Why does material science play a critical role in the construction industry's transition?

Karin Gäbel
Chief Sustainability Officer
Thomas Concrete Group AB

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Chief Sustainability Officer, Thomas Concrete Group

- Master of Science in Civil Engineering, 1995.
- Licentiate of Engineering degree in Environmental Science, 2001.
- Heidelberg Materials in Sweden and internationally since 1995.
- Trade Association in Brussels for almost 10 years.
- Sustainability, public affairs, communication.
- Chairman of the research board for cement and concrete at RISE.

Thomas® CONCRETE GROUP

- Family owned
- Independent
- International
- Four terminals for binders and other raw materials
- C-lab, R&D unit and accredited testing laboratory
- 12.1 billions of SEK in turnover

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1. Discussing sustainability and innovation in the cement, concrete and construction industry.

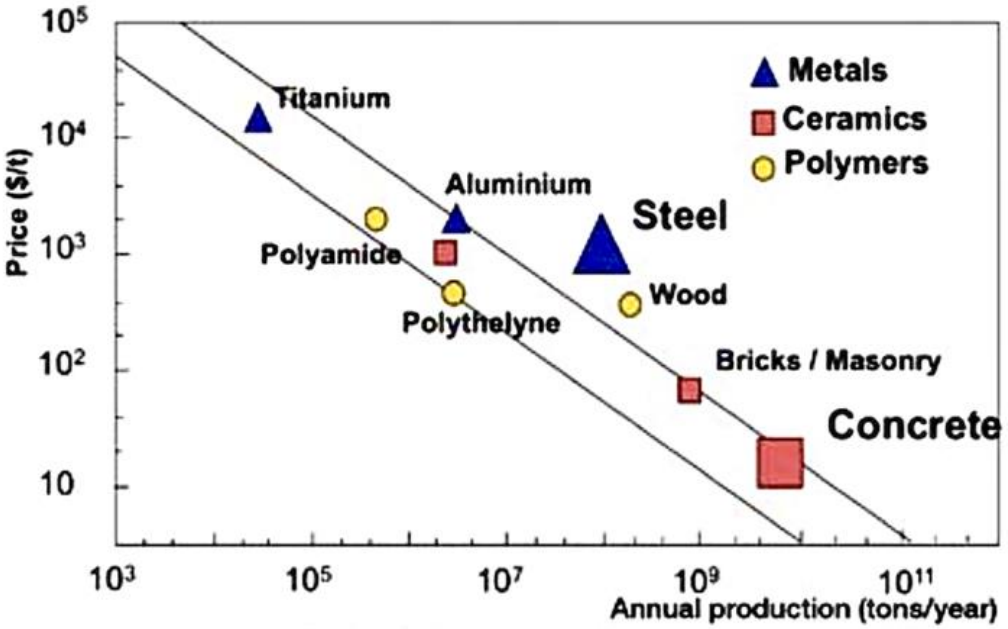
2. Addressing life cycle assessment of concrete and wood buildings.

3. Exploring the role of material science in the construction industry's transition.

4. Conclusion.

Concrete is the world's most widely used construction material

- More than ten billion m³ (24 billion tons) per year.
- Raw materials abundantly available everywhere.
- Few relevant alternatives that can be delivered on a sufficient scale.
- Competitive, durable, resistant to extreme weather, fire, moisture, and mold.
- Versatile, long service-life, requires little maintenance, and recyclable.
- Concrete is and will be decisive in building robust, resilient and sustainable societies.



Source: INTRODUCTION À LA SCIENCE DES MATÉRIAUX, Kurz, Mercier, Zambelli. PPUR, 3rd ed 2002.

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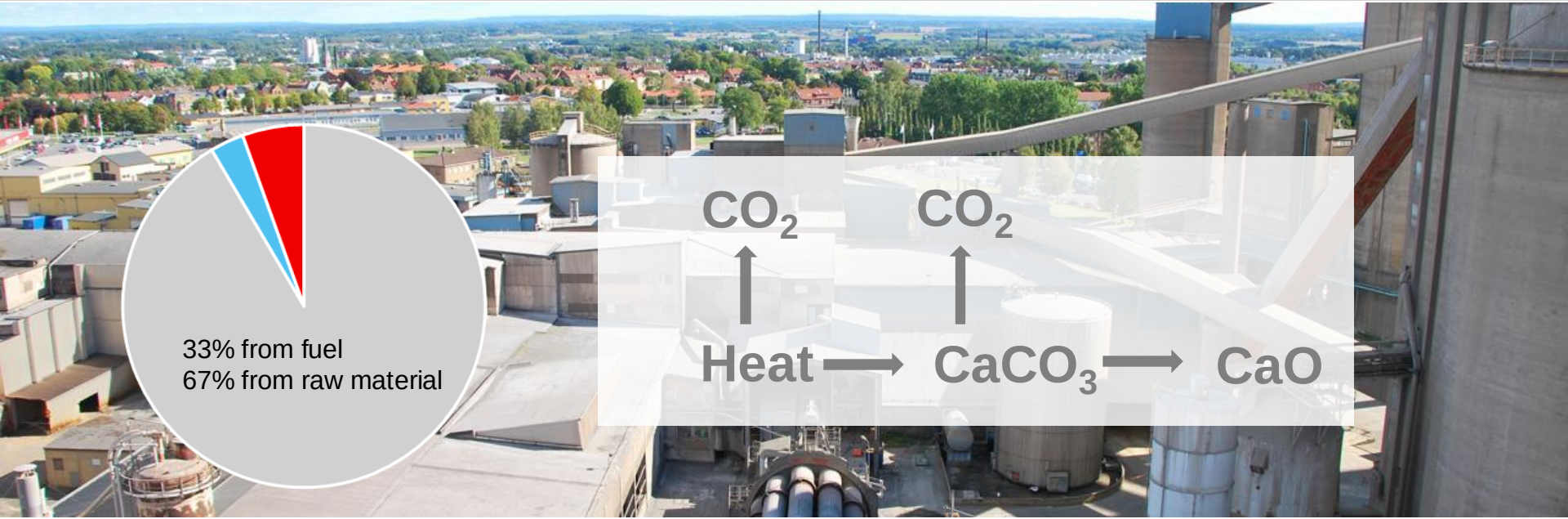
More than 90% of concrete's CO_2 comes from cement



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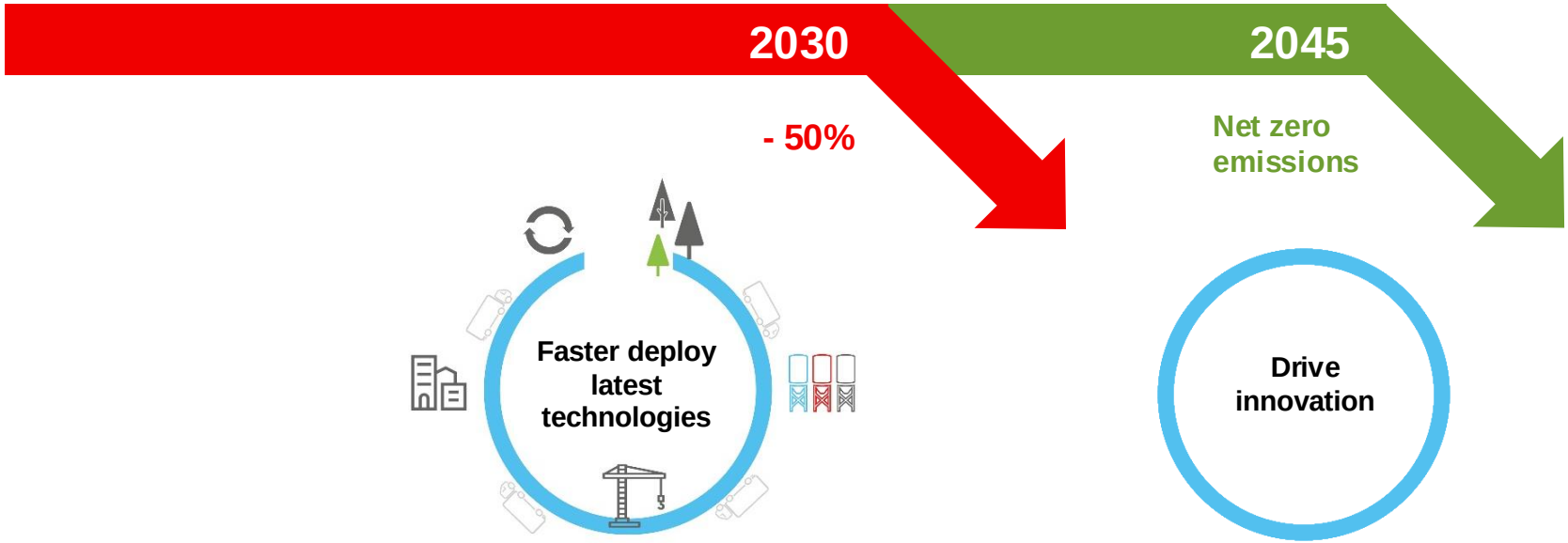
Accelerating the sustainability transition

Faster deploy latest technologies and drive development and

Illustrated with the Swedish construction industry roadmap for fossil free competitiveness



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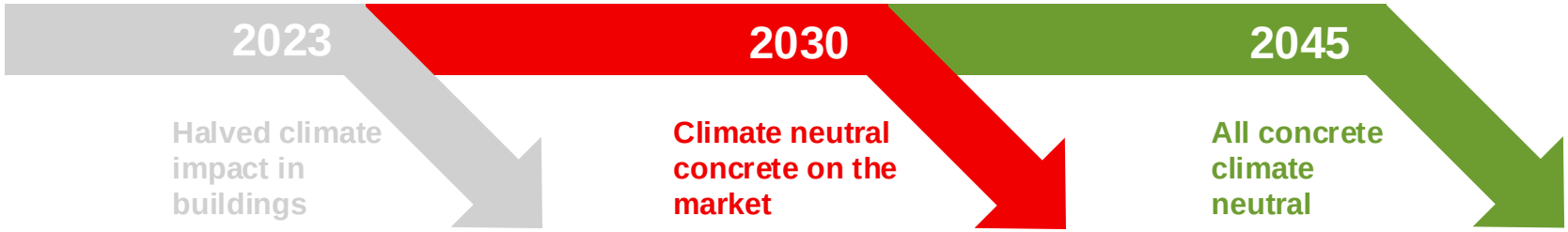
Halved climate impact from concrete today

Crucial role and more ambitious

Illustrated with the Swedish concrete industry roadmap for fossil free competitiveness



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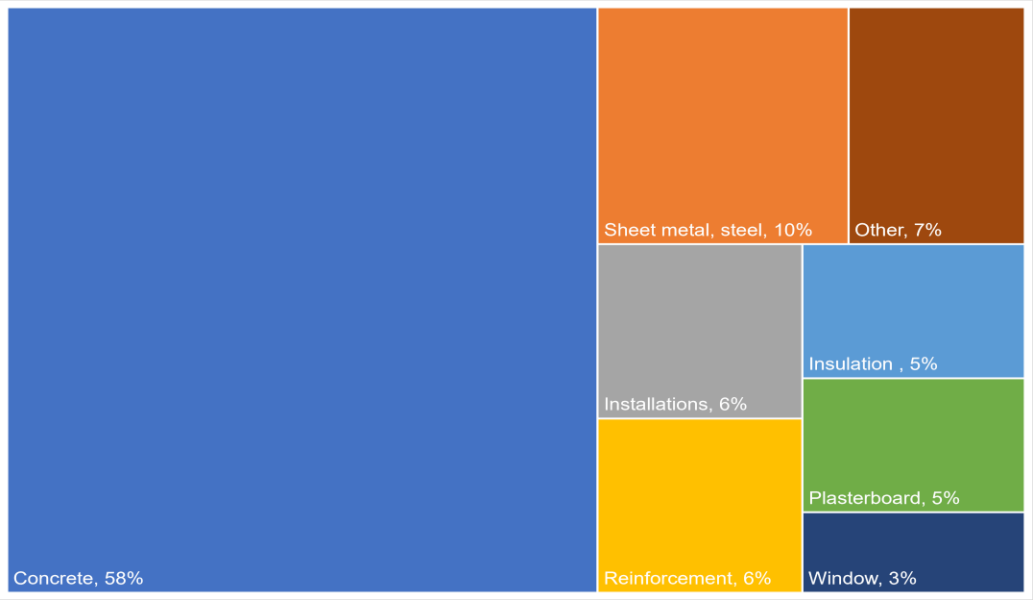
Low-carbon concrete

One of the most impactful measure to reduce climate impact

- Replace cement with alternative binders.
- Optimize the amount of binder.
- Low carbon cement.

Low-carbon concrete has the potential to reduce CO_2 by 50% or more.



Example of climate impact from materials in a building

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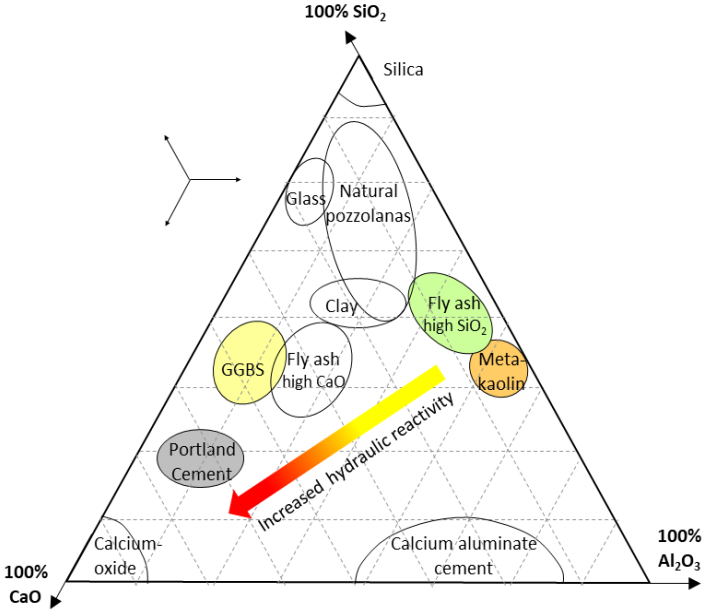
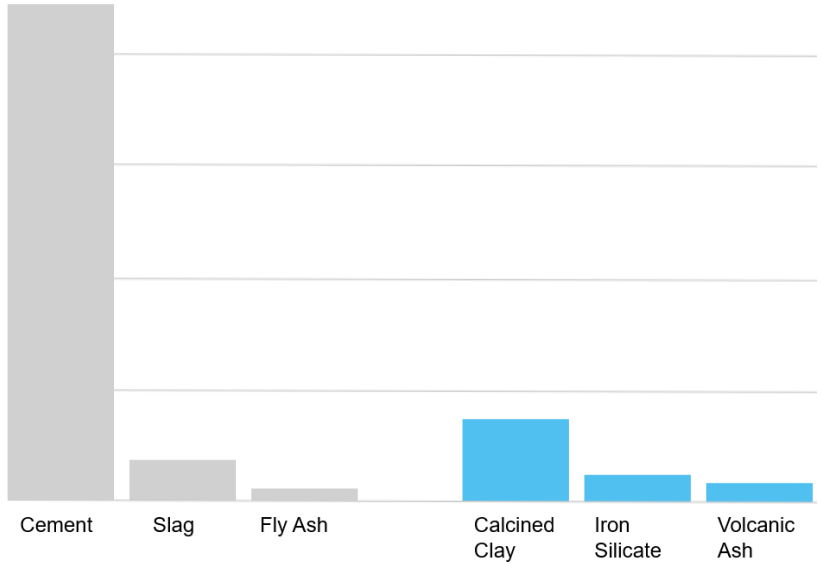
More and new alternative binders

Supplementary Cementitious materials (SCM)

Similar reactive properties as cement



Significantly lower CO_2 footprint



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Early collaboration

Resource-efficient design

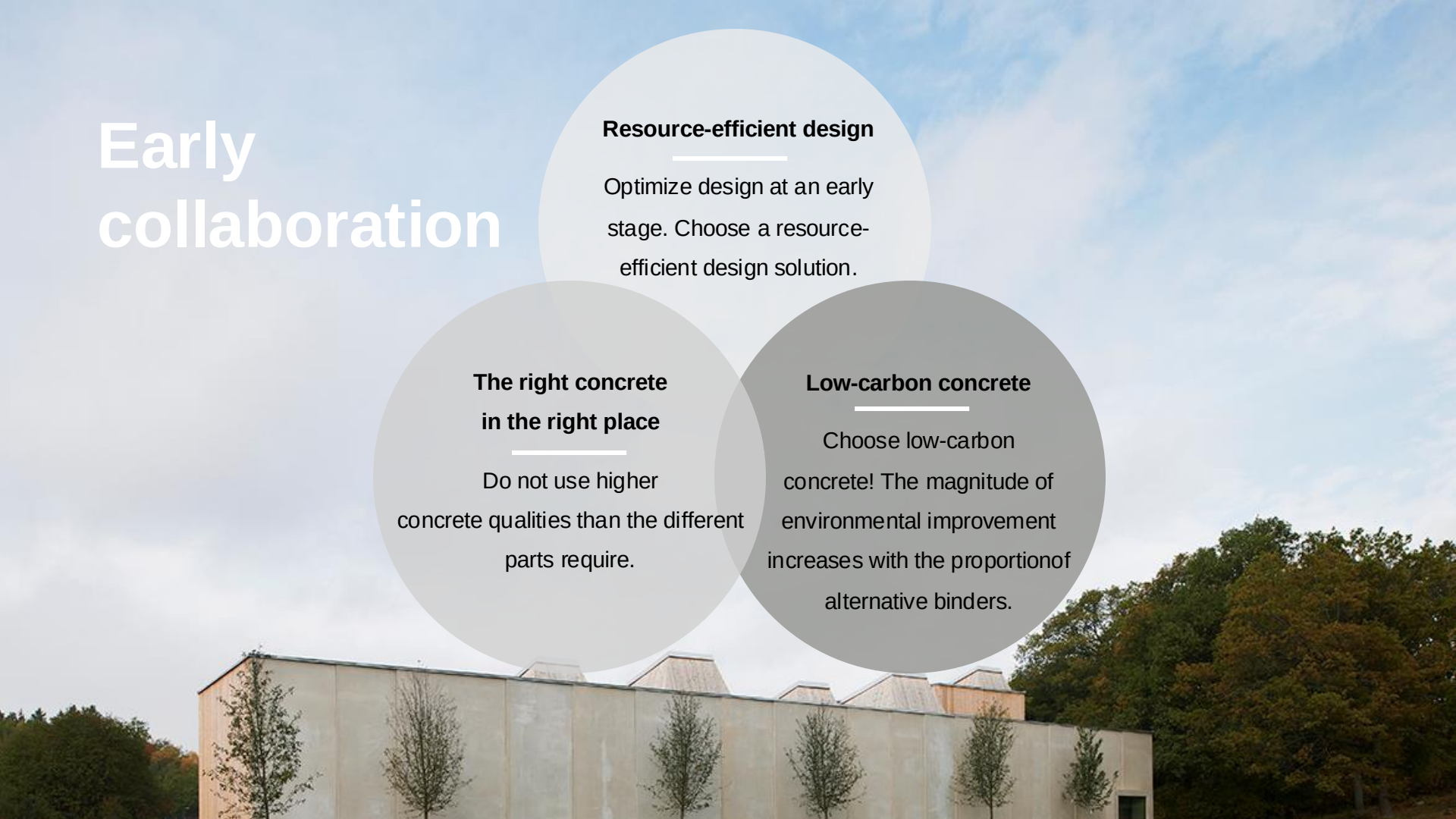
Optimize design at an early stage. Choose a resource-efficient design solution.

The right concrete in the right place

Do not use higher concrete qualities than the different parts require.

Low-carbon concrete

Choose low-carbon concrete! The magnitude of environmental improvement increases with the proportionof alternative binders.



Why does material science play a critical role in the construction industry's transition?

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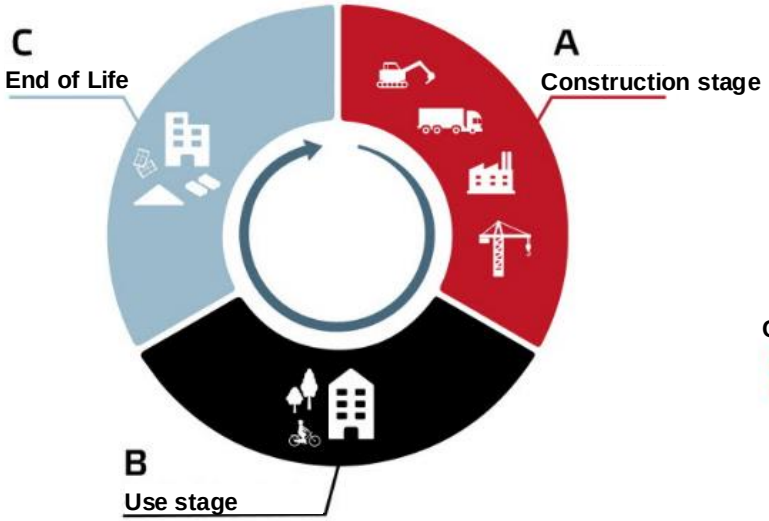
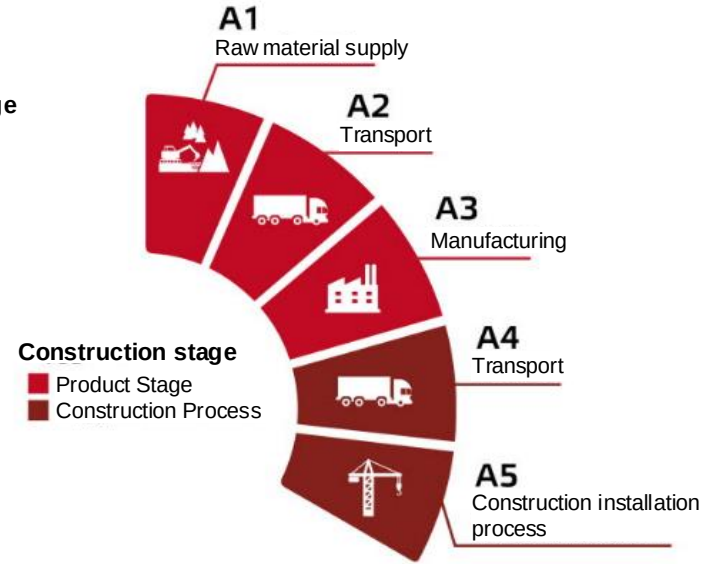
Life cycle assessment (LCA) & environmental product declaration (EPD)

In the construction industry





Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method (EN 15978:2011)

Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products (EN 15804:2012+A2:2019/AC:2021)

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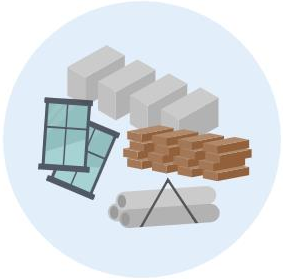
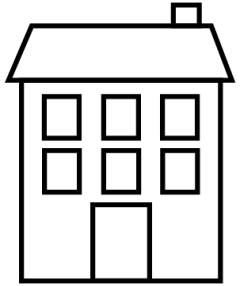
Assessment over the entire life cycle, and 100 years

Avoid sub-optimization

EPD for building materials should be used in LCA for buildings and construction works.



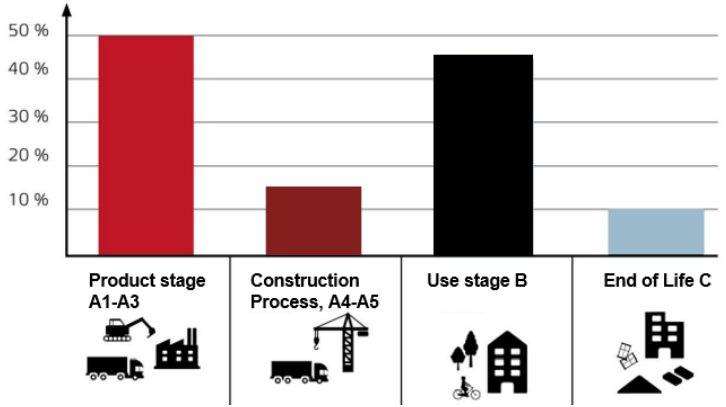
e.g., kg CO_2-eq. per kg, m^2, or m^3



e.g., kg CO_2-eq. per m^2

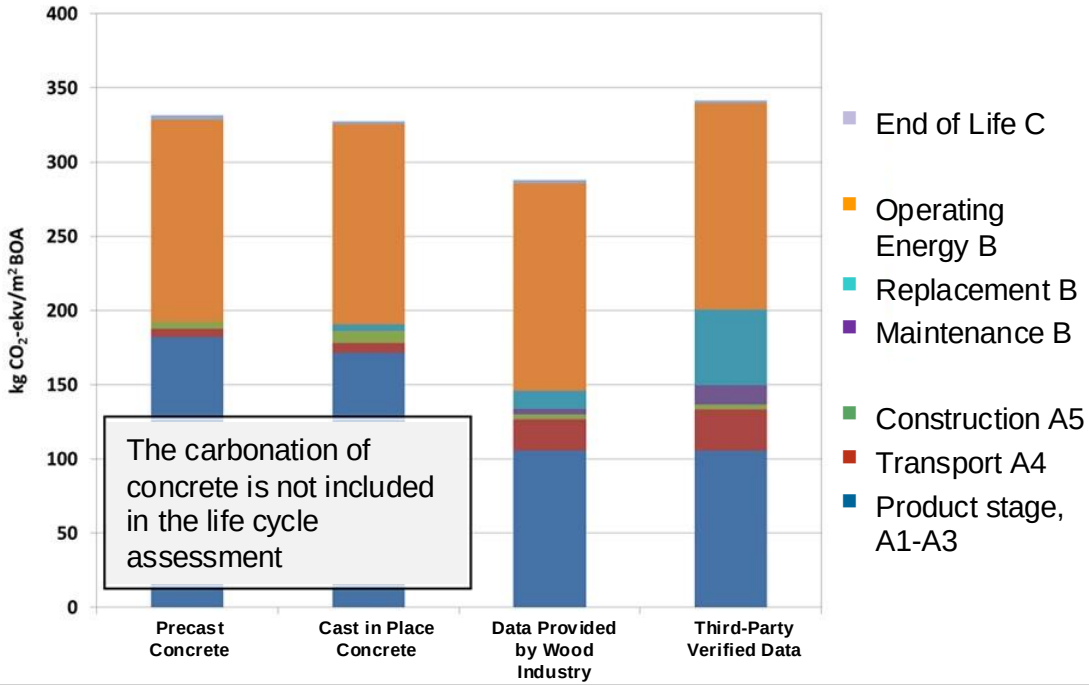
Building materials can only be compared if

- They are incorporated into equivalent buildings with the same function and performance.
- Assessed over the entire life cycle, more than 100 years.



Example of climate impact from different stages in a building's life cycle (Boverket)

Life cycle assessment
Concrete and wood building



Energi och klimateffektiva byggsystem Miljövärdering av olika stomalternativ. SP 2015, Eva-Lotta Kurkinen, Joakim Norén, Diego Penaloza, Nadia Al-Ayish, Otto During

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Independent study by IVL, Swedish Environmental Research Institute

Cast-in-place concrete frames together with semi-precast meet the strict requirements

The passive house Blå Jungfrun in Stockholm is chosen as reference house for a new independent theoretical study by IVL.

IVL study in real life:
We will reach even lower than in the theoretical study. Project in a large Swedish city.

The Viva study in 2015 shows "no significant differences between wood and concrete".

Result from study:
In-situ cast low-carbon concrete combined with semi-prefabricated low-carbon concrete elements from Thomas Betong can meet the requirements for halved climate impact.

In-situ cast concrete frame with semi-precasting based on the Blå Jungfrun reference house. IVL 2023, Martin Erlandsson, Daniel Peterson, Carlos Gil Berrocal

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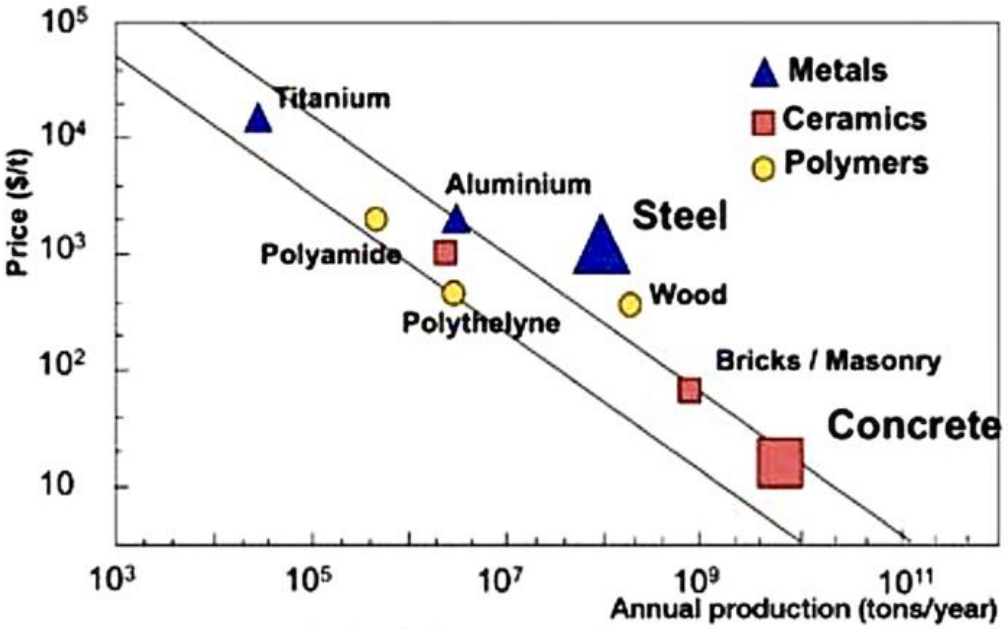

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Source: Heidelberg, Stock, Thomas Betong



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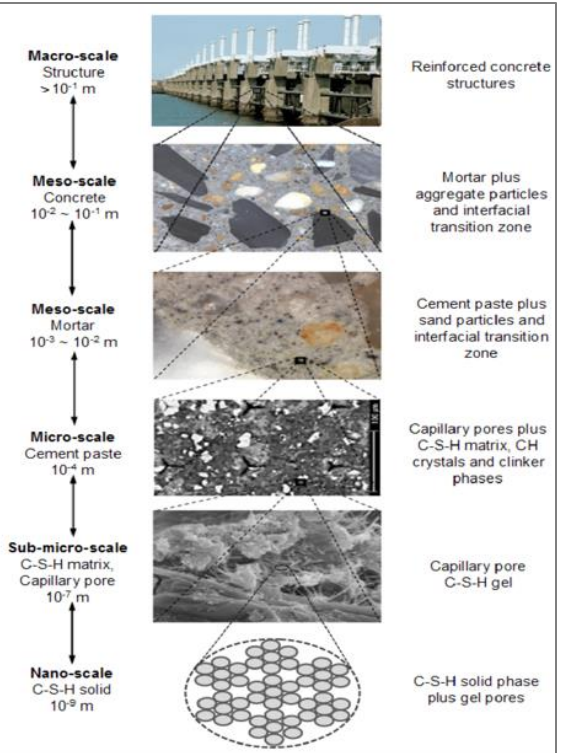
An advanced and complex material

Excerpt presentation by Ingemar Löfgren, R&D Manager and Adj. Professor Chalmers

Concrete, a complex material

- Used in “large” constructions
- Consists of aggregates with sizes from 25 mm to < 63μm
- Has pores that vary from 1 mm to 1 nm (from macropores to “gel pores”)
- Consists of “loose-”, “hard-” & “chemically-” bound water.
- But the “binder” (C-S-H or C-A-S-H) is difficult to characterize



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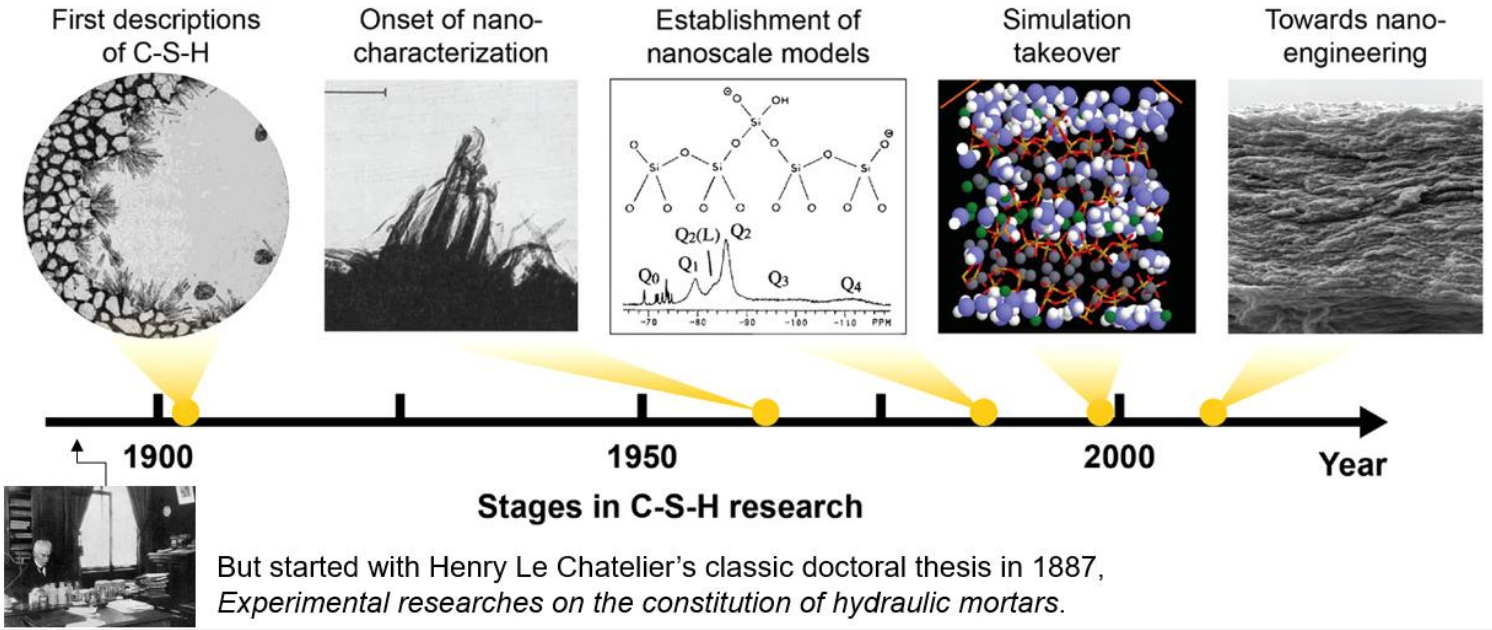
Know a lot, but a lot more to learn

Excerpt presentation by Ingemar Löfgren, R&D Manager and Adj. Professor Chalmers

Development of understanding & opportunities



Stages in C-S-H research

But started with Henry Le Chatelier's classic doctoral thesis in 1887, *Experimental researches on the constitution of hydraulic mortars*.

Basquiroto de Souza F, Sagoe-Crentsil K, Duan W. A century of research on calcium silicate hydrate (C–S–H): Leaping from structural characterization to nanoengineering. J Am Ceram Soc. 2022; 105: 3081–3099. https://doi.org/10.1111/jace.18304

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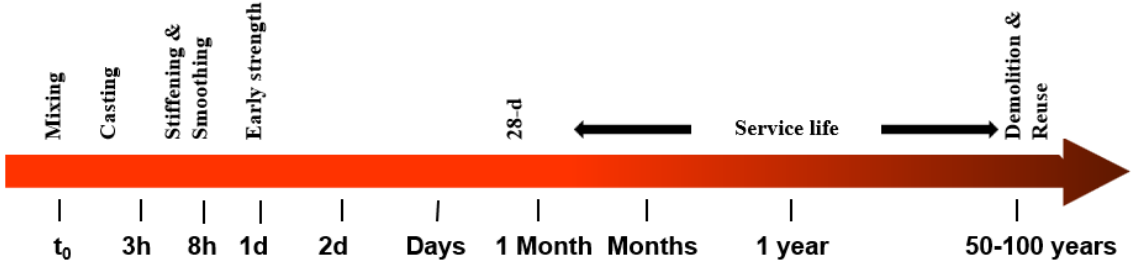
Maintaining properties and resistance over 100 year

Excerpt presentation by Ingemar Löfgren, R&D Manager and Adj. Professor Chalmers

Concrete timeline



Concrete, during its service life,

- must meet requirements regarding a number of properties, e.g., setting time, strength & strength development, temperature development, shrinkage, etc.,
- and be resistant to the environment in which it is to be placed, e.g., frost resistant, chlorides, sulfates, acids, etc.

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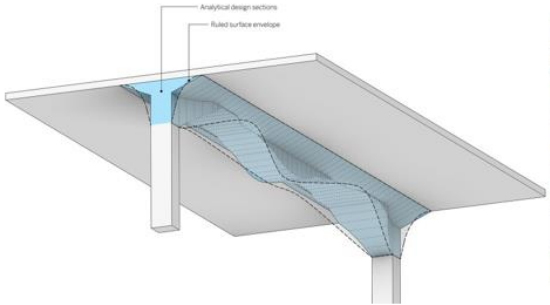
Structural optimization

Excerpt presentation by Ingemar Löfgren, R&D Manager and Adj. Professor Chalmers

Further development and optimization

Pier Luigi Nervi
Gatti Wool Factory Floor System (1953)
https://en.wikipedia.org/wiki/Pier_Luigi_Nervi



Skidmore, Owings & Merrill "Stereoform slab" with half the thickness of a typical flat plate
https://www.som.com/research/stereoform-slab/

Daliform "U-boot"
2-way voided slabs
https://www.daliform.com/en/disposable-formwork-for-two-way-lightened-voided-slabs/

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3. Exploring the role of material science in the construction industry's transition:
   - Concrete is the world’s most widely used construction material.
   - Concrete is an advanced and complex material.
   - Maintaining properties and resistance over 100 years.
   - Know a lot, but a lot more to learn.
4. Conclusion.

- Advancements in material science plays a critical role in building robust, resilient and sustainable societies.
- We need to build more with less:
  - Use less materials.
  - Use more new “new” materials made from “old” materials.
  - Optimize structures.
  - Structures that maintains its properties and resistance over hundreds of years.
- To accelerate the transition in the construction industry, we rely on advancement in material science.