



TERRE

Training Engineers and Researchers to Rethink geotechnical Engineering for a low carbon future

*European Commission – Horizon 2020
Marie Skłodowska-Curie European Training Networks (ETN)*

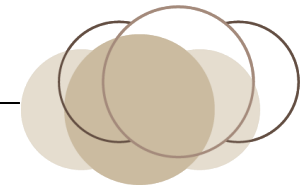
TERRE International School

**Life Cycle Assessment and the environmental costs of
geo-structures**

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Agenda

- 1) Context**
- 2) LCA main characteristics**
- 3) How it works in practice**
- 4) Examples**
- 5) Conclusion**

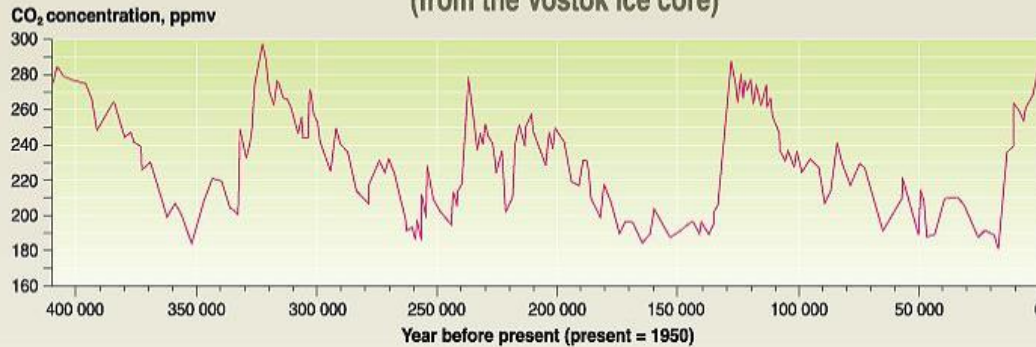


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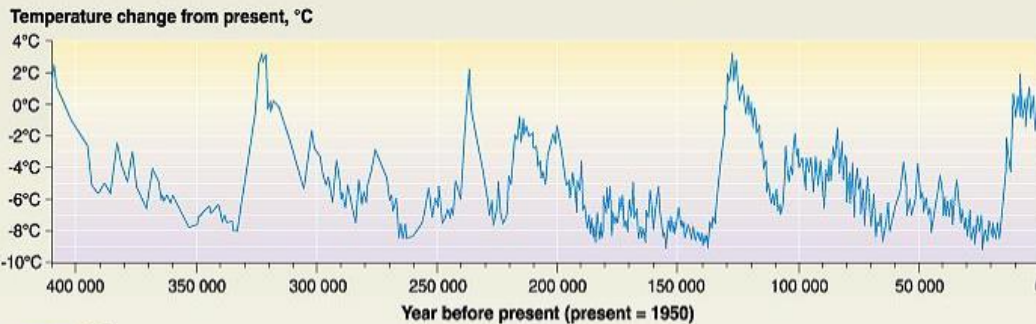
CONTEXT

CO₂ and Temperature increase

Temperature and CO₂ concentration in the atmosphere over the past 400 000 years
(from the Vostok ice core)

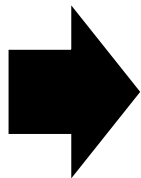
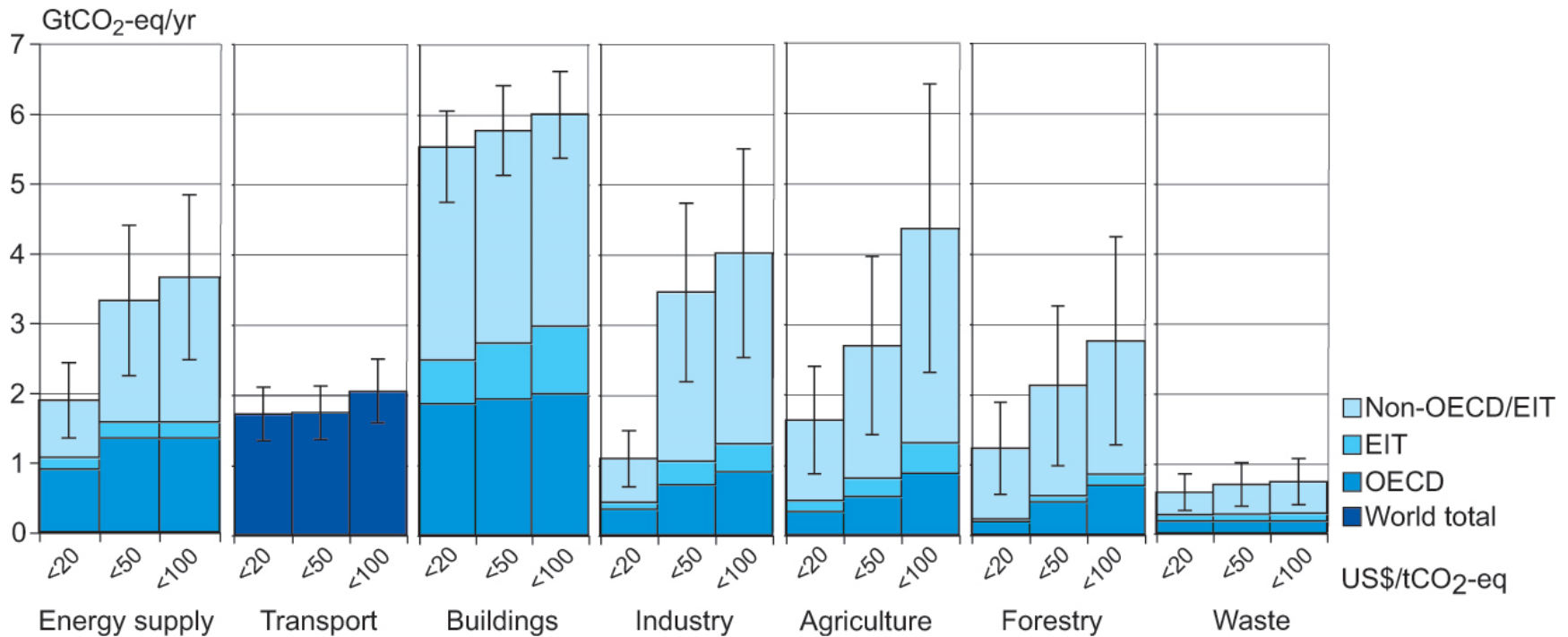


Current CO₂ concentration in the atmosphere: 402 ppm
(Source: NOAA)



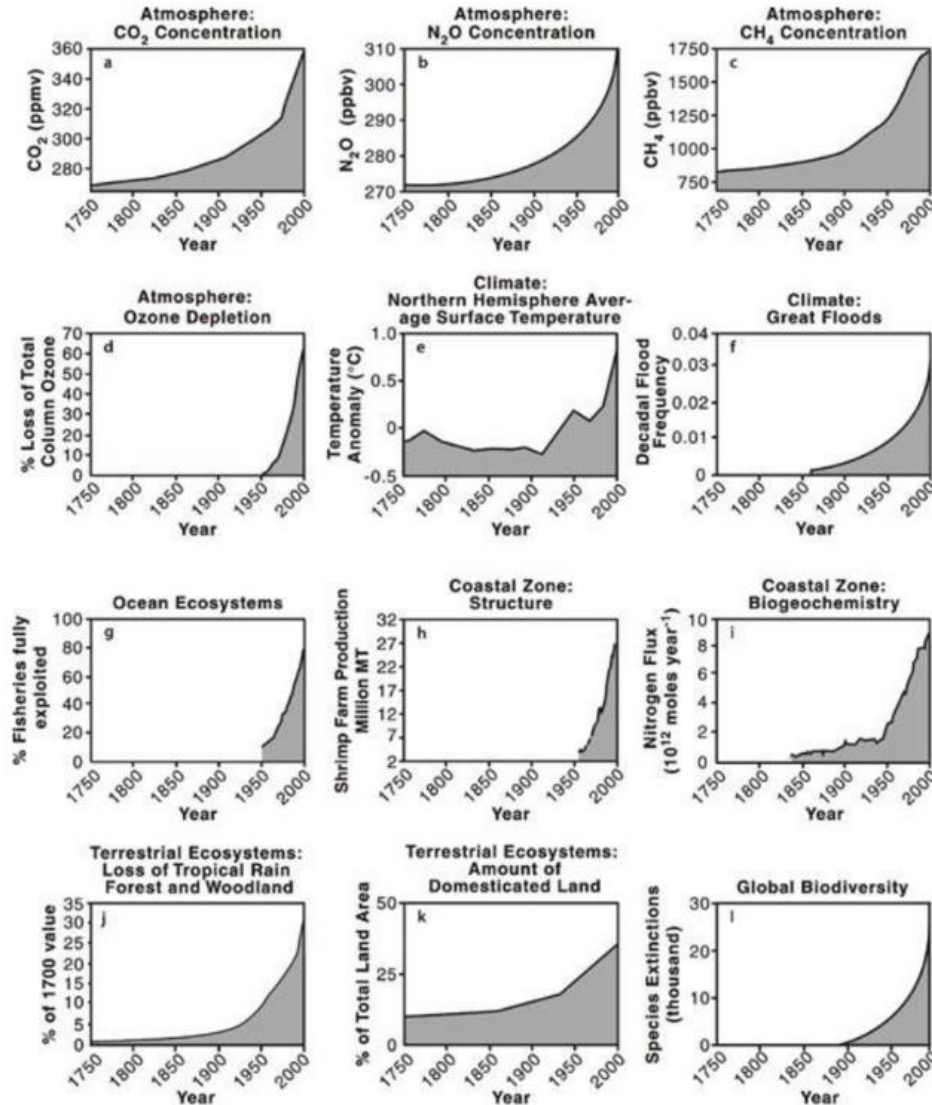
Current temperature change from 1950: +0.8°C

Which sectors?



BUILDING SECTOR AS THE MOST « AFFORDABLE » and « GREATEST POTENTIAL » SECTOR

Not only climate change



LCA MAIN CHARACTERISTICS

What is LCA?



- A methodology to quantify the environmental impacts of a product/service (the « system »)
- Investigates the whole life cycle of this system
- Uses a wide set of environmental indicators
- Used to start eco-design
- Used to benchmark the environmental « performance » of a product/service





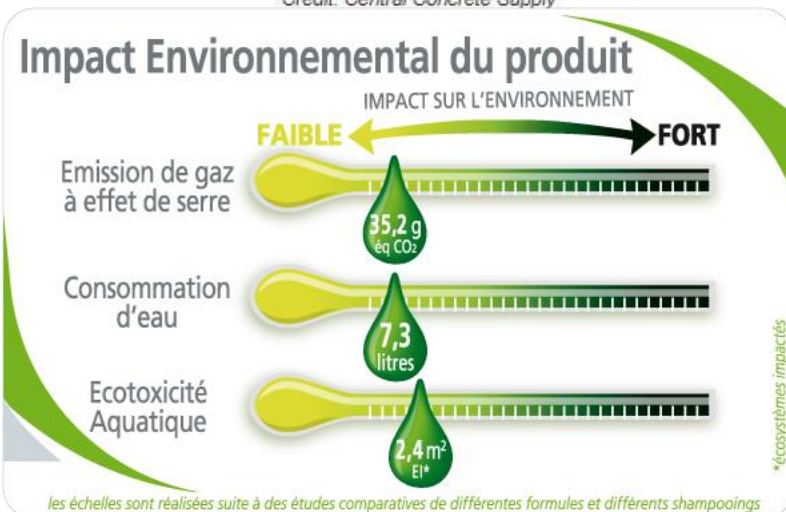
What is the aim?

- **QUANTIFY** the environmental impacts of a system

Summary of Environmental Product Declaration		Environmental Impacts 			
Central Concrete		Impact name	Unit	Impact per m3	Impact per cyd
Mix	340PG9Q1	Total primary energy consumption	MJ	2,491	1,906
San Jose Service Area		Concrete water use (batch)	m3	6.66E-2	5.10E-2
EF V2 Gen Use P4000 3" Line 50% SCM		Concrete water use (wash)	m3	8.56E-3	6.55E-3
Performance Metrics 		Global warming potential	kg CO2-eq	271	207
		Ozone depletion	kg CFC-11-eq	5.40E-6	4.14E-6
		Acidification	kg SO2-eq	2.26	1.73
28-day compressive strength	4,000 psi	Eutrophication	kg N-eq	1.31E-1	1.00E-1
Slump	4.0 in	Photochemical ozone creation	kg O3-eq	46.6	35.7

A sample EPD for a concrete mix design by Central Concrete Supply Co.

Credit: Central Concrete Supply



Apple and the Environment

Life Cycle Impact Product Usage Impact Reports News

We account for everything. Including our products.

To accurately measure a company's environmental footprint, you must look at the impact that company's products have on the planet. Apple uses comprehensive life cycle analysis to determine exactly where our greenhouse gas emissions — all 10.2 million metric tons of them¹ — come from.



Definition

- LCA is an analytical tool for the **systematic** and **quantitative** evaluation of the environmental impacts of a **product or service** through its **whole life cycle**

THE LCA OF A CONSTRUCTION PRODUCT



Characteristics

- **Multi-step:** A whole life cycle approach to avoid pollution transfer from one life cycle step to another.

Impacts

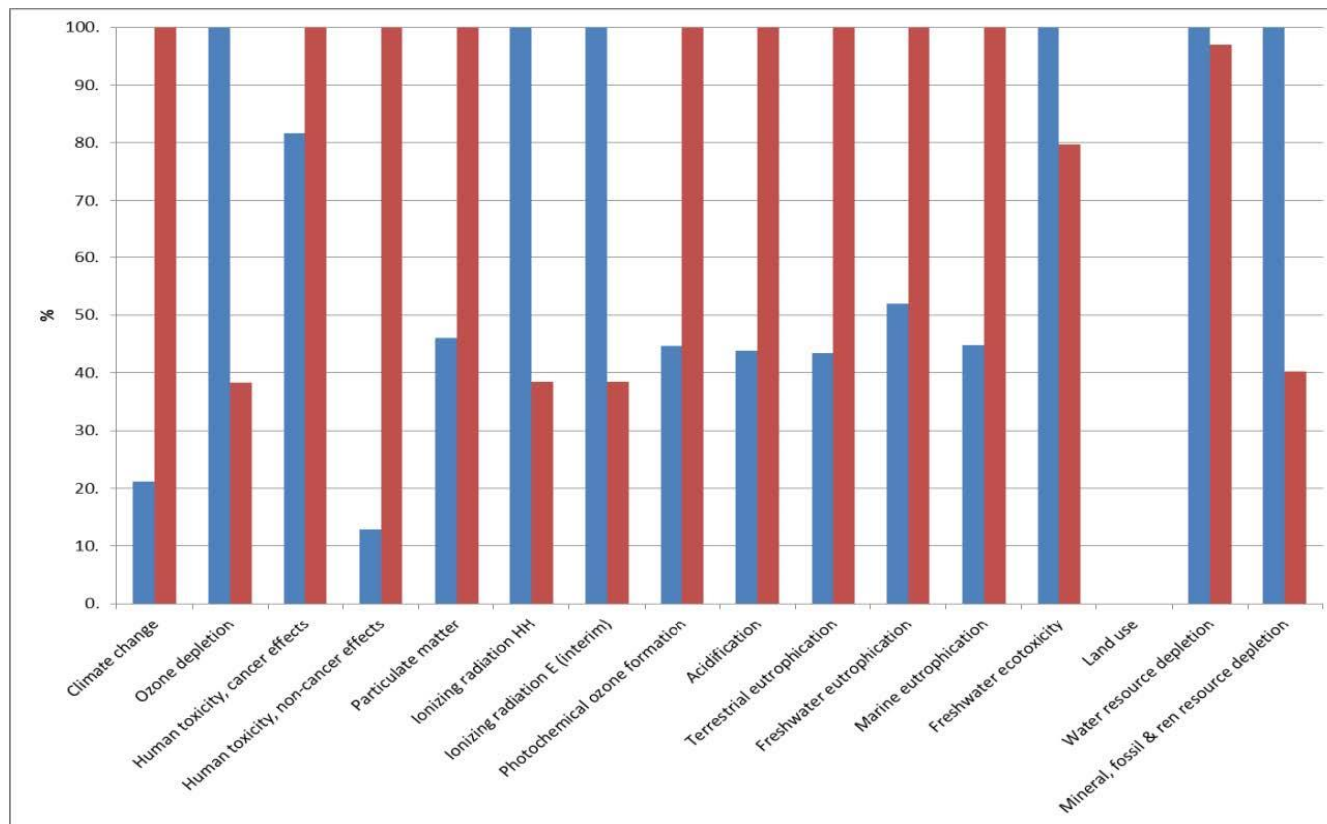


Impacts

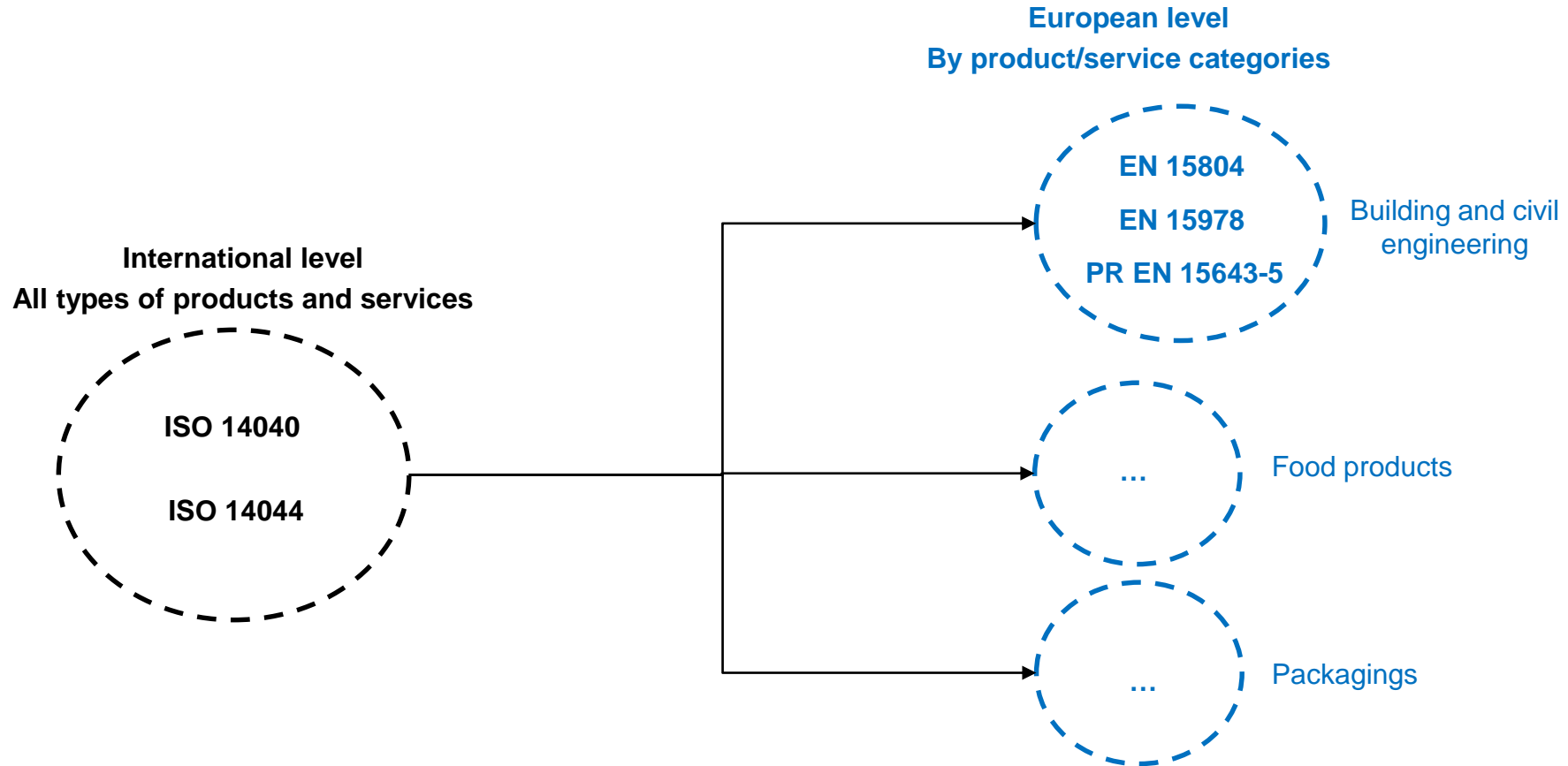


Characteristics

- **Multi-criteria:** An investigation of different environmental issues to avoid pollution transfer from one issue to another



Existing standards for LCA



ISO 14040:2006: Environmental management - Life cycle assessment - Principles and framework

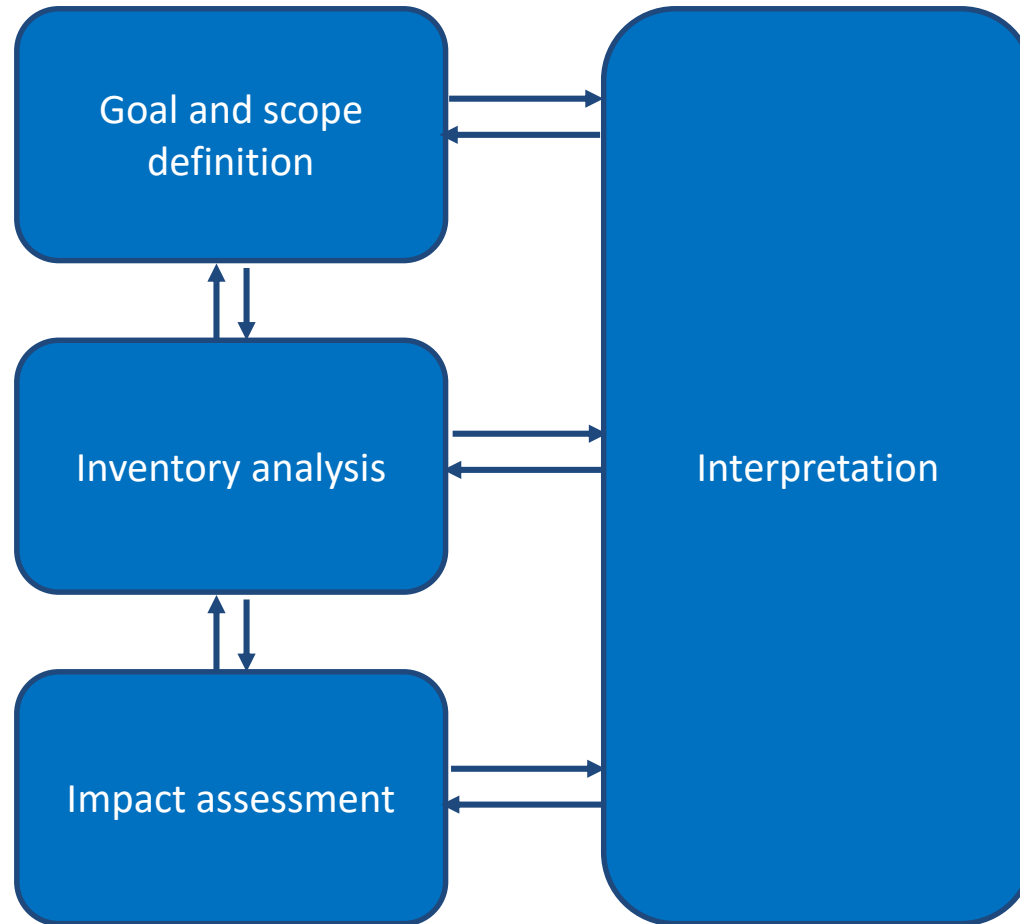
ISO 14044:2006: Environmental management - Life cycle assessment - Requirements and guidelines

EN 15804:2012: Sustainability of construction works, Environmental **product** declarations, Core rules for the product category

EN 15978:2012: Sustainability of construction works - Assessment of environmental performance of **buildings** - Calculation method

PR EN 15643-5: Sustainability of construction works – Sustainability assessment of buildings and **civil engineering works** – Part 5: Framework for the assessment of sustainability performance of civil engineering works

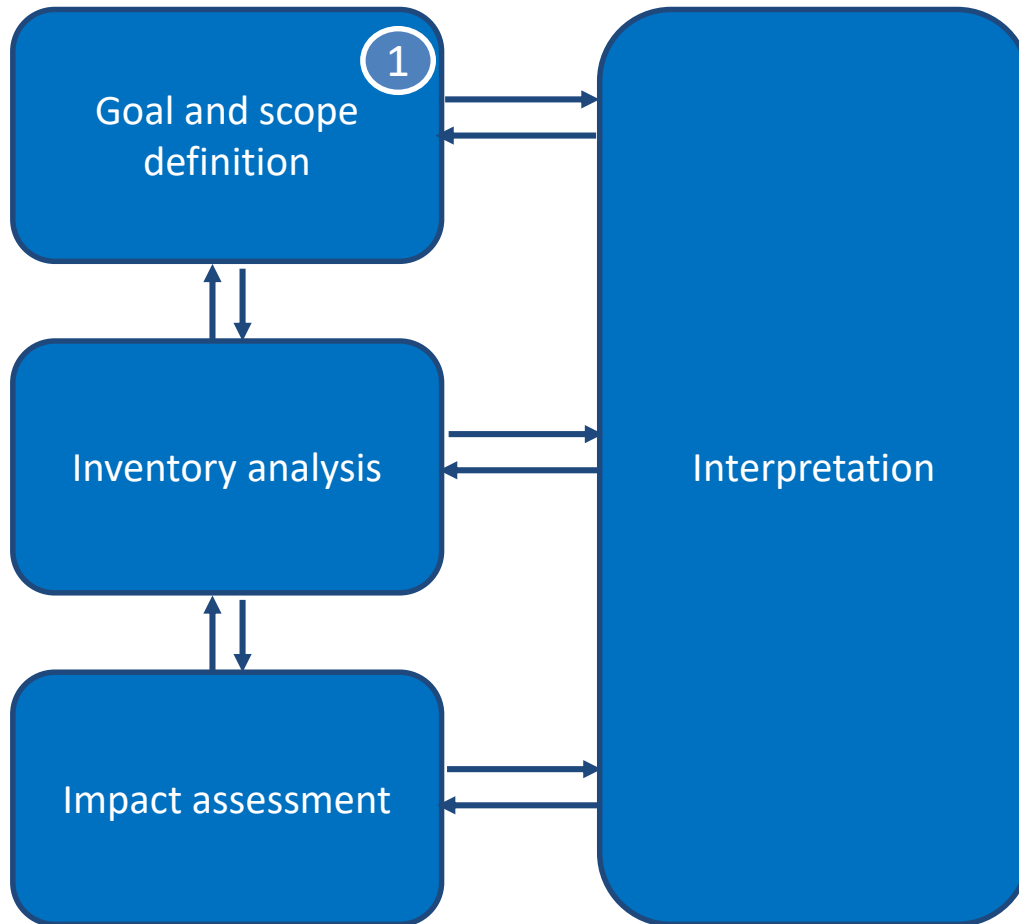
ISO 14040 – General principles



TRANSPARENCY – ITERATIVE PROCESS

***HOW IT WORKS IN
PRACTICE***

ISO 14040 – General principles



Goal and scope definition

Aim of the study

System to be studied

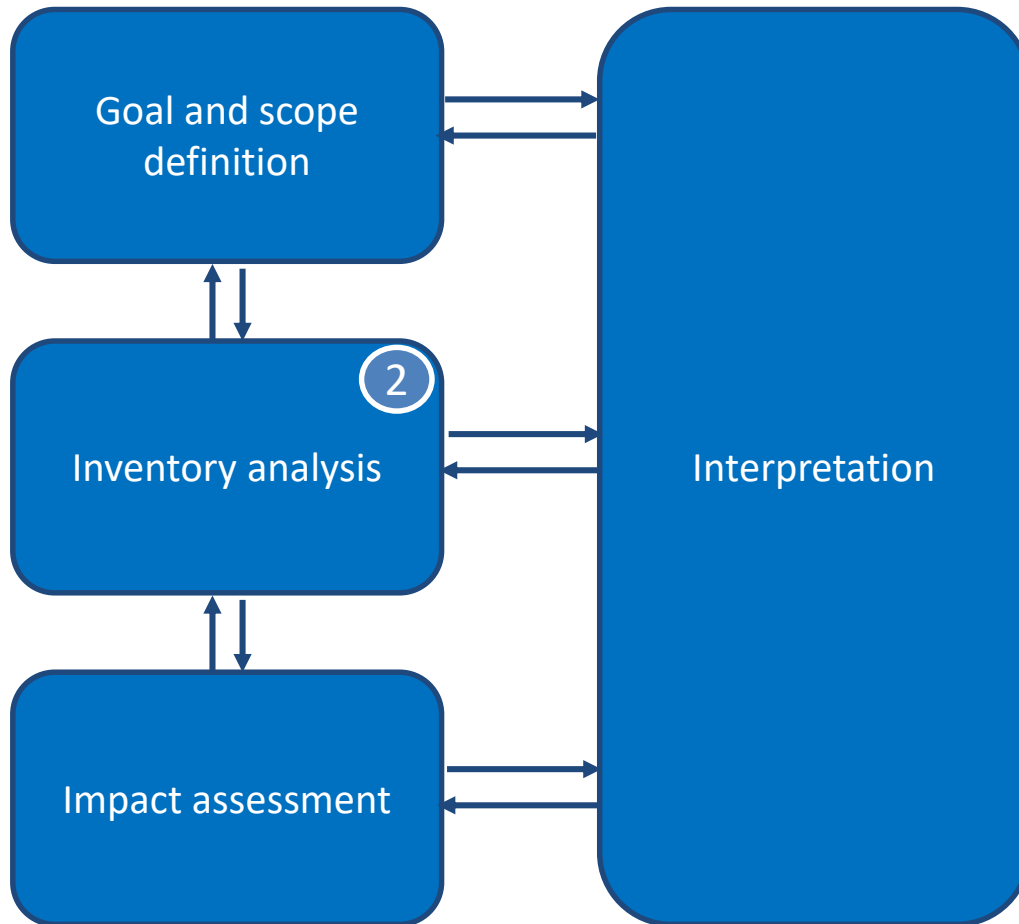
System boundaries

Scopes (geo, techno, temp)

Indicators

Functional unit

ISO 14040 – General principles



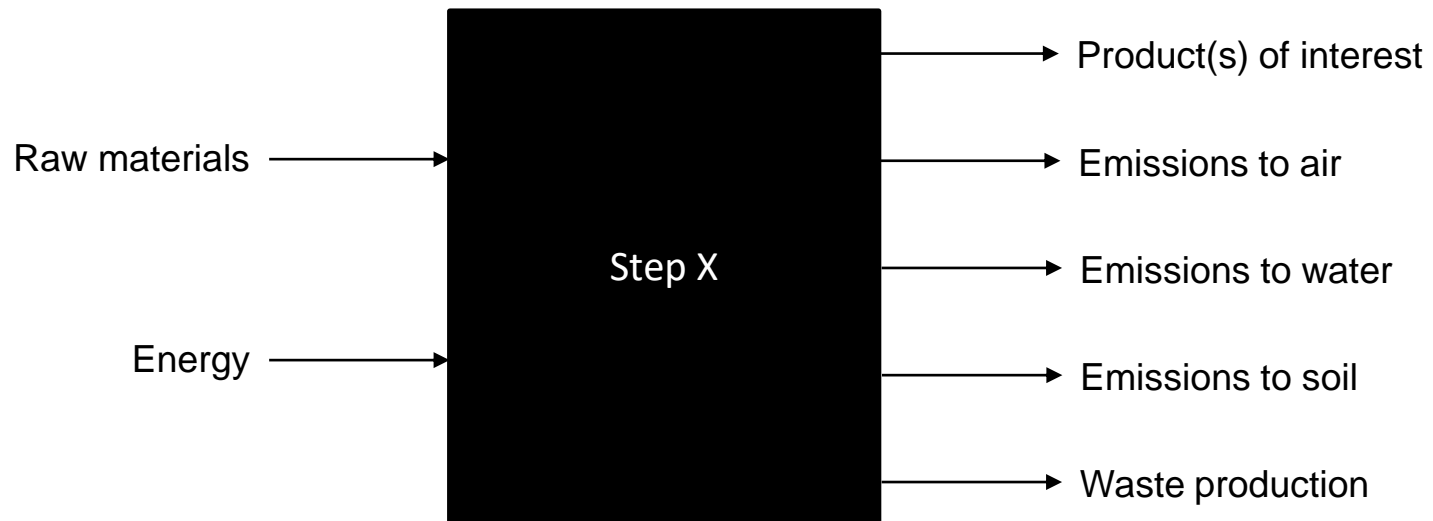
Inventory analysis

Inventory of all flows going into / leaving the system

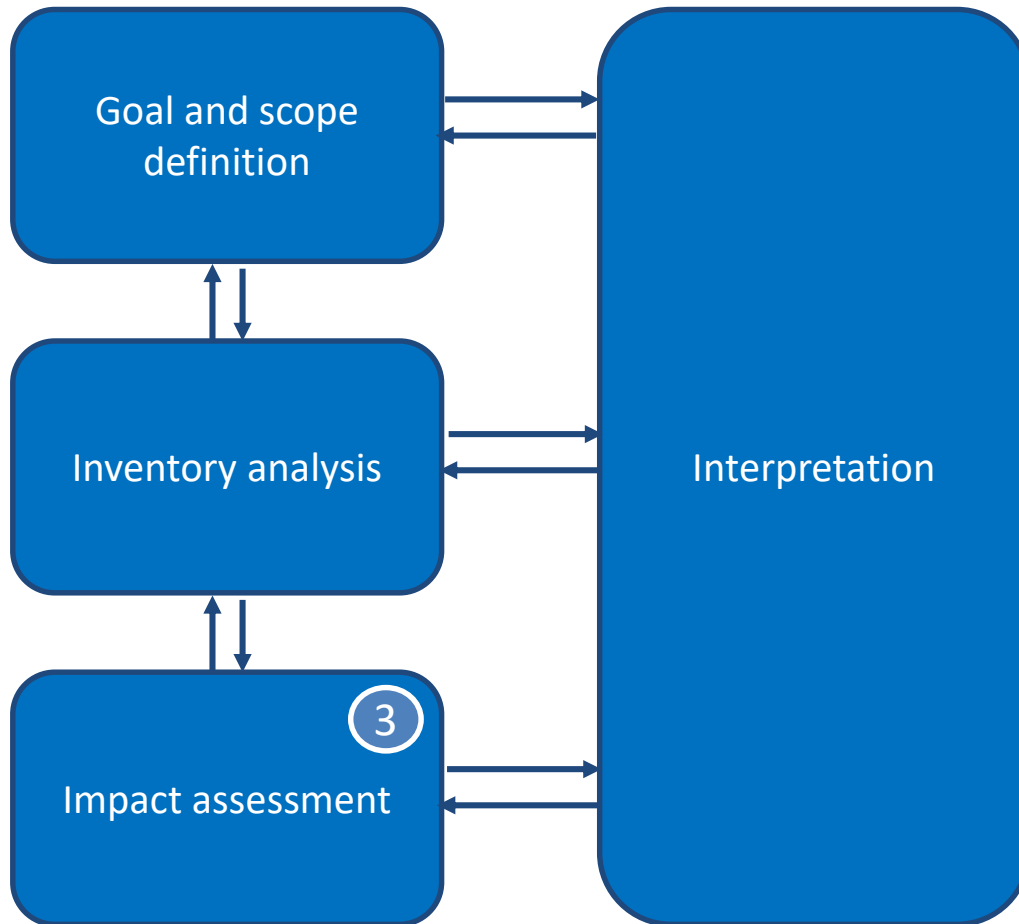
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Step 2 – Inventory analysis

- For each life step, quantifying all the inputs and outputs of the system



ISO 14040 – General principles



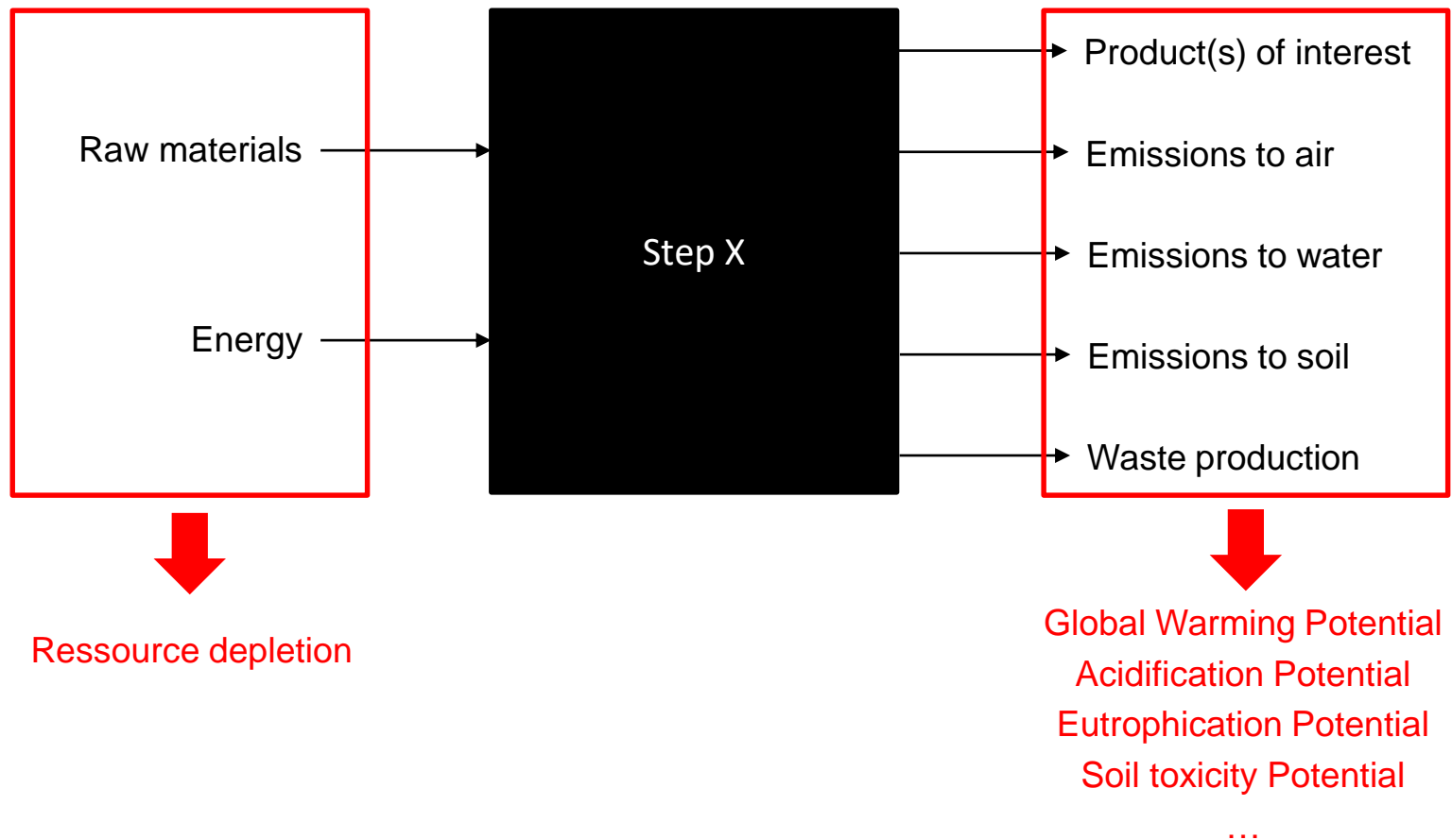
Impact assessment

Transformation of the inventoried flows into environmental impact indicators

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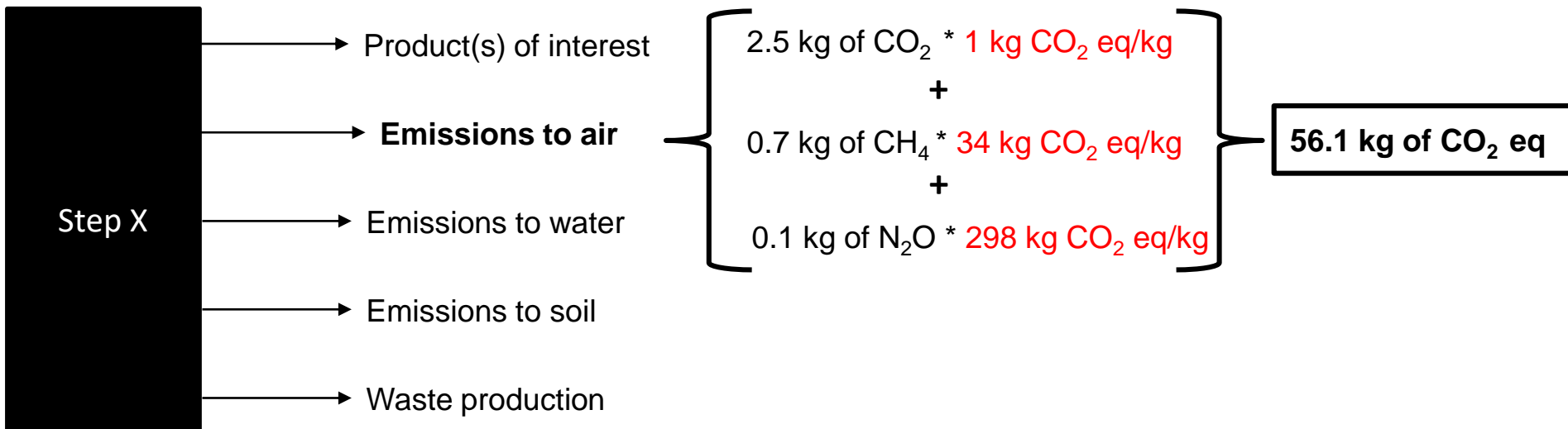
Step 3 – Impact assessment

- Converting flows into environmental indicators



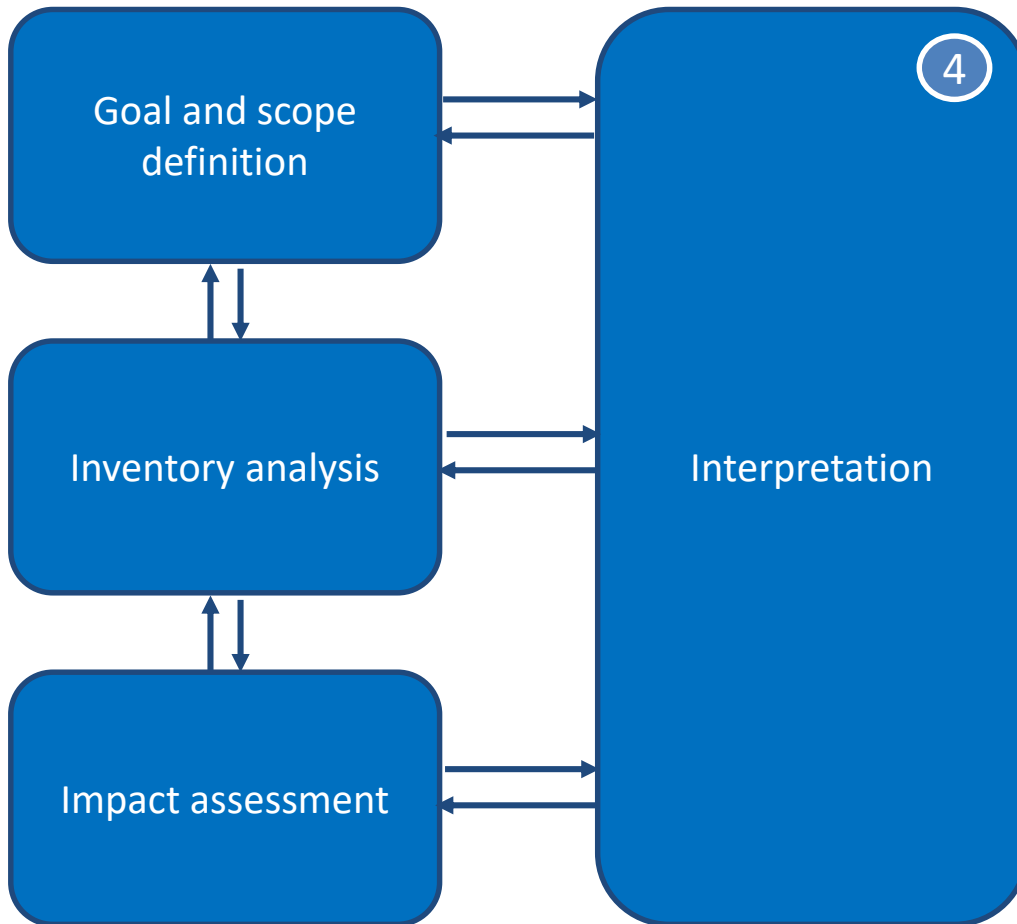
Step 3 – Impact assessment

- Converting flows into environmental indicators



Characterisation factors: For each environmental impact indicator, defined by specific models. Represent the « effect » of a molecule on a given environmental phenomenon.

Step 4 – Interpretation



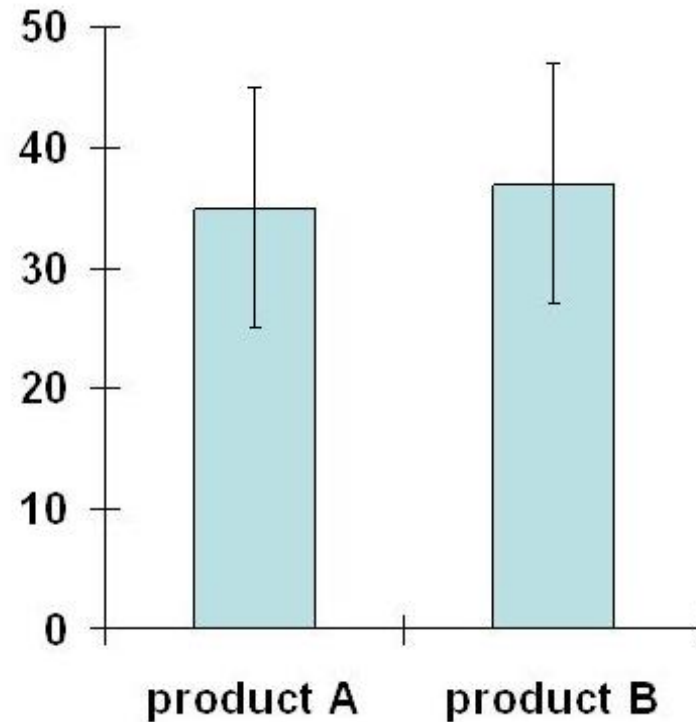
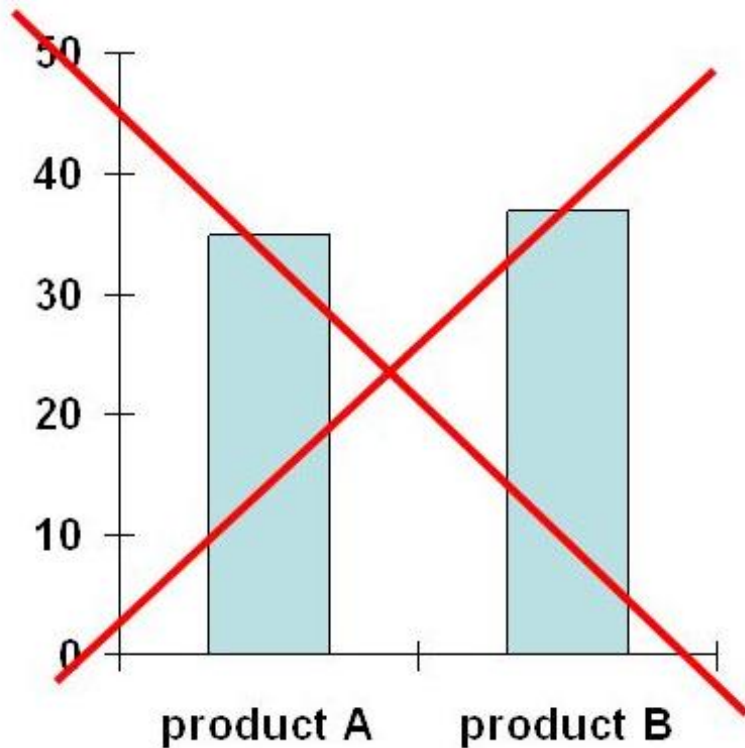
Interpretation

Discussion about the overall results

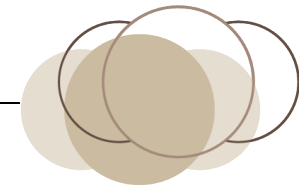
Comparison with similar technologies

Influence of the hypothesis on the results (sensitivity analysis, uncertainty analysis)

Step 4 – Interpretation



Uncertainty analysis are important to ensure a relevant comparison between two options

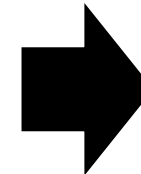
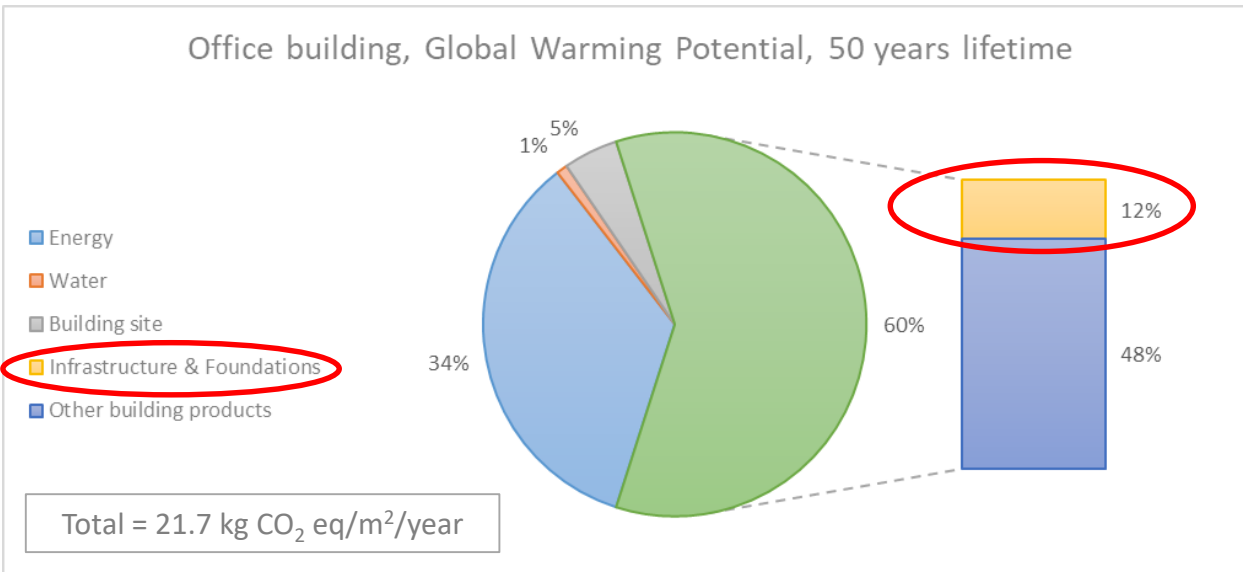
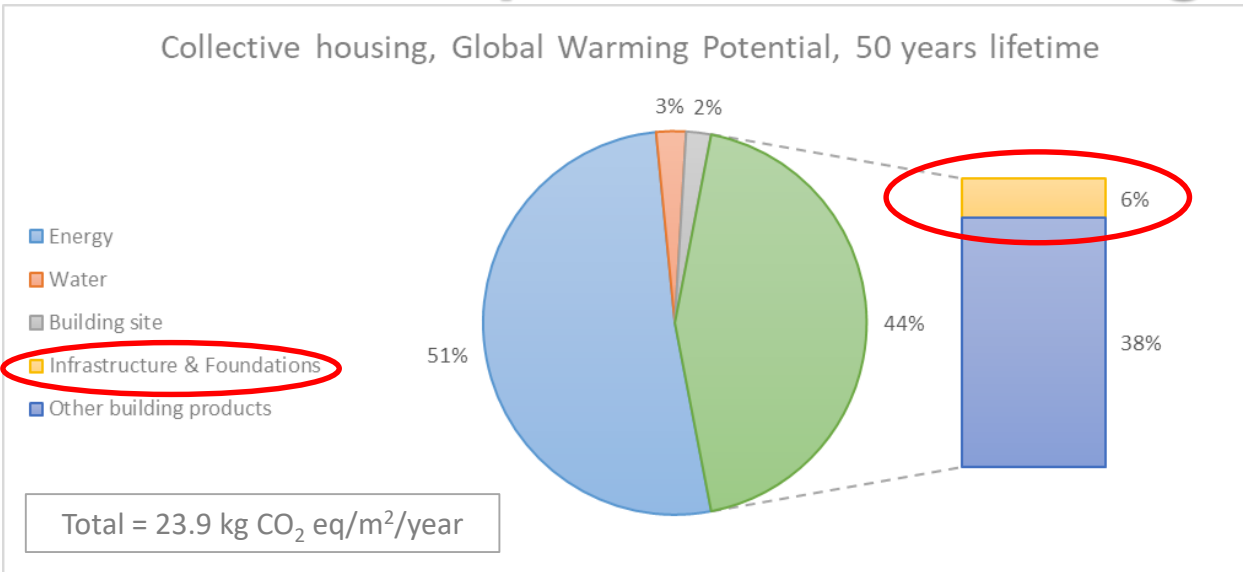


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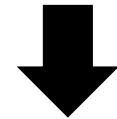
Examples



How much impacts are we talking about



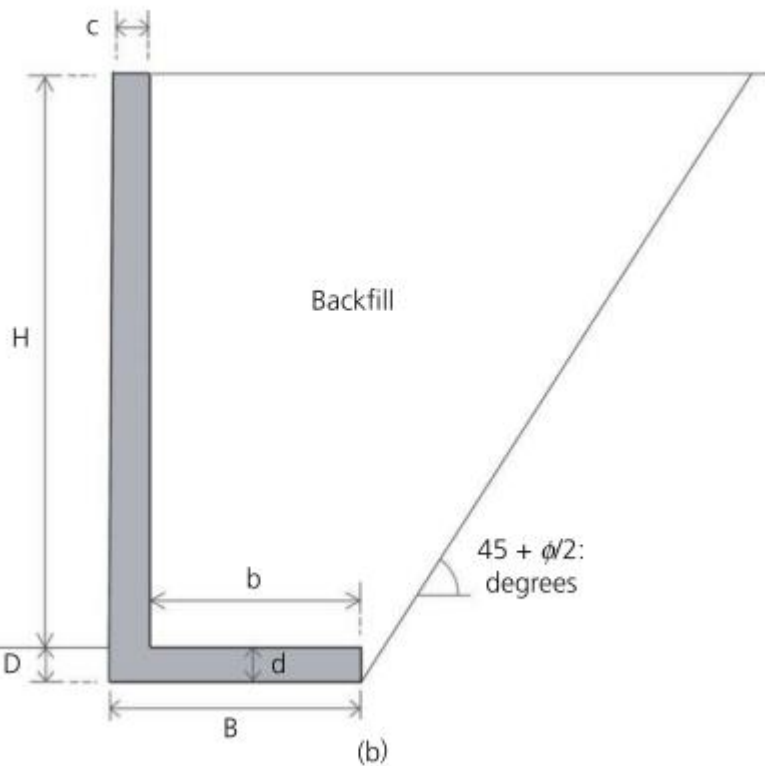
Around 10% of buildings' GHG emissions



More important in the future with the improvement of energy performance

LCA of cantilever wall

- Goal and scope definition



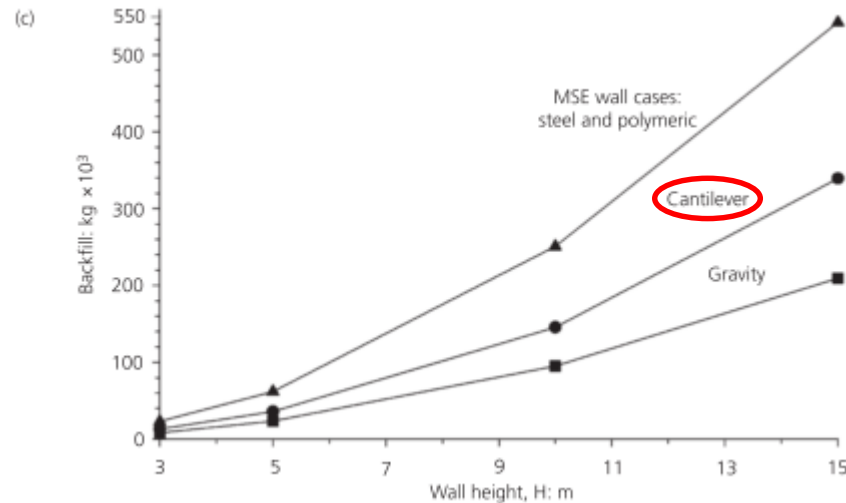
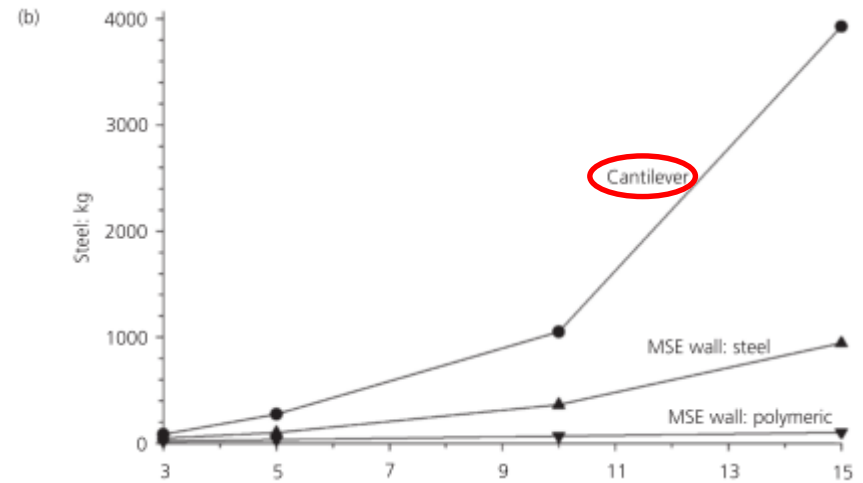
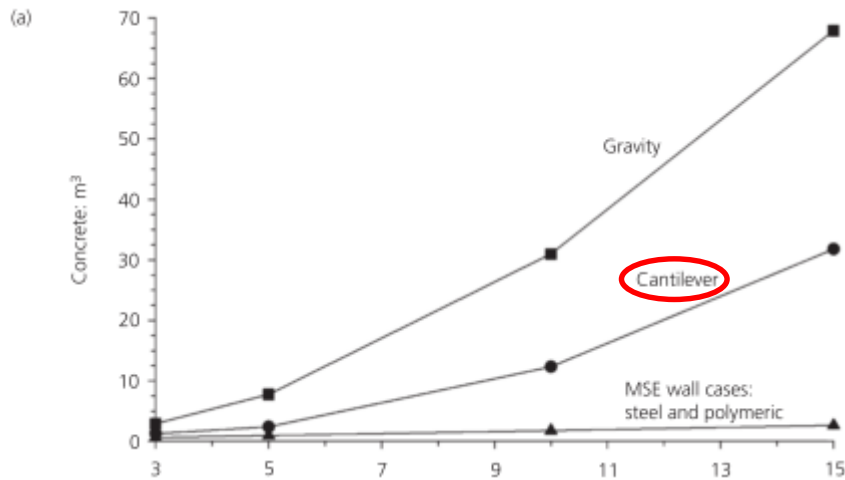
Parameter	Backfill	Foundation
Unit weight: kN/m^3	20	20
Friction angle, ϕ : degrees	30 (gravity and cantilever) 34 (MSE wall cases)	30
Cohesion: kPa	0	0
Soil/structure interface friction angle: degrees	24	27

Table 1. Backfill and foundation soil material properties

Wall type	Parameter or number ^a		Wall height ^b (H)			
			3 m	5 m	10 m	15 m
Cantilever	D (= d)	m	0.25	0.40	1.00	1.70
	B	m	1.30	2.20	4.60	7.40
	c	m	0.25	0.25	0.40	0.80
	b	m	1.05	1.90	3.70	6.00

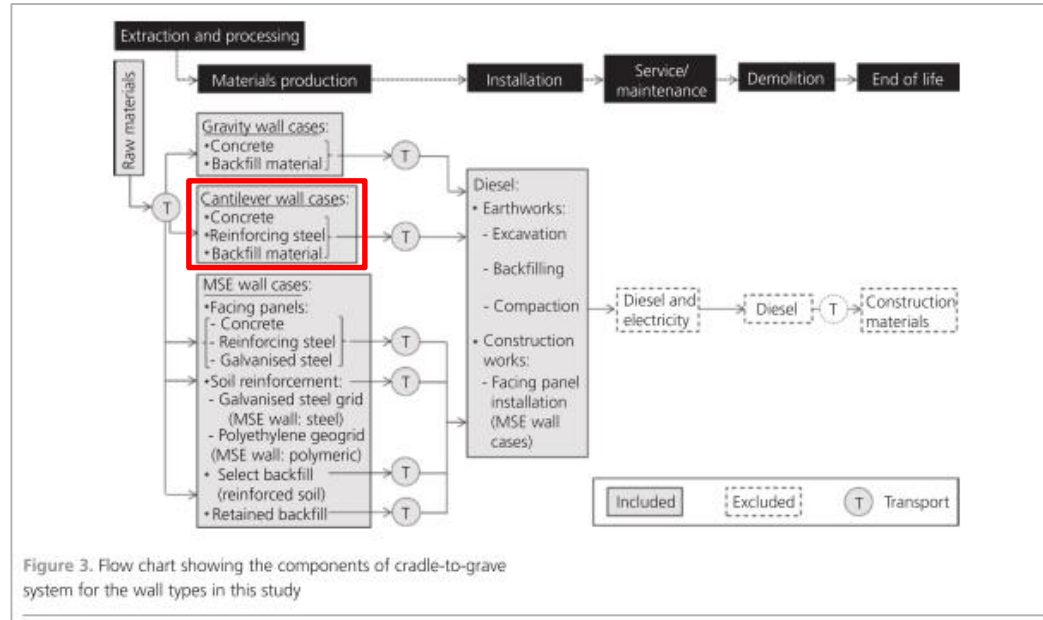
LCA of cantilever wall

- Inventory analysis



LCA of cantilever wall

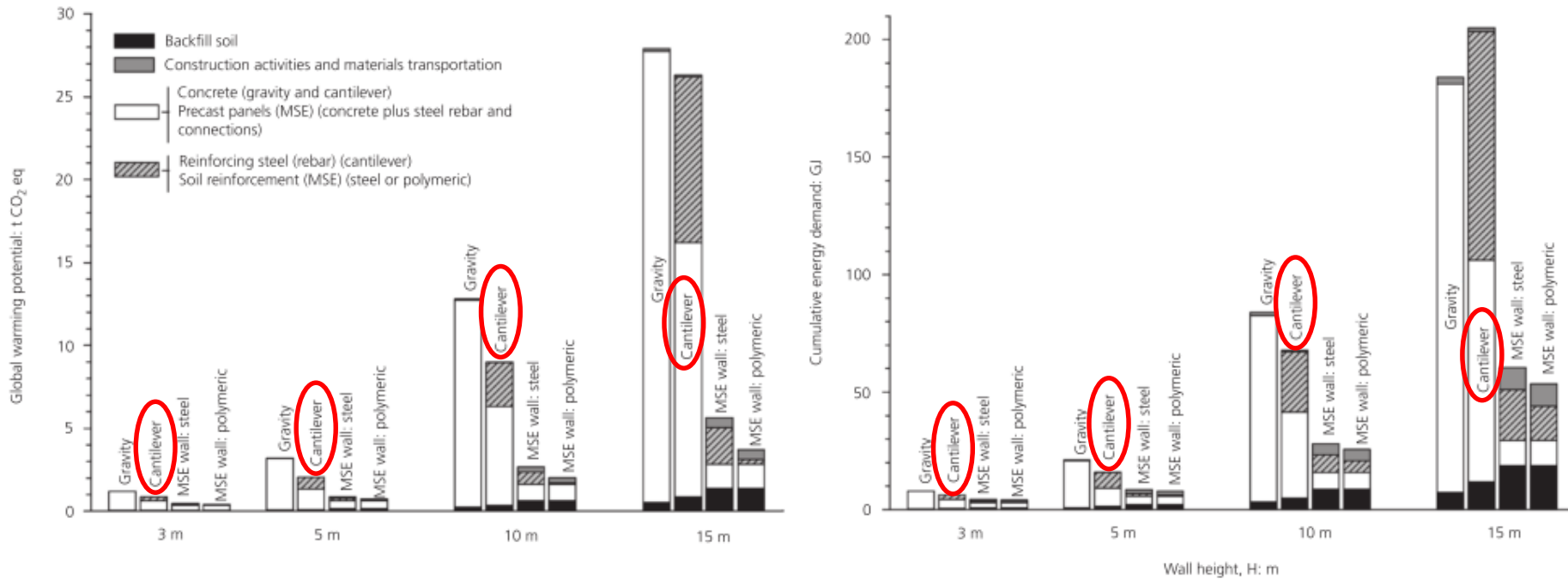
- Inventory analysis



Case	Category	Related items and components	Units	Wall height (H)			
				3 m	5 m	10 m	15 m
Cantilever	Structural materials	Concrete	m ³	1.1	2.3	11.1	29.1
		Reinforcing steel (rebar)	t	0.08	0.27	1.04	3.93
	Soil materials	Retained backfill ^a	t	13.2	35.9	139	339
	Earthworks	Excavation	m ³	0.3	0.9	4.6	12.6
		Backfilling and compaction	h (x10 ⁻³)	1.0	2.8	11.0	25.8
Transportation	Concrete and steel	km	10	10	10	10	

LCA of cantilever wall

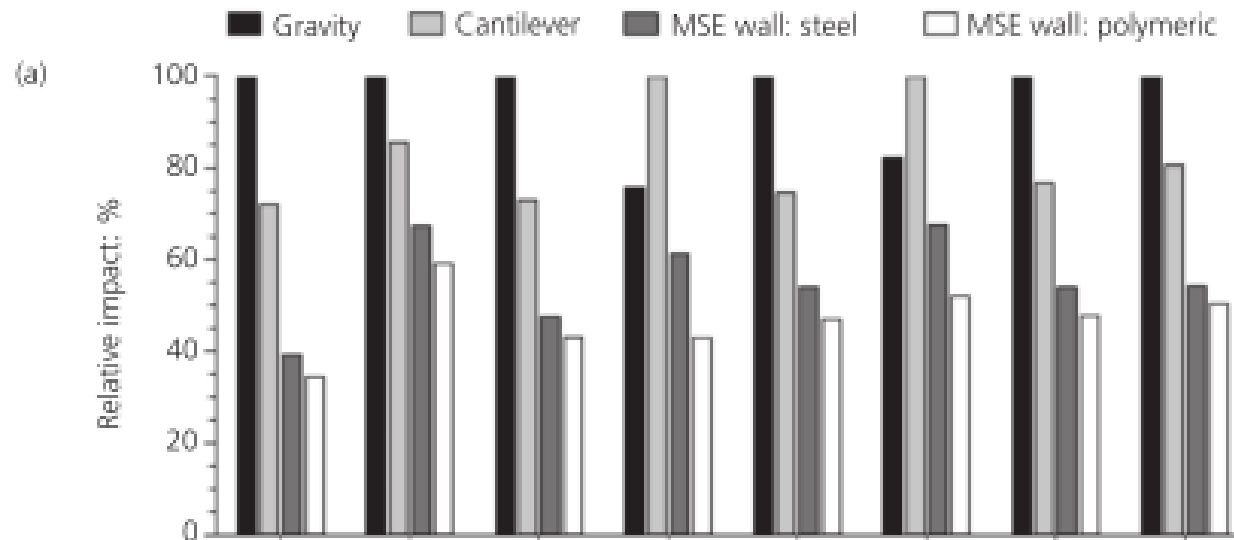
- Impact assessment



Source: Damians et al., Environmental assessment of earth retaining wall structures, *Environmental Geotechnics*, 2015.

LCA of cantilever wall

- Interpretation
 - Comparison between the different studied alternatives



LCA of cantilever wall

- Interpretation
 - Comparison between the different studied alternatives
 - Comparison with existing studies

Source	H: m	Climate change: kg CO ₂ eq.		Energy consumption: GJ	
		Gravity	MSE ^b	Gravity	MSE ^b
Stucki <i>et al.</i> (2011)	3.0	1300	230	13	3.1
Current study	3.0	1200	410	7.9	3.9
Rafalko <i>et al.</i> (2010) ^a	4.6	3200 ^c	850	17 ^c	7.7
Current study	5.0	3200	880/750 ^d	21	8.5/7.8 ^d
Heerten (2012) ^a	5.5	3600	670	30	9

^a Reported results converted to 1 m width of wall to match functional unit in current study and results reported by Stucki *et al.* (2011).

^b Polymeric soil reinforcement used in studies by Heerten (2012) and Stucki *et al.* (2011).

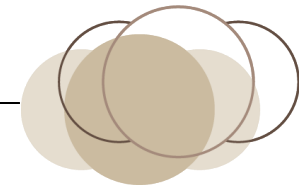
^c Concrete and soil materials only.

^d Both steel and polymeric (steel/polymeric) reinforcement types are included.

Table 4. Comparison of results with data reported by Heerten (2012), Rafalko *et al.* (2010) and Stucki *et al.* (2011)

LCA of cantilever wall

- Interpretation
 - Comparison between the different studied alternatives
 - Comparison with existing studies
 - Identification of main contributors
 - Sensitivity analysis
 - Uncertainty analysis
 - ...



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OVERALL CONCLUSION



Home messages

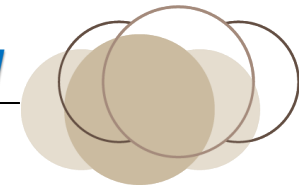
- LCA = Quantify the environmental impacts of a product/service
- Multi-step and multi-criteria
- Existing standards at international, european and national levels (and per sectors at the european and national levels)
- Based on the service provided by the system
- Transparent and iterative process
- Application to geostructures still recent

Scientific challenges

- Develop **methodological rules** for the proper inclusion of « **plants-based** » geotechnical solutions in LCA (land use change and associated effects on carbon stocks are of particular importance)
- **Refine existing indicators** such as resource depletion through the development of regionalised characterisation factors (for instance considering the EU's Raw Material Initiative)
- Create **new indicators for soil erosion** for instance
- Refine the combination of **sensitivity analysis and uncertainty analysis** in LCA
- Integrate **economical aspects** with LCC (and social aspects with S-LCA)
- Create a **tool for the assessment of geotechnical solutions** environmental impacts (tools are existing for building materials and for buildings in general but they are not adapted to geotechnical solutions)

For further insights

- EC Joint Research Center : <http://eplca.jrc.ec.europa.eu/>
- Life Cycle Initiative: <http://www.lifecycleinitiative.org/>
- The International Journal of LCA: <http://www.springer.com/environment/journal/11367>
- ISO standards:
 - ISO 14040:2006: http://www.iso.org/iso/catalogue_detail?csnumber=37456
 - ISO 14044:2006:
http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=38498
- EN standards for building products, buildings and civil engineering:
 - EN15804:2012: <http://www.en-standard.eu/din-en-15804-sustainability-of-construction-works-environmental-product-declarations-core-rules-for-the-product-category-of-construction-products-includes-amendment-a1-2013/>
 - EN15978:2012: <http://www.en-standard.eu/csn-en-15978-sustainability-of-construction-works-assessment-of-environmental-performance-of-buildings-calculation-method/>



Questions?

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