Increased circularity and reduced CO_2 footprint of concrete production by use of industrial wastes, calcinated clays and bio-ashes

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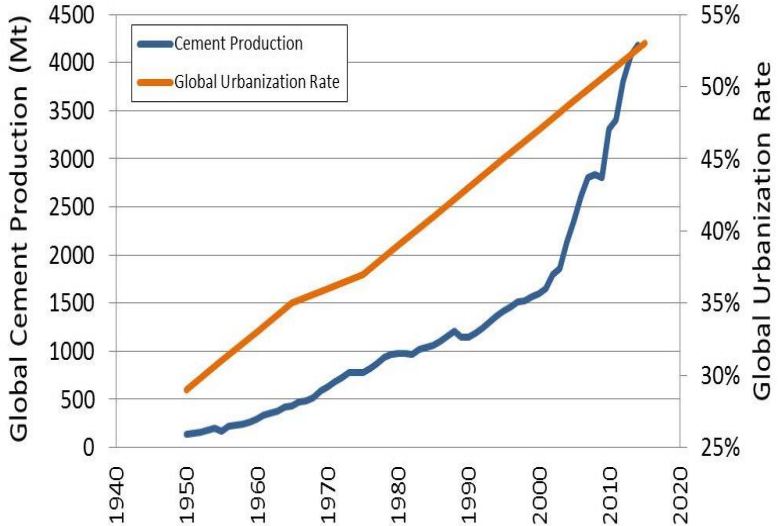
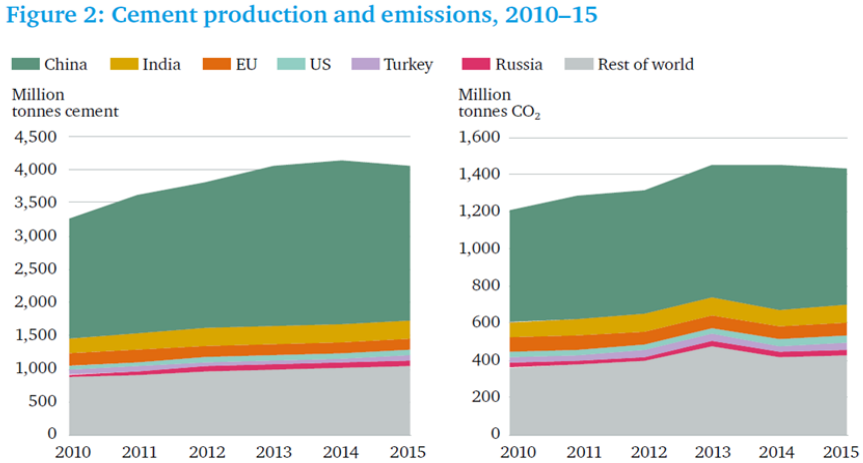
Urbanisation and increased demand of cement

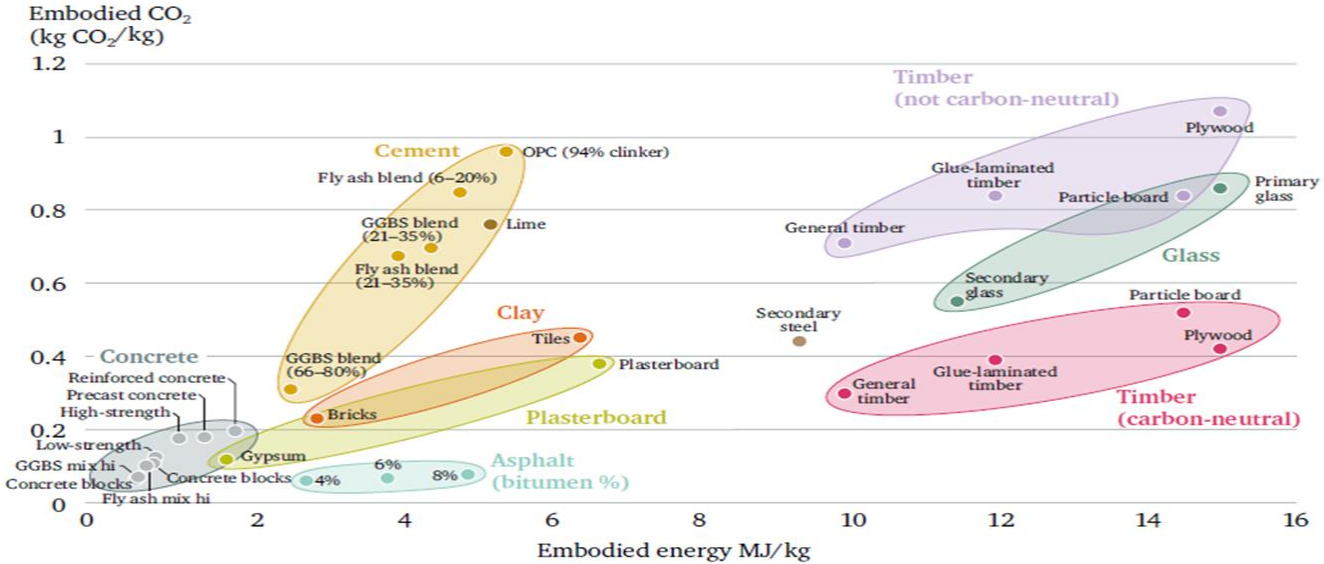
- Cement production: 4800 Mt 2018 - 6% of the total anthropogenic CO_2 emissions
- Concrete production: 30000 Mt 2015
- Urbanisation and economic development increase
- 2050 - 3 mld people from poor areas in need of housing





From: A sustainable future for the European cement and concrete industry; ETH/EPFL, 2018

Embodied emissions and energy for materials used in construction (UK)



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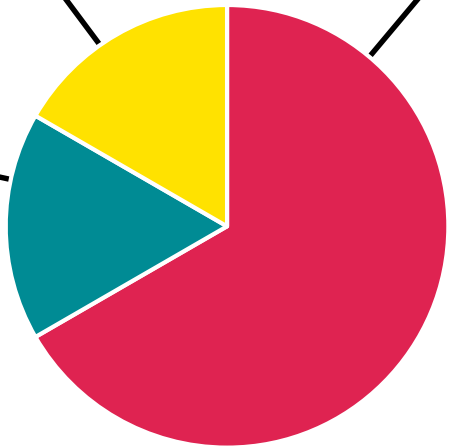
How can we reduce the CO_2 emissions in concrete production?

"Fuel CO_2"
Combustion of fuel to retrieve the thermal energy needed for the calcination

"Process CO_2"
Calcination of the raw materials causing inevitable chemical reaction
$CaCO_3 \rightarrow CaO + CO_2$

"Indirect CO_2"
e.g. transport, electricity…



Decrease the amount of cement in concrete

Replacing a part of it with Supplementary Cementitious Materials (SCMs)

Less cement – less natural resources - lower CO_2

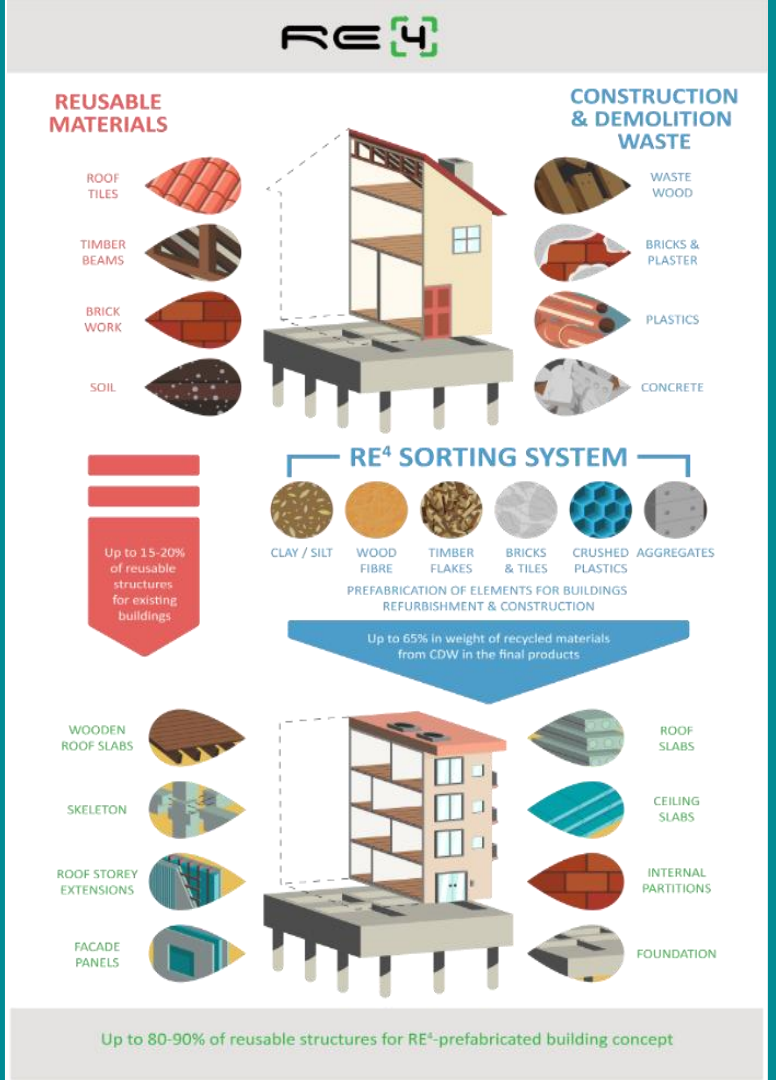
- CDW – construction demolition waste
- SCMs – supplementary cementitious materials
  - fly-ash, slag, bio-ashes, clays

Use of CDW in concrete

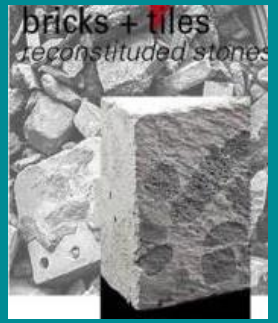
Some objectives

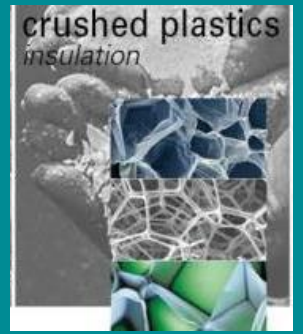
- Reuse of CDW in real construction
- Lower use of natural resources
- Development of prefab elements integrating a high level of CDW-derived materials
- To build a house of CDW

http://www.re4.eu/



Sorting of CDW → valuable resources





CDW as concrete aggregate

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2/8

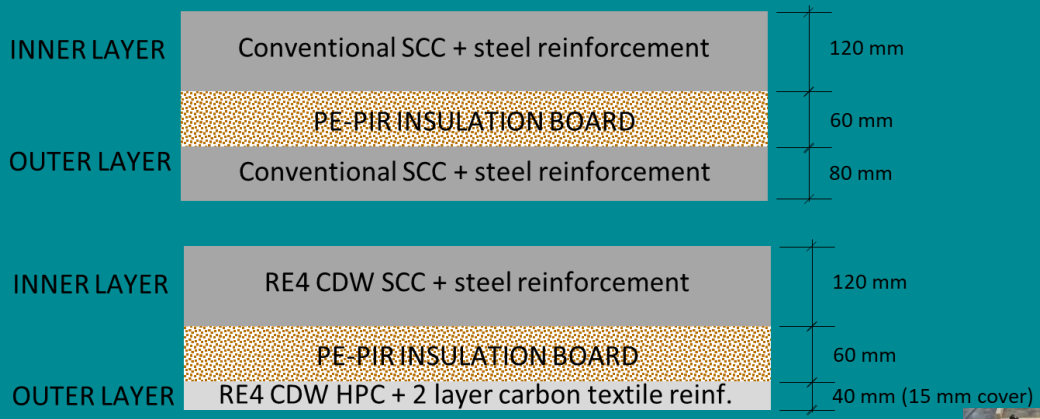
0/2

Recycled aggregates from the CDE recycling centre outside Marseille, southern France (fraction limits in mm)

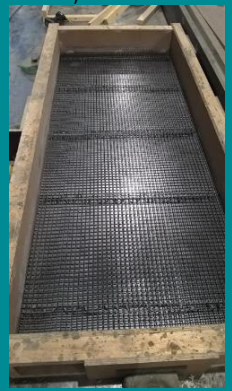
New CDW quality classes – a proposal
Instead 2 classes → 4

Property	Type A+	Type A	Type B	Type L
Density (oven dry) [kg/m³]	> 2000	> 2000	> 2000	≤ 2000 (To be declared)
Rc+Ru [%]	≥ 95 %	≥ 90 %	≥ 70 %	---
Rb [%]	≤ 5 %	≤ 10 %	≤ 30	---
Rc+Ru+Rb [%]	---	----	≥ 90 %	≥ 95 %
Ra [%]	≤ 1 %	≤ 5 %	≤ 10 %	≤ 5 %
FL	≤ 0,2 %	≤ 2 %	≤ 2 %	≤ 5 %
X+Rg [%]	≤ 1 %	≤ 5 %	≤ 5 %	≤ 5 %
Shape	≤ FI_{35} or ≤ SI40	≤ FI_{50} or ≤ SI_{55}	To be declared	To be declared
Water soluble sulfates	≤ $SS_{0,2}$	≤ $SS_{0,2}$	≤ $SS_{0,2}$	≤ $SS_{0,2}$
Influence on setting time	≤ A_{10}	≤ A_{40}	≤ A_{40}	≤ A_{40}
Water absorption	≤ 5%	≤ 10 %	To be declared	To be delared

Sandwich element production – upscaling at Creagh Concrete



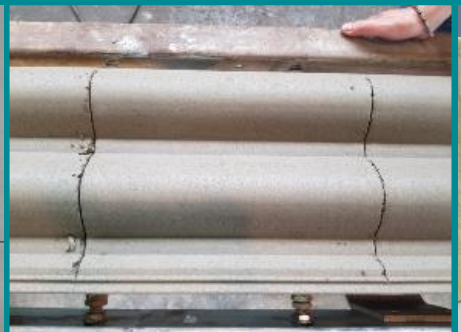
- Self-Compacting Concrete with 50% of aggregates being CDW (Type B)
- High-Performance Concrete with 50% of aggregates being CDW (Type B)
- With CDW quality class Type A, usage levels were 80 and 90 %, respectively



Achievements:
Prefab elements constituting 30-95 % CDW







Demo buildings in Spain and UK (below from Creagh Concrete, UK)

Use of clays and bio ashes in concrete:

The path towards a better sustainability and increased circular economy

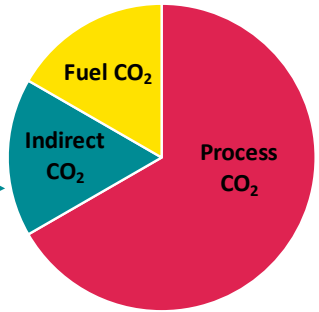
Which SCM?

- Chemical composition
- Availability
- Reactivity

- Commonly use SCMs are waste products from other industries:
  - they are often imported
  - have a limited availability
  - shortage is forecasted
- New sources of SCMs are needed, ideally local ones

→ Clays

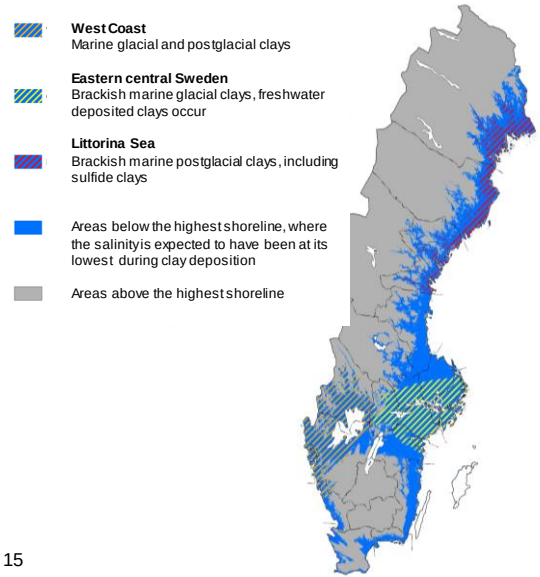
→ Bioashes

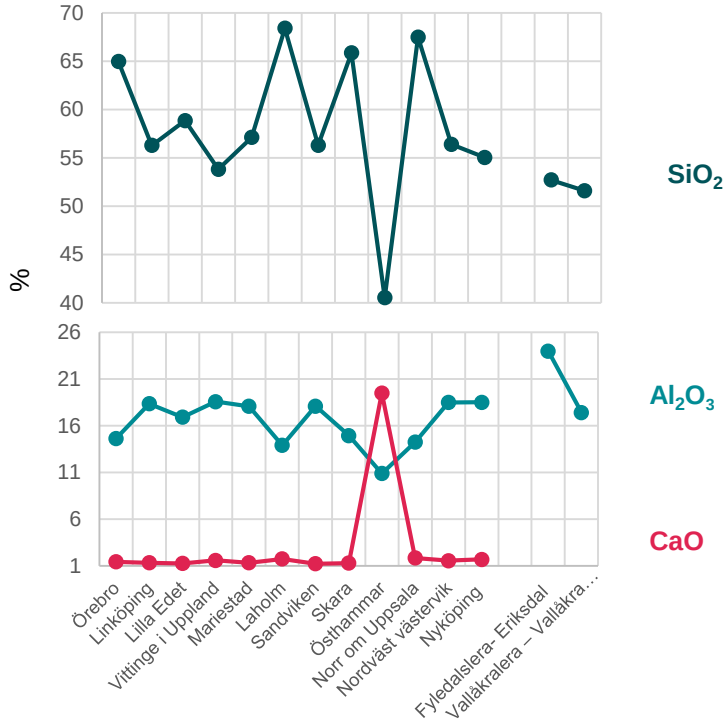


Swedish clays as SCM

- Availability ✓
- Composition ✓
- Reactivity

Available in many part of the world, including Sweden



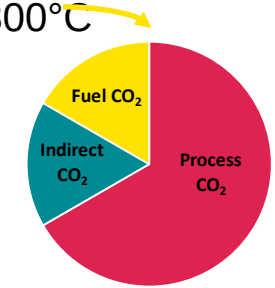


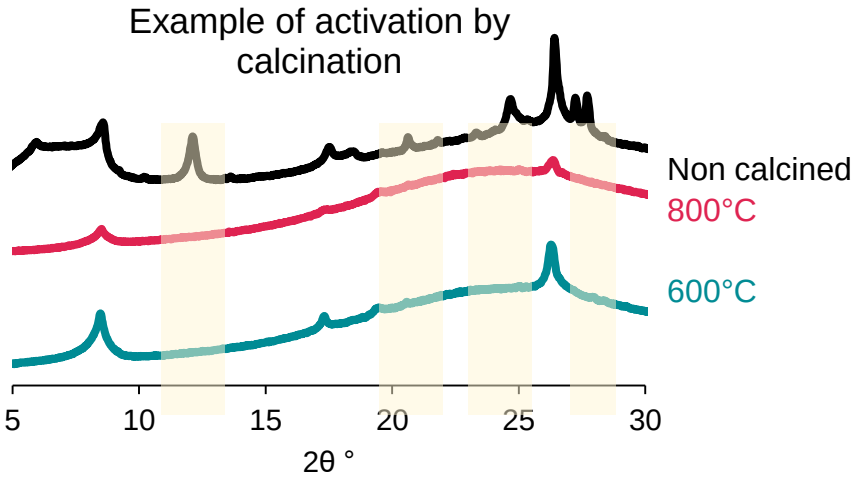
Their chemical composition make them compatible with cement

Clay as SCM

- Availability ✓
- Composition ✓
- Reactivity

- To be used with cement, clays must be activated, usually by heating at 600-800°C

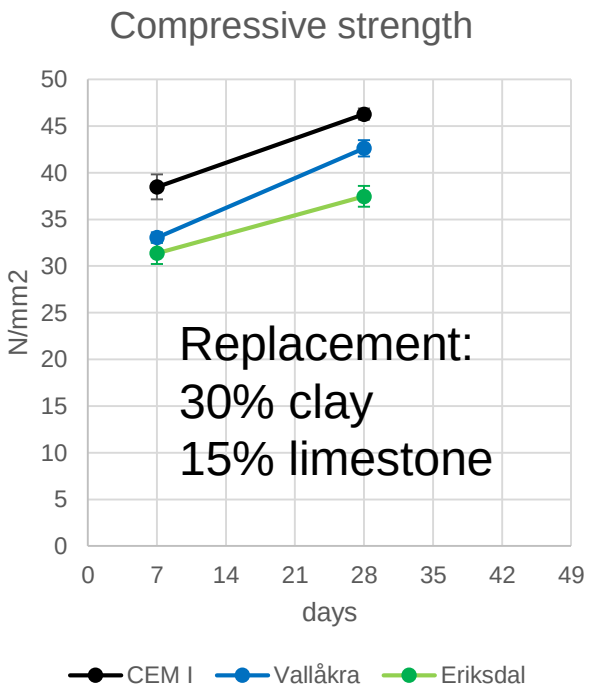




Clay as SCM

- Availability ✓
- Composition ✓
- Reactivity ✓

- Can be used together with limestone to reduce even more the amount of cement (up to 50% replacement)
- Swedish clays show promising results: good reactivity and mechanical strength



Bio-ashes as SCM

- Availability ✓
- Composition
- Reactivity

- According to Energiforsk:
  1.7 M t/ year of ashes is produced by Swedish energy production
  Bottom ash – 0.7 M t a year has a priority to be used in other industries

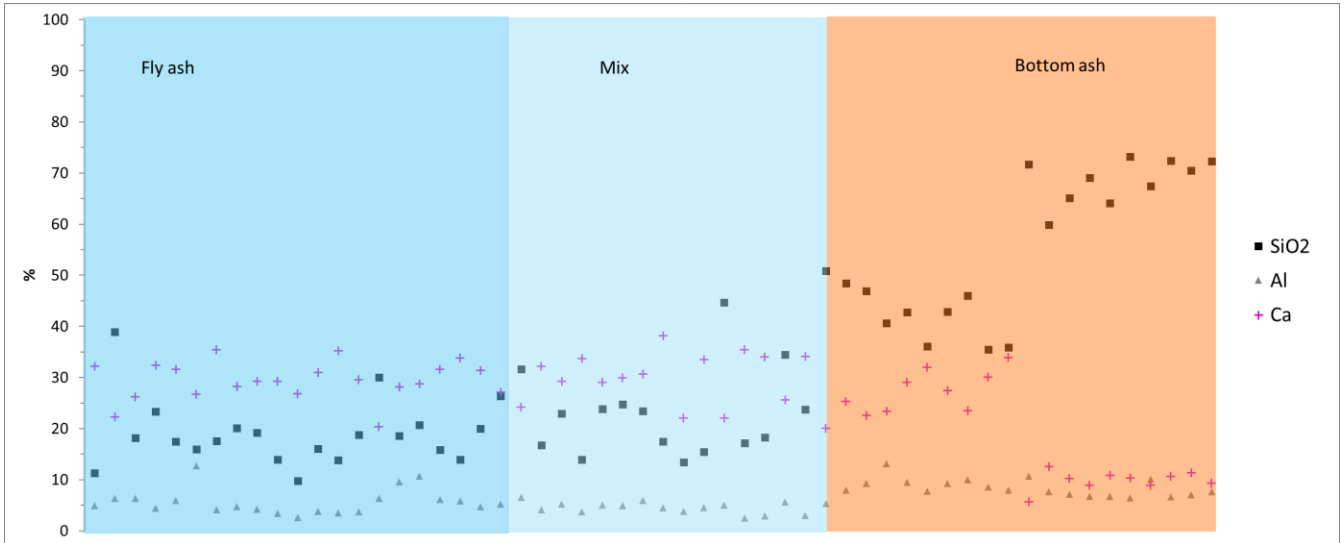
- Pulp and paper industry: approx. 1.5 M t/year,
  most of it is landfilled.

Can we use this waste to replace cement,
and contribute to a circular economy?

Bio ashes as SCM

- Availability ✓
- Composition ✓
- Reactivity

- Chemical requirements:
  - The chemical composition should not vary over time to ensure a constant quality
  - No chloride (washable if present), no heavy metals



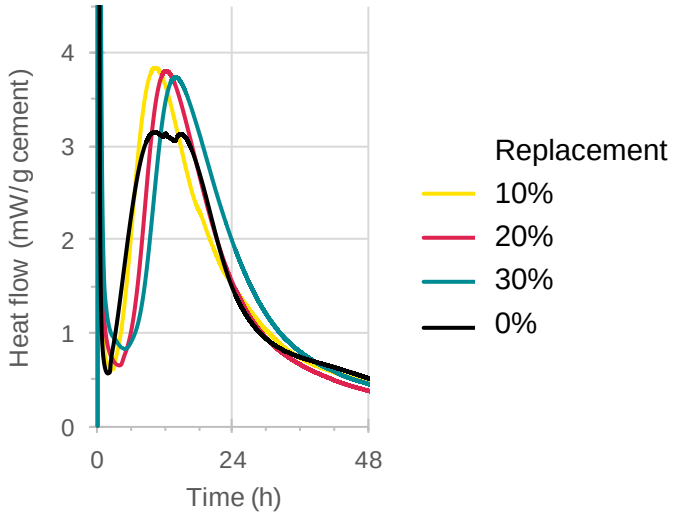
→Check and approved for 7 different Swedish companies, with sampling up to 6 months

Bio-ashes as SCM

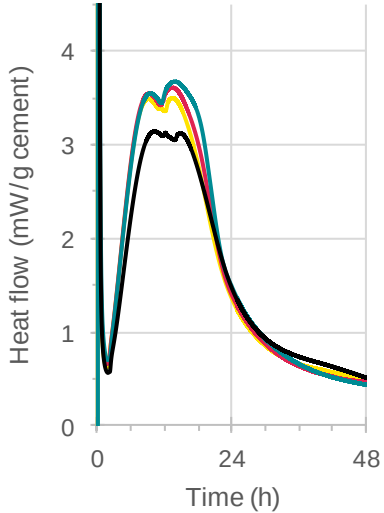
- Chemical composition ✓
- Availability ✓
- Reactivity ✓

- The tested bio-ashes exhibit good reactivity with cement

Example fly ash

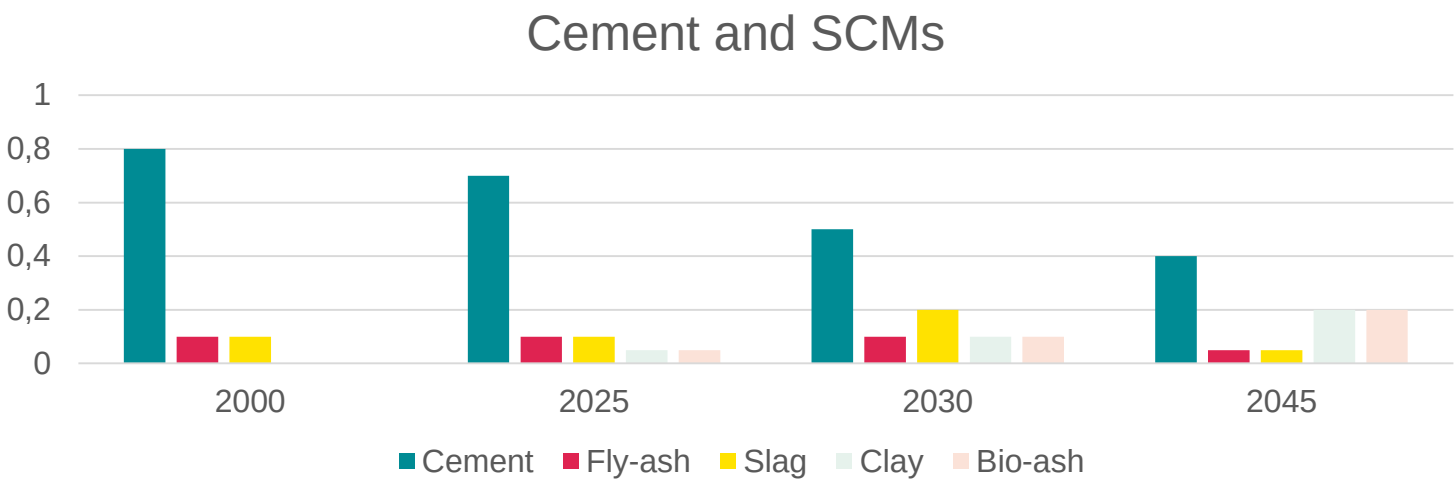


Example bottom ash



→Development of binders in process

A possible future use of cement?



Thank you for your attention!

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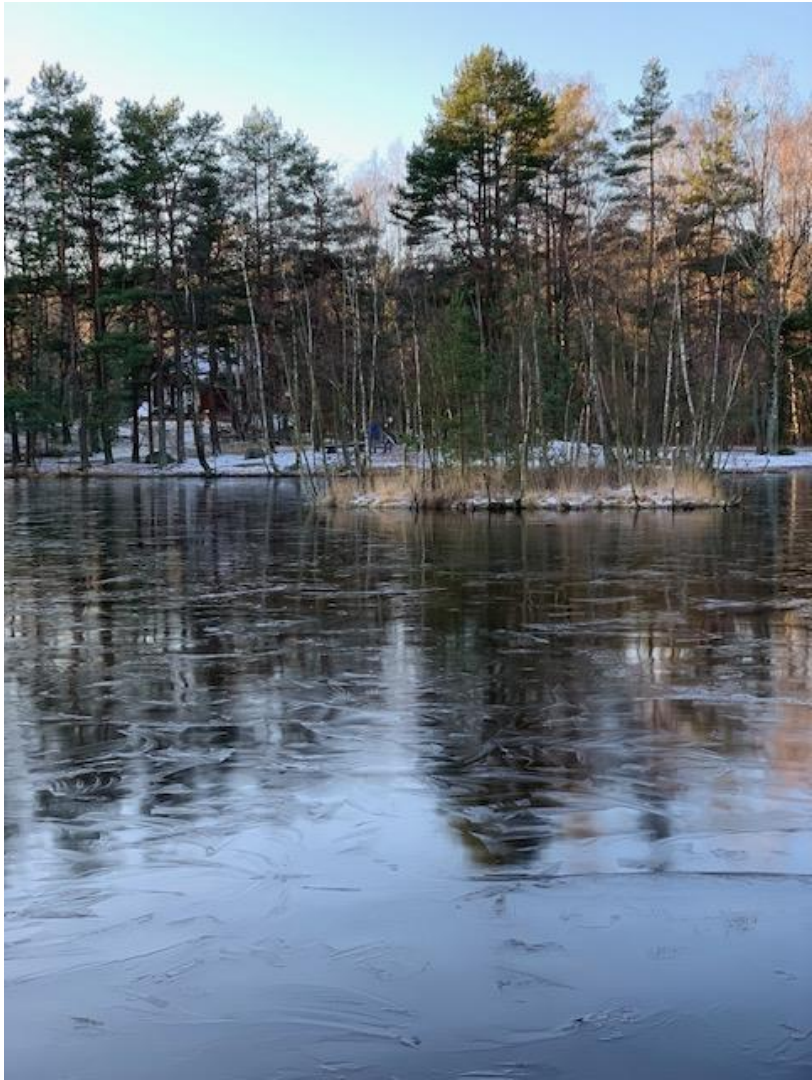

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