Advanced cementitious materials
MSE 420

Lecture 1: Introduction

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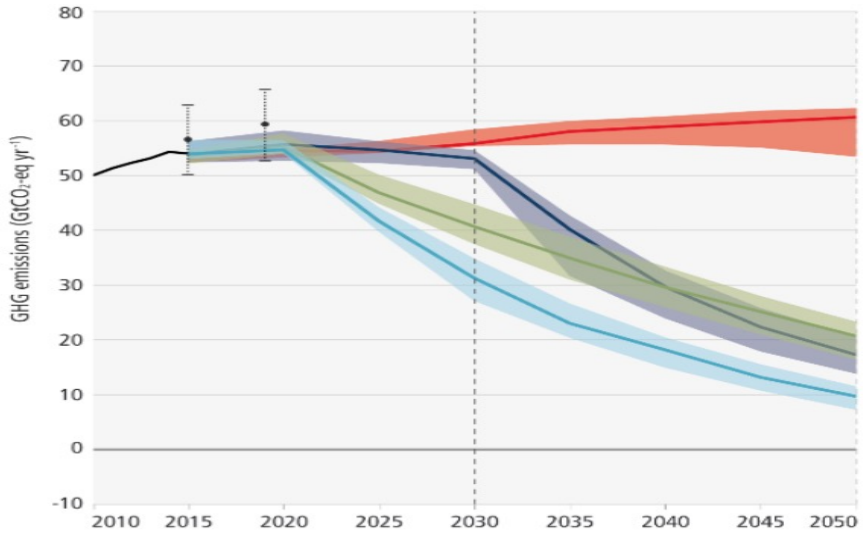
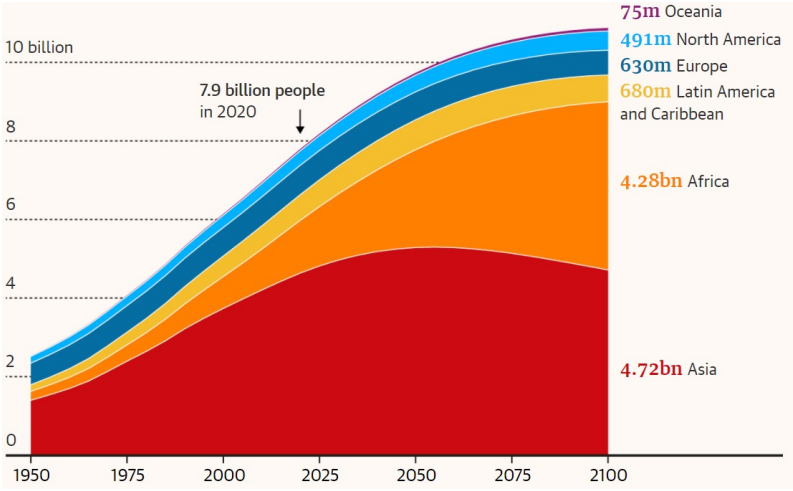
Introduction

Rising urbanization trends to meet the increase in population is alarming given the global warming crisis and the established construction methods

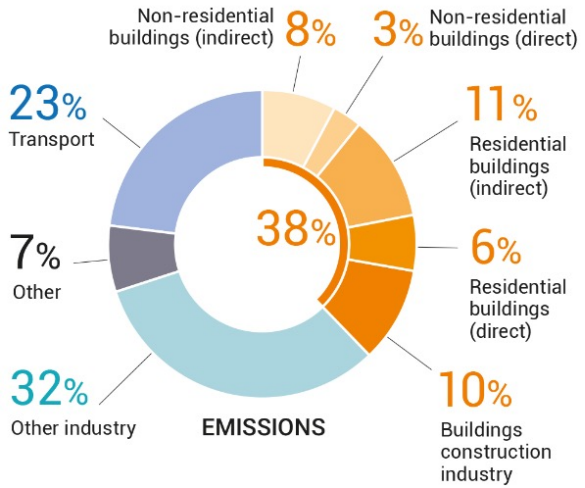


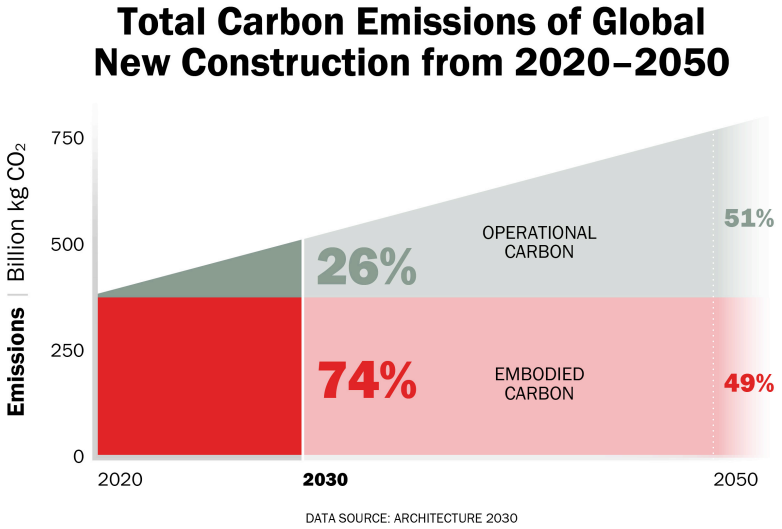


https://www.theguardian.com/global-development/2022/jan/20/by-2050-a-quarter-of-the-worlds-people-will-be-african-this-will-shape-our-future

How do buildings contribute?

- Embodied impact is that attributed to the materials that comprise the building
- Operational impact is that of the activities while the building is in-use such as: heating, cooling, lighting ..etc.





How could we decrease operational carbon?

- Environmental building design
- Smart energy management
- Renewable sources of energy

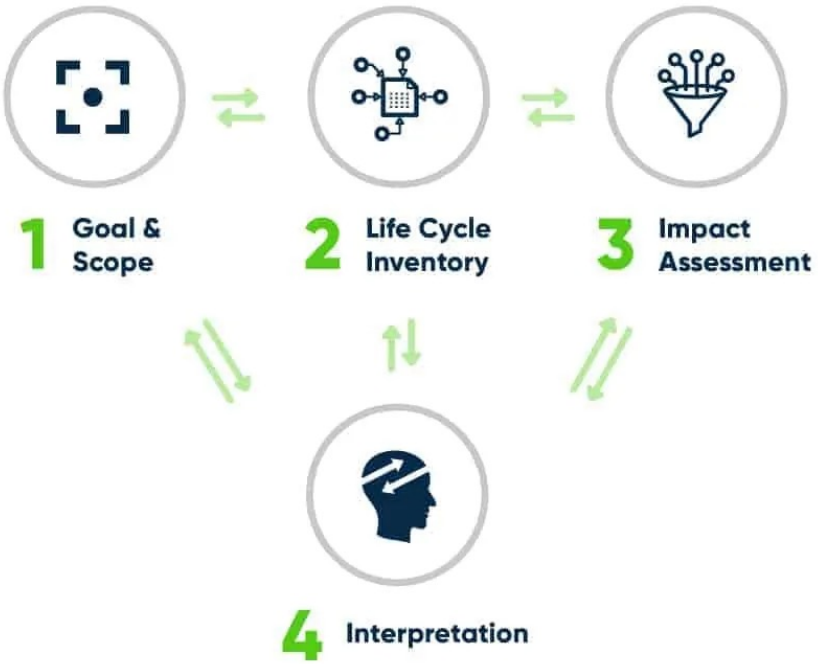
http://www.energateinc.com/blog/2012/09/12/smart-home-energy-management-without-smart meter/#.XDI8Q_n7SUk

How could we decrease embodied carbon?

- Build with local bio-materials (only 20% possible)
- The remaining 80% will still be built with concrete
  - If a unit built-up area of a concrete building is a football,
  - That for a bamboo based building would be an Olympic swimming pool
  - And that for a timber based building would be that of three football fields

How do we measure embodied impact?

A life cycle assessment (LCA) is a methodology for assessing environmental impacts associated with all the life stages of a product, process, or service



Why is an LCA important?

- The ISO: 14040 and 14044 provide guidelines to the use and purpose of LCA
- LCA addresses the environmental aspects and potential environmental impacts throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal.
- LCA can assist in
  - Identifying opportunities to improve the environmental performance of products
  - Informing decision-makers in industry, government or non-government organizations
  - Selecting relevant indicators of environmental performance

LCA example

- Which has a higher environmental impact?

Breaded chicken

- 1 x breaded chicken breast
- 1 x deep fried potato

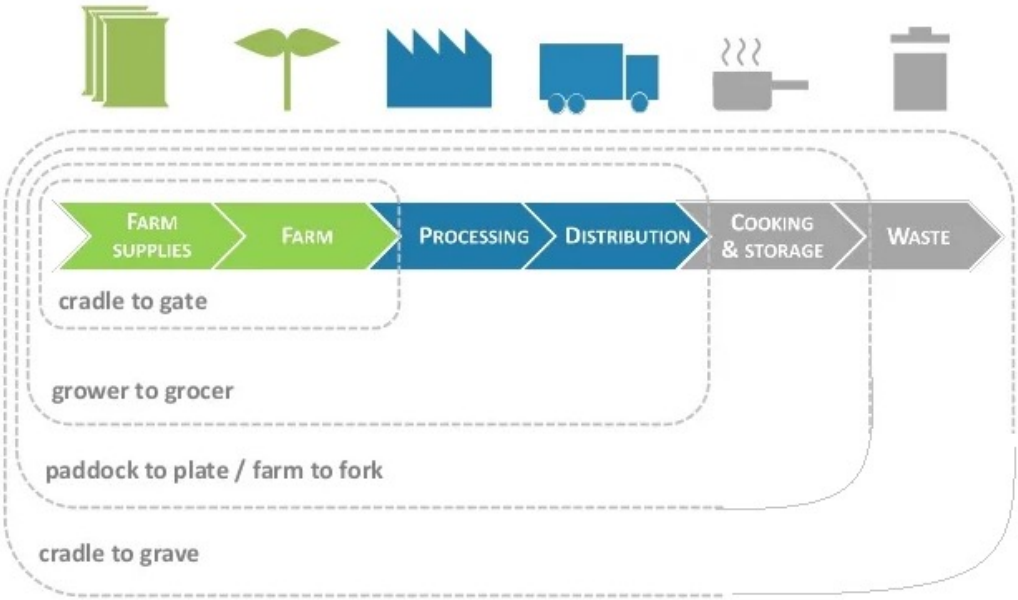
vs

Avocado salad

- 1 x avocado
- 1 x tuna can
- 1 x onion
- 1 x cucumber

LCA example cont'd

- Scope:
  - Extraction, transportation, production
- Functional unit:
  - by mass, by calories
- Inventory data source:
  - Google!
- Impact indicator:
  - Global warming potential



LCA example cont'd

Breaded chicken

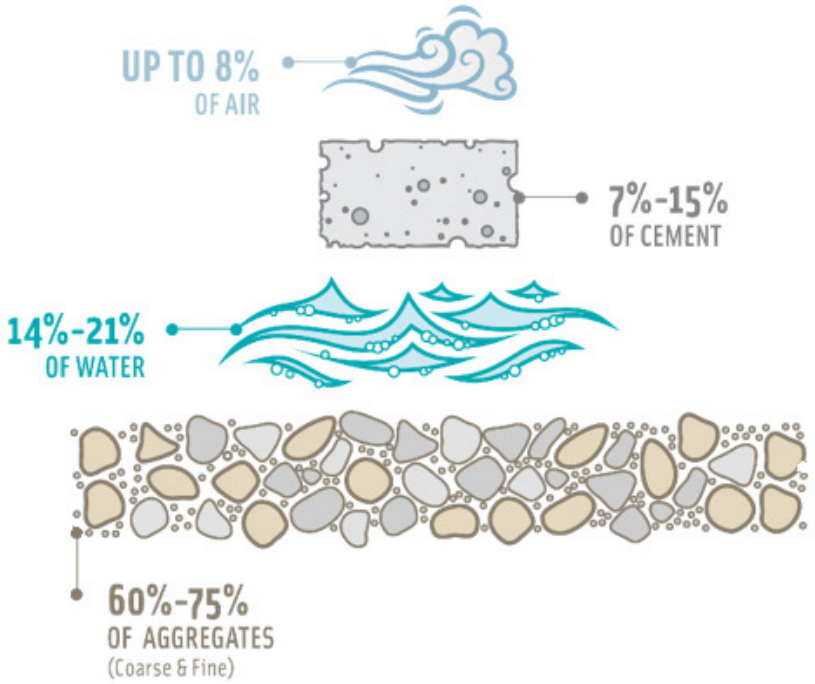
Ingredients	GWP (eq. g CO_2)	Weight (g)	Calories (kCal)
Chicken	905	150	400
Potatoes	580	300	300
Total	1485	450	700
Per g	**3.30**		
Per kCal	**2.12**		

Avocado salad

Ingredients	GWP (eq. g CO_2)	Weight (g)	Calories (kCal)
Avocado	423	150	240
Tuna	900	150	170
Onion	50	100	40
Cucumber	15	100	10
Total	1388	500	460
Per g	**2.78**		
Per kCal	**3.02**		

How do we measure embodied impact of concrete?

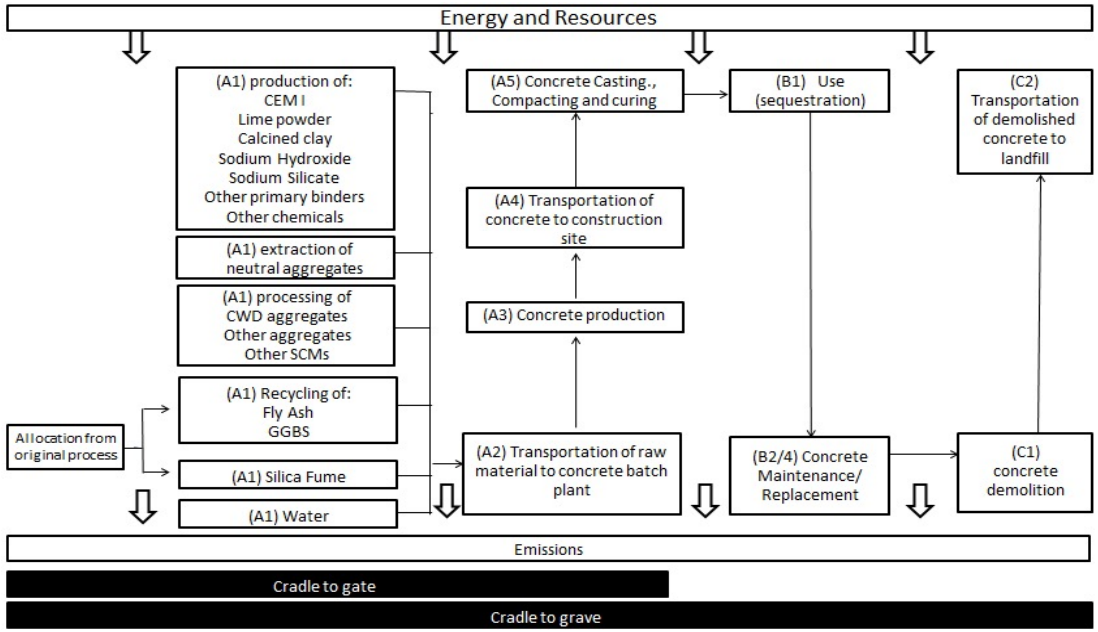
- What is concrete?



How do we measure embodied impact of concrete?

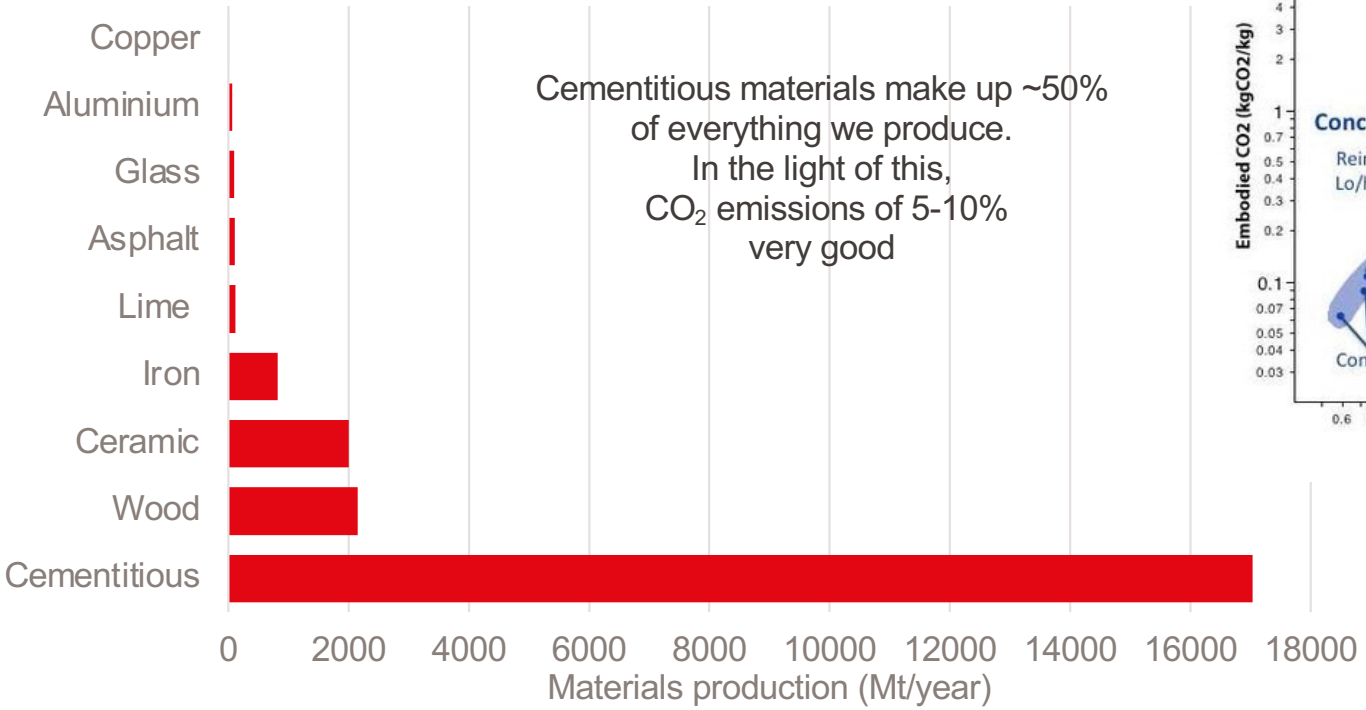
Concrete LCA parameters

- Scope
  - Boundary condition
  - Functional unit
- Inventory data
- Impact assessment
- Sensitivity analyses
- Scenario comparisons

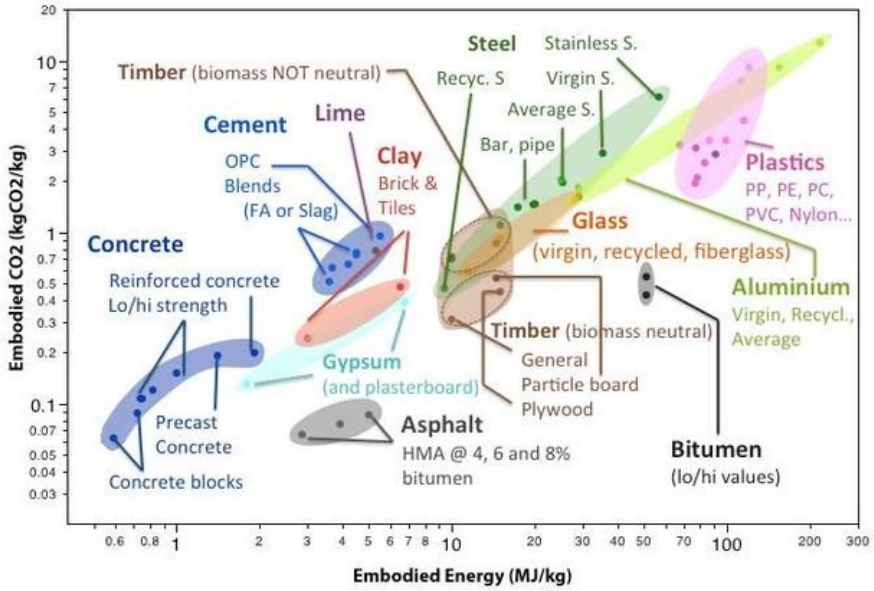


How do we make concrete construction more sustainable?

- What is wrong with concrete?

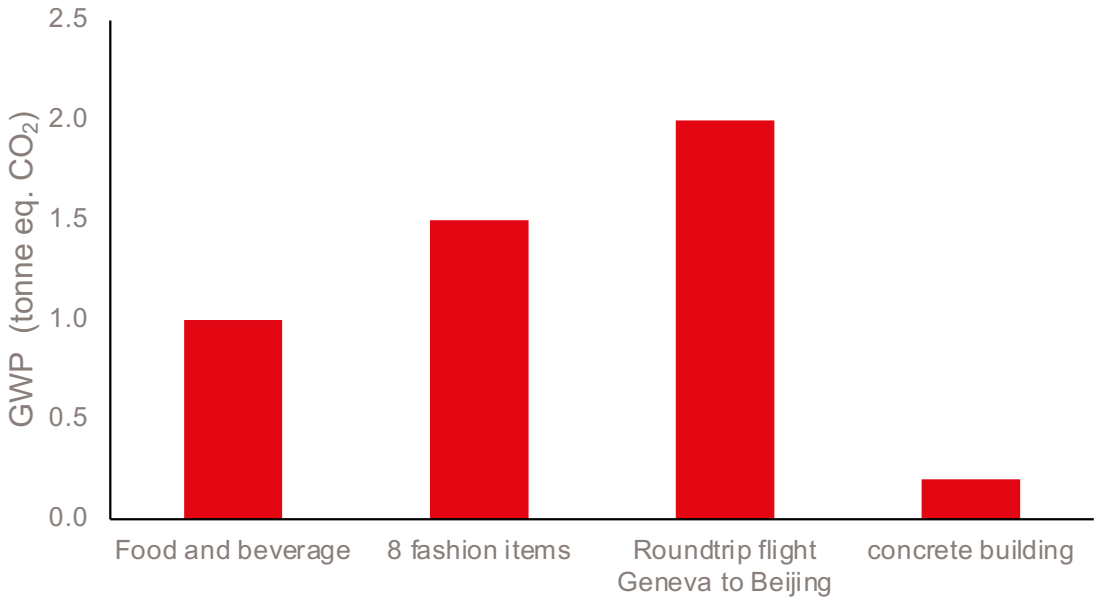


Cementitious materials make up ~50%
of everything we produce.
In the light of this,
CO_2 emissions of 5-10%
very good



How do we make concrete construction more sustainable?

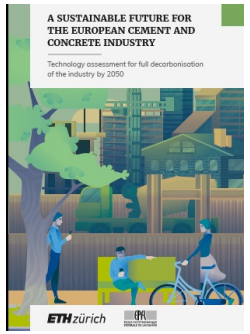
- How do you rank the following impacts?
  - Yearly per capita food consumption
  - Buying 8 fast fashion items
  - Roundtrip flight Geneva-Beijing
  - Building a concrete house



How do we make concrete construction more sustainable?

- How could we make it better?

Few producers Quick wins implemented	Few producers Large remaining potential	Many producers Implementation very difficult	Chain of deciders Implementation very difficult	Requires big changes in mindset
Reduce CO_2 from clinker production	Reduce clinker in cement	Reduce cement in concrete	Reduce concrete in building	More efficient (re)use of buildings
• Efficient plants • Waste fuels • Alternate raw materials	• SCMs	• Aggregate grading • Good admixtures • Use filler		



Course objectives

You will be divided into 4 groups, 3-4 members each. Each group acts as a consultancy team which has been engaged to advise a construction company on the environmental impact of a concrete structure using life cycle analysis as a tool.

1. Learn how to obtain information from a variety of sources:
   - Scientific literature
   - Internet at large
   - “Experts”

2. Work in a team to critique information, analyse and present it in a realistic scenario

Project groups/case studies

As explained, a LCA examining/comparing the environmental and economic impact of concrete could vary widely depending on the way it is done.

- Group 1: compare between the LCA results for a concrete mix while varying the boundary conditions between Cradle-to-gate and Cradle-to-grave
- Group 2: compare between the LCA results for ordinary Portland cement vs LC^3 while changing the functional unit between kg of cement and m^3 of concrete
- Group 3: compare between the LCA results for 1 kg of OPC vs SCMs such as (FA, GGBS, SF, CC) while changing the inventory data sources between databases and published data
- Group 4: compare between the LCA results of 1 m^2 of a multi-story building when using low strength concrete, medium strength concrete, high strength concrete, ultra high strength concrete and timber

Literature review

- **What is a critical literature review ?**
  - A literature review is a review of the state of art, summary of previous work in your field.
  - It has a logical structure: objectives and purpose need to be clear to the reader with an ADDED dimension = YOUR INTERPRETATION
- **What it means to be critical ?**
  - To have the capacity to evaluate what you read and to relate what you read to other information
  - Assume authors are knowledgeable, while remaining alert for possible flaws in the reasoning
  - To find the weaknesses and the strengths ? (date of paper, methods used …etc.)

Methodology

1. **Define the research question**
2. **Search for literature**
   - Google scholar ➔ peer-reviewed articles
3. **Critical reading of the paper**
   - Is this reading relevant to your study ?
   - Make notes :
     1. What are the authors trying to do writing this ?
     2. Key points of this paper
     3. How convincing is what the authors are saying?
     4. In conclusion, what use can I make of this?
   - Compare with other papers on the same topic

Example

- **Title, date, authors, publication editor information**
  - The influence of supplementary cementitious materials on climate impact of concrete bridges exposed to chlorides
  - Al-Ayish et al., 2018
  - Journal of Construction and Building Materials, Volume 188, Pages 391-398
- **Why am I reading this ?**
  - Information about climate impact of concrete with supplementary cementitious materials
- **Methods and Materials used ?**
  - Life Cycle Assessment comparing between concrete with OPC and that with partial replacement with fly ash

Example - continued

- **Assumptions / Results**
  - Fly ash has no allocated impact (GWP of FA is 0!)
  - Fly ash based concrete has 17% lower

- **Analysis**
  - This is a simplification that goes against the rules of the ISO 14040 and 14044
  - FA is a by-product not a waste as per the definition since it is commercially integrated in an industrial use
  - Hence, it should be allocated some burden from the original process, which is coal combustion

- **Comparison**
  - Rahla et al., 2019 added an economic allocation impact of 200 kg CO_{2eq}/kg of fly ash
  - Accordingly 1 m3 of concrete with 20% replacement with FA is only 15% better (lower) in GWP

Course deliverables

- **Presentation 1: week 5: 19th October**
  - What are the different components of a concrete LCA?
  - What are the main sources of environmental impact in a concrete structure?
  - How could the changes in each component impact the concrete LCA results?

- **Presentation 2: week 10: 23rd November**
  - Select 3 papers from the literature: at least one “Good” and one “bad”?
  - Summarise the findings in these papers indicating why they are either “good” or “bad”?

- **Presentation 3: week 14: 21st December**
  - Make a presentation for your “clients” explaining your take on performing a reliable LCA of a concrete structure and your roadmap to make is as sustainable as possible

Course schedule

Week 1	21 September	HH lecture: Introduction
Week 2	28 September	HH lecture: “LCA for cement and concrete”
Week 3	5 October	Guest lecture: “LC^3 technology”
Week 4	12 October	HH lecture: “concrete durability”
Week 5	**19 October**	**Presentation 1**
Week 6	26 October	Guest lecture: “sustainability through building design”
Week 7	2 November	HH lecture: “dynamic LCA and material flow analyses”
Week 8	9 November	Guest lecture: “chemical admixtures use in concrete”
Week 9	16 November	Guest lecture: “ultra-high performance concrete structures”
Week 10	**23 November**	**Presentation 2**
Week 11	30 November	KS lecture: “cement hydration”
Week 12	7 December	Guest lecture: “cement characterization and analytical methods”
Week 13	14 December	Study session
Week 14	**21 December**	**Presentation 3**