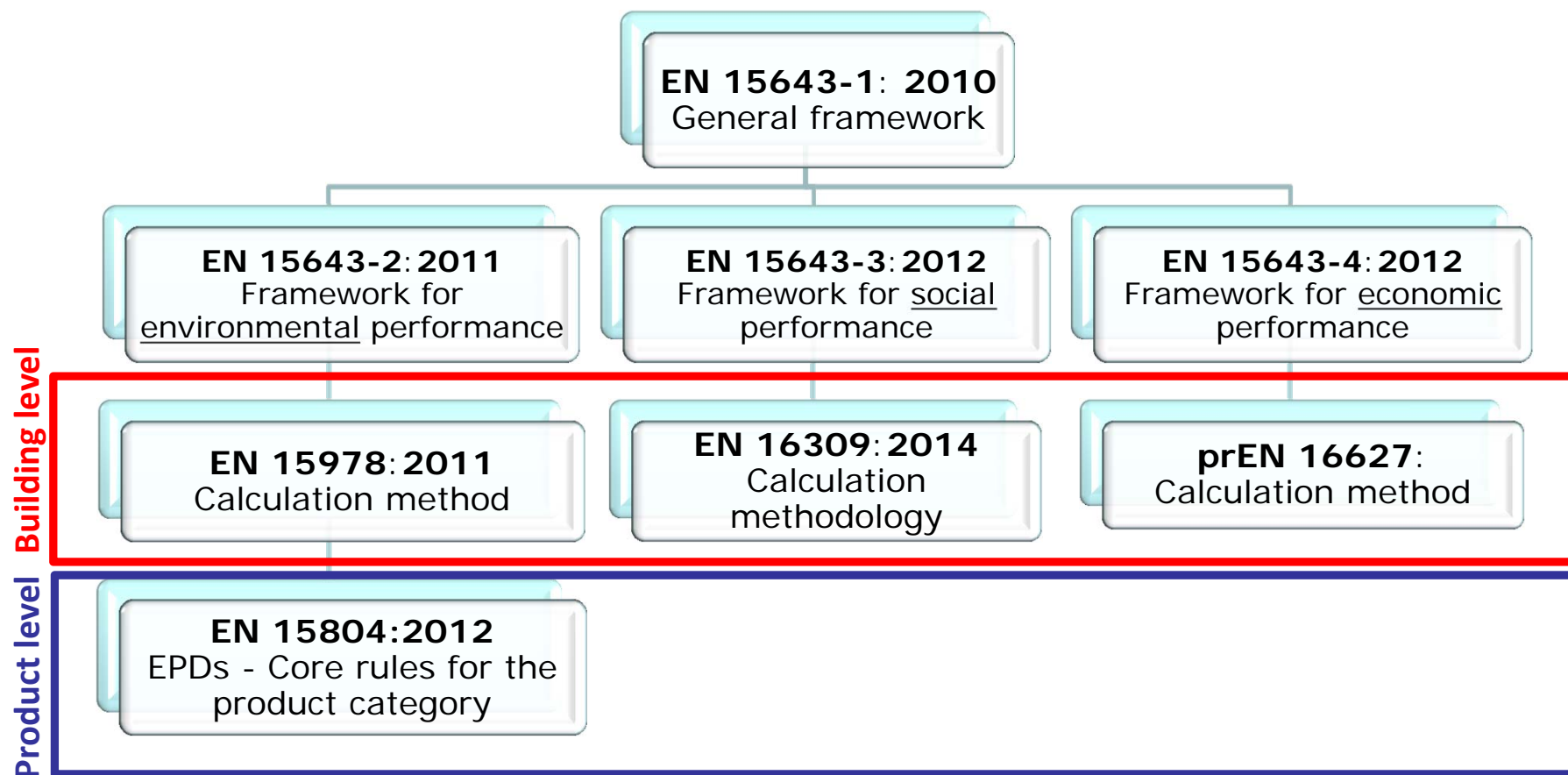
CEN/TC 350 – SUSTAINABILITY OF CONSTRUCTION WORKS





LIFE CYCLE ANALYSIS

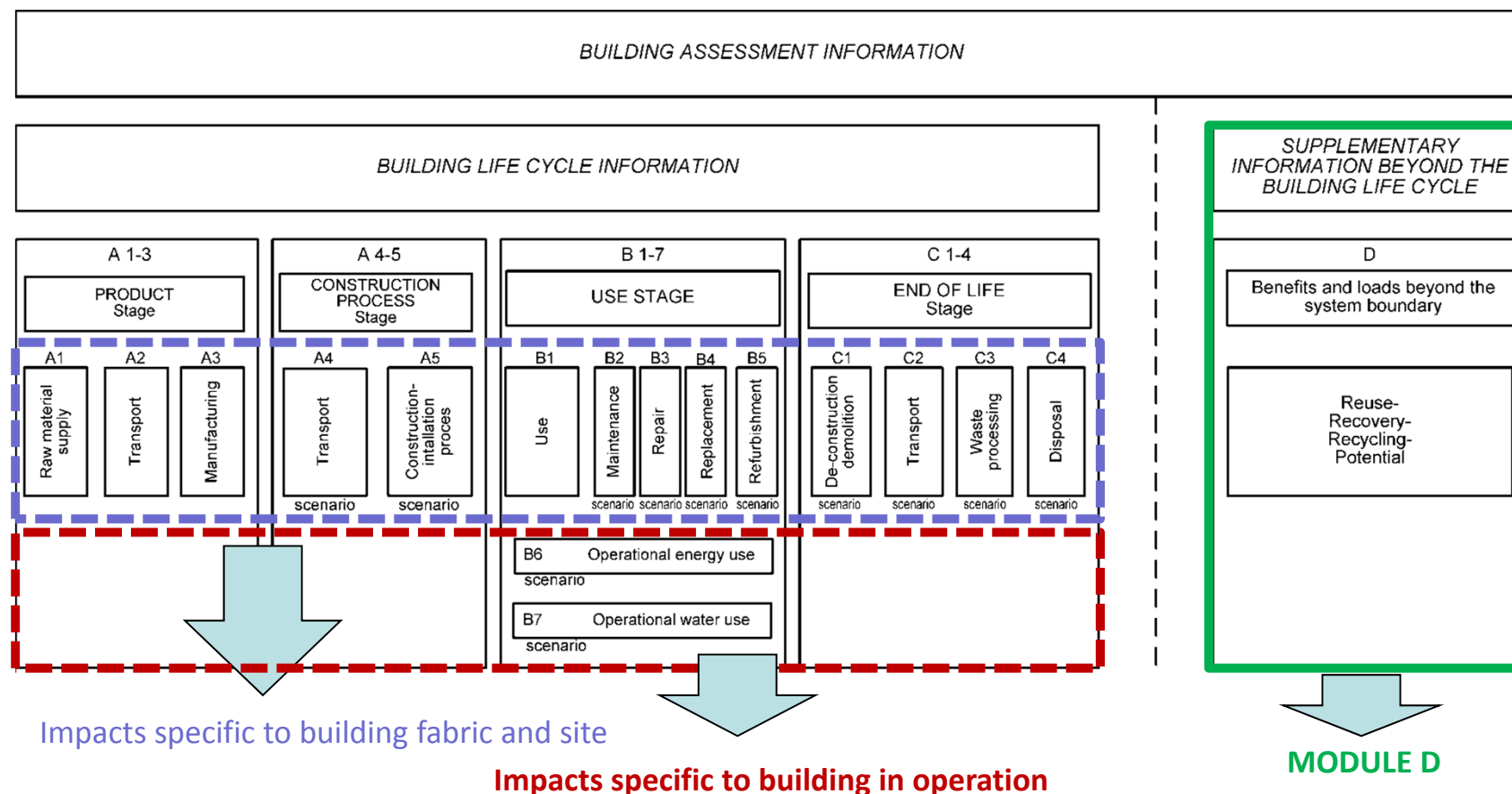
CEN/TC 350 – SUSTAINABILITY OF CONSTRUCTION WORKS: ASSESSMENT OF BUILDINGS





LIFE CYCLE ANALYSIS

MODULAR INFORMATION FOR THE DIFFERENT STAGES OF BUILDING ASSESSMENT (EN15978:2011)



LIFE CYCLE ANALYSIS

MODULAR INFORMATION FOR THE DIFFERENT STAGES OF BUILDING ASSESSMENT
(EN15978:2011)

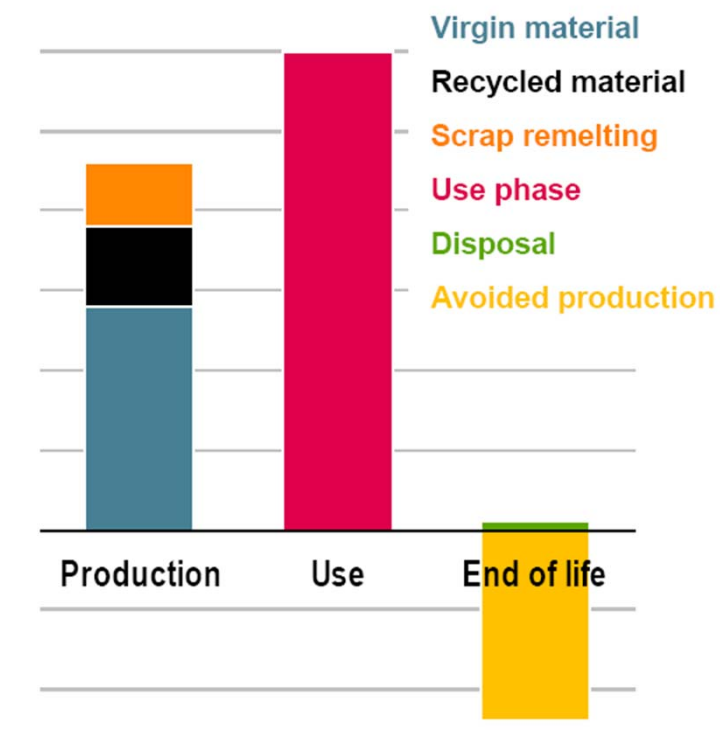


MODULE D includes:

Any declared net benefits and loads from net flows leaving the product system that have not been allocated as co-products and that have passed the end-of-waste state.

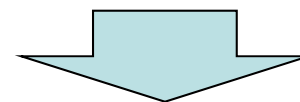
LIFE CYCLE ANALYSIS

STEEL RECYCLING – ALLOCATION PROCEDURE: CLOSED - LOOP



Source: worldsteel (2011)

- ✓ The recycling material at end of life is credited to the system with an avoided burden;
- ✓ Any recycled content adds the same burden to the product system in order to share the burden with the previous life cycle;
- ✓ This is a **closed material loop method** as recycling saves the production of virgin material with the same properties.



Methodology supported by the metals industry

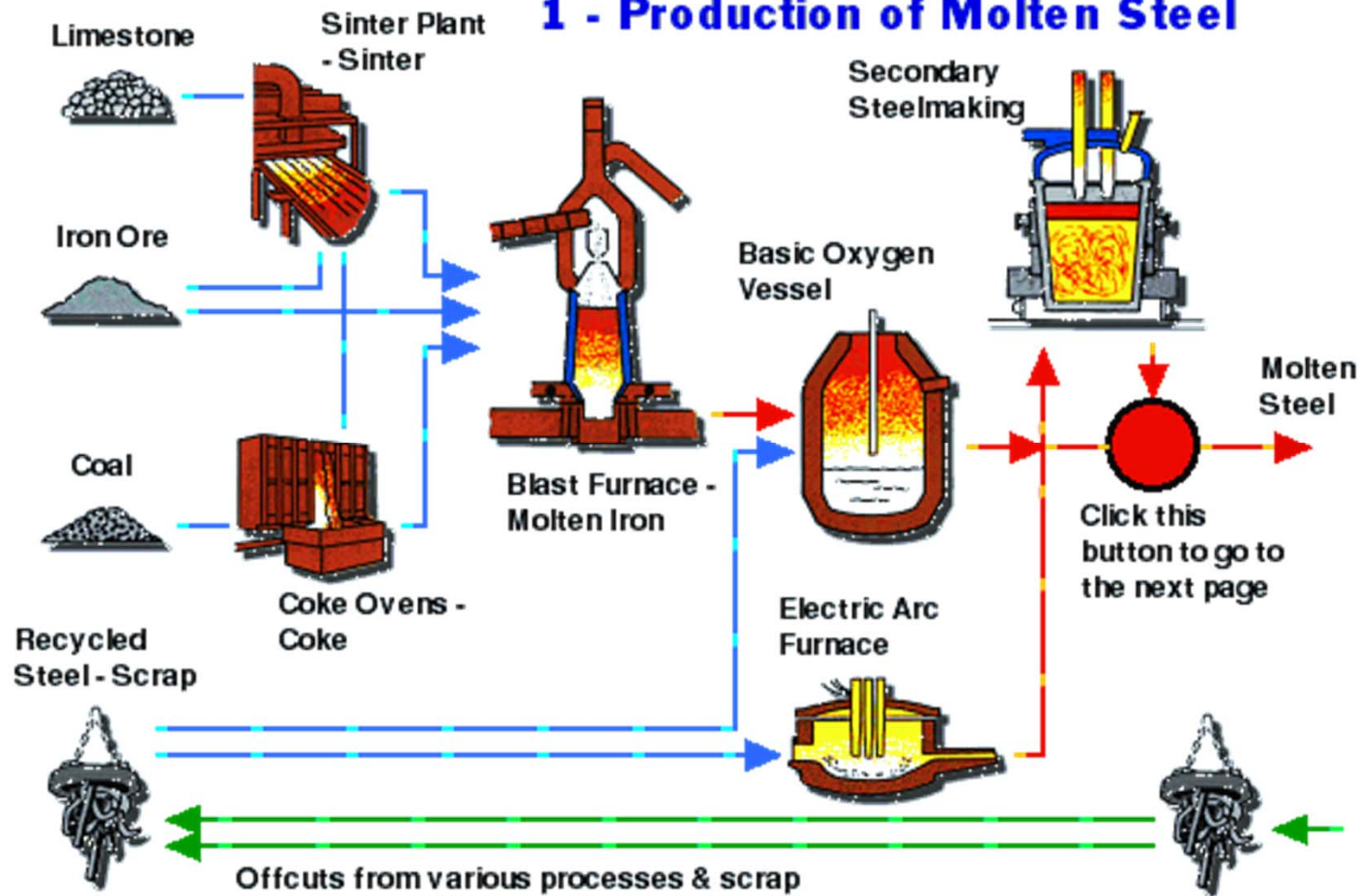
[see “Declaration by the Metals Industry on Recycling Principles” (Atherton, 2006)]



Sustainability and LCA of steel structures

PRODUCT LEVEL

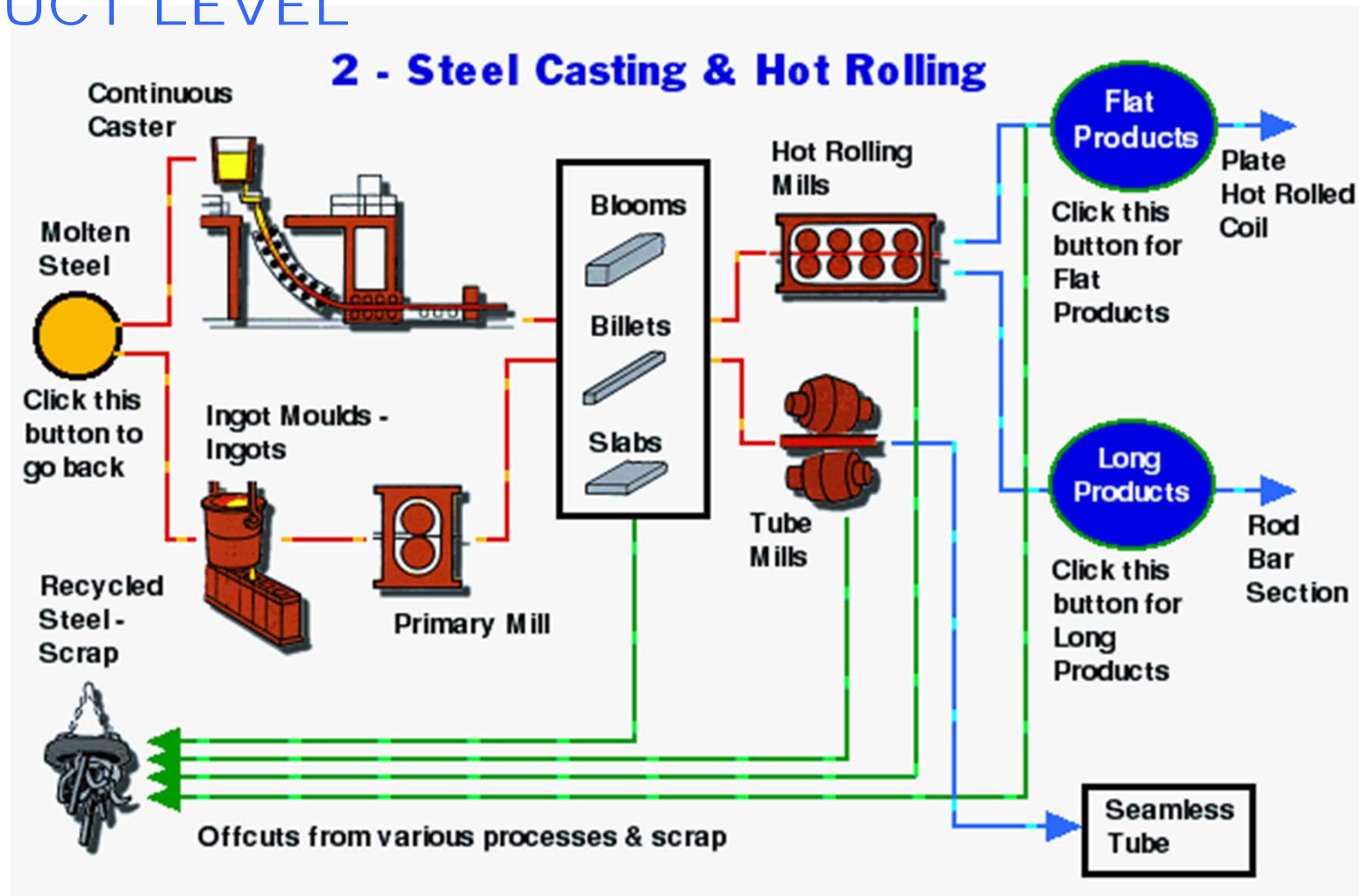
1 - Production of Molten Steel



Source: UK Steel (<http://www.eef.org.uk/uksteel/default.htm>)



PRODUCT LEVEL

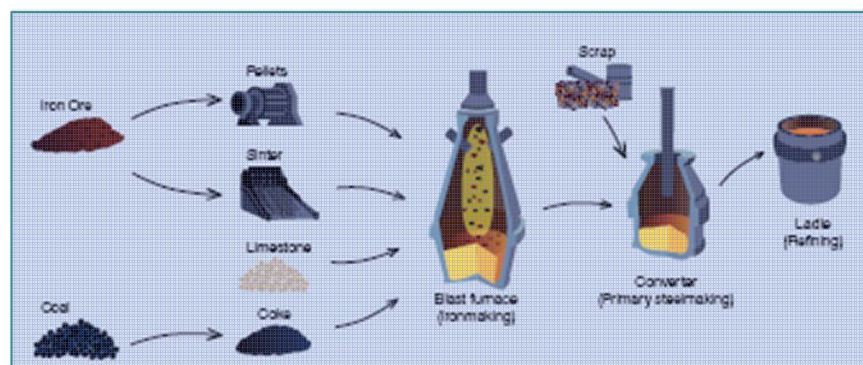


Source: UK Steel (<http://www.eef.org.uk/uksteel/default.htm>)

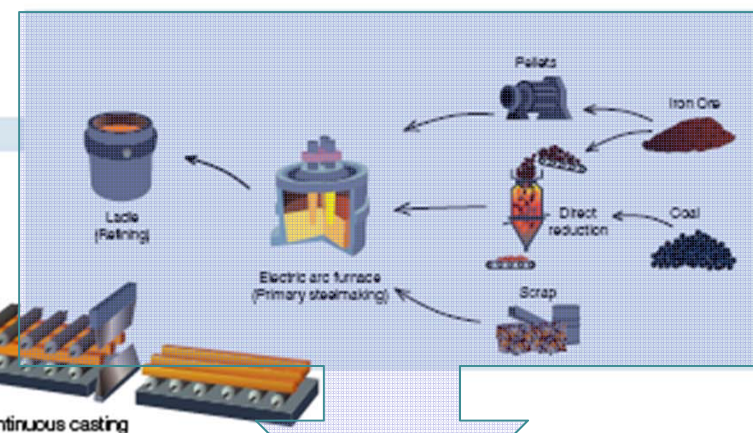
PRODUCT LEVEL

STEELMAKING PROCESS

BLAST FURNACE



ELECTRIC ARC FURNACE



e.g. Energy intensity in the production of 1 tonne of crude steel

19.8 – 31.3 GJ

9.1 – 12.5 GJ

Source: Worldsteel Organization, 2011

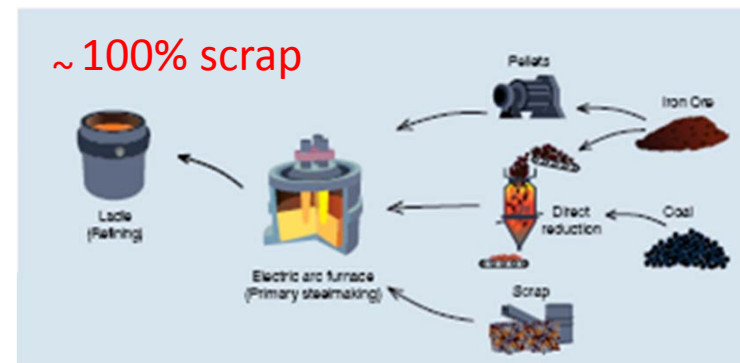
PRODUCT LEVEL

STEEL RECYCLING – ALLOCATION PROCEDURE: CLOSED-LOOP

BLAST FURNACE (*)

 X_{pr}

ELECTRIC ARC FURNACE (*)

 X_{re}

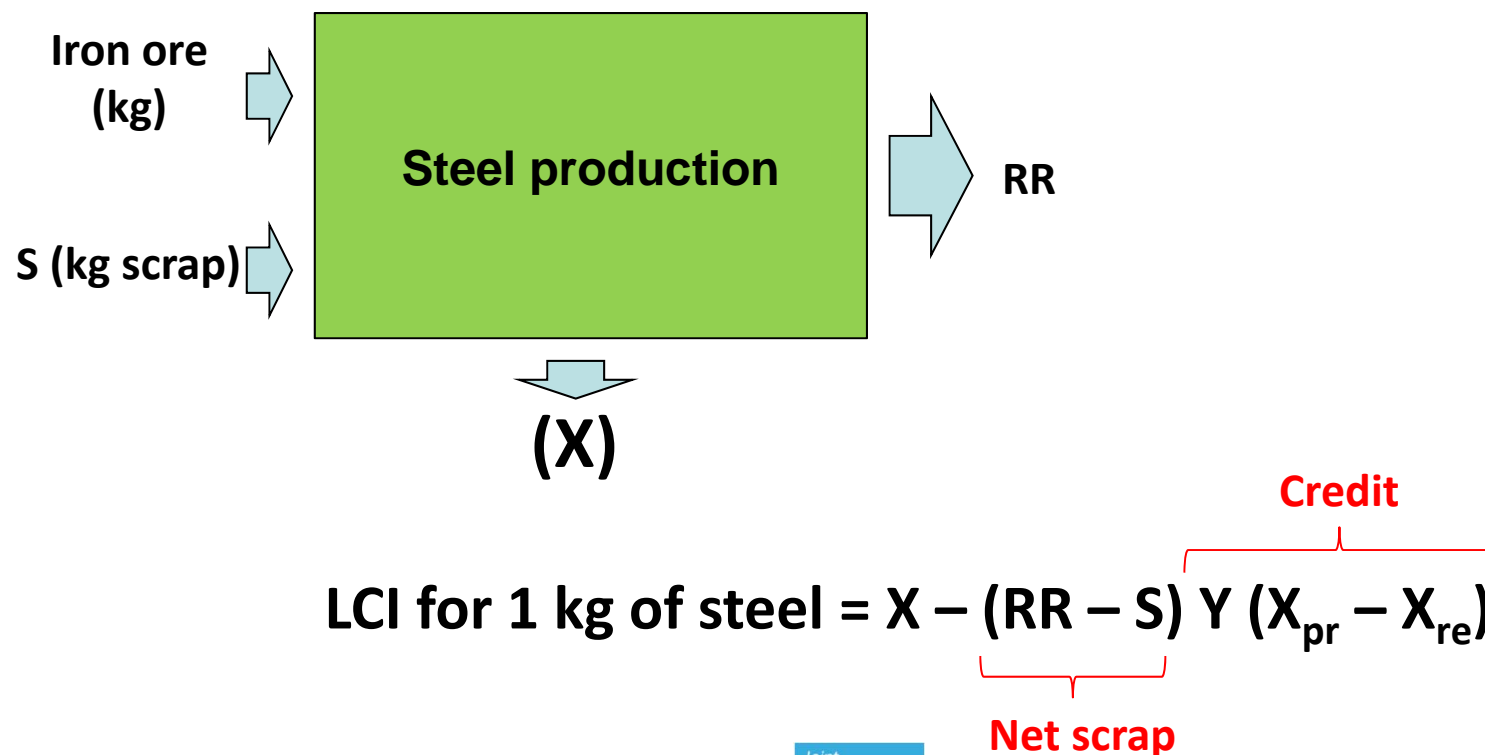
$$LCI \text{ scrap} = Y (X_{pr} - X_{re})$$

(*) theoretical assumptions

PRODUCT LEVEL

STEEL RECYCLING – ALLOCATION PROCEDURE: CLOSED-LOOP

General case of steel production including recycling:

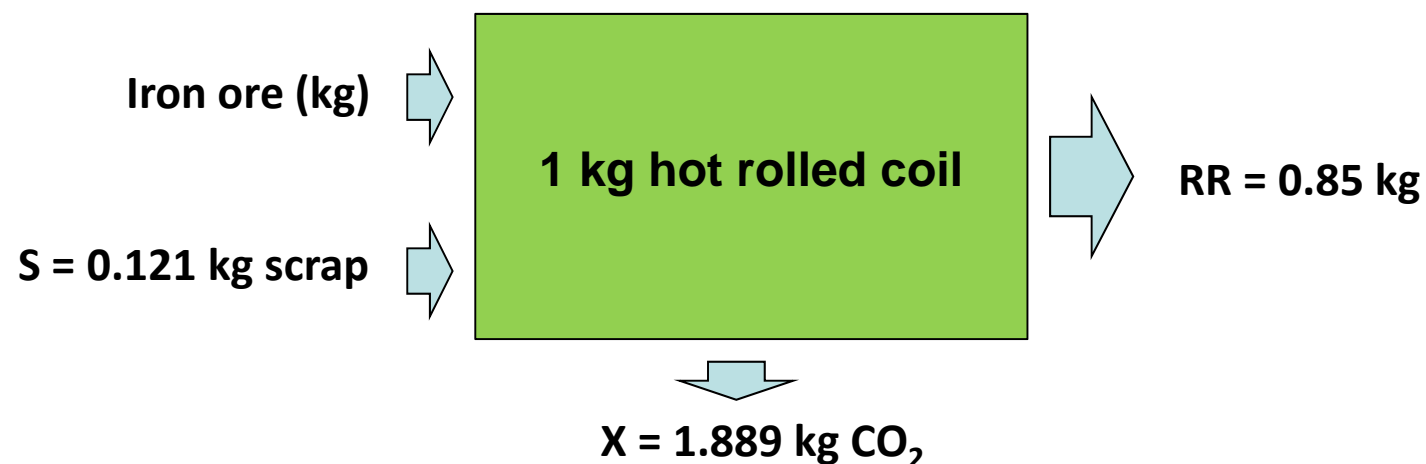


PRODUCT LEVEL

STEEL RECYCLING – ALLOCATION PROCEDURE: CLOSED-LOOP

General case of steel production including recycling

e.g.: LCI calculation of 1 kg hot rolled coil for CO₂ emissions



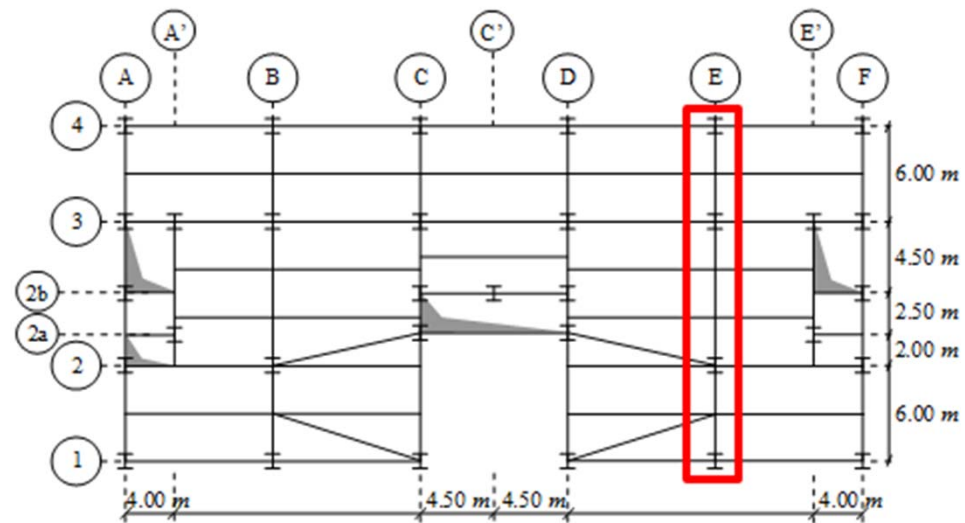
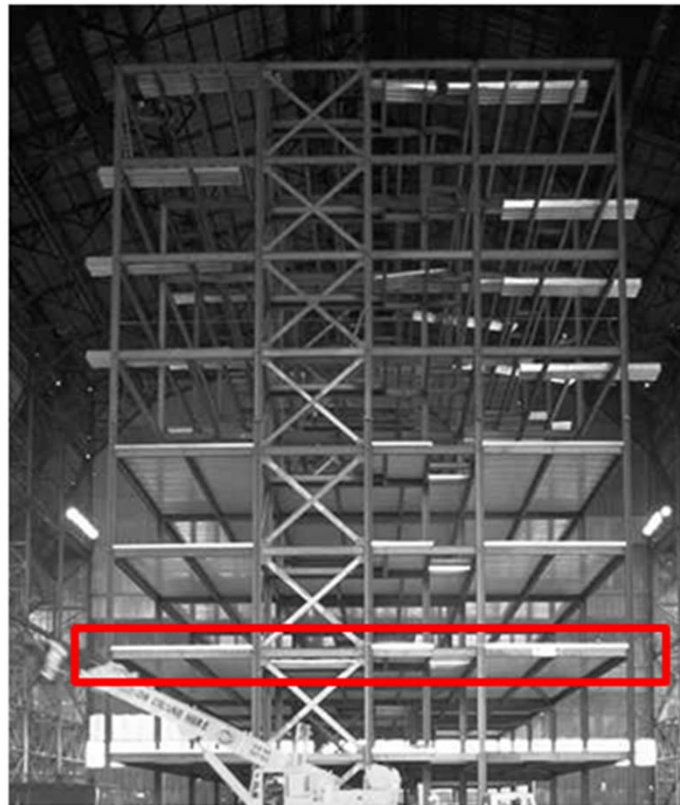
$$\text{LCI for 1 kg of steel} = 1.889 - \underbrace{(0.85 - 0.121) \times 1.41}_{\text{Module D}}^{(*)} = 0.86 \text{ kg CO}_2$$

(*) value from Worldsteel Organization for CO₂ emissions

Module D

Source: worldsteel (2011)

EXAMPLE 1: LCA OF A BEAM



LCA of a steel beam with a total length of 21 m and a **IPE 600 section**, in steel S355.

EXAMPLE 1: LCA OF A BEAM

Cradle-to-gate analysis

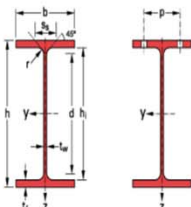
No SIM 12:37 100%

or H sections CALCULATOR Calculate

IPE

- IPE 500
- IPE A 500
- IPE O 500
- IPE 550
- IPE A 550
- IPE O 550
- IPE 600**
- IPE A 600
- IPE O 600
- IPE 750 x 147
- IPE 750 x 173
- IPE 750 x 196

IPE 600



+ Add your company MAP

Designation

G	122.45	[kg/m]
---	--------	--------

Dimensions

h	600.00	[mm]
b	220.00	[mm]
t.w	12.00	[mm]
t.f	19.00	[mm]

Inputs Parameters

Length [m]	21
Lifespan [Years]	50
Steel Grade	S355
Quality	JR
Fabrication Procedure	Hot Rolled

Scope of the Analysis

Cradle-to-gate

Coating System

EXAMPLE 1: LCA OF A BEAM

Cradle-to-gate analysis

Full Report - LVS3

LCA of IPE 600: Cradle-to-gate

Indicators describing environmental impacts

Indicator	Unit	A1-A3	TOTAL
ADP elements	[kg Sb Eq.]	-2.84e-2	-2.84e-2
ADP fossil	[MJ]	4.89e+4	4.89e+4
AP	[kg SO2 Eq.]	1.16e+1	1.16e+1
EP	[kg PO4- Eq.]	9.07e-1	9.07e-1
GWP	[kg CO2 Eq.]	4.06e+3	4.06e+3
ODP	[kg CFC-11 Eq.]	9.14e-5	9.14e-5
POCP	[kg C2H4 Eq.]	2.05e+0	2.05e+0

Indicators describing primary energy demand

Indicator	Unit	A1-A3	TOTAL
Total demand (g.c.v)	[MJ]	5.29e+4	5.29e+4
Total demand (n.c.v)	[MJ]	5.05e+4	5.05e+4
Non ren. Resources (g.c.v)	[MJ]	5.14e+4	5.14e+4
Non ren. Resources (n.c.v)	[MJ]	4.90e+4	4.90e+4
Ren. Resources (g.c.v)	[MJ]	1.51e+3	1.51e+3
Ren. Resources (n.c.v)	[MJ]	1.51e+3	1.51e+3

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Full Report

EXAMPLE 1: LCA OF A BEAM

Cradle-to-gate + recycling (module D)

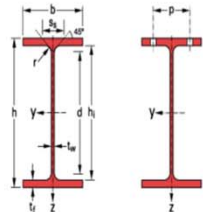
No SIM 12:38 100%

[I or H sections](#) **CALCULATOR** [Calculate](#)

IPE

- IPE 500
- IPE A 500
- IPE O 500
- IPE 550
- IPE A 550
- IPE O 550
- IPE 600**
- IPE A 600
- IPE O 600
- IPE 750 x 147
- IPE 750 x 173
- IPE 750 x 196

IPE 600



+ Add your company

Designation

G 122.45 [kg/m]

Dimensions

h 600.00 [mm]

b 220.00 [mm]

t.w 12.00 [mm]

t.f 19.00 [mm]

Inputs Parameters

Length [m] 21

Lifespan [Years] 50

Steel Grade S355

Quality JR

Fabrication Procedure Hot Rolled

Scope of the Analysis

Cradle-to-gate + Recycling

End-of-life recycling

Recycling rate [%] 99

Coating System

EXAMPLE 1: LCA OF A BEAM

Cradle-to-gate + recycling (module D)

Full Report - LVS3

Indicators describing environmental impacts

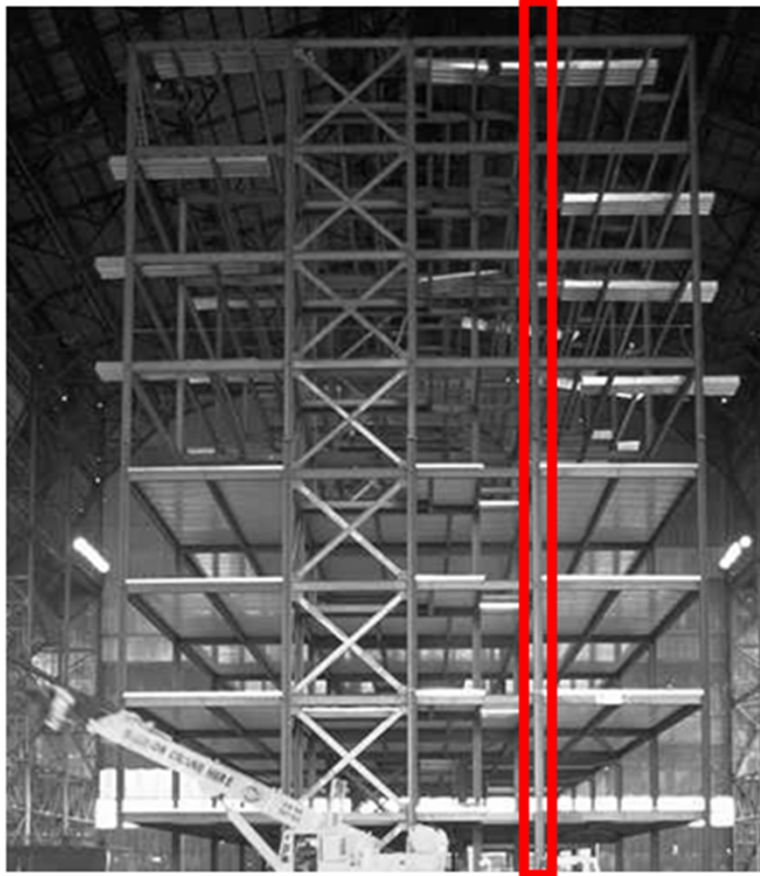
Indicator	Unit	A1-A3	D	TOTAL
ADP elements	[kg Sb Eq.]	-2.84e-2	-1.52e-2	-4.36e-2
ADP fossil	[MJ]	4.89e+4	-1.40e+4	3.49e+4
AP	[kg SO ₂ Eq.]	1.16e+1	-3.55e+0	8.10e+0
EP	[kg PO ₄ - Eq.]	9.07e-1	-9.80e-2	8.09e-1
GWP	[kg CO ₂ Eq.]	4.06e+3	-1.49e+3	2.57e+3
ODP	[kg CFC-11 Eq.]	9.14e-5	4.75e-5	1.39e-4
POCP	[kg C ₂ H ₄ Eq.]	2.05e+0	-7.93e-1	1.25e+0

Indicators describing primary energy demand

Indicator	Unit	A1-A3	D	TOTAL
Total demand (g.c.v)	[MJ]	5.29e+4	-1.35e+4	3.94e+4
Total demand (n.c.v)	[MJ]	5.05e+4	-1.32e+4	3.73e+4
Non ren. Resources (g.c.v)	[MJ]	5.14e+4	-1.43e+4	3.71e+4
Non ren. Resources (n.c.v)	[MJ]	4.90e+4	-1.40e+4	3.50e+4
Ren. Resources (g.c.v)	[MJ]	1.51e+3	8.08e+2	2.32e+3
Ren. Resources (n.c.v)	[MJ]	1.51e+3	8.08e+2	2.32e+3

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EXAMPLE 2: LCA OF A COLUMN



LCA of a steel column with a total height of 30 m and a **HEB 320 section**, in steel S355.

EXAMPLE 2: LCA OF A COLUMN

No SIM 12:59 94%

Calculator

HE

HE 340 AA

HE 340 A

HE 340 B

HE 340 M

HE 360 AA

HE 360 A

HE 360 B

HE 360 M

HE 400 AA

HE 400 A

HE 400 B

HE 400 M

HE 360 B

Designation

G 141.80 [kg/m]

Dimensions

h 360.00 [mm]

b 300.00 [mm]

t.w 12.50 [mm]

t.f 22.50 [mm]

Inputs Parameters

Length [m] 30

Lifespan [Years] 50

Steel Grade S355

Quality JR

Fabrication Procedure Hot Rolled

Scope of the Analysis

Cradle-to-grave + Recycling

End-of-life recycling

Recycling rate [%] 99

Coating System

Coating System On

Type of Coating

EXAMPLE 2: LCA OF A COLUMN

No SIM 13:00 94%

← I or H sections **CALCULATOR** Calculate

HE

HE 340 AA >

HE 340 A >

HE 340 B >

HE 340 M >

HE 360 AA >

HE 360 A >

HE 360 B >

HE 360 M >

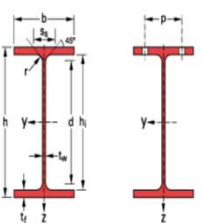
HE 400 AA >

HE 400 A >

HE 400 B >

HE 400 M >

HE 360 B



+ Add your company MAP

Designation

G	141.80	[kg/m]
---	--------	--------

Dimensions

h	360.00	[mm]
b	300.00	[mm]
t.w	12.50	[mm]
t.f	22.50	[mm]

Scope of the Analysis

Cradle-to-grave + Recycling

End-of-life recycling

Recycling rate [%] 99

Coating System

Coating System On

Type of Coating Solvent paint

Total/partial replacement [%] 80

every [Years] 10

Transportation

Maintenance
of the column
over the
lifespan of
analysis

EXAMPLE 2: LCA OF A COLUMN

Full Report - LVS3

Indicators describing environmental impacts

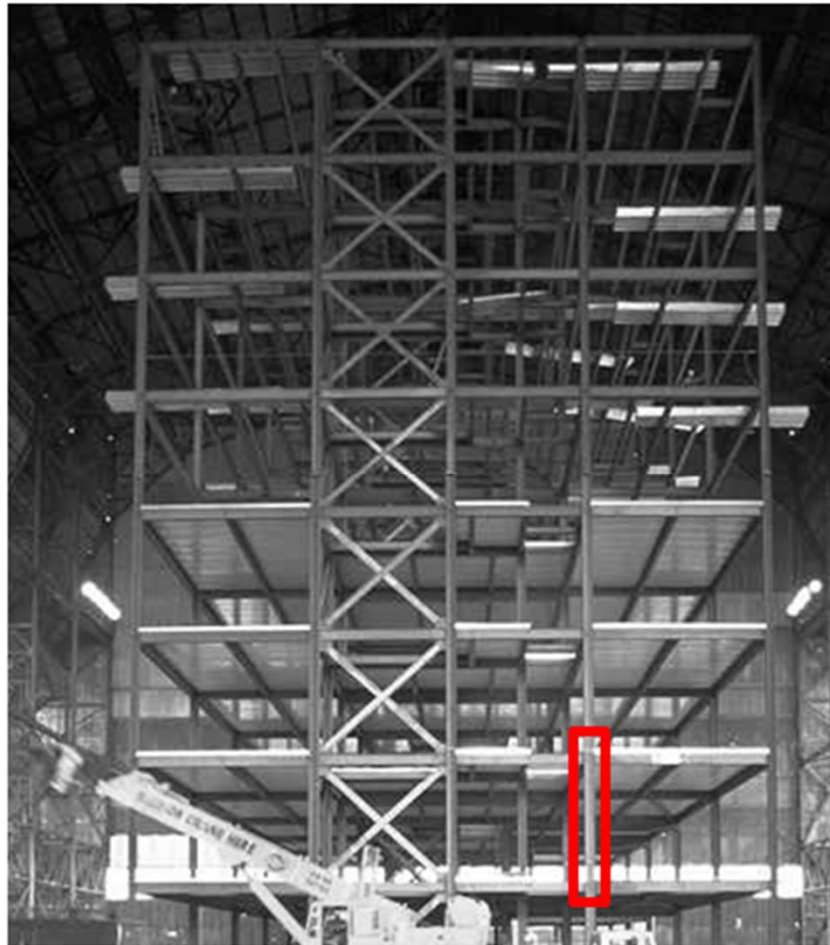
Indicator	Unit	A1-A3	A4	B2	C2	C4	D	TOTAL
ADP elements	[kg Sb Eq.]	-4.69e-2	0.00e+0	1.00e-4	0.00e+0	2.13e-7	-2.51e-2	-7.19e-2
ADP fossil	[MJ]	8.28e+4	0.00e+0	6.22e+3	0.00e+0	8.31e+0	-2.32e+4	6.59e+4
AP	[kg SO ₂ Eq.]	1.97e+1	0.00e+0	1.35e+0	0.00e+0	3.63e-3	-5.87e+0	1.52e+1
EP	[kg PO ₄ - Eq.]	1.52e+0	0.00e+0	5.82e-2	0.00e+0	5.55e-4	-1.62e-1	1.42e+0
GWP	[kg CO ₂ Eq.]	6.83e+3	0.00e+0	3.45e+2	0.00e+0	2.44e+0	-2.47e+3	4.71e+3
ODP	[kg CFC-11 Eq.]	1.51e-4	0.00e+0	6.30e-8	0.00e+0	4.56e-10	7.86e-5	2.30e-4
POCP	[kg C ₂ H ₄ Eq.]	3.72e+0	0.00e+0	1.06e+0	0.00e+0	9.42e-4	-1.31e+0	3.47e+0

Indicators describing primary energy demand

Indicator	Unit	A1-A3	A4	B2	C2	C4	D	TOTAL
Total demand (g.c.v)	[MJ]	8.98e+4	0.00e+0	7.07e+3	0.00e+0	9.56e+0	-2.24e+4	7.45e+4
Total demand (n.c.v)	[MJ]	8.56e+4	0.00e+0	6.51e+3	0.00e+0	8.93e+0	-2.18e+4	7.03e+4
Non ren. Resources (g.c.v)	[MJ]	8.72e+4	0.00e+0	6.78e+3	0.00e+0	8.94e+0	-2.37e+4	7.02e+4
Non ren. Resources (n.c.v)	[MJ]	8.30e+4	0.00e+0	6.22e+3	0.00e+0	8.31e+0	-2.31e+4	6.61e+4
Ren. Resources (g.c.v)	[MJ]	2.60e+3	0.00e+0	2.91e+2	0.00e+0	6.18e-1	1.34e+3	4.22e+3
Ren. Resources (n.c.v)	[MJ]	2.60e+3	0.00e+0	2.91e+2	0.00e+0	6.18e-1	1.34e+3	4.22e+3

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EXAMPLE 3: COMPARATIVE LCA OF A COLUMN



Comparative LCA of a steel column with a total height of 4.335 m, in steel S355, considering:

- ✓ HEB 280
- ✓ SHS 260 x 12
- ✓ CHS 323.9 x 12

Note: All alternative designs for the column **fulfill the same functional unit** - a restrained column, 4.335 m long, with a load bearing capacity of an axial force of 1704 kN and a bending moment of 24.8 kNm (around the strong axis for the profile column).

EXAMPLE 3: COMPARATIVE LCA OF A COLUMN

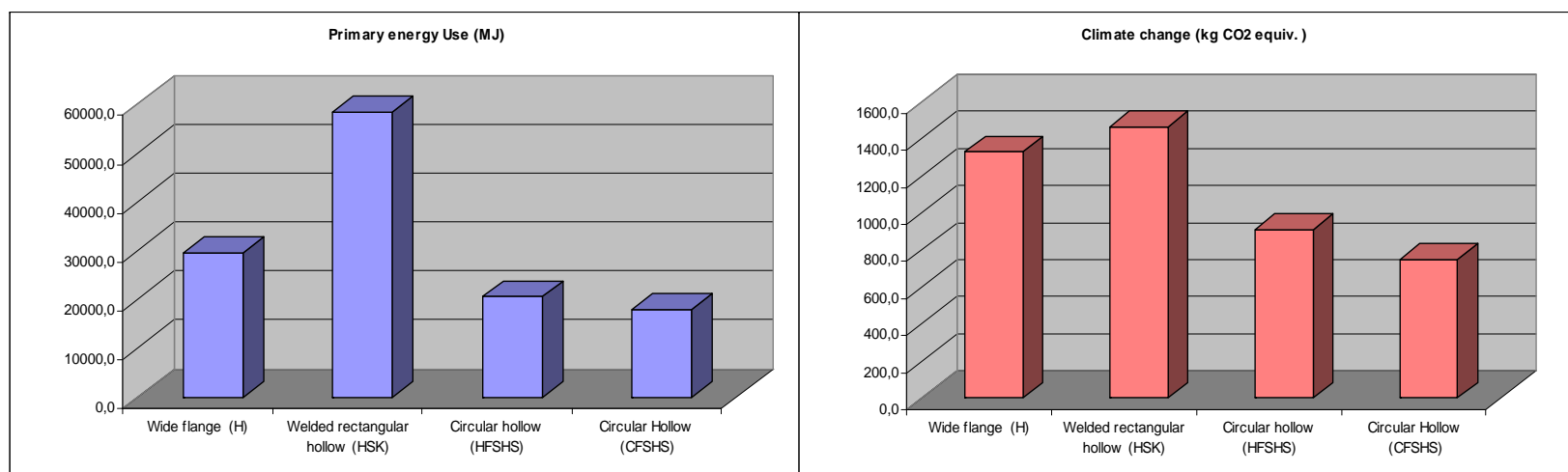
Indicators describing environmental impacts

Indicator	Unit	HEB 280	SHS 260x12	CHS 323.9x12
ADP elements	[kg Sb Eq.]	-7.57E-03	-6.77E-03	-6.78E-03
ADP fossil	[MJ]	6.06E+03	5.42E+03	5.43E+03
AP	[kg SO ₂ Eq.]	1.41E+00	1.26E+00	1.26E+00
EP	[kg PO ₄ - Eq.]	1.41E-01	1.26E-01	1.26E-01
GWP	[kg CO ₂ Eq.]	4.47E+02	4.00E+02	4.00E+02
ODP	[kg CFC-11 Eq.]	2.41E-05	2.16E-05	2.16E-05
POCP	[kg C ₂ H ₄ Eq.]	2.18E-01	1.95E-01	1.95E-01
		92.98 kg/m	92.23 kg/m	92.30 kg/m

Note: considering hot rolled sections

Comparison between cold-formed and hot finished sections (data from EPDs)

Note: These results are not about the previous case study, they are based on a similar case-study



Wide flange HD 400.237 1181 kg

Welded rectangular HSK 400.350 984 kg

Cold formed circular hollow d=559mm

t=12,5mm 842 kg

Hot finished circular hollow d=559mm

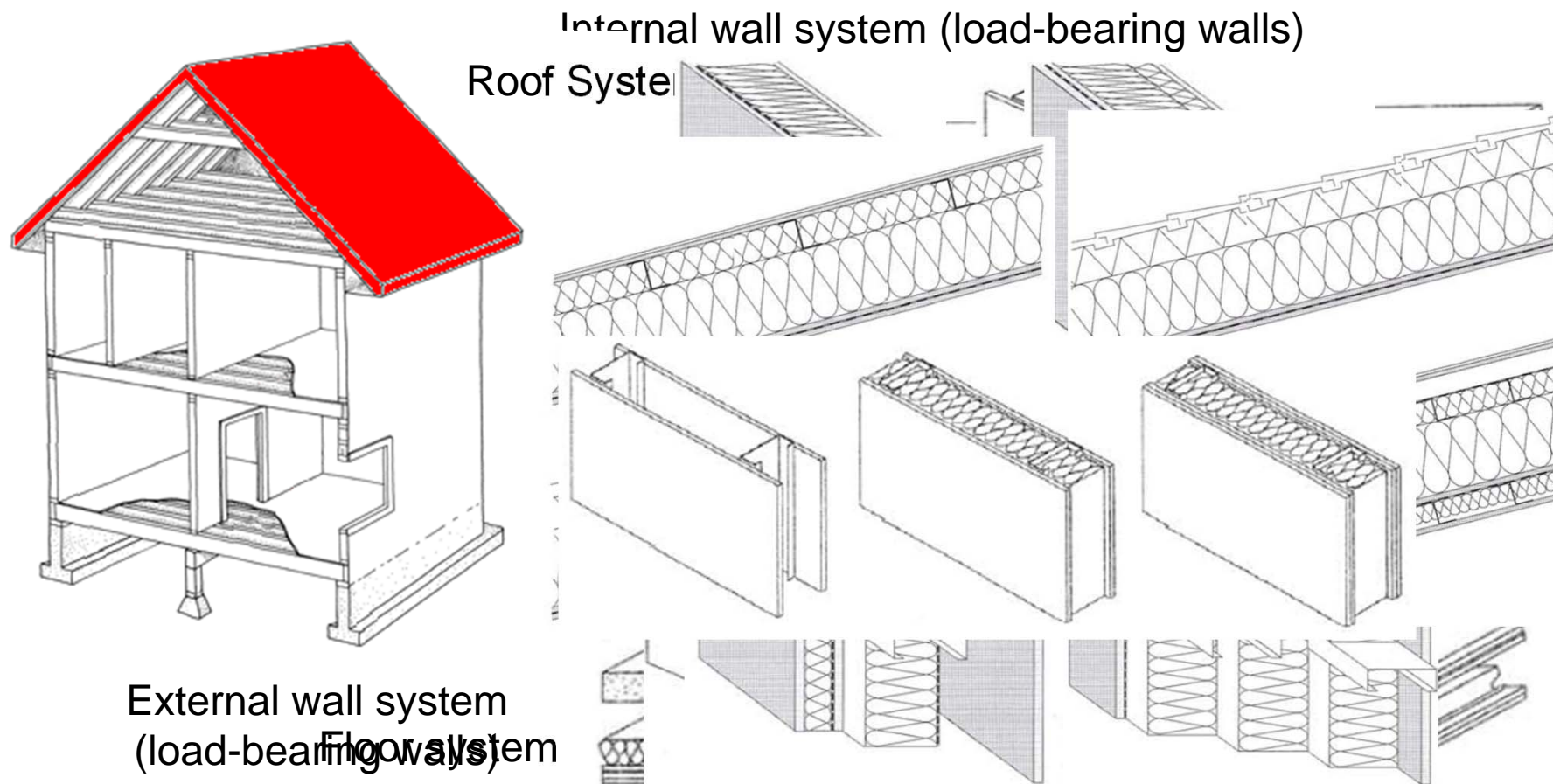
t=12,5mm 842 kg



More recent data may be found in: <http://www.epd-norge.no/>

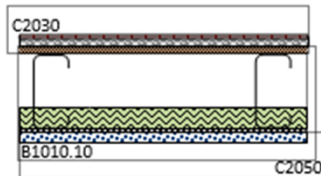
BUILDING LEVEL

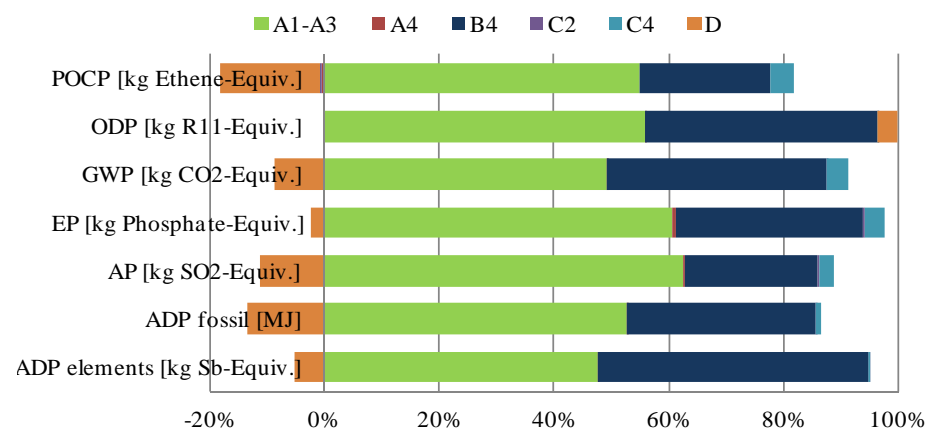
SIMPLIFIED APPROACH BASED ON MACRO-COMPONENTS



BUILDING LEVEL

SIMPLIFIED APPROACH BASED ON MACRO-COMPONENTS

Macro-components assemblage	Macro-components	Material	Thickness (mm)/ Density (kg/m ²)
	C2030 Flooring	Ceramic tiles	31 kg/m ²
		Concrete screed	13 mm
	B1010.10 Floor structural frame	OSB	18 mm
		Air cavity	160 mm
		Rock wool	40 mm
		Light weight steel	14 kg/m ²
	C2050 Ceiling finishes	Gypsum board	15 mm
		Painting	0.125 kg/m ²



Note: Environmental Impacts

- ✓ Abiotic Resource Depletion Potential for elements (ADP elements)
- ✓ Abiotic Resource Depletion Potential of fossil fuels (ADP fossil fuels)
- ✓ Acidification potential of land and water (AP)
- ✓ Eutrophication potential (EP)
- ✓ Global warming potential (GWP)
- ✓ Depletion potential of the stratospheric ozone layer (ODP)
- ✓ Formation potential of tropospheric ozone photochemical oxidants (POCP)

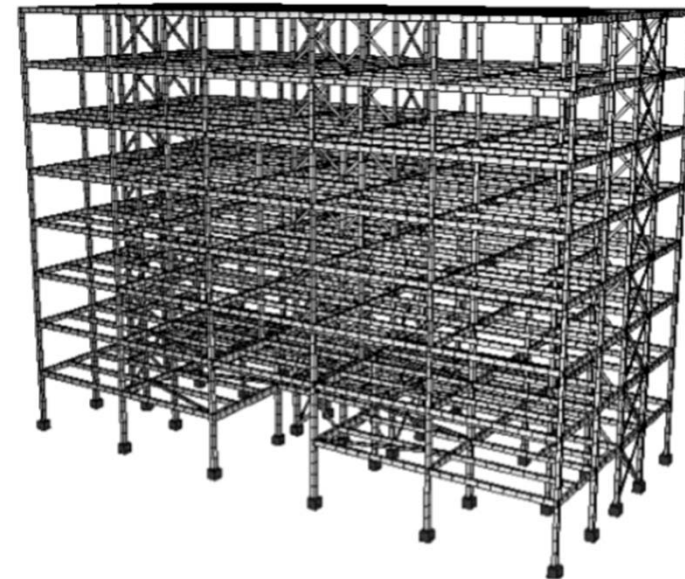
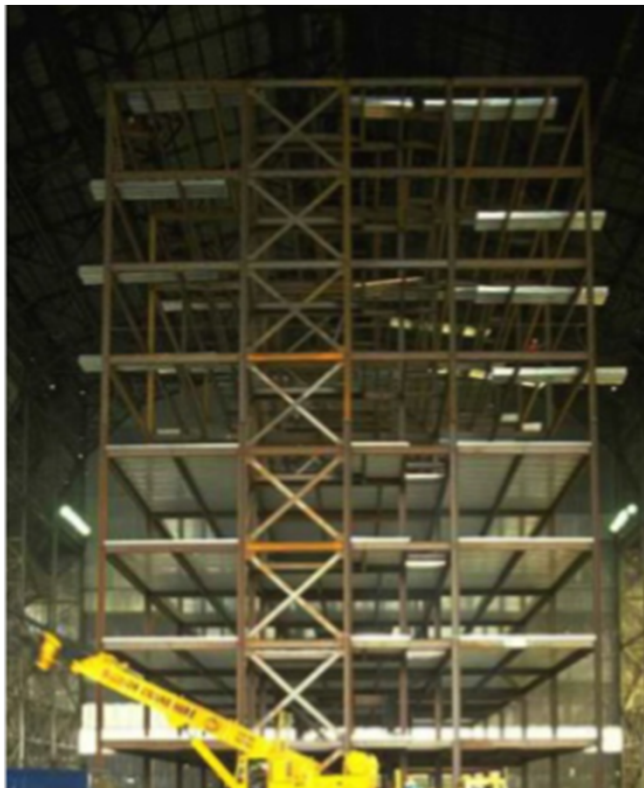
Source: Gervásio et al. (2014)

Impact category	A1-A3	A4	B4	C2	C4	D	TOTAL
ADP elem. [kg Sb-Eq.]	1.86E-03	6.59E-09	1.83E-03	5.76E-09	5.93E-07	-1.96E-04	3.49E-03
ADP fossil [MJ]	1.31E+03	2.45E+00	8.12E+02	2.14E+00	2.31E+01	3.35E+02	1.82E+03
AP [kg SO ₂ Eq.]	2.47E-01	7.91E-04	9.14E-02	6.85E-04	1.01E-02	-4.45E-02	3.05E-01
EP [kg PO ₄ Eq.]	2.61E-02	1.82E-04	1.40E-02	1.57E-04	1.54E-03	-1.01E-03	4.09E-02
GWP [kg CO ₂ Eq.]	8.38E+01	1.77E-01	6.48E+01	1.54E-01	6.80E+00	1.45E+01	1.41E+02
ODP [kg R11 Eq.]	2.80E-06	3.09E-12	2.04E-06	2.70E-12	1.27E-09	1.76E-07	5.01E-06
POCP [kg Ethene Eq.]	3.41E-02	-2.58E-04	1.43E-02	-2.23E-04	2.62E-03	-1.07E-02	3.98E-02



European
Commission

EXAMPLE 4: LCA OF A STEEL BUILDING



- ✓ Floor area of 21 m by 45 m;
- ✓ Total height of 33;
- ✓ 8 storeys.

EXAMPLE 4: LCA OF A STEEL BUILDING

Life cycle analysis of steel structure

Beams	Length (m)
IPE 400	2239
IPE 600	160
IPE 360	1916
HEA 700	32

Columns	Length (m)
HEB 340	93
HEB 320	438
HEB 260	567

⇒ Total weight of steel structure – 405 tonnes

Scope of the analysis: Cradle-to-grave + Recycling

Assumptions:

- ✓ Type of coating: Water based paint, with a partial replacement of 50% every 20 years;
- ✓ Transportation Module A4: 100% of steel transported by truck over 200 km;
- ✓ Transportation Module C2: 100% of steel transported by truck over 100 km;
- ✓ RR = 99% for all steel elements

EXAMPLE 4: LCA OF A STEEL BUILDING

Life cycle analysis of steel structure

Indicators describing environmental impacts

Indicator	Unit	A1-A3	A4	B2	C2	C4	D	TOTAL
ADP elements	[kg Sb Eq.]	-4.47E+00	1.53E-04	8.31E-03	7.58E-05	2.03E-05	-2.39E+00	-6.84E+00
ADP fossil	[MJ]	7.95E+06	5.69E+04	2.53E+05	2.81E+04	7.91E+02	-2.20E+06	6.08E+06
AP	[kg SO2 Eq.]	1.87E+03	1.82E+01	3.59E+01	9.02E+00	3.45E-01	-5.58E+02	1.37E+03
EP	[kg PO4- Eq.]	1.46E+02	4.18E+00	3.12E+00	2.07E+00	5.29E-02	-1.54E+01	1.40E+02
GWP	[kg CO2 Eq.]	6.55E+05	4.10E+03	1.52E+04	2.03E+03	2.32E+02	-2.35E+05	4.41E+05
ODP	[kg CFC-11 Eq.]	1.44E-02	7.17E-08	3.52E-06	3.55E-08	4.33E-08	7.47E-03	2.19E-02
POCP	[kg C2H4 Eq.]	3.51E+02	-5.92E+00	2.80E+01	-2.93E+00	8.97E-02	-1.25E+02	2.45E+02



EXAMPLE 4: LCA OF A STEEL BUILDING

Life cycle analysis of steel structure

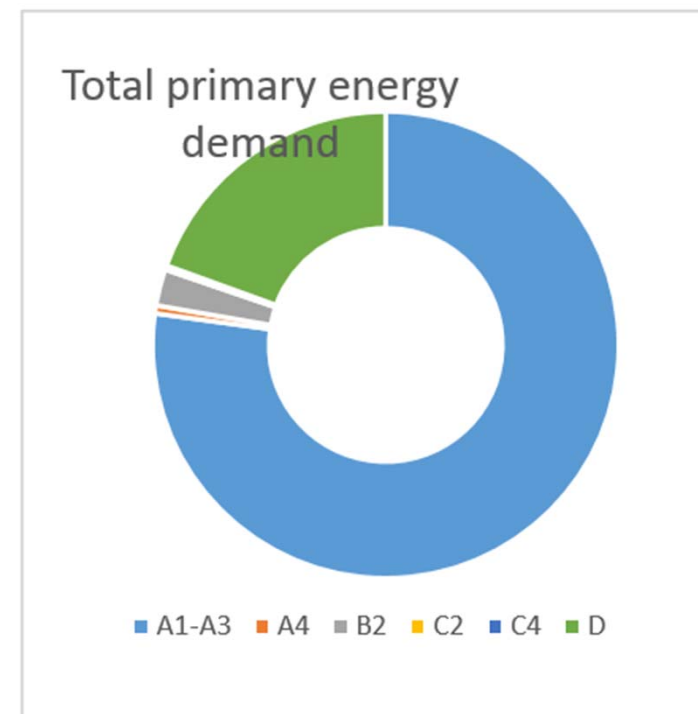
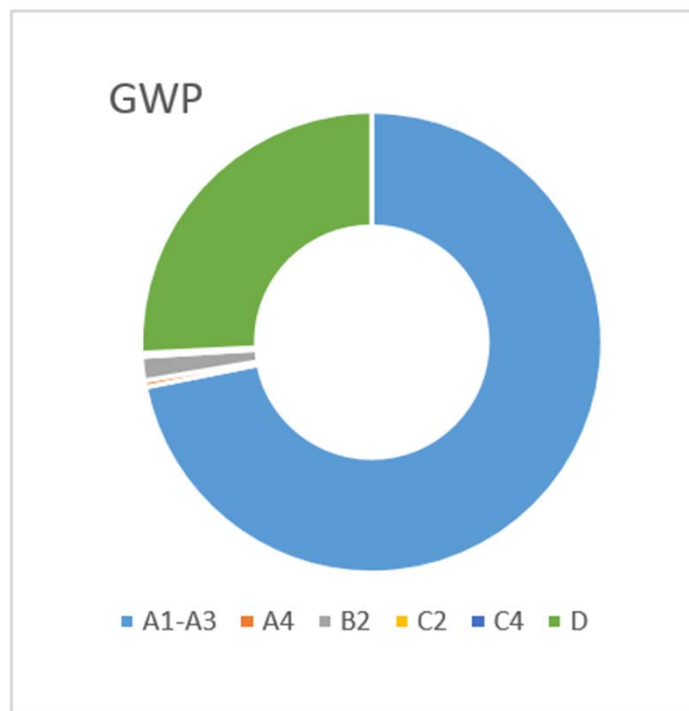
Indicators describing primary energy demand

Indicator	Unit	A1-A3	A4	B2	C2	C4	D	TOTAL
Total demand (g.c.v)	[MJ]	8.63E+06	6.32E+04	2.92E+05	3.13E+04	9.11E+02	-2.13E+06	6.88E+06
Total demand (n.c.v)	[MJ]	8.21E+06	5.91E+04	2.68E+05	2.92E+04	8.50E+02	-2.07E+06	6.50E+06
Non ren. Resources (g.c.v)	[MJ]	8.37E+06	6.10E+04	2.75E+05	3.02E+04	8.51E+02	-2.26E+06	6.48E+06
Non ren. Resources (n.c.v)	[MJ]	7.96E+06	5.69E+04	2.53E+05	2.81E+04	7.91E+02	-2.20E+06	6.10E+06
Ren. Resources (g.c.v)	[MJ]	2.54E+05	2.23E+03	1.59E+04	1.10E+03	5.87E+01	1.27E+05	4.00E+05
Ren. Resources (n.c.v)	[MJ]	2.54E+05	2.23E+03	1.59E+04	1.10E+03	5.87E+01	1.27E+05	4.00E+05

EXAMPLE 4: LCA OF A STEEL BUILDING

Life cycle analysis of steel structure

Summary of results for the steel structure



EXAMPLE 4: LCA OF A STEEL BUILDING

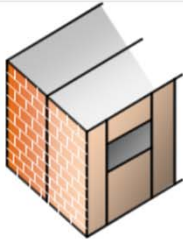
Definition of building geometry



14:08 75%

Single & multi-family... CALCULATOR Calculate

Category 2

- Façades ✓
- Partitions ✓
- Internal Floors ✓
- Ground Floor ✓
- Roof ✓



 Add your company 

Façades

Partitions

Internal Floors

Ground Floor

Roof

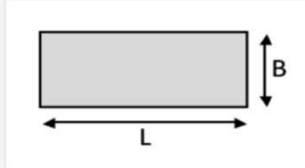
Number of floors
[n] 8

Height of building
[m] 33

Lifespan
[Years] 50

Scope of the Analysis
Cradle-to-grave + Recycling

Selection of Building Type



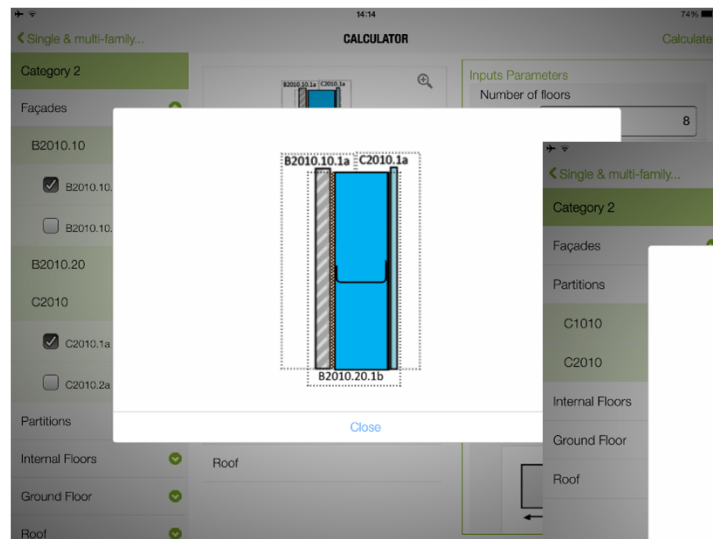
B [m] 21

L [m] 45

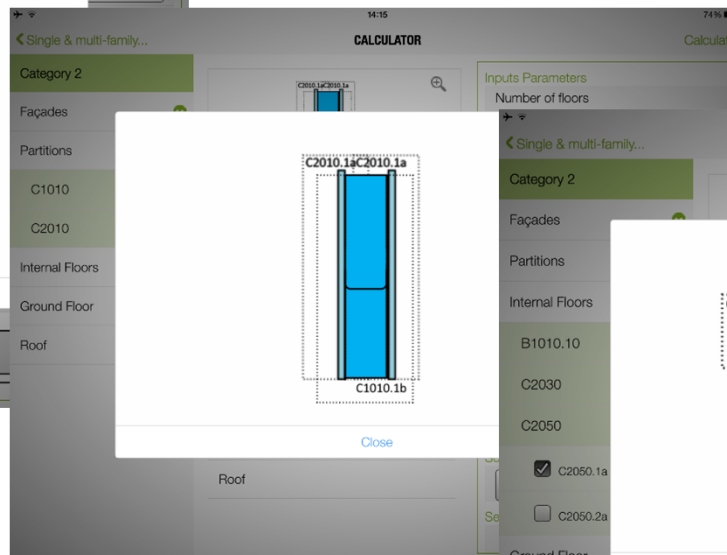
EXAMPLE 4: LCA OF A STEEL BUILDING

Selection of building macro-components

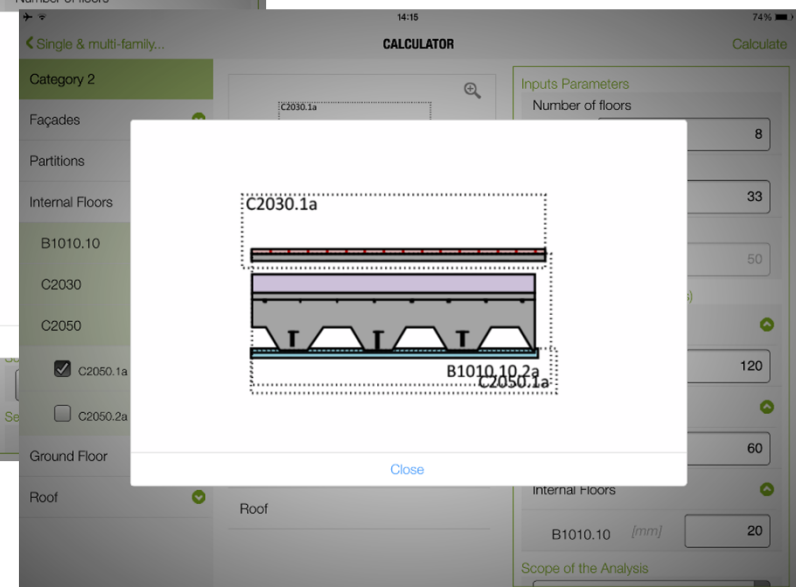
Façade



Internal walls



Internal floors



EXAMPLE 4: LCA OF A STEEL BUILDING

Results per macro-components

LCA of Façades

Indicators describing environmental impacts

Indicator	Unit	A1-A3	A4	B2	C2	C4	D	TOTAL
ADP elements	[kg Sb Eq.]	5.21e-1	1.10e-5	3.98e-1	9.33e-6	3.07e-4	-9.70e-1	-5.02e-2
ADP fossil	[MJ]	4.43e+6	4.10e+3	1.49e+6	3.47e+3	1.05e+4	-2.15e+6	3.79e+6
AP	[kg SO ₂ Eq.]	8.71e+2	1.33e+0	2.46e+2	1.11e+0	4.93e+0	-3.60e+2	7.65e+2
EP	[kg PO ₄ - Eq.]	6.96e+1	3.06e-1	2.48e+1	2.55e-1	8.19e-1	-8.61e+0	8.72e+1
GWP	[kg CO ₂ Eq.]	2.95e+5	2.96e+2	7.07e+4	2.50e+2	3.03e+4	-6.34e+4	3.33e+5
ODP	[kg CFC-11 Eq.]	5.98e-3	5.18e-9	2.44e-3	4.37e-9	5.07e-7	-1.03e-4	8.32e-3
POCP	[kg C ₂ H ₄ Eq.]	5.17e+2	-4.33e-1	2.41e+2	-3.61e-1	1.02e+0	-5.63e+1	7.02e+2

EXAMPLE 4: LCA OF A STEEL BUILDING

Results per macro-components

LCA of Partitions

Indicators describing environmental impacts

Indicator	Unit	A1-A3	A4	B2	C2	C4	D	TOTAL
ADP elements	[kg Sb Eq.]	3.69e-2	2.70e-6	1.52e-3	2.29e-6	7.19e-5	-2.44e-1	-2.06e-1
ADP fossil	[MJ]	6.77e+5	1.00e+3	2.50e+4	8.53e+2	2.50e+3	-2.81e+5	4.25e+5
AP	[kg SO2 Eq.]	1.56e+2	3.24e-1	4.88e+0	2.73e-1	1.16e+0	-7.82e+1	8.49e+1
EP	[kg PO4- Eq.]	9.77e+0	7.47e-2	3.41e-1	6.27e-2	1.91e-1	-2.82e+0	7.62e+0
GWP	[kg CO2 Eq.]	5.25e+4	7.22e+1	1.16e+3	6.13e+1	6.18e+3	-2.82e+4	3.18e+4
ODP	[kg CFC-11 Eq.]	4.69e-4	1.26e-9	2.93e-7	1.07e-9	1.24e-7	7.63e-4	1.23e-3
POCP	[kg C2H4 Eq.]	6.18e+1	-1.06e-1	3.87e+0	-8.88e-2	2.50e-1	-1.40e+1	5.17e+1

EXAMPLE 4: LCA OF A STEEL BUILDING

Results per macro-components

LCA of Internal Floor

Indicators describing environmental impacts

Indicator	Unit	A1-A3	A4	B2	C2	C4	D	TOTAL
ADP elements	[kg Sb Eq.]	6.25e+0	1.42e-4	6.02e+0	1.24e-4	1.00e-2	-8.26e-1	1.15e+1
ADP fossil	[MJ]	7.27e+6	5.28e+4	2.36e+6	4.62e+4	3.90e+5	-1.01e+6	9.11e+6
AP	[kg SO ₂ Eq.]	1.53e+3	1.70e+1	2.28e+2	1.47e+1	1.71e+2	-2.90e+2	1.67e+3
EP	[kg PO ₄ - Eq.]	1.78e+2	3.93e+0	2.61e+1	3.38e+0	2.61e+1	-9.51e+0	2.28e+2
GWP	[kg CO ₂ Eq.]	7.20e+5	3.80e+3	1.68e+5	3.31e+3	1.24e+5	-1.08e+5	9.11e+5
ODP	[kg CFC-11 Eq.]	8.77e-3	6.65e-8	6.75e-3	5.80e-8	2.14e-5	2.60e-3	1.81e-2
POCP	[kg C ₂ H ₄ Eq.]	2.13e+2	-5.57e+0	3.07e+1	-4.79e+0	4.41e+1	-5.38e+1	2.24e+2



EXAMPLE 4: LCA OF A STEEL BUILDING

Results for the building

LCA of building (structure + macro-components)

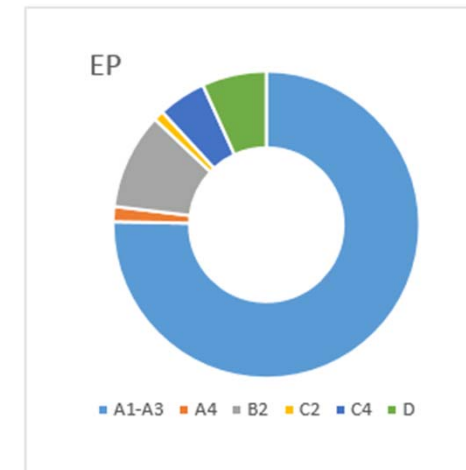
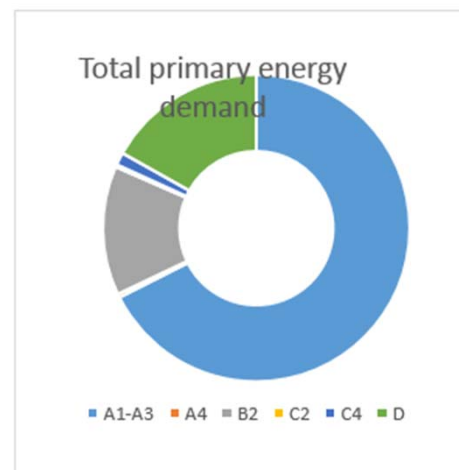
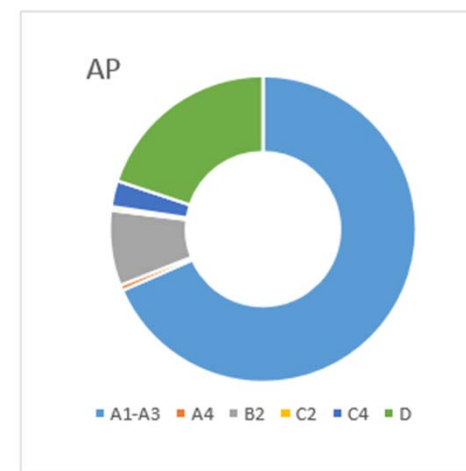
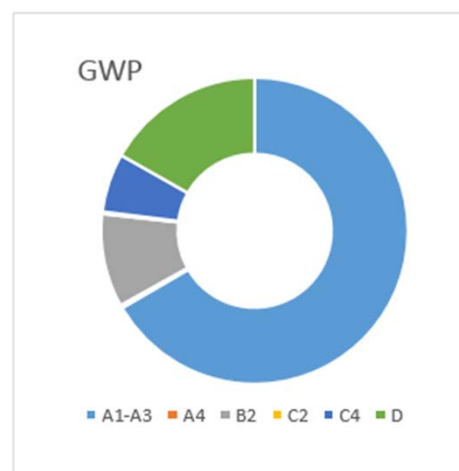
Indicators describing environmental impacts

Indicator	Unit	A1-A3	A4	B2	C2	C4	D	TOTAL
ADP elements	[kg Sb Eq.]	2.34E+00	3.09E-04	6.43E+00	2.11E-04	1.04E-02	-4.43E+00	4.40E+00
ADP fossil	[MJ]	2.03E+07	1.15E+05	4.13E+06	7.86E+04	4.04E+05	-5.65E+06	1.94E+07
AP	[kg SO2 Eq.]	4.43E+03	3.69E+01	5.15E+02	2.51E+01	1.77E+02	-1.29E+03	3.89E+03
EP	[kg PO4- Eq.]	4.03E+02	8.49E+00	5.44E+01	5.77E+00	2.72E+01	-3.64E+01	4.63E+02
GWP	[kg CO2 Eq.]	1.72E+06	8.26E+03	2.55E+05	5.65E+03	1.61E+05	-4.34E+05	1.72E+06
ODP	[kg CFC-11 Eq.]	2.96E-02	1.45E-07	9.19E-03	9.89E-08	2.21E-05	1.07E-02	4.95E-02
POCP	[kg C2H4 Eq.]	1.14E+03	-1.20E+01	3.04E+02	-8.17E+00	4.55E+01	-2.49E+02	1.22E+03

EXAMPLE 4: LCA OF A STEEL BUILDING

Results for the building

LCA of building (structure + macro-components)



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Thank you for your attention!!

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