How do we carbonise

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Part 1: Busting the myths
Part 2: Research needs

Part 1: Busting the myths

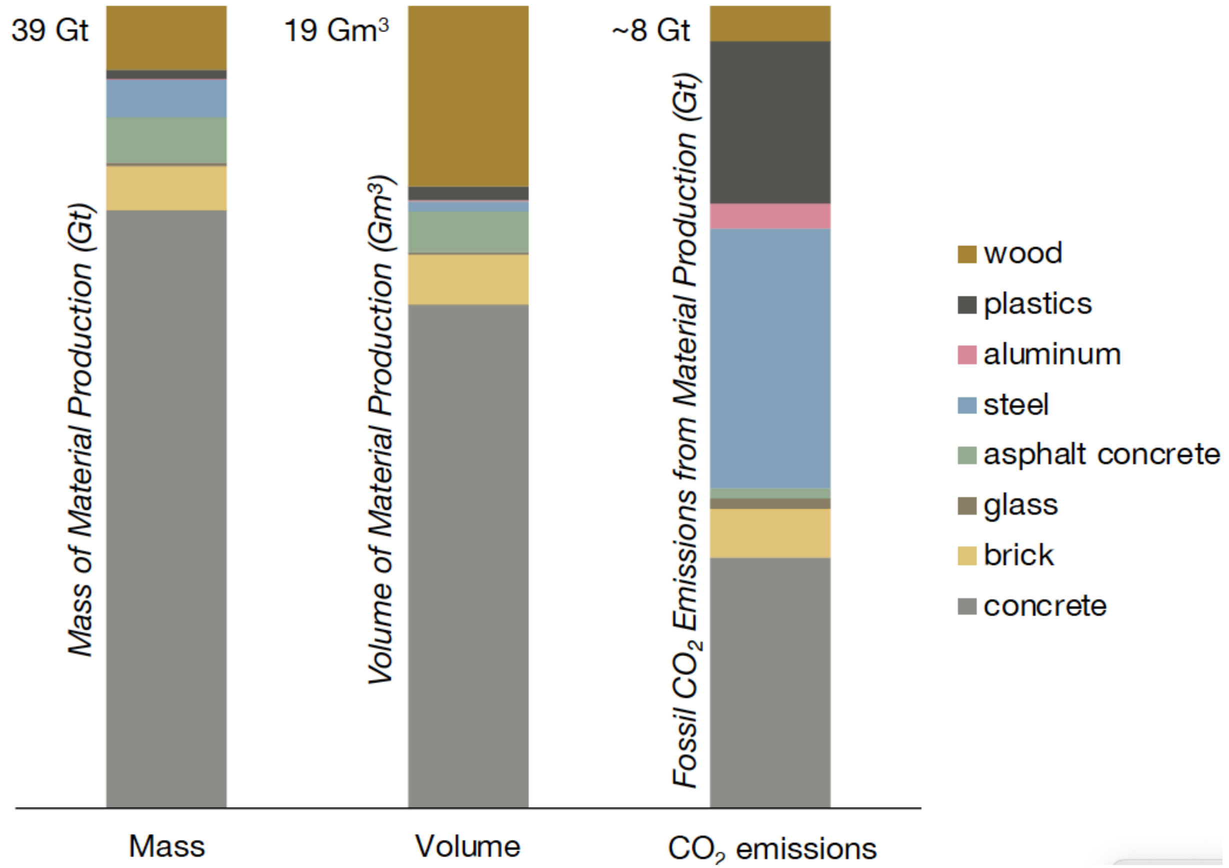
The challenge

- Huge volumes
- Low cost
- Already low carbon
- Robust

What's behind the success of Portland cement

- Raw Materials available everywhere
- Add water and stir
- Room temperature – minimal volume change

All the Materials we use



Replacing just 25% of concrete with wood sustainably would require new forest 1.5 times the size of India

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Is concrete really the bad guy?

- Cement and concrete » 6-8%
- Iron and steel » 11%
- Clothing » 10%
- Passenger transport, road » 9.5%
- Food loss/ waste » 6%
- Deforestation » 11%

We can achieve a lot more by making lowering the carbon footprint of concrete than persisting in the delusion that it can be replaced by something else.

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Alternatives to Portland cement?

14/11/25

What are the boundaries?

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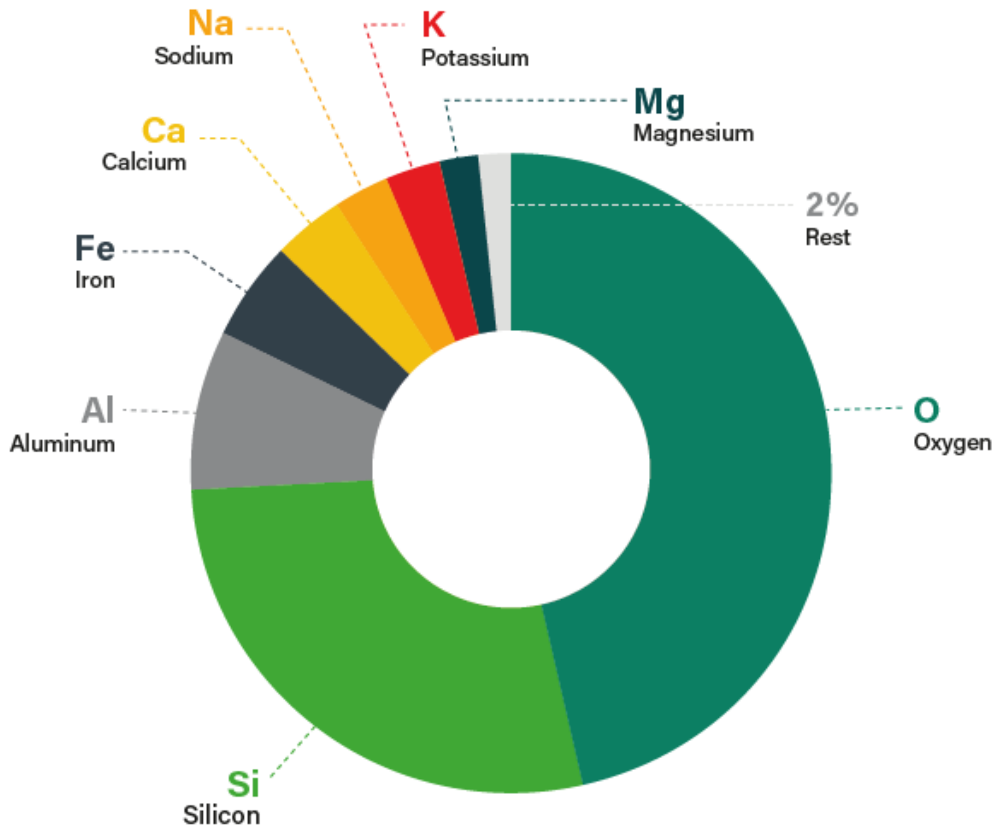
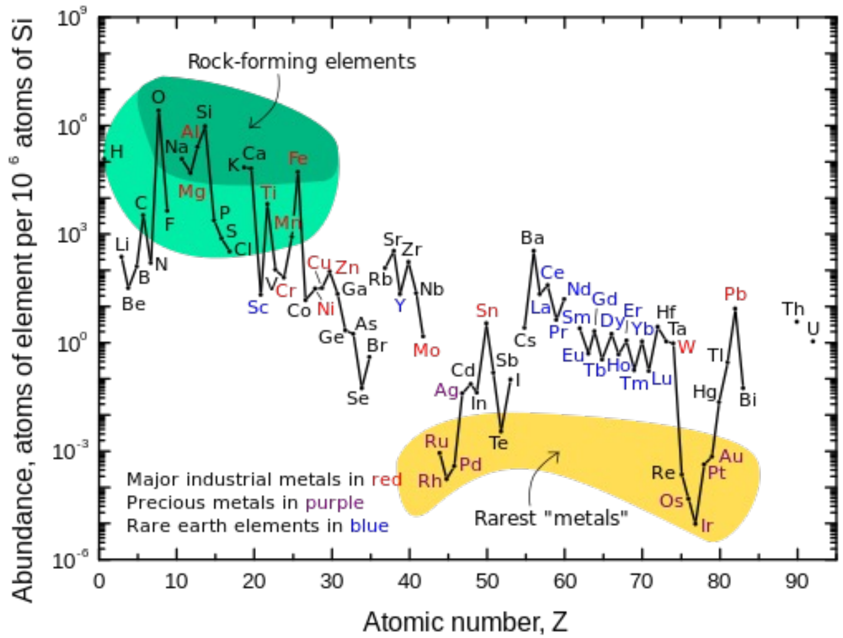
What is available on earth?



8 elements make up more than **98%** of the earth's crust



Due to the processes of forming elements in stars other rocky planets will be similar

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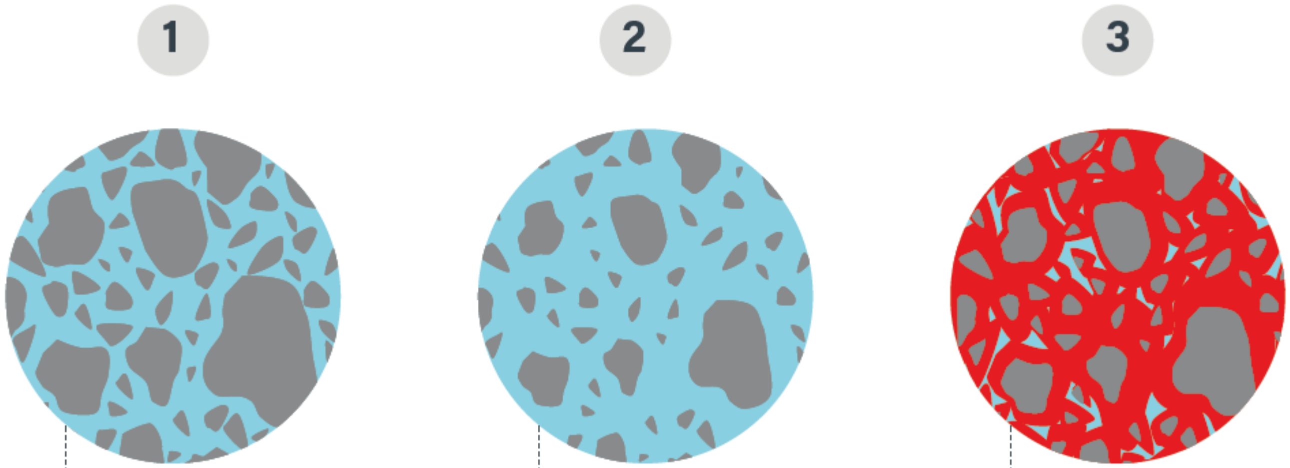
How does cements work?



We mix the grey cement powder with water.

To start with the grains are just floating about in the water and we can cast the concrete into moulds

The cement grains dissolve in the water

The cement grains dissolve in the water

And then precipitate Hydrates – new solids which have higher volume and hold the grains together: creating a rigid solid

Cement grain

Water

Dissolution > Precipitation

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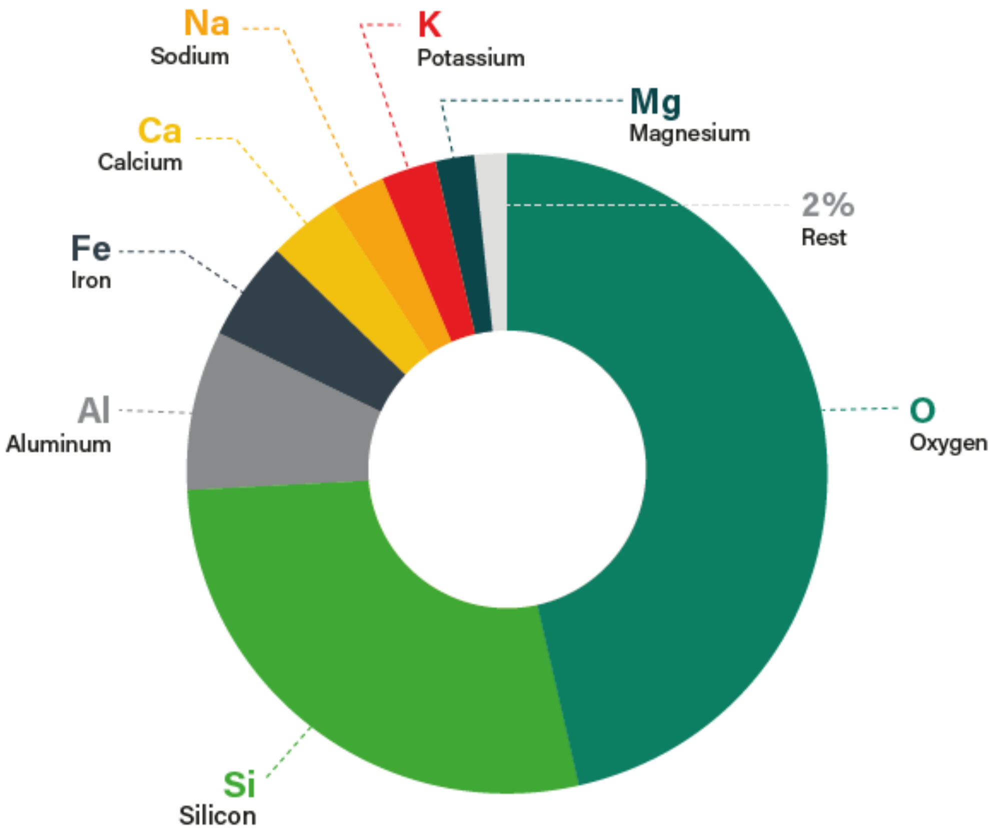


Na_2O

K_2O

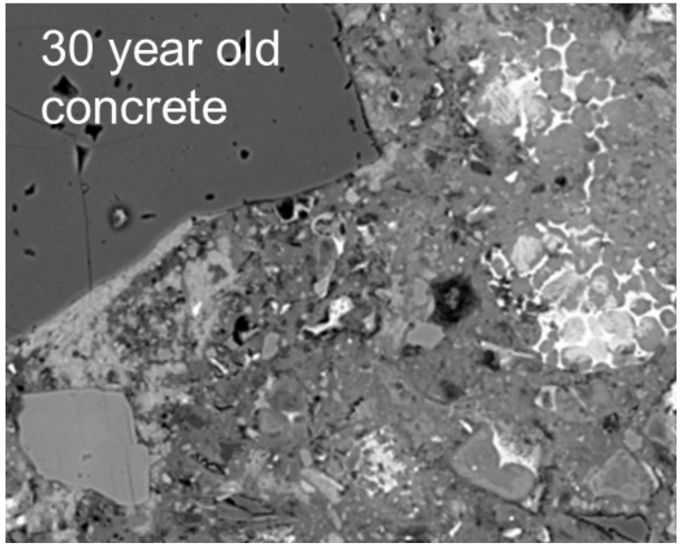
Fe_2O_3

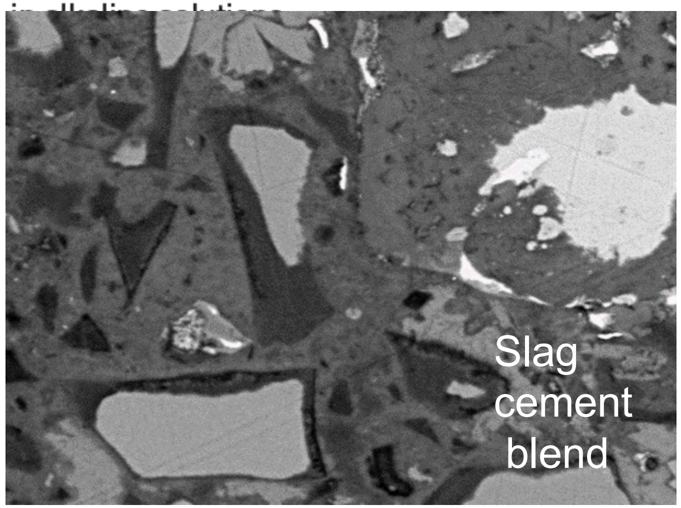
MgO

CaO

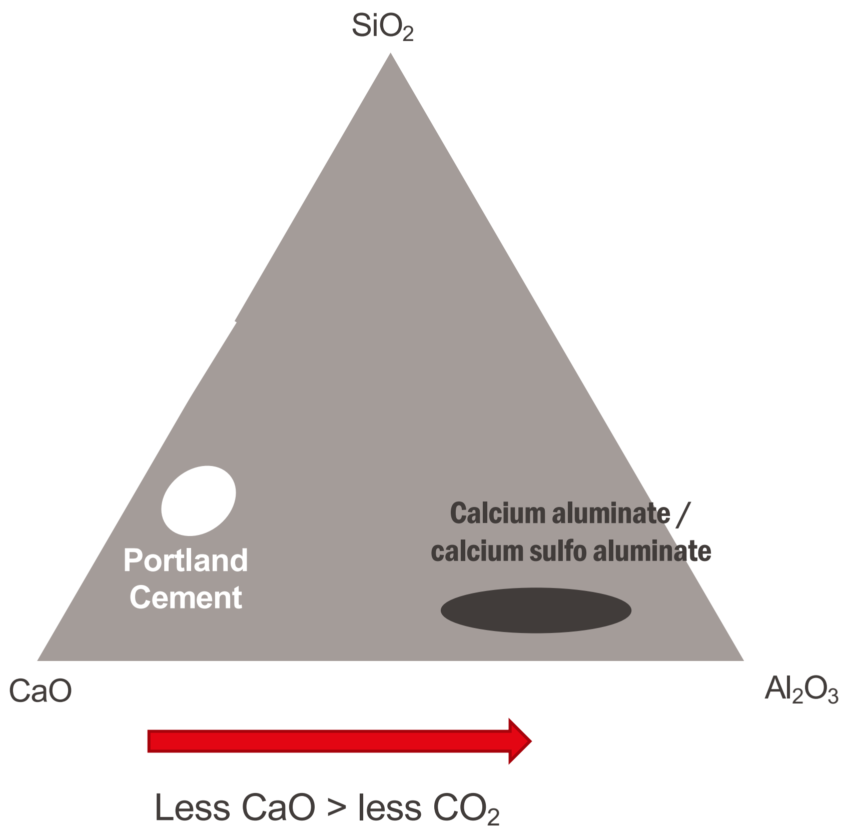
SiO_2

Al_2O_3





Hydraulic minerals in system $CaO-SiO_2-Al_2O_3$



BUT, what sources of minerals are there which contain Al_2O_3 >> SiO_2 ?

Bauxite – localised,
under increasing demand for Aluminium production,
EXPENSIVE

Even if all current bauxite production diverted would still only replace 10-15% of current demand.

Even after nearly 50 years CSA production in China is <0.1% of OPC

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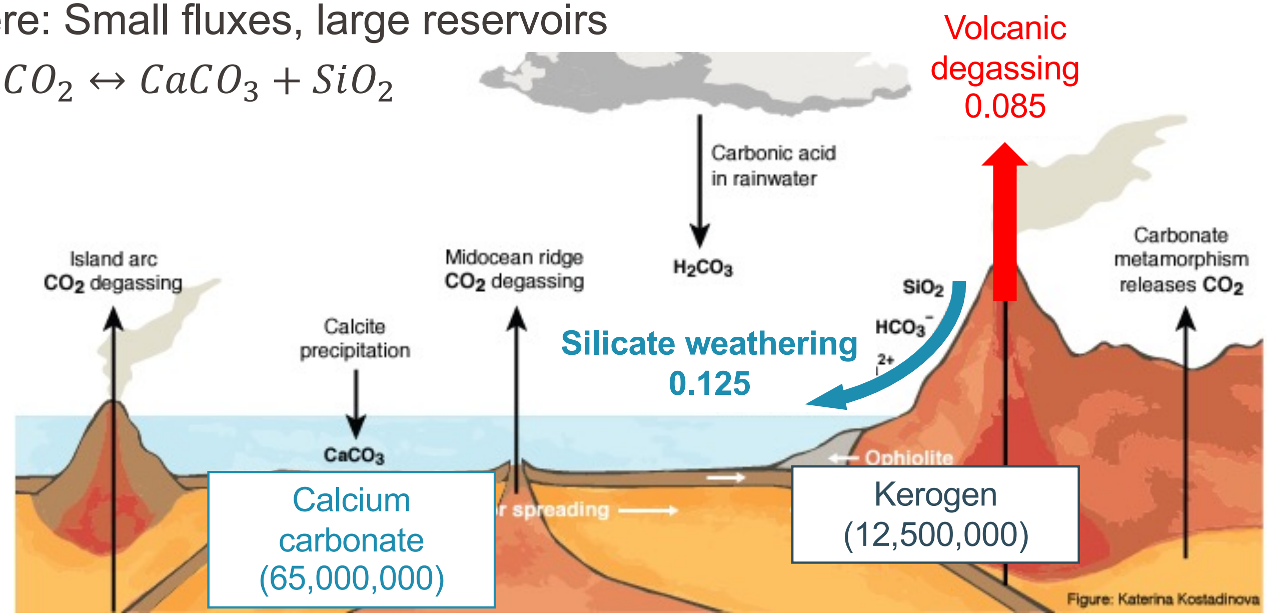
The advantages of limestone

- A concentrated source of calcium due to geological slow carbonate silicate cycle
- Long time scales
  - Lithosphere: Small fluxes, large reservoirs
  - $CaSiO_3 + CO_2 \leftrightarrow CaCO_3 + SiO_2$



[numbers in Gt C per year, number in parentheses in Gt C; source: Kasting, 2019; Hilton & West, 2020]

Slide from Ruben Snellings

KULeuven

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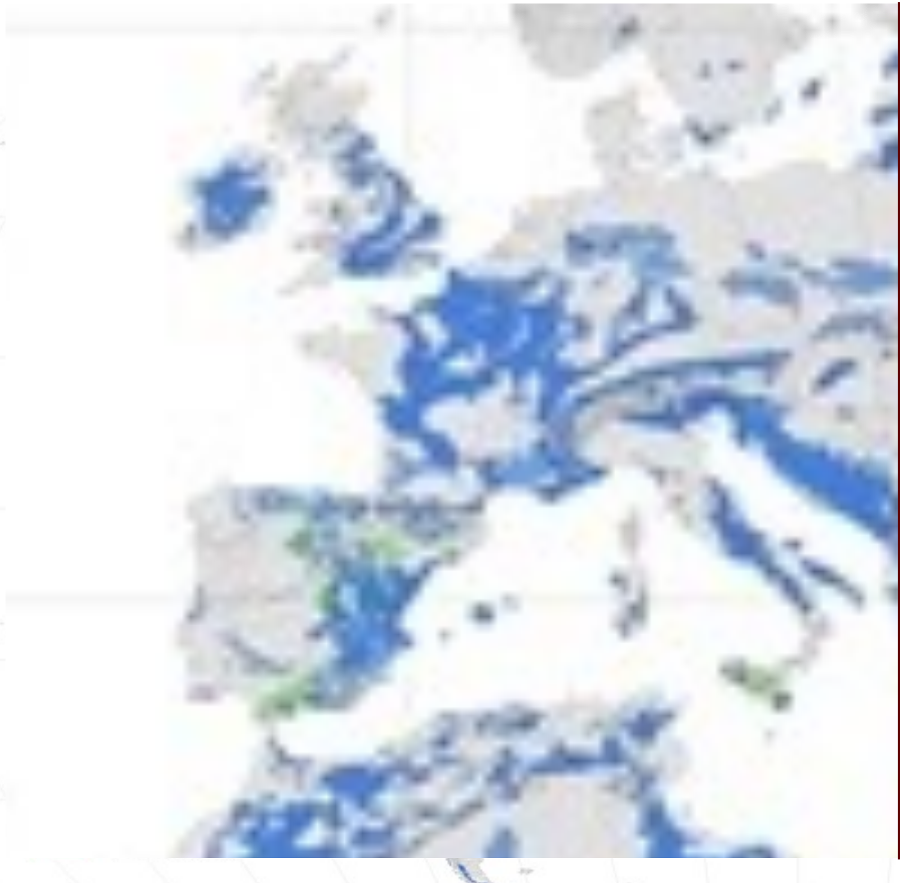
- Because of the weathering process,
  what is not limestone is dominated by aluminosilicate rock, eventually clay



No surprise that the interesting properties of limestone – clay combinations were discovered in Europe

It is not by chance Portland cement is the most used material on earth

It is a direct consequence of chemistry and geology

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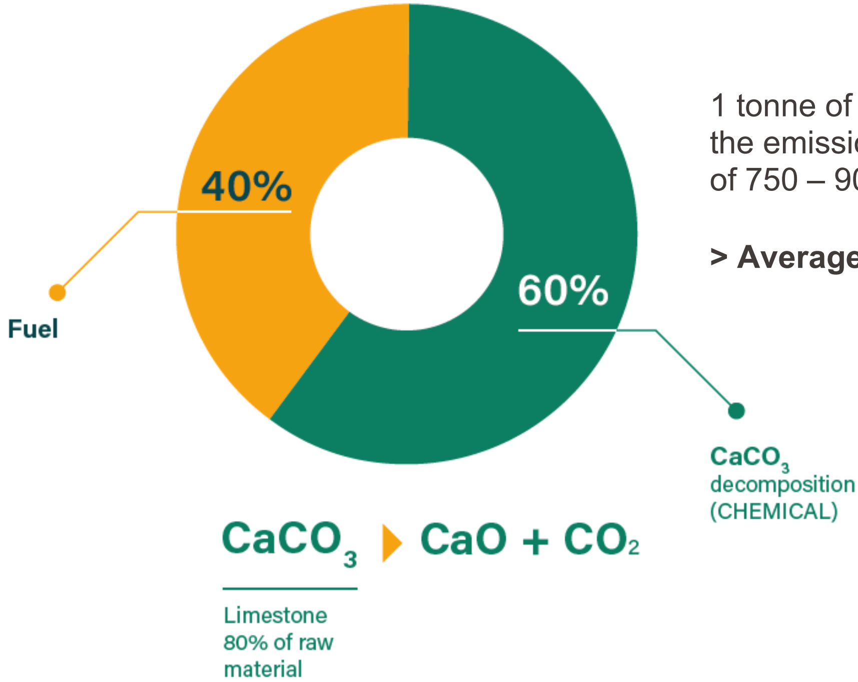
limestone leads to substantial CO_2 emissions

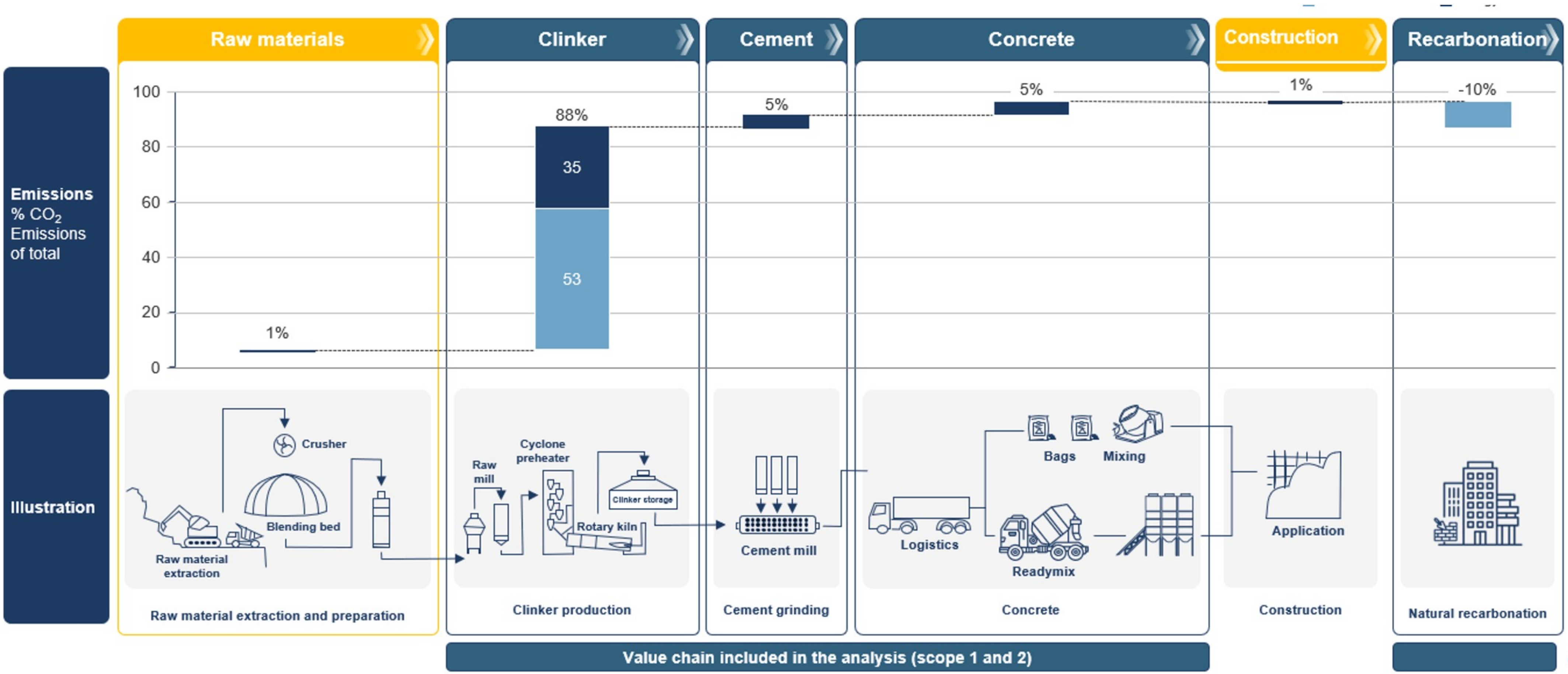
- The production process is highly optimised up to around 80% of thermodynamic limit.
- It is estimated that **< 2%** further savings can be made here
- Use of waste fuels, which can be **> 80%** reduces the demand for fossil fuels



1 tonne of clinker leads to the emission of 750 – 900 kg CO_2

> Average 830kg/t

Clinker is responsible for 85-90% of CO2 emissions for cement-based materials



Source: Mission Possible Partnership

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Obstacles to decarbonisation

- Thinking there are miracle alternatives
- Wasting time, effort and money on unscalable or ideas of dubious honesty

- Getting the different parts of the industry to work together

Miracle “green” solutions

Everyone plays along:

Researchers want funding

Venture Capitalists want to make money

Big companies want to give impression they are green

Alkali activated materials / Geopolymers

Have been around for more than 50 years

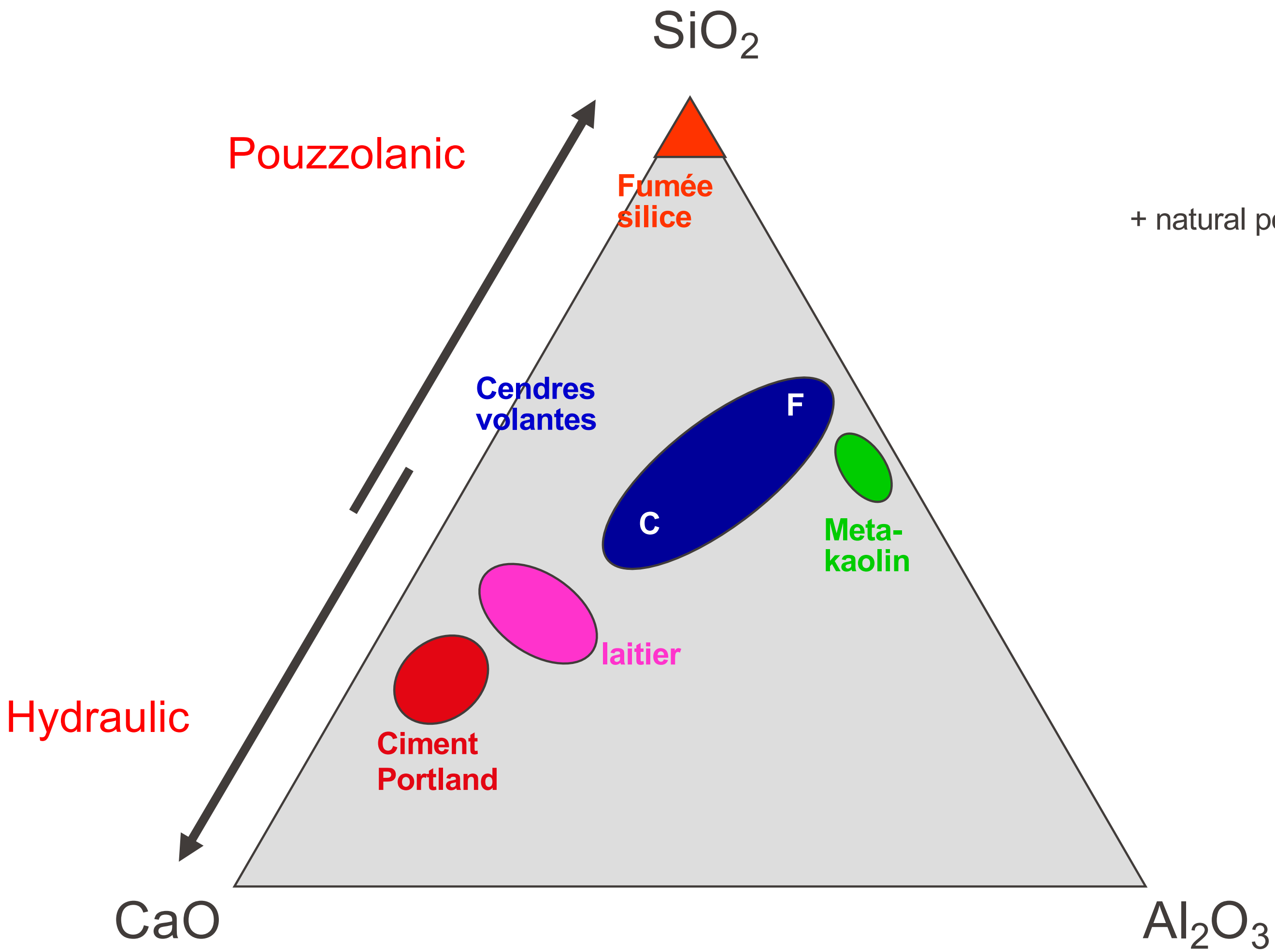
Little significant use beyond demo projects.

10s of companies bankrupt

Billions wasted in research funding

100s of young minds expended with no impact!

Chemical composition of SCMs



+ natural pozzolans

Alkali activated materials / Geopolymers

Vicious circle

Low volumes of consistent raw materials

Lack of robustness

High cost

Questionable CO_2 reduction on global level

What about getting Ca not from Limestone?

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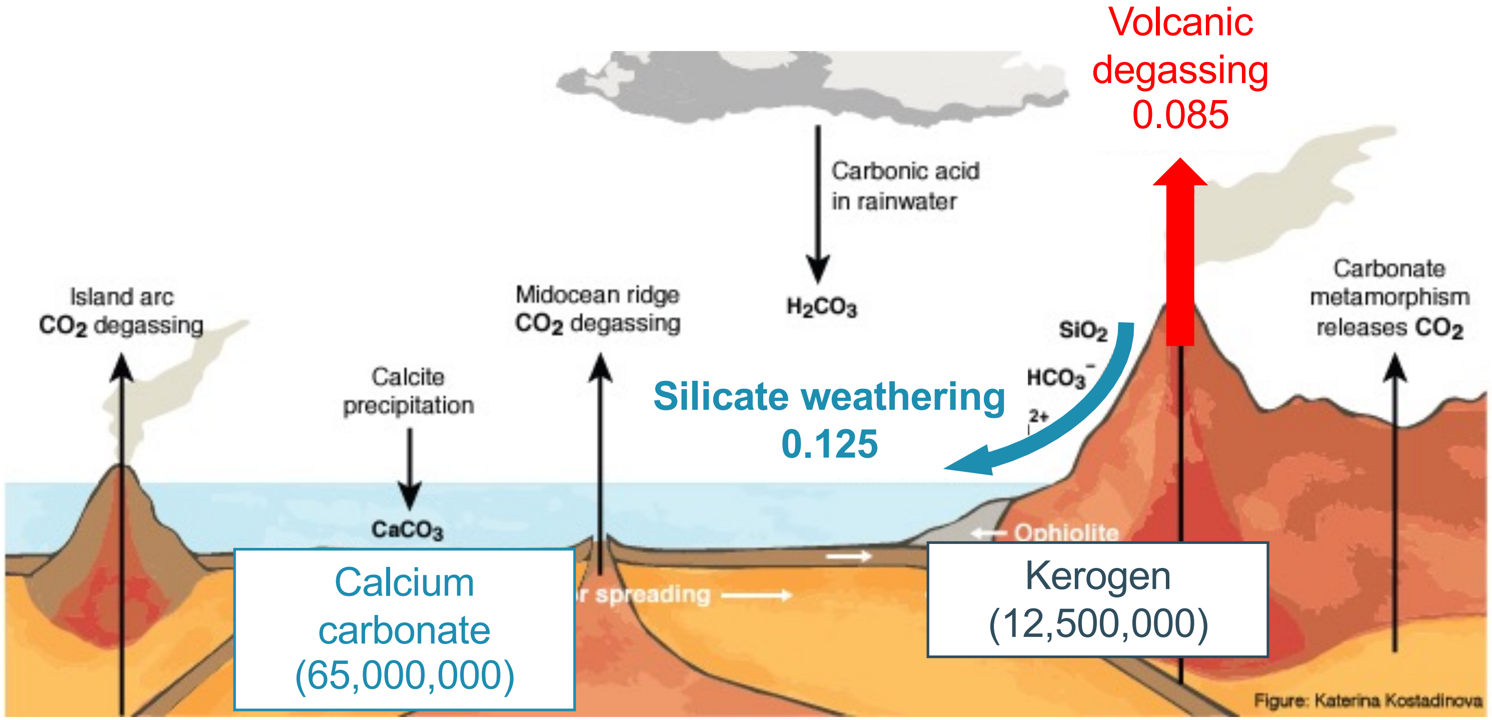
Volcanic rocks: ex Basalt



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Basalt

Name of oxide	Content, % by weight
SiO_2	46.5 – 51.5
Al_2O_3	15.0 – 19.0
MgO	4.0 – 10.5
CaO	7.5 – 11.5
$FeO+Fe_2O_3$	8.0 – 12.0
K_2O+Na_2O	3.0 – 6.0
TiO_2	0.3 – 2.5
Cr_2O_3	0.02 – 0.05
MnO	< 0.1
Other	Up to 100

Source: research gate

Dissolve in acid

Precipitate oxide separately

Common technology
in mining industry

Make clinker with
uncarbonated calcium oxide

Estimated cost ~ $800 / ton

>80% reject materials

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Accelerated weathering: ground basalt

https://un-do.com/enhanced-rock-weathering/

Ca from Seawater?

400ppm,

 28

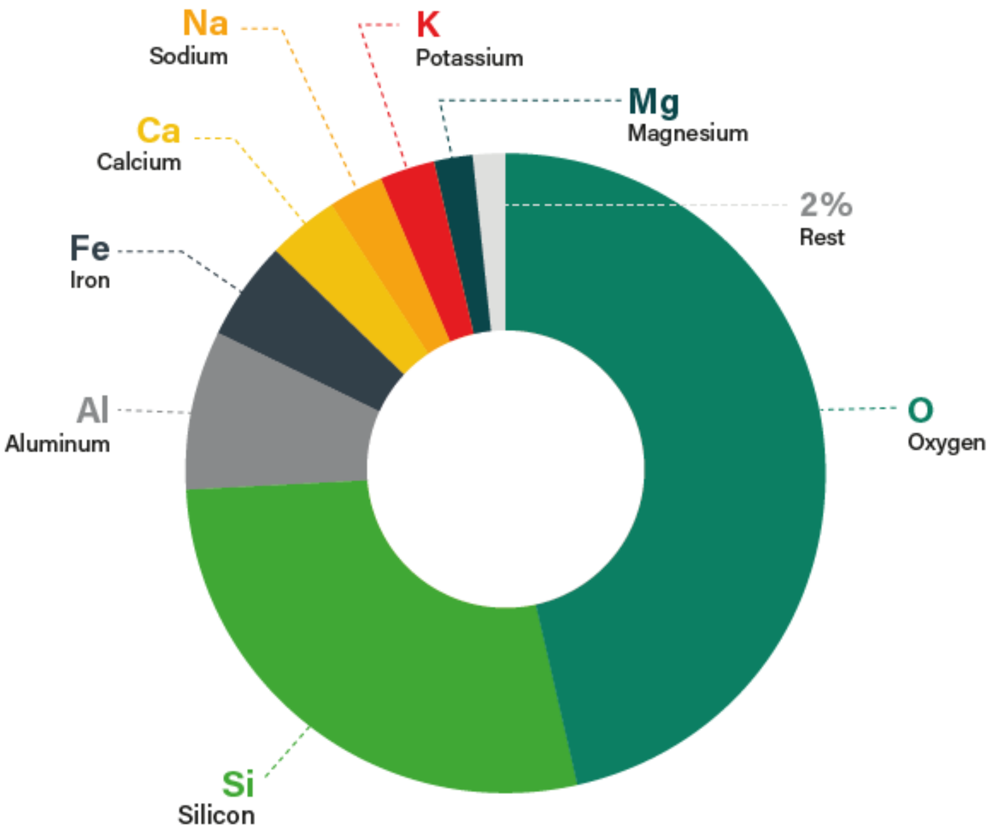
Inverse of desalination

- 3 kWH for desalination of 1 tonne of water
- ~$300 for seawater containing 1 tonne of Calcium
- But the desalination residue is still very wet
- 10X more energy to get a dry residue
- Then have to separate the elements in the residue
- Back to situation of basalt

- Cost range of $1000 - $ 10,000 per tonne of CaO (remember clinker<$50, clinker + CCUS <$150)
- All the desalination plants in the world today could potentially supply the equivalent of 5-10 clinker plants

Magnesium Silicates cements?

What is available on earth?



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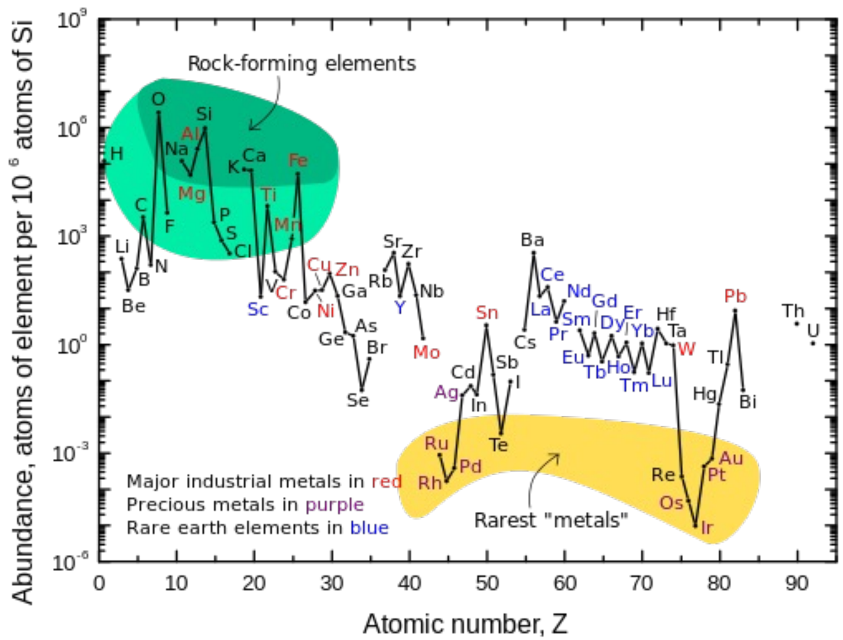

Due to the processes of forming elements in stars other rocky planets will be similar

"Chemical" CO_2 emissions of hydraulic minerals

Clinker compound:	Chemical CO_2 emissions, kg/tonne
Alite (C_3S)	579
Belite (C_2S)	512
Tricalcium Aluminate (C_3A)	489
Tetracalcium Alumino-Ferrite (C_4AF, "Ferrite")	362
Quicklime (CaO)	786
Wollastonite (CS) [a major component in Solidia clinkers]	379
Ye'elimite ($C_4A_3\$$) [made with $CaSO_4$ as sulphur source]	216
Periclase (MgO) [made from magnesium carbonate]	1100
Periclase (MgO) [made from basic magnesium silicate rocks]	0

Belite rich clinkers <10% reduction more than offset by slower kinetics

Good reduction potential

Much worse than calcium silicates

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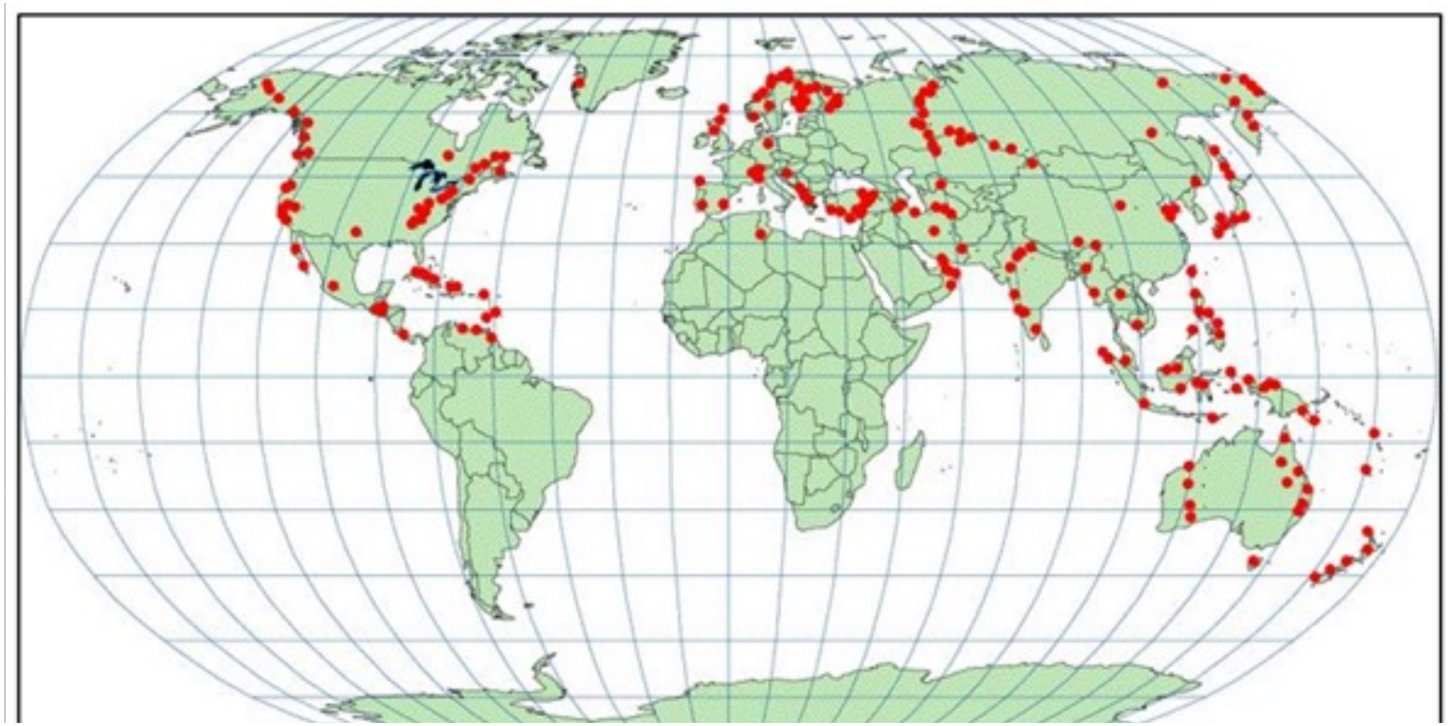
Global availability of magnesium silicates

Global reserves of basic magnesium silicates are large but they are not available everywhere.

Only sporadically close to surface, need to avoid deep mining

Nothing in Africa – region where there will be most growth in coming decades



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Overall reaction

- Mg_2SiO_4 + $2CO_2$ $\Rightarrow$ $2MgCO_3$ + SiO_2

  Via MgO and other intermediates:

  residue

  This is the challenging step

Let us suppose solutions can be found,
which do not require too much energy and can be scaled up

Carbonation hardening

- Two key points:
  - Getting CO_2 into element – limit of size, really only blocks, tiles, etc possible
  - pH low will not protect steel reinforcement

Standardisation

- Completely new chemistry no knowledge of long term performance
- It takes 5- 10 years even to make simple changes in standards

Magnesium Silicates

- (very) long term prospect, Will remain a niche
  - Cost, scalability, small elements
  - Trying to compete with blocks is very challenging as these are very low cost, low carbon and carbonate naturally
- Approx. same volume of residue generated
- Magnesium as metal is a critical material, competing uses
- Accelerated weathering of Mg Silicates also actively investigated

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Alternative hydraulic binders

- **Belite rich Portland clinker:** **no significant CO2 saving**
- **Hydrothermal synthesis of C2S:** **high purity raw materials, low CO2 saving**
- **Ye'elimite based binders:** **lack of raw materials: variability**
- **Alkali Activated binders:** **lack of precursors notably slag**
- **Magnesium based binders:** **distribution of raw materials; practical conversion processes**

No silver bullet

Despite the media interest they attract, most niche technologies – such as alkali activated materials, cement from algae, etc are:

- impractical,
- costly,
- unscalable,
- will take too long to mature

so have little to no possibility of delivering any significant impact.

Part 2: Research needs

Need to act through the value chain

Report for European Climate Foundation 2017

Reduce CO_2 from clinker production → Reduce clinker in cement — Reduce cement in concrete — Reduce concrete in building — More efficient (re)use of buildings

Reduce CO_2 from clinker production
- Efficient plants
- Waste fuels
- Alternate raw materials

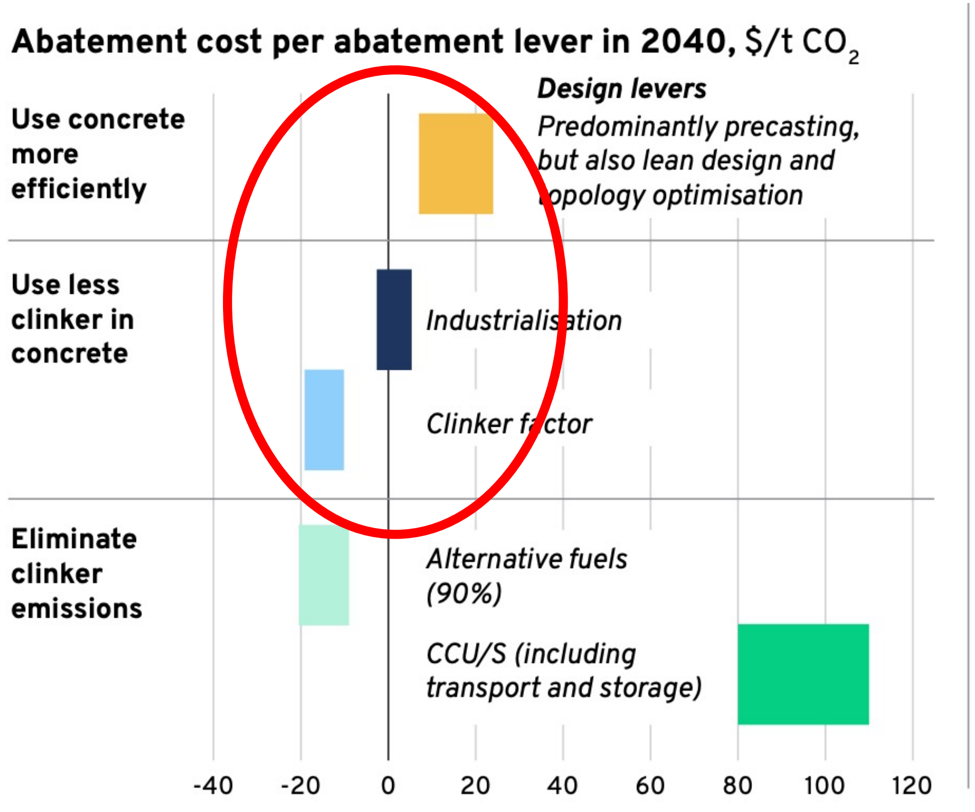
Reduce clinker in cement
- SCMs

Reduce cement in concrete
- Aggregate grading
- Good admixtures
- Use filler

More efficient (re)use of buildings

RECYCLE!

We have a lot of the solution



CCS is expensive, but a lot less than many of the so called "green" solutions out there

Source MPP report

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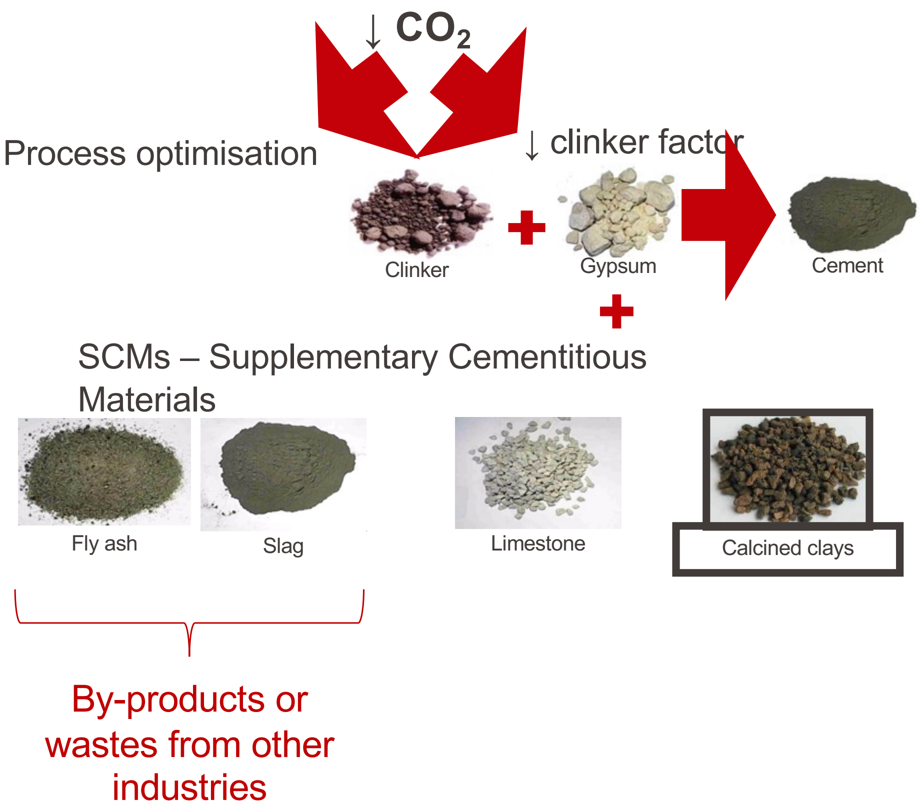
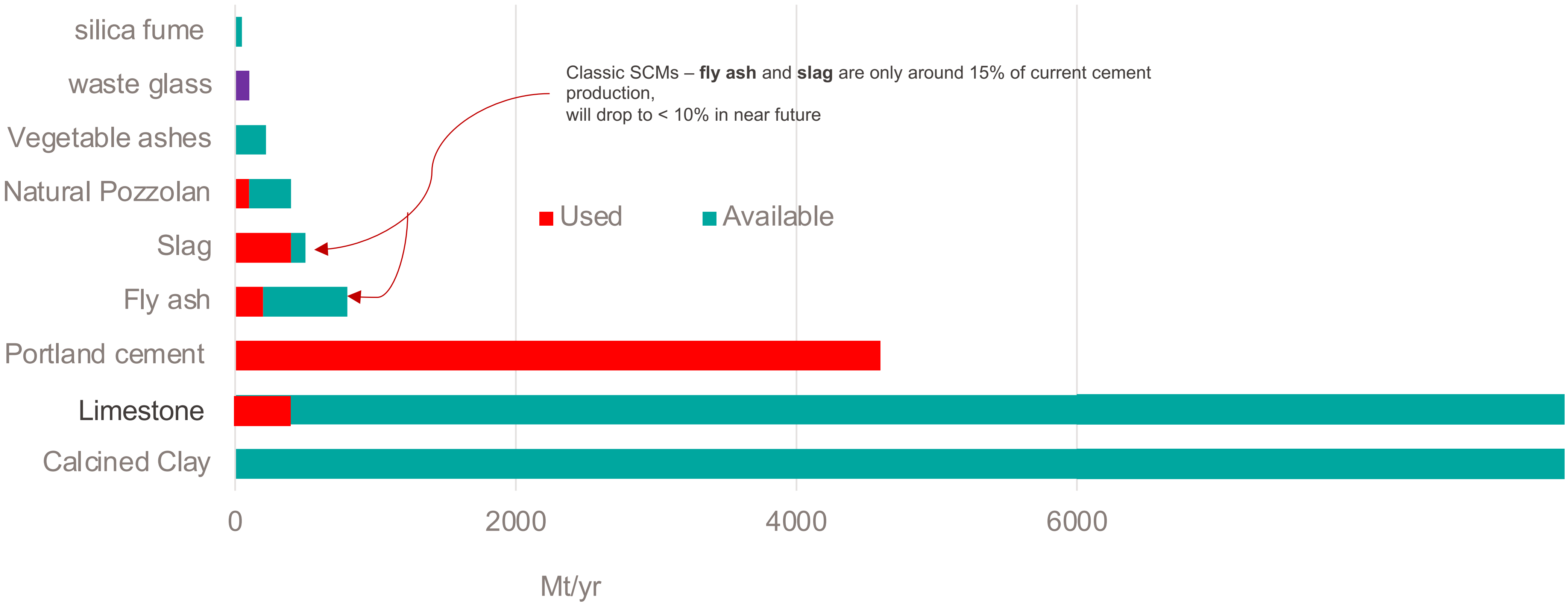
Most promising approach – reducing the clinker factor



Availability of SCMs



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There is no magic solution

- Blended with SCMs will be best solution for sustainable cements for the foreseeable future.
- **Only material** really potentially available in viable quantities **is clay**.
- **Synergetic reaction** of calcined clay and limestone allows high levels of substitution
- EPFL led the LC^3 Project supported by **Swiss Agency for Development and Cooperation (SDC)**, 2013-2022.
- **Climateworks Foundation** supporting the LC^3 Project since 2022.

LC^3 PROJECT

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

climateworks FOUNDATION

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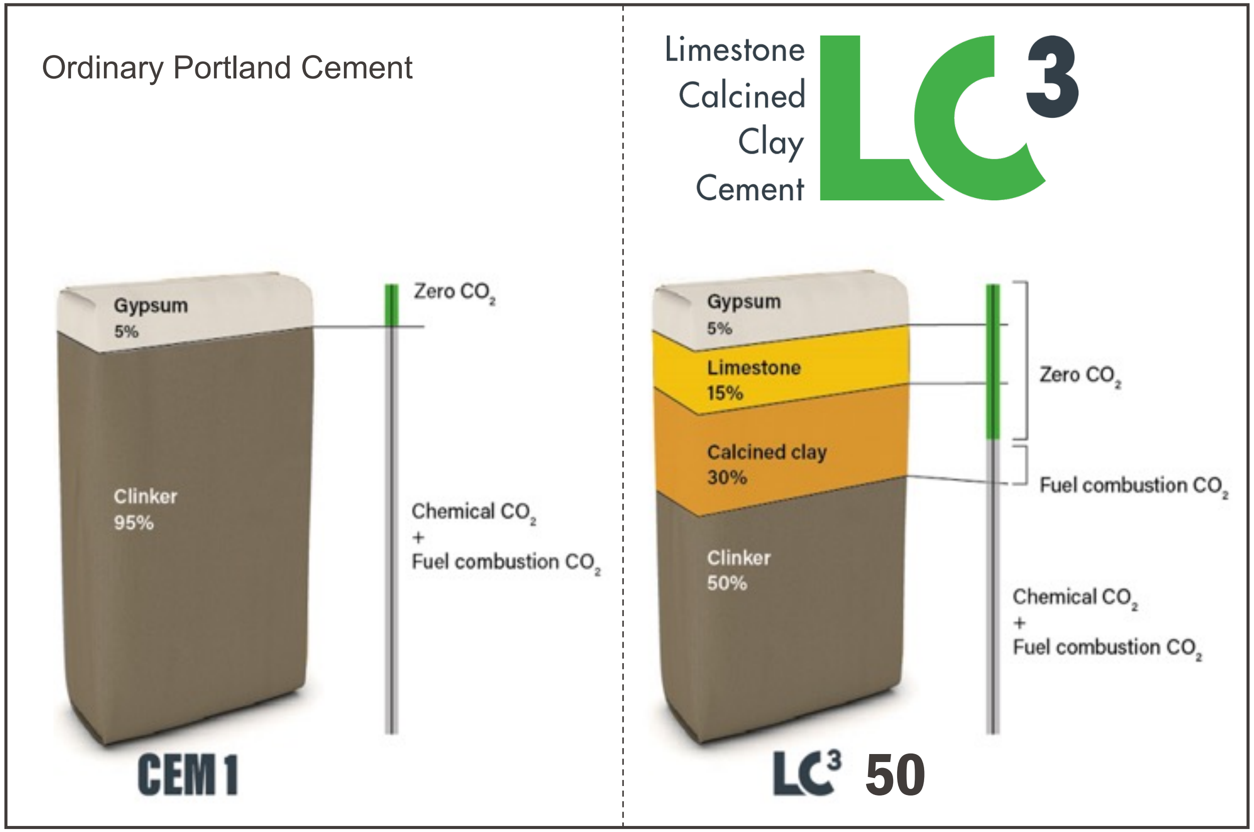
LC^3 – Limestone Calcined Clay Cement



- LC^3 is a fanily of **low-carbon** blended cements
- **Reduces CO_2 emissions in cement by 40%**

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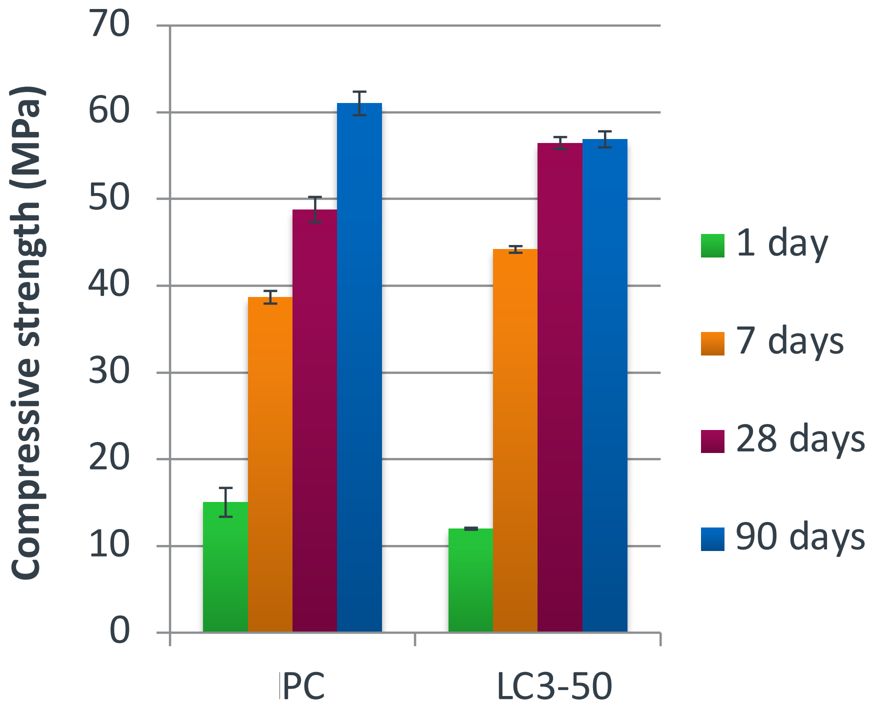
LC^3 has comparable strength to OPC



LC^3-50 = 50% clinker.

- 50% less clinker
- 40% less CO_2
- Similar strength
- Better chloride resistance
- Resistant to alkali silica reaction

HIGH PERFORMANCE

What kinds of clay are suitable?

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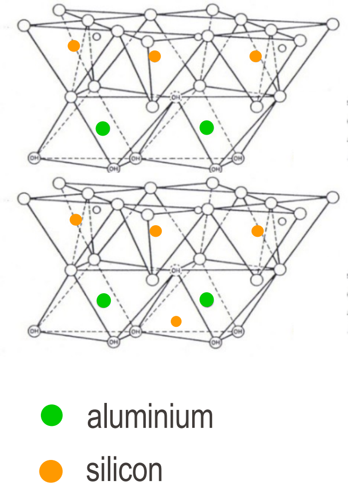
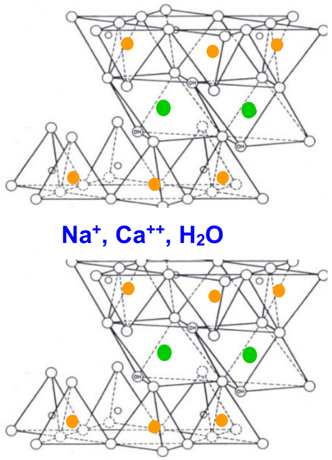
Three basic clay structures

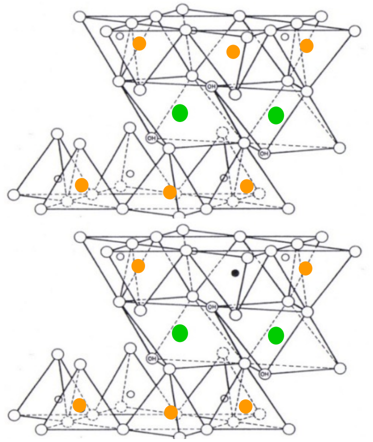
Kaolinite (1:1)



Montmorillonite (2:1)
(Smectites)



Illite (Micas)
(2:1)



“Metakaolin”, sold as high purity product for paper, ceramic, refractory industries
Requirements for purity, colour, etc, mean expensive 3-4x price cement

Clays containing metakaolin available as wastes
– over or under burden NOT agricultural soil
Much much less expensive often available close to cement plants

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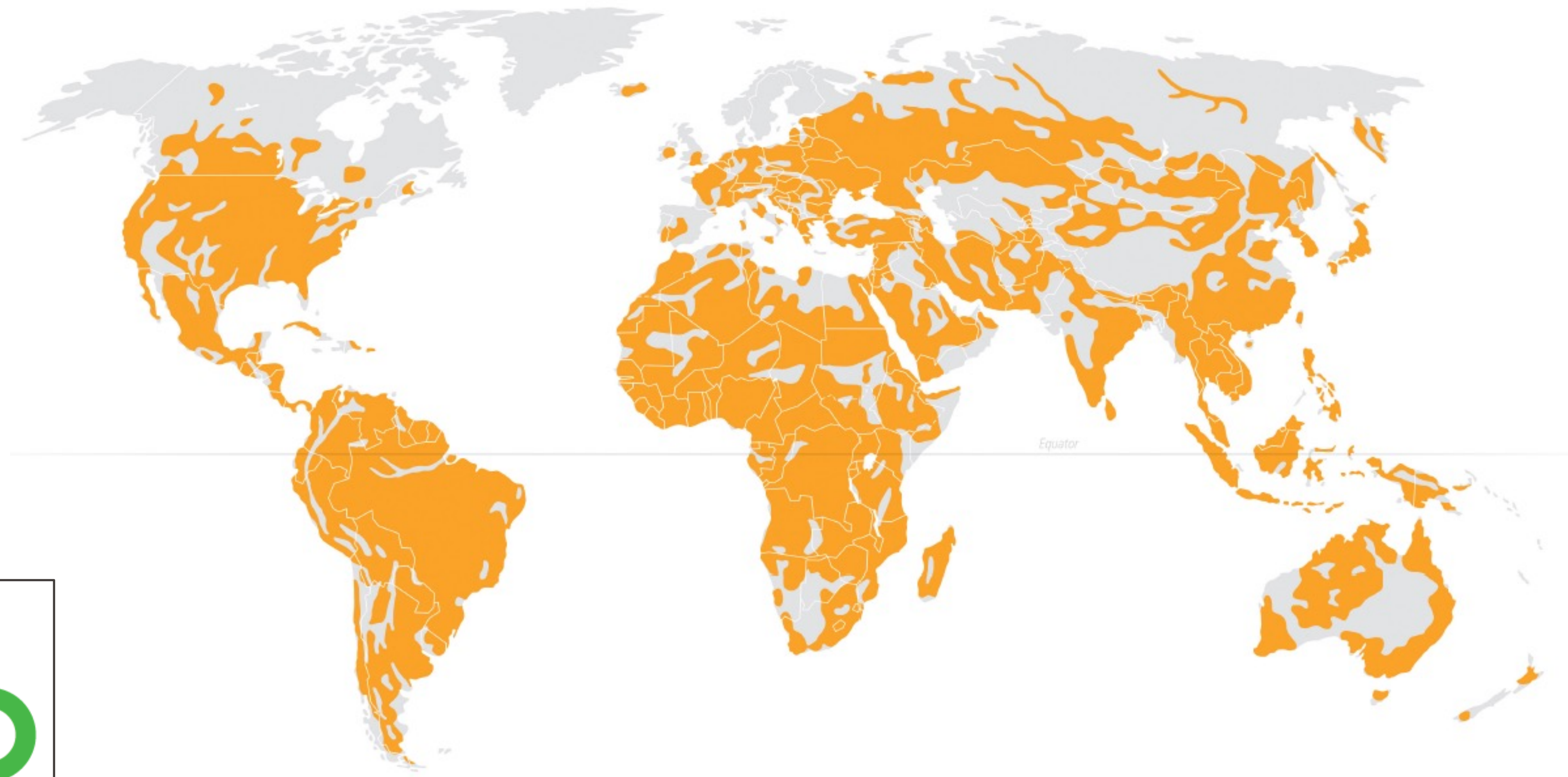
World distribution of kaolinitic clays



Source: Ito and Wagai, Scientific data 2017

kaolinitic clays

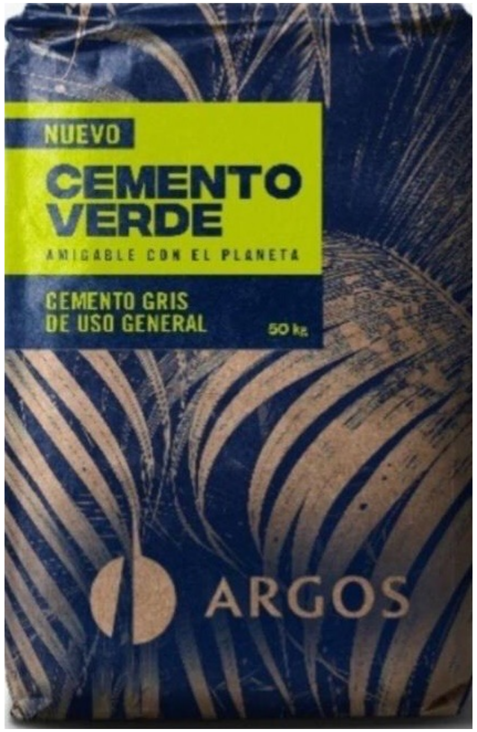
Dredge sediments:
experience in Belgium with
actual production of SCM

Clay impurities in production of
aggregates (sand and gravel):
France, Portugal, USA, Spain

Coal gangue:
Spain, Colombia,
Brazil

Slide Fernando Martirena

Industrial projects: Cemento Verde ARGOS, Colombia



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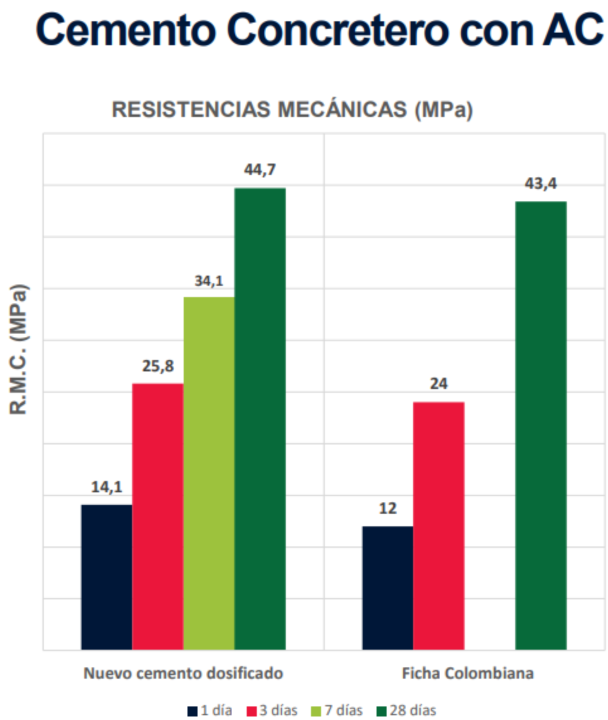
2023: Large scale construction (Colombia)



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Presentation FICEM, 2019

Argos Colombia 2022

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Industrial projects: CIMPOR, Ivory Coast

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LC^3-45 being delivered from world's largest calcined clay plant in Ghana

Construction with LC3 materials

2014 → 2024


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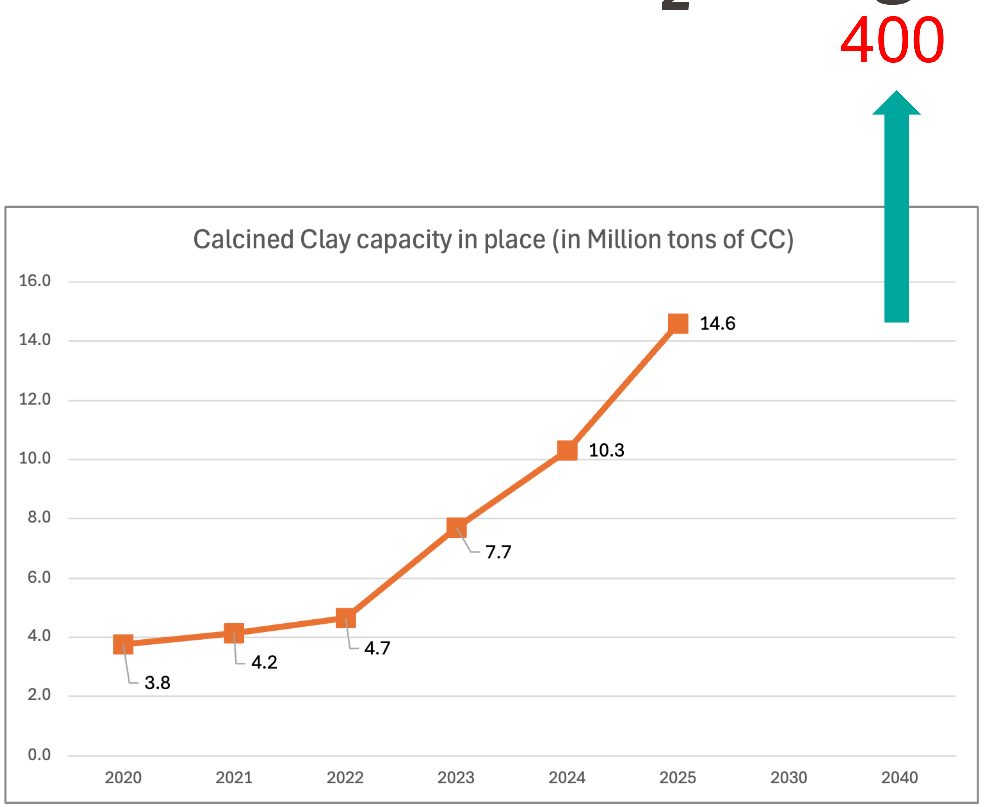
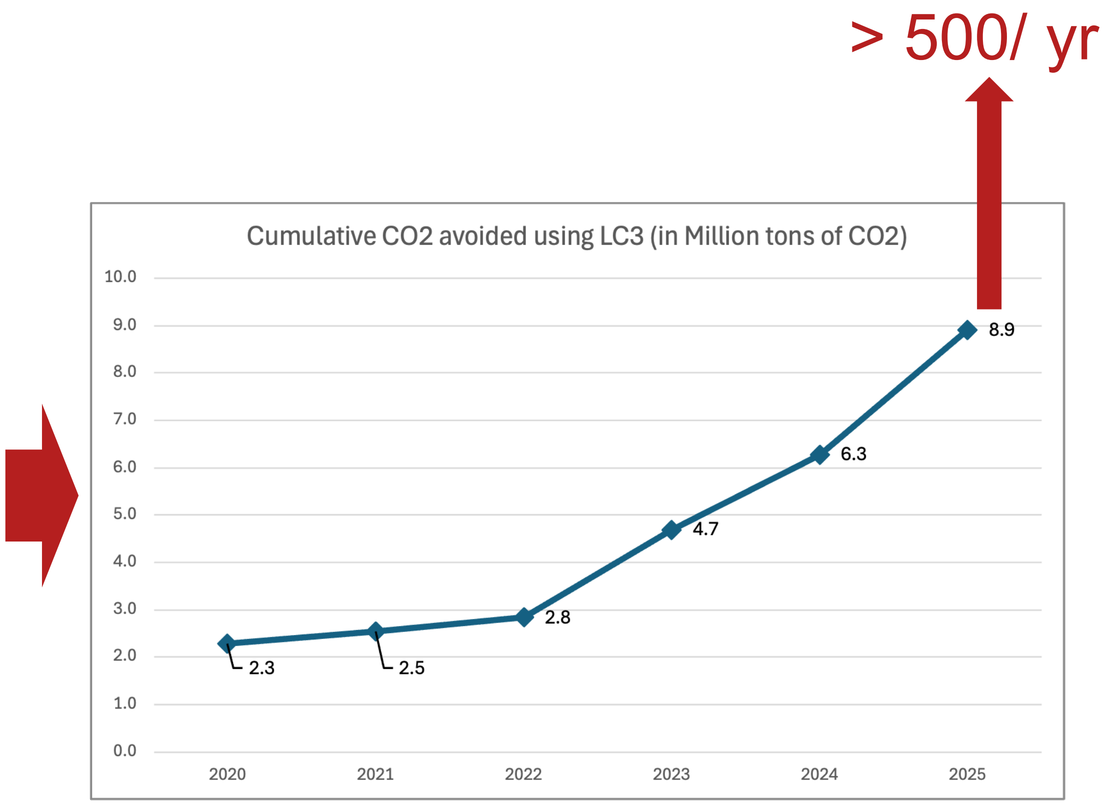
OCEAN
NORTH AMERICA
EUROPE
ASIA
PACIFIC OCEAN
AFRICA
SOUTH AMERICA
AUSTRALIA
ATLANTIC OCEAN
19 plants in operation
24 plants in progress:
- North America: 1
- South America: 4
- Europe: 10
- Africa: 5
- Asia: 4

Capacity development and cumulative CO_2 savings





By 2040, the goal of achieving one-third of global cement production with LC3 would require reaching a calcined clay production capacity of 400 million tons, which means an increase of 25 million tons annually.

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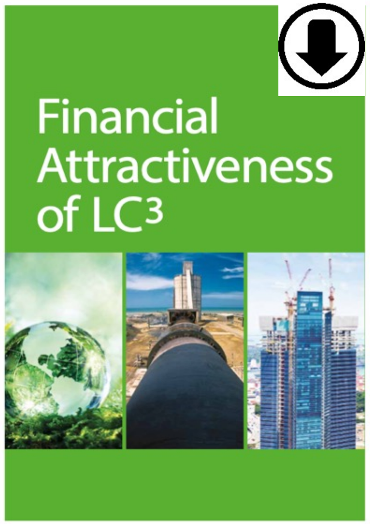
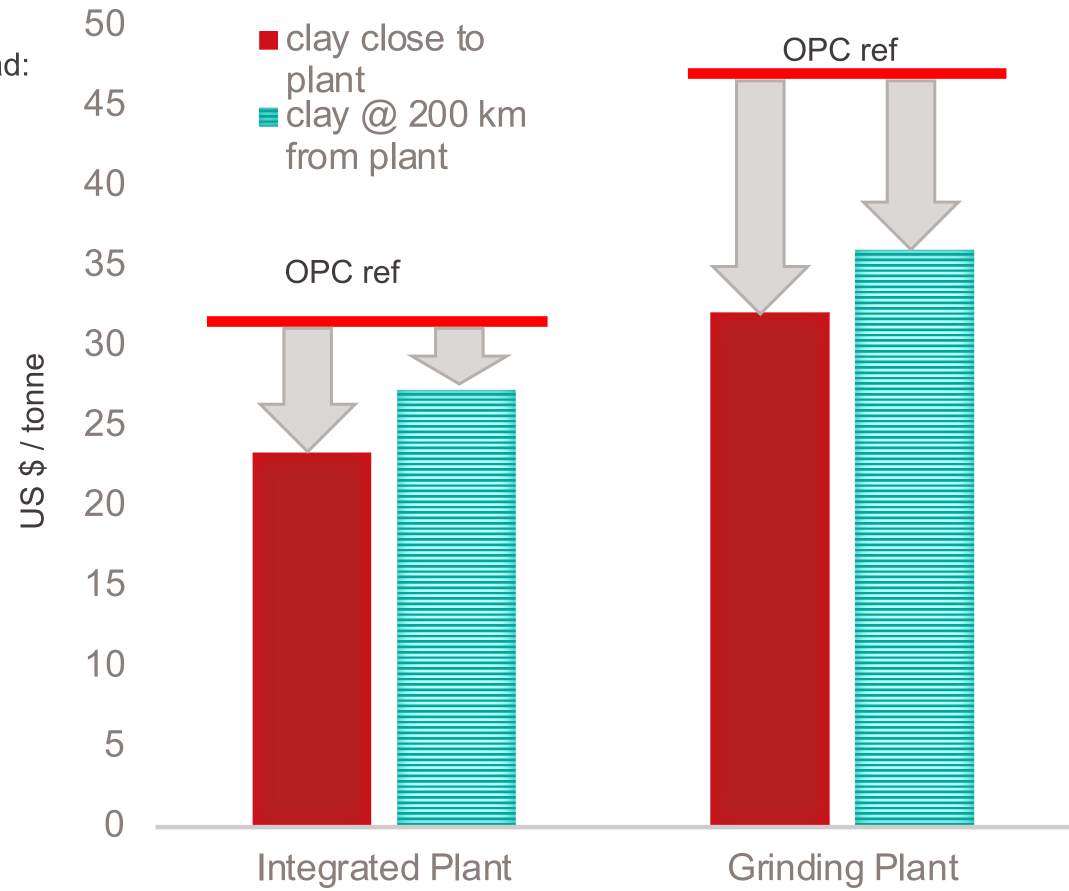
Financial Feasibility



Report available to download:
www.lc3.ch

Study by LC3 Project partner CEMENTIS



Karen Scrivener

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What is behind the relative success of LC^3?

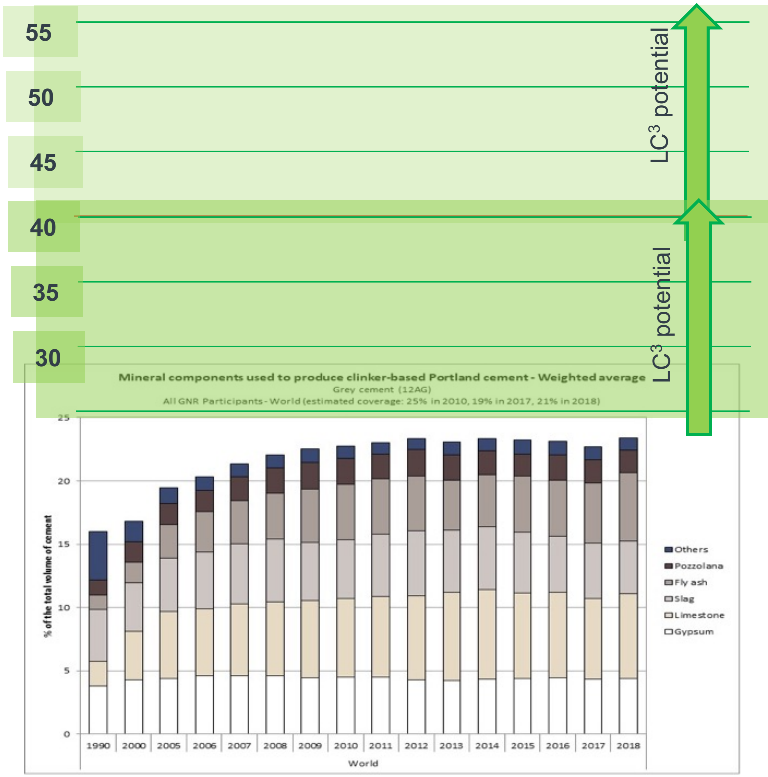
- Another blended cement – same hydrates – decades of experience
- Materials widely available
- Existing technology
- In standards
- **Lower cost!**
- ……

And yet!

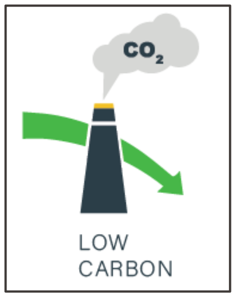
- Its an uphill battle
- Inertia
- Overcapacity

World Potential
of clinker substitution?

Calcined Clay only SCM which can expand substitution



- ✓ 800 million tonnes CO_2/yr
- ✓ 400 million tonnes CO_2/yr



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Research Needs

RILEM Technical Letters (2022) 7: 220-252
https://doi.org/10.21809/rilemtechlett.2022.165

RILEM technical letters

Research needs for cementitious building materials with focus on Europe

Karen Scrivener[1], Mohsen Ben Haha[2], Patrick Juilland[3], Christophe Levy[4]

[1] Laboratory of Construction Materials, EPFL, Lausanne, Switzerland
[2] HeidelbergCement Technology Centre, Leimen, Germany
[3] Sika Technology, Zurich, Switzerland
[4] Holcim innovation Centre, Saint Quentin Fallavier, France

Watermelon: and 30 key questions

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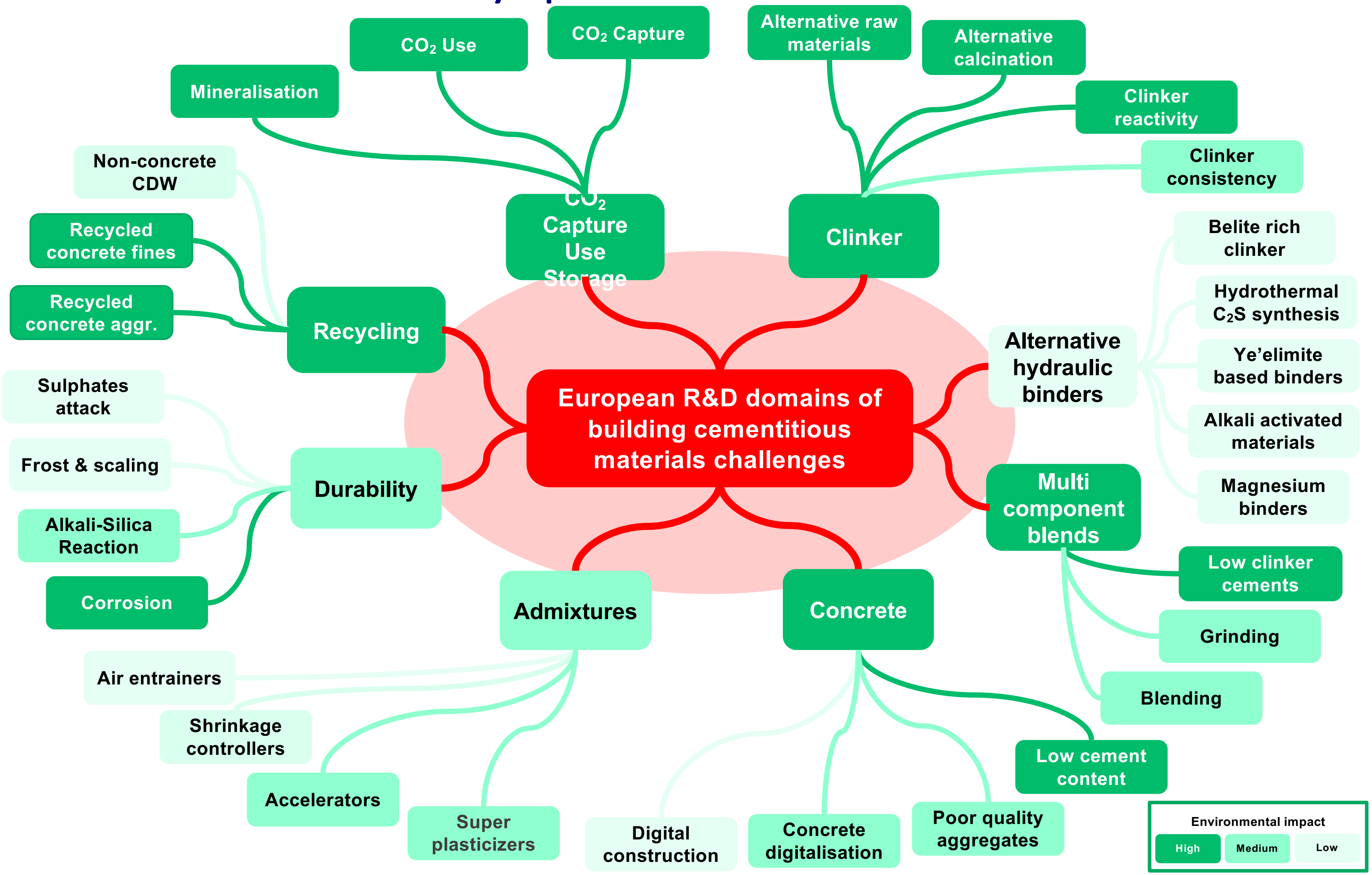
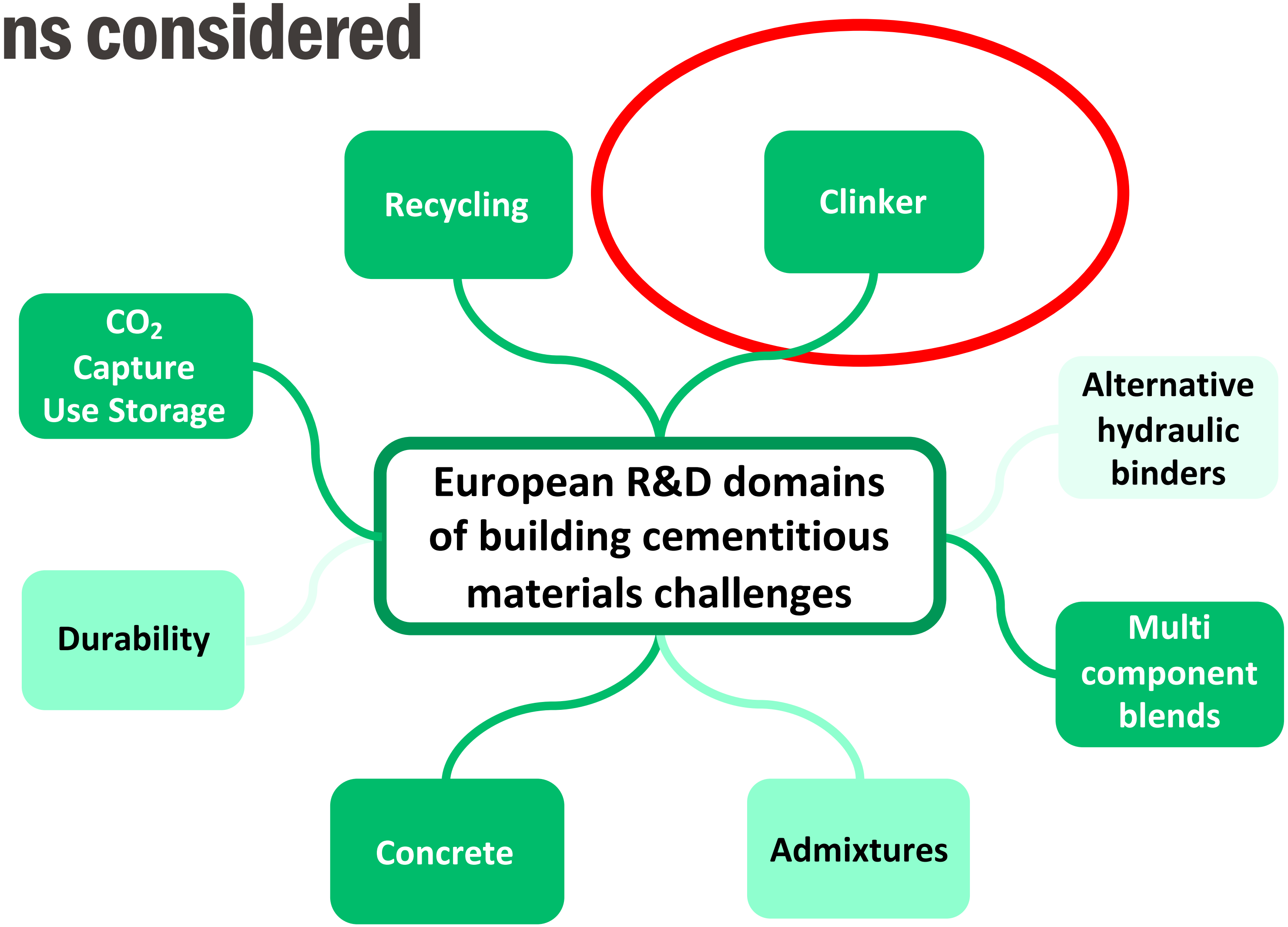


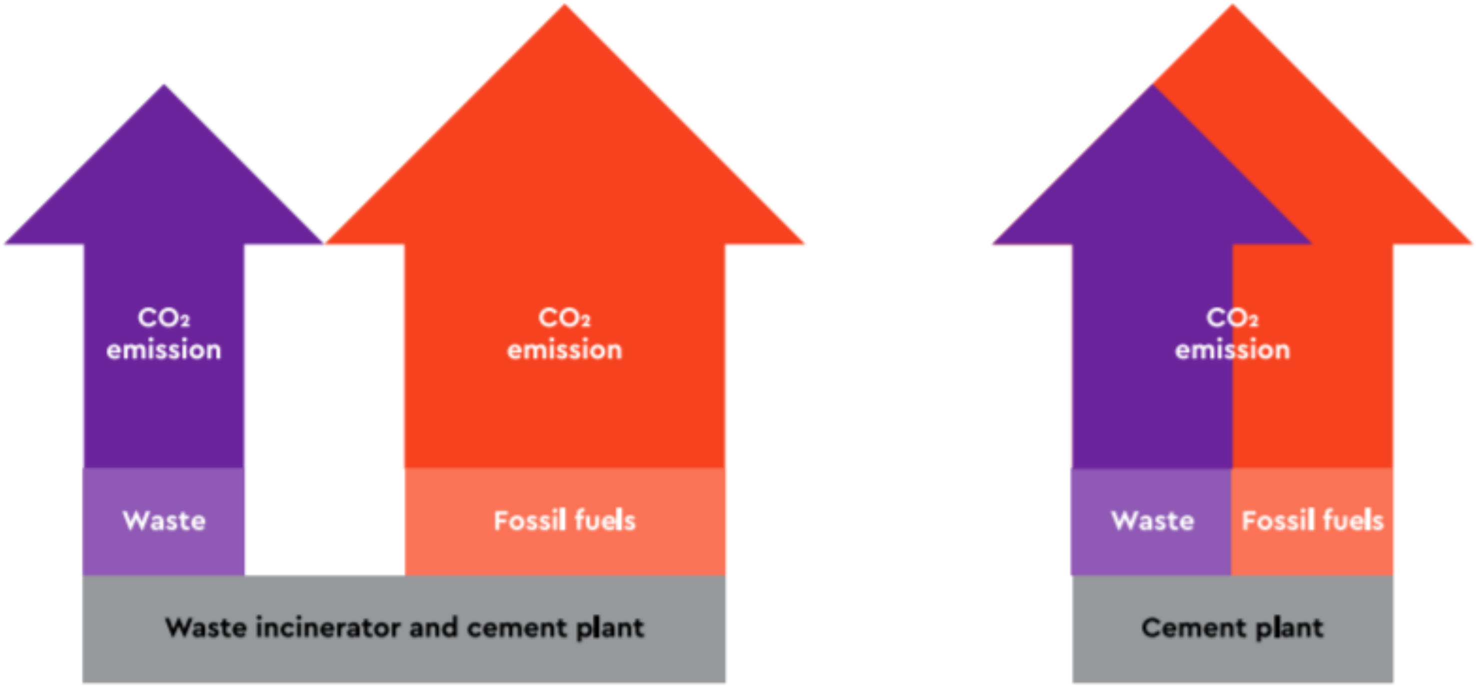
Domains considered



Clinker

- **Increasing use of alternative fuels and raw materials (AFR)**

Waste fuels still emit CO2, but overall reduction



Clinker

- Increasing use of alternative fuels and raw materials (AFR)
- Predictable and consistent performance

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Clinker

- Increasing use of alternative fuels and raw materials (AFR)
- Predictable and consistent performance
- Complexity of process parameters:
  - Material
  - Kiln design
  - Kiln dimensions
  - Speed of rotation
  - Fuel mix
  - Dwell time
  - Temperature profiles
  - Etc
- Cannot be reproduced in lab conditions

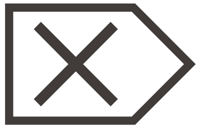
And in the future
Alternative calcination technologies!

% Alite

%Belite

% Aluminate

%Ferrite



Performance

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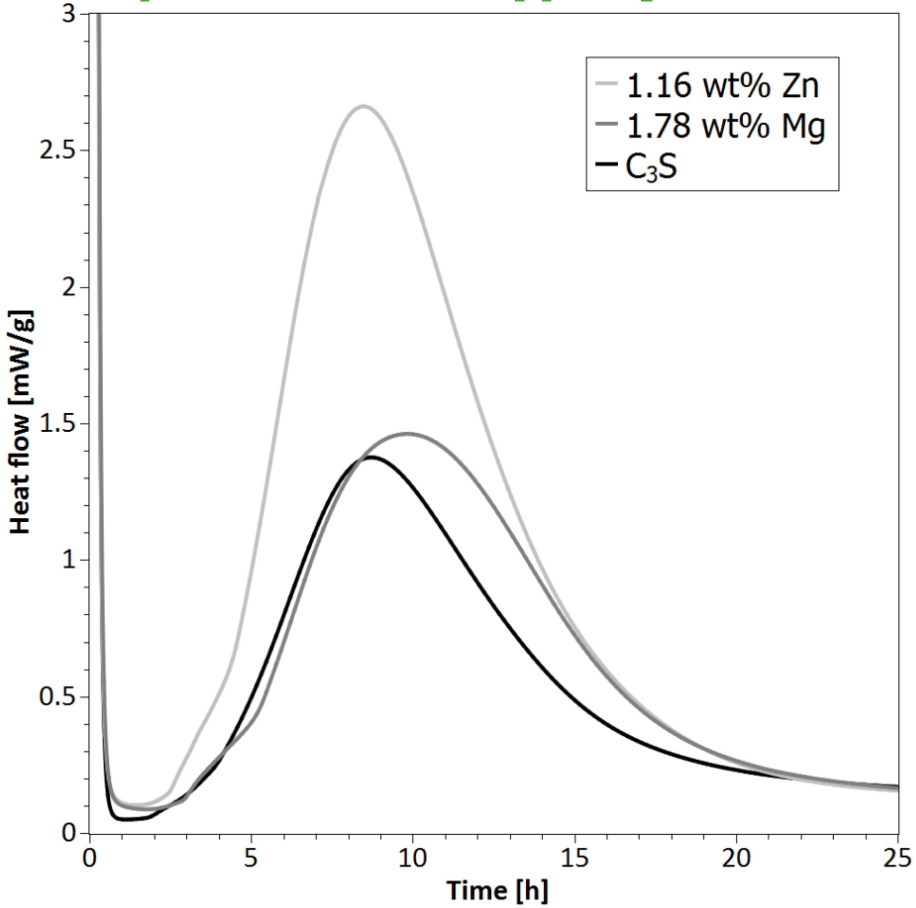
Many fallacies: E.g impact of alite polymorph



Bazzoni, et al:
Journal of the America Ceramic 2014

With Zn same polymorph

With Mg different polymorph

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Prospects for Machine learning

- **Based on interpolation**
  – does not work outside of data range for learning
- **Needs (lots of) training data covering actual production process**
- **It is a mathematical function.**
  Classification of outliers depends on variables selected
- **It does not *know* the cement and production process.**
  User needs to judge significance of output

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Topics	N°	Key-questions to be solved thanks to new research
Alternative fuel and raw materials	1	Determine criteria and their limits to enlarge the scope of by-products used as ARM and ARF (minor elements impact, thresholds for hazardous components)
Alternative calcination	2	Understand impacts and reduce the cost of calcination with electrification
	3	Determine the most promising and cost-effective processes for CO2 purification (kiln oxy-fuel combustion, calciner CO_2 separation)
Clinker reactivity	4	Better understand the link between process parameters and clinker performance such as rheology, interaction with admixtures and reactivity to **maximise substitution**
	5	Model the impact of clinkering and cooling conditions on clinker reactivity
Clinker consistency	6	Develop laboratory methods to simulate real industrial kiln conditions
	7	Develop tools to improve clinker consistency, for example machine learning.

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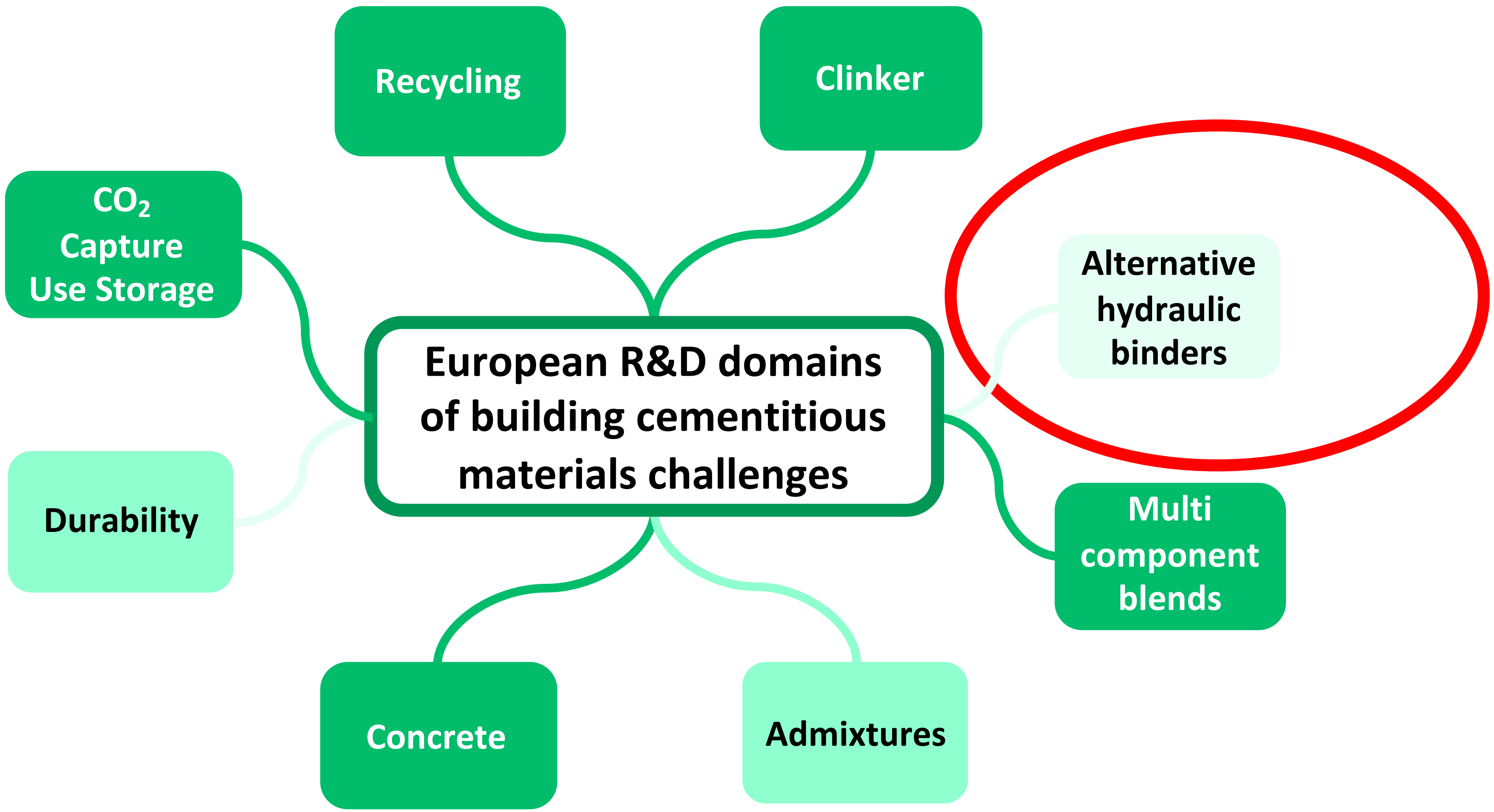
Domains considered

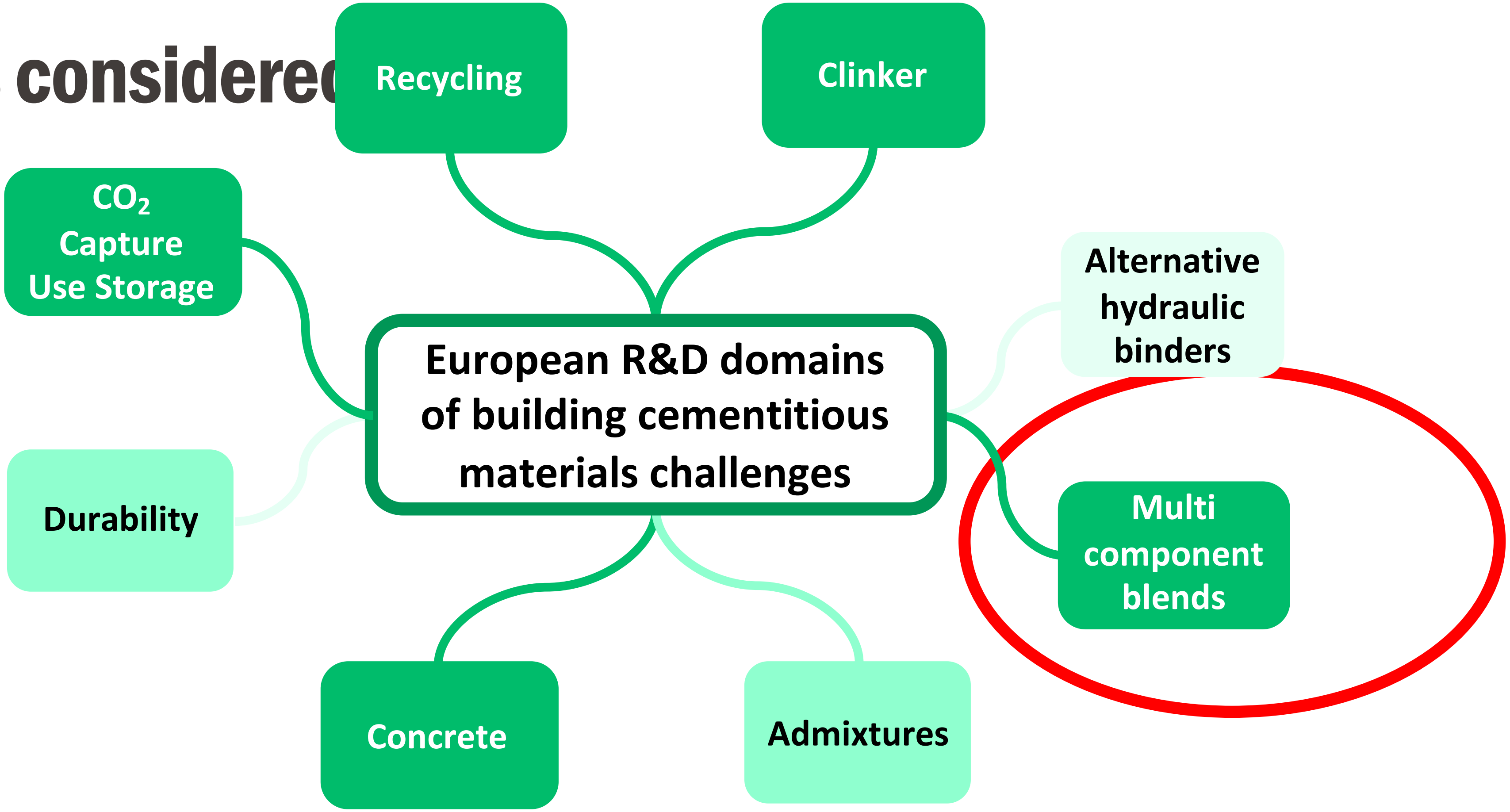


Alternative binders

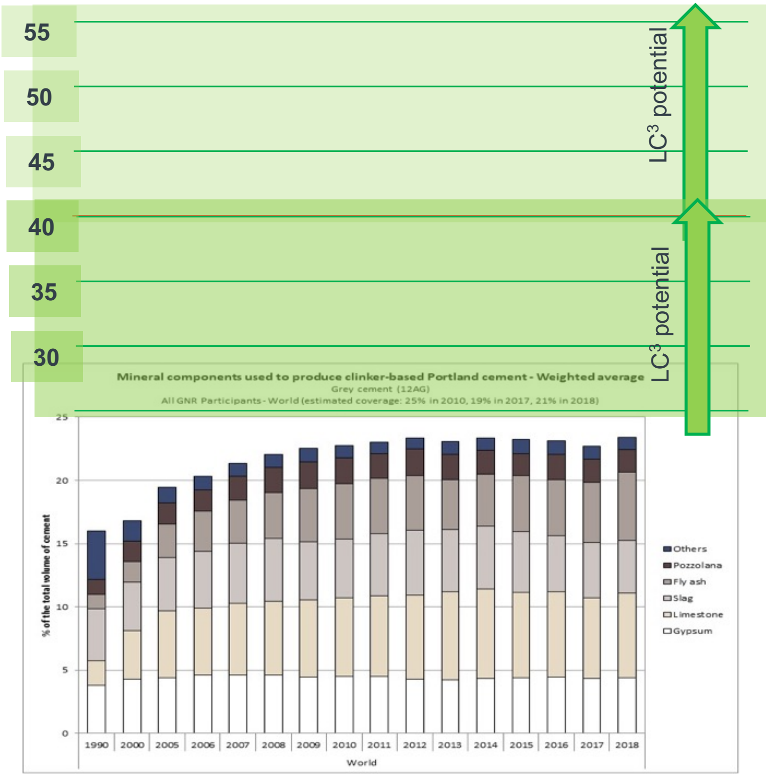
- **Overall, we do not see strong potential for CO_2 reduction coming in the short term from alternatives to Portland cement-based materials**

Topics	N°	Key-questions to be solved thanks to new research
Alkali-activated materials	8	Only for precursors other than slag or fly ash, understand and mitigate the issues of AAM slump loss, short setting & shrinkage

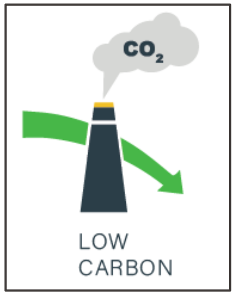
Domains considered



Calcined Clay only SCM which can expand substitution



- ✓ 800 million tonnes CO_2/yr
- ✓ 400 million tonnes CO_2/yr



Needs to increase substitution of clinker

- Quantify SC reactivity

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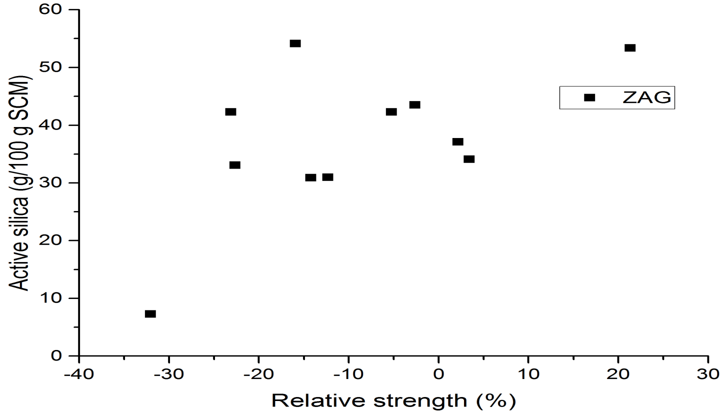
SCM reactivity

- Many materials with very low reactivity can meet current standards for "pozzolans"
- $\Sigma SiO_2 + Al_2O_3 + Fe_2O_3$ meaningless if these are crystalline materials
- Reactive silica shows no correlation with strength: TC 267 TRM
- Can be passed by inactive materials, e.g basalt



- Strength activity test ASTM C311 can be passed by fillers
  - 85% of strength with 20% substitution

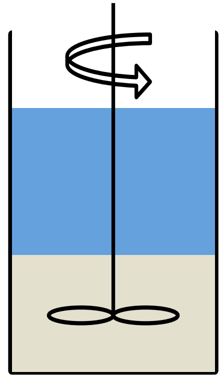
SCM reactivity: R^3 test: ASTM C1897

- Rapid, Relevant and Reliable (R^3)

- Focus on SCM reaction only:
  - Adjustment of sulfate and alkali content to reproduce the reaction environment of hydrating blended cements

H_2O
+Alkali
+Sulfate

Portlandite
SCM

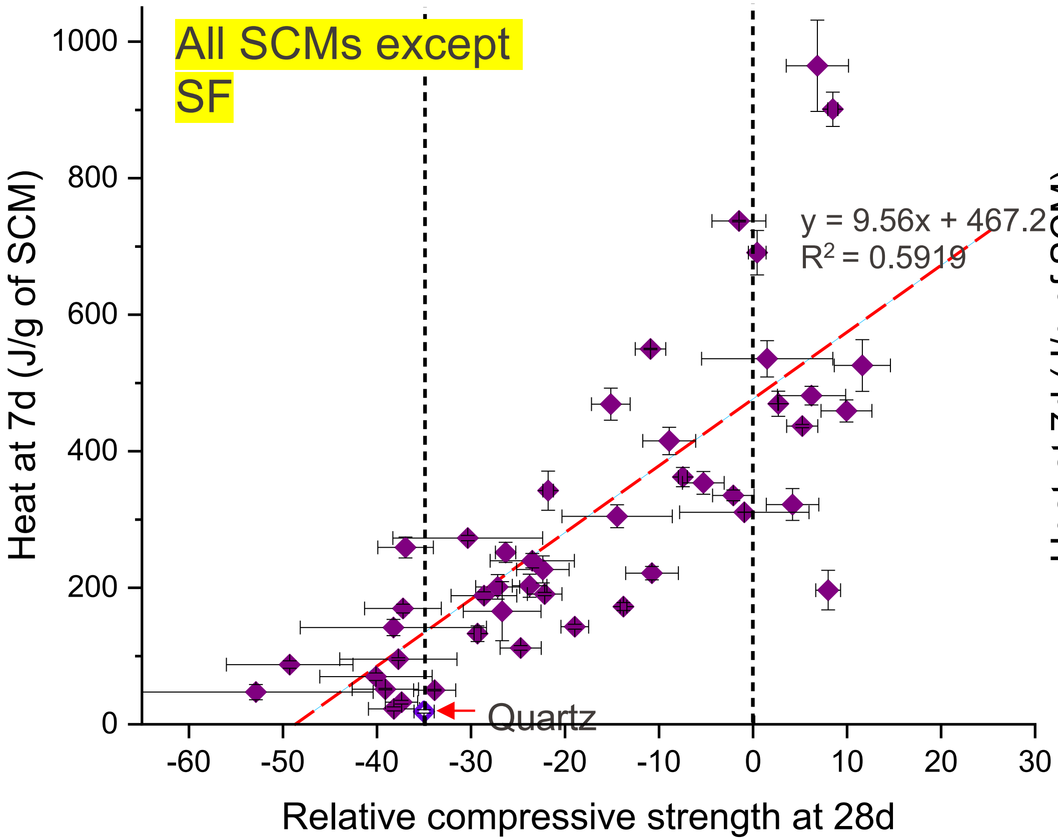


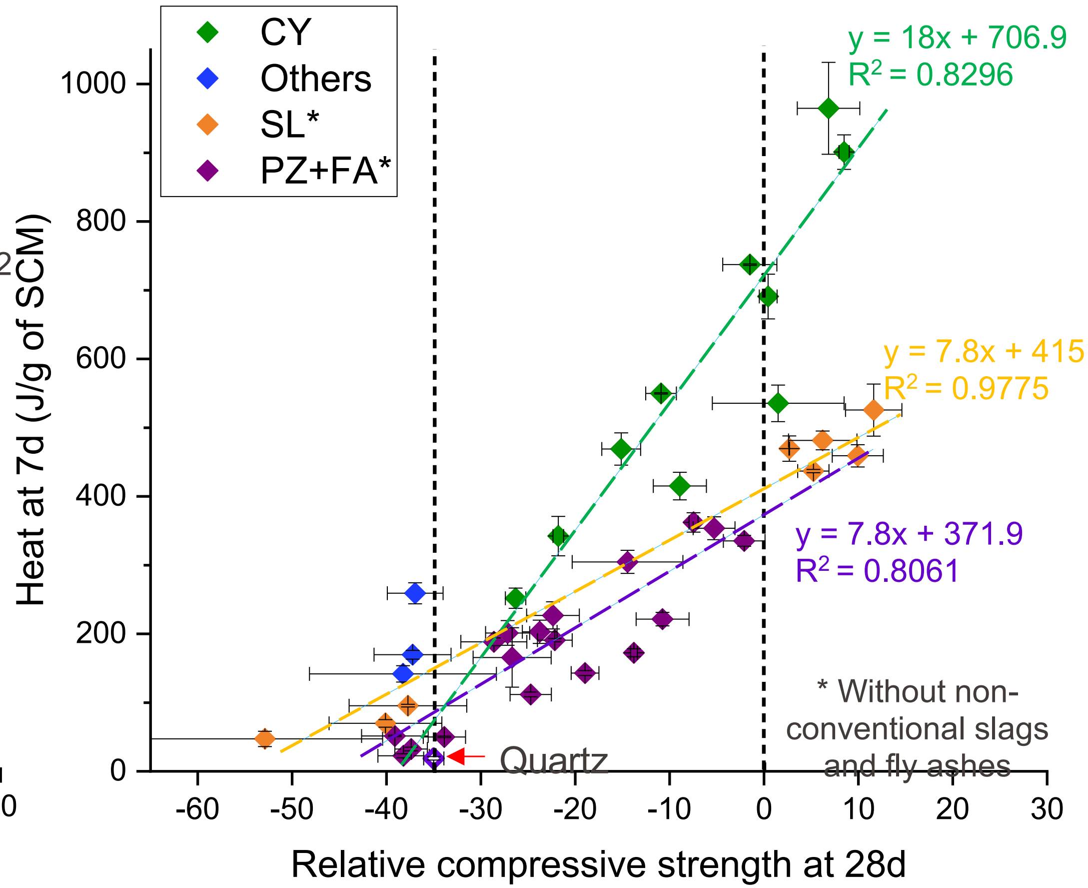
Two ways of measuring the reactivity

Isothermal calorimetry at 40°C Heat release 7d

Oven thermal treatment at 350°C Bound water 7d

TC 267 TRM Phase R3 test on 53 materials





Needs to increase substitution of clinker

- **Quantify SC reactivity**
- **Increase early strength**

Comparison of calcined kaolinitic clay, slag and fly ash

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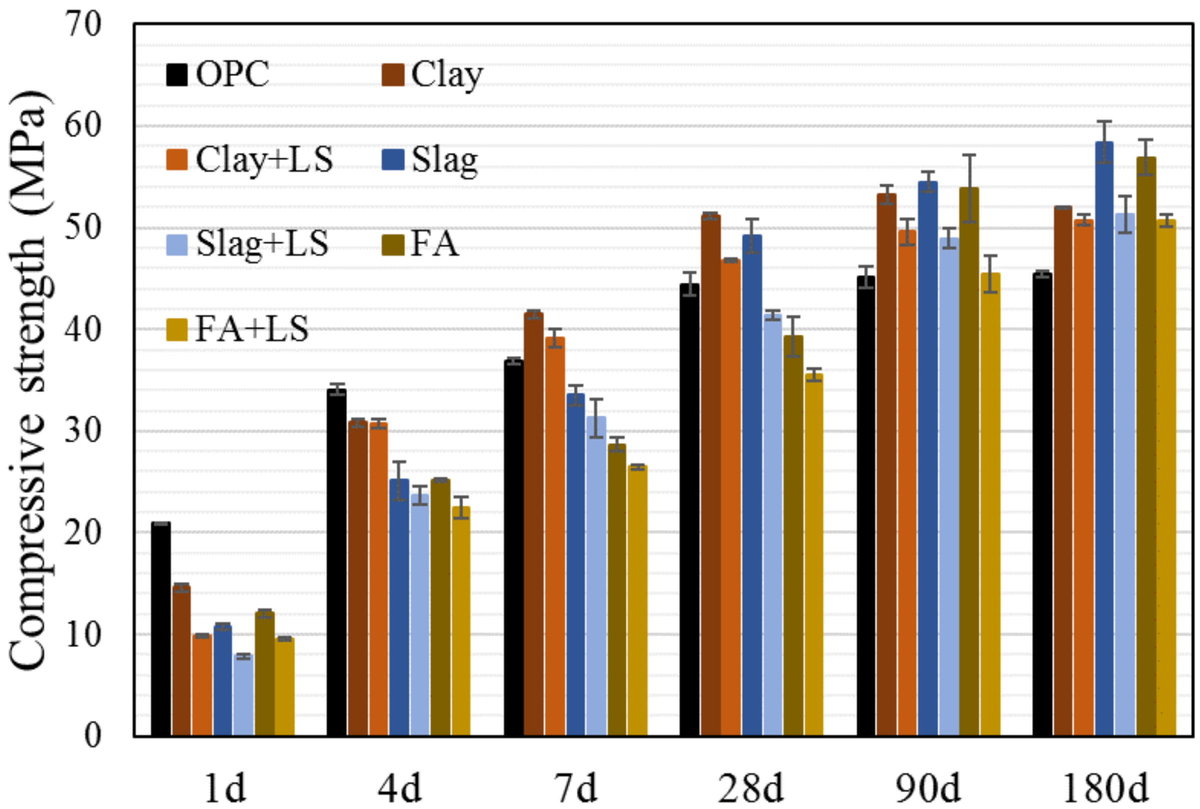
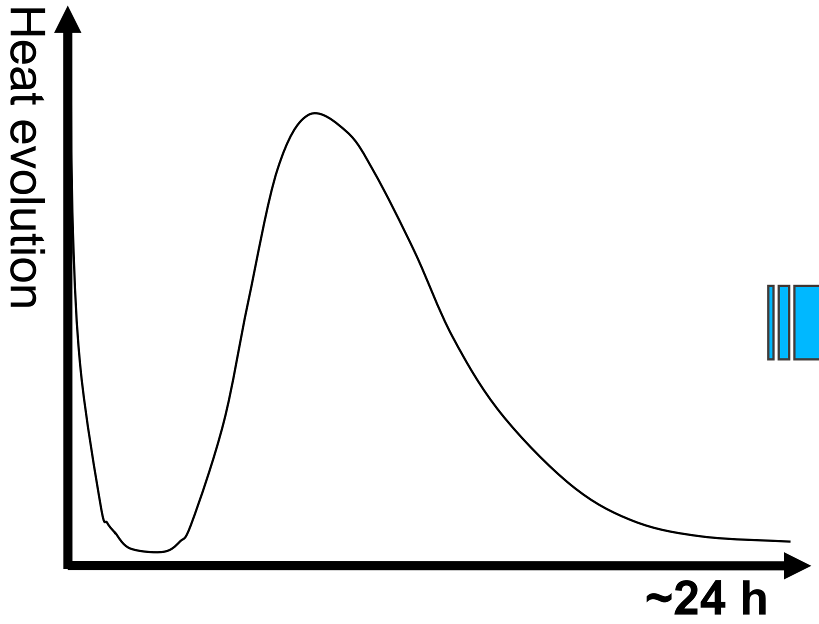


Binary systems 70% clinker, 30% SCM

Ternary systems, with limestone 50% clinker, 30% SCM, 15% limestone

Hydration process: limitation



28 days

~ 50% reaction
~ 25% strength

~ 80% (+30) reaction
~ 80% (+65) strength

Increase early strength

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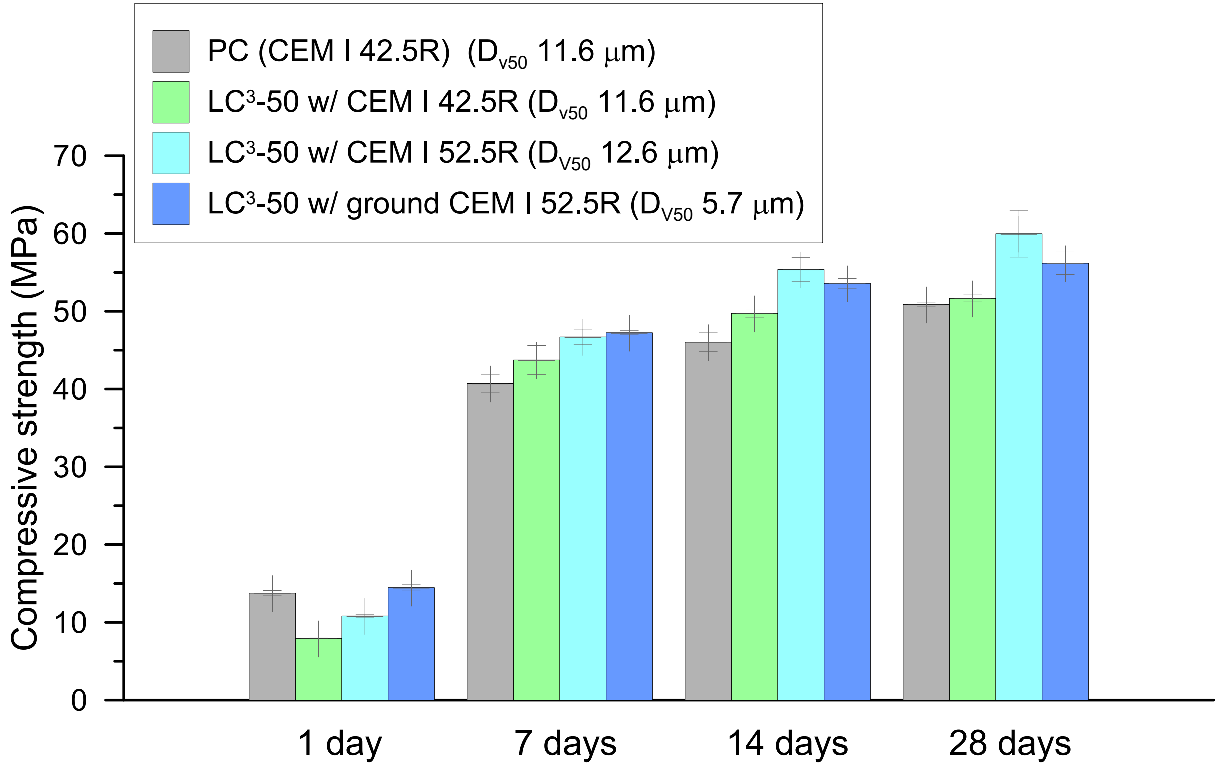
➢ **Optimise grinding**



Increase early strength

- Seeding: limited
- Grinding aids and alkali sulfate
- admixtures

- At a more basic level
  - Better understand factors controlling C-S-H growth

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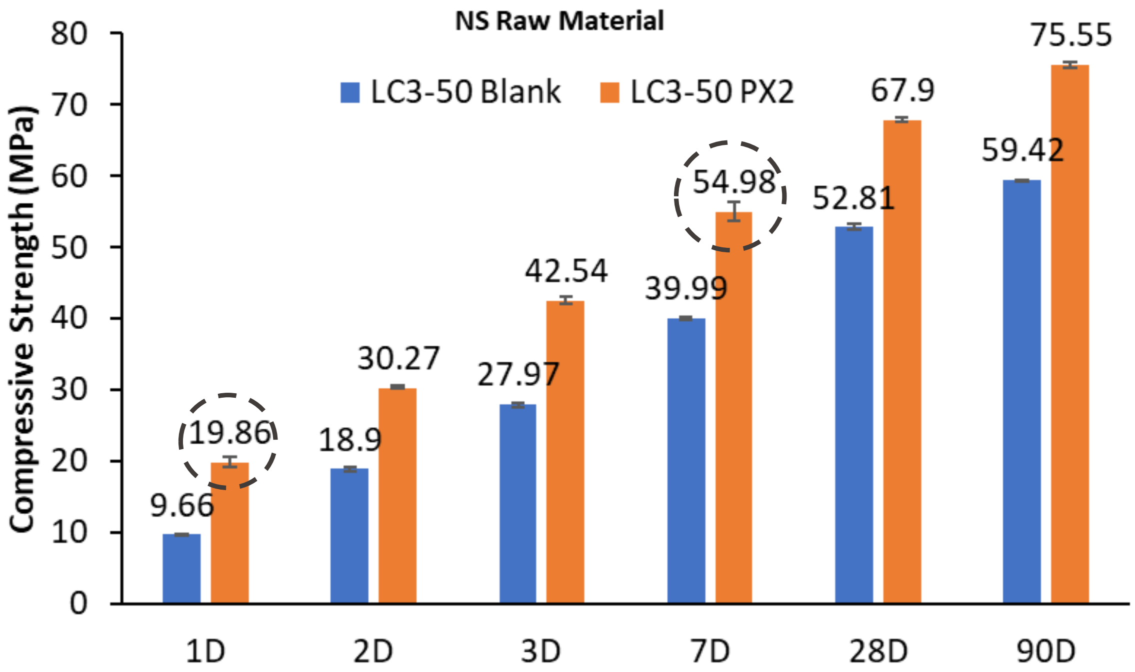
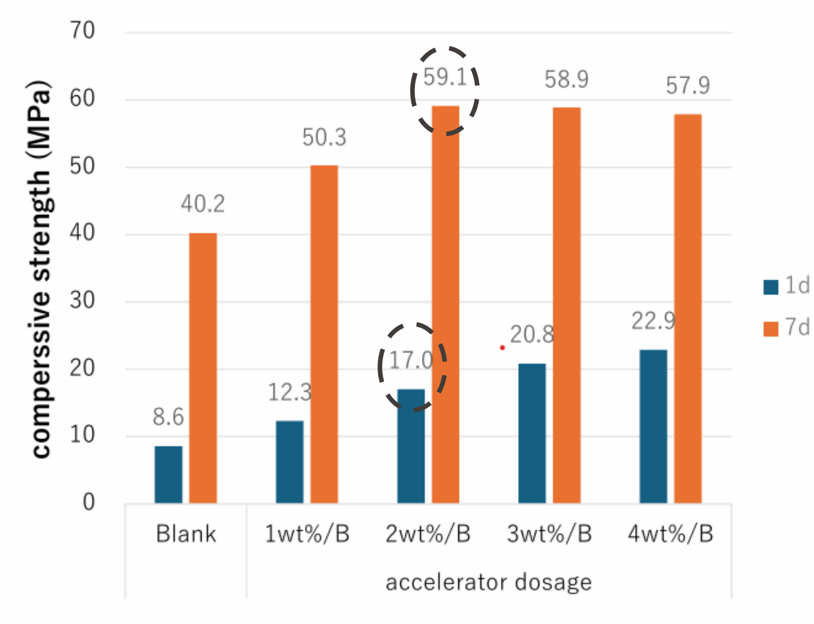
Compressive strength LC^3-50





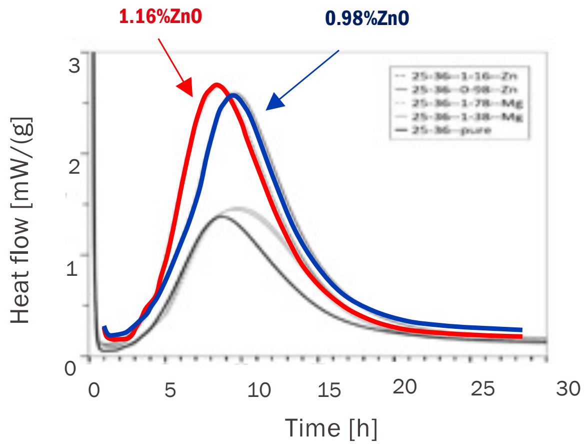
Results from NS

Addition of PX2 enhances the strength

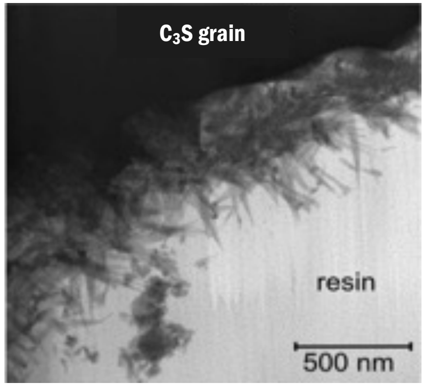
Mehnaz Dhar

Increased reactivity: Zn doping

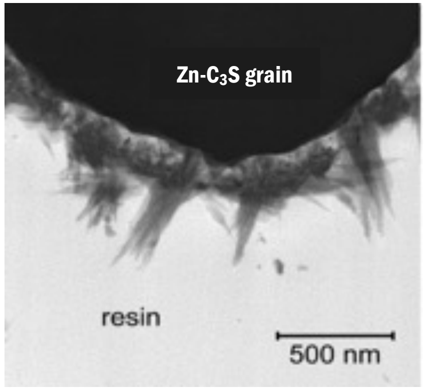
Isothermal Calorimetry



- Minor amounts of Zn in C_3S increases by double the heat released
- Longer needles with Zn doping - Incorporation of Zn in C-S-H



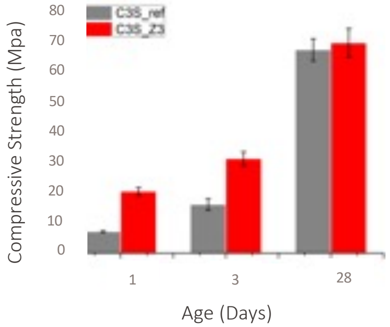
C_3S



Alite 1.16% zinc

Mechanical Properties

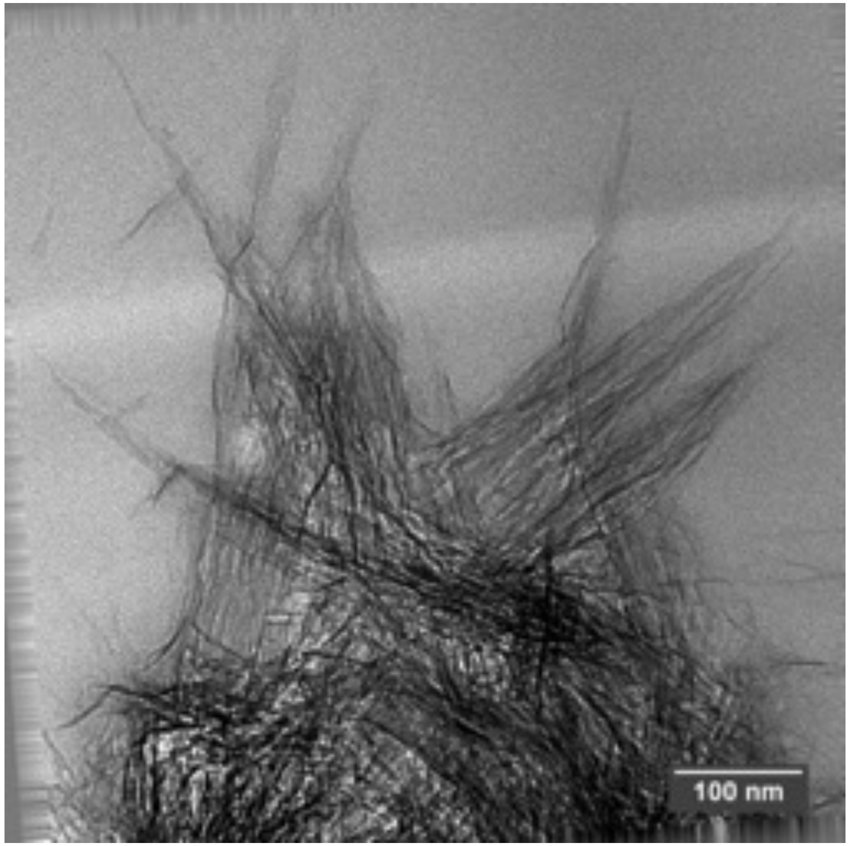
Compressive strength enhanced until 3 days

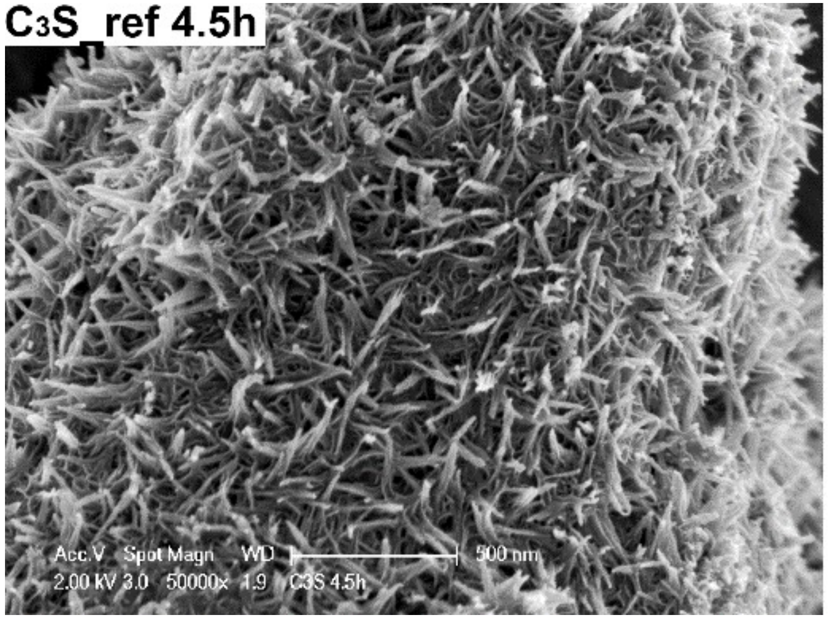


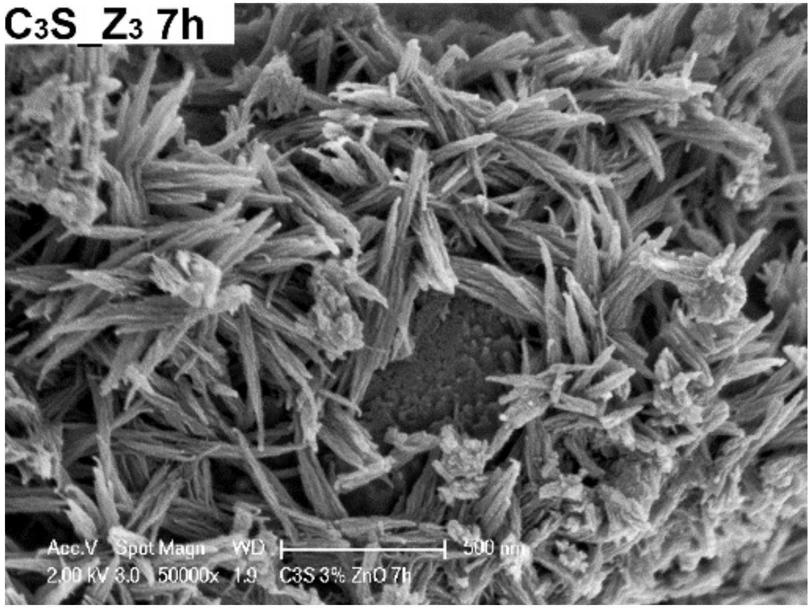
Reactivity enhancement in the main cement phase (C_3S) + Compressive strength enhanced until 3 days

"Zn in C_3S increases the reactivity, therefore it has potential to increase cement reactivity as well"

[Bazzoni , 2014] [Li, unpublished work]


100 nm


C3S_ref 4.5h
Acc.V Spot Magn WD 500 nm
2.00 kV 3.0 50000x 1.9 C3S 4.5h


C3S_Z3 7h
Acc.V Spot Magn WD 500 nm
2.00 kV 3.0 50000x 1.9 C3S 3% ZnO 7h

Needs to increase substitution of clinker

- Quantify SC reactivity
- Increase early strength
- Optimise workability and robustness: Admixture section
- Ensure good service life: Durability section
- Develop performance standards for cement

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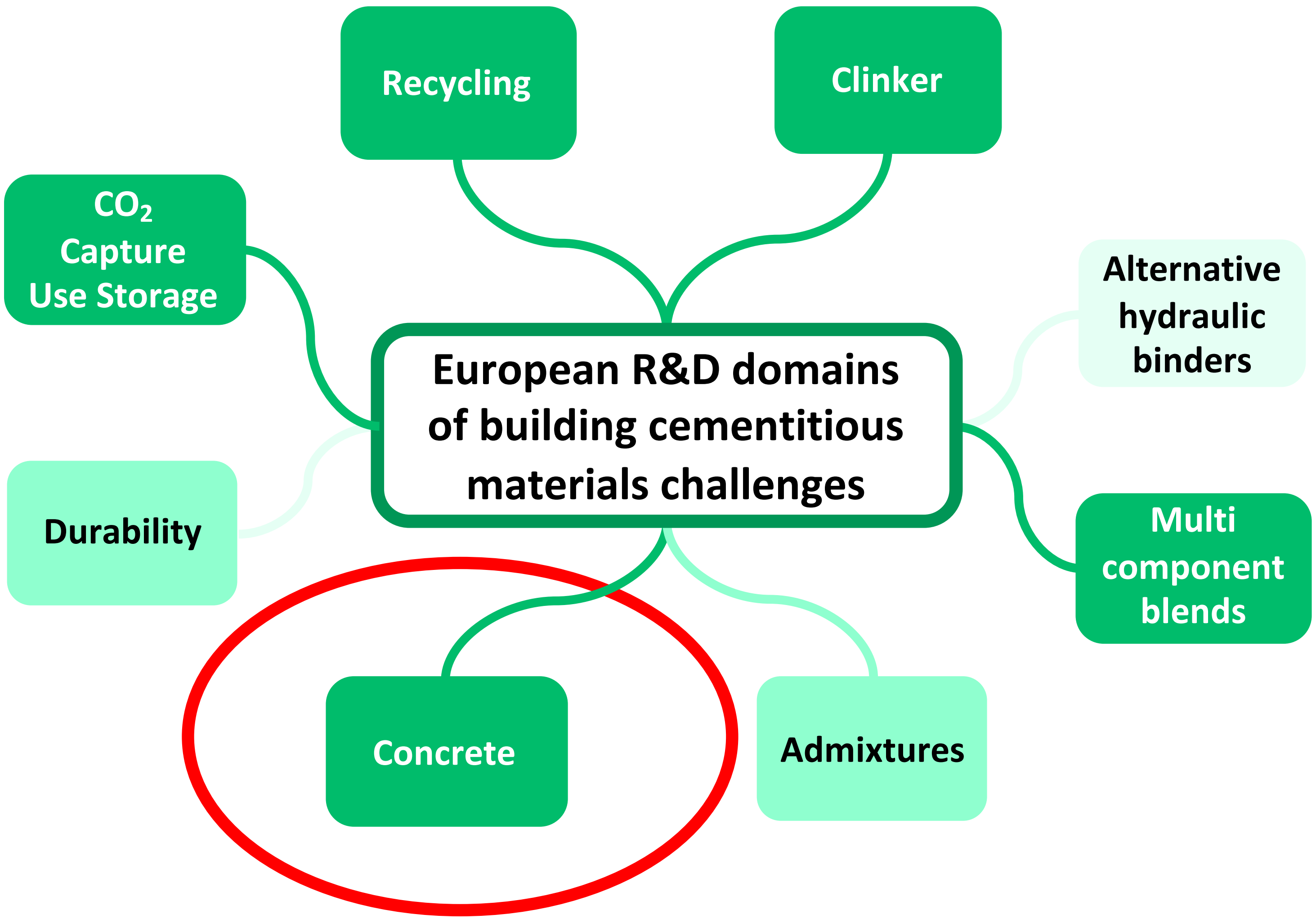
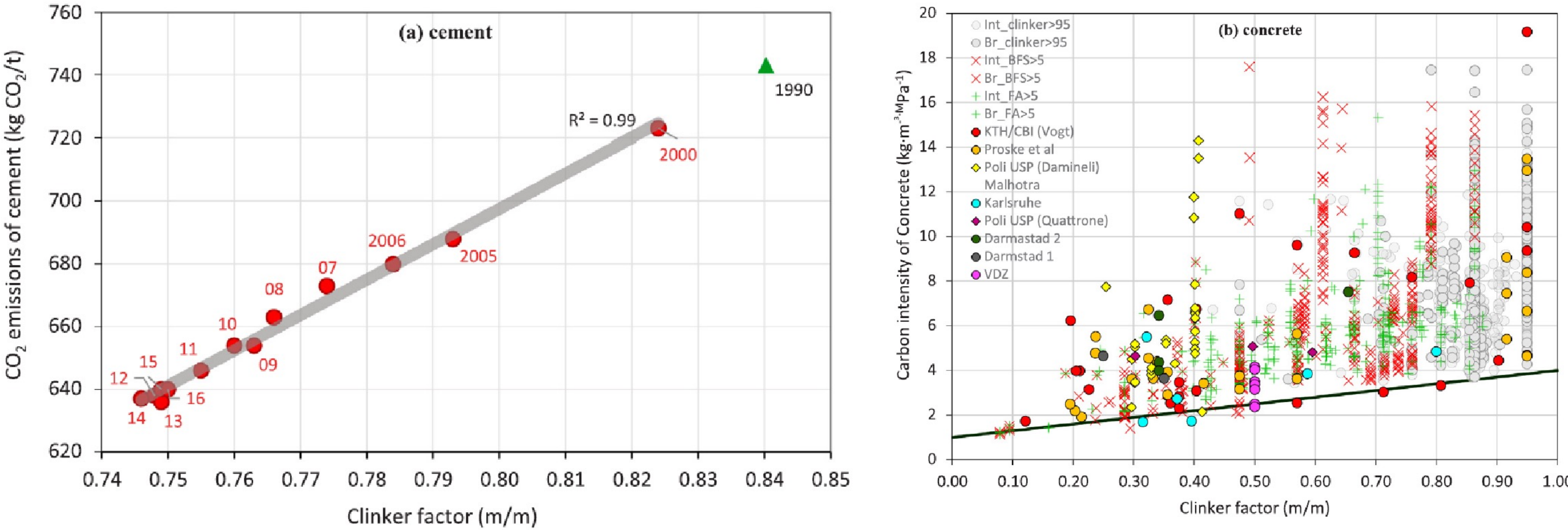
Multi component blends: Research Priorities

Topics	N°	Key-questions to be solved thanks to new research
Low clinker cements	9	Develop reliable and rapid reactivity tests for SCMs
	10	Model the sulphate-silicate-aluminate-alkalis balance to understand the hydration-rheology link with high SCMs content binders
	11	Enhance hydration in main peak, for example by: understanding limitations of C-S-H growth and impact of alkalis
	12	Understand the long-term behaviour: reaction limitations and performance
	13	Extend range of clays & carbonates and improve early age strengths for calcined clays/filler/clinker binders
Grinding & Blending	14	Develop more efficient mills, blending techniques to optimise the particle size distributions of the different components in multicomponent blends

Domains considered



Concrete



D.C. Reis, P.C.R.A. Abrao, T. Sui, V.M. John, Influence of cement strength class on environmental impact of concrete, Resources, Conservation & Recycling, vol. 163 - 2020

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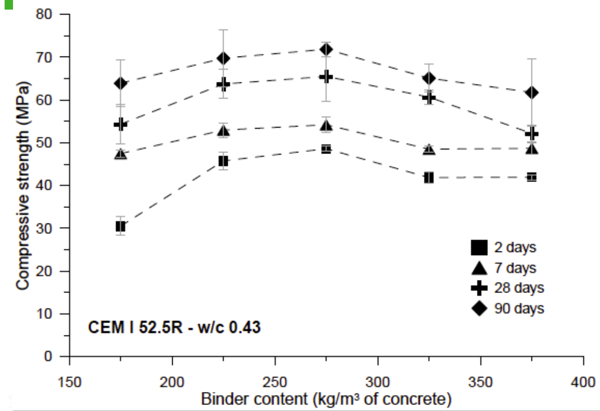
Concrete: Low paste volume

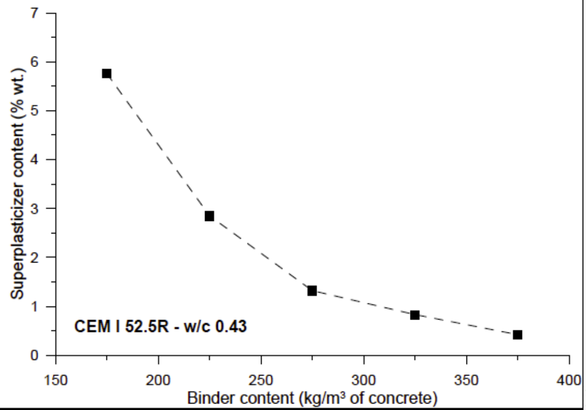
- Many benefits
  - Reduce Thermal cracking
  - Reduce shrinkage
  - Improved durability
  - Reduced cost
  - Reduced environmental impact

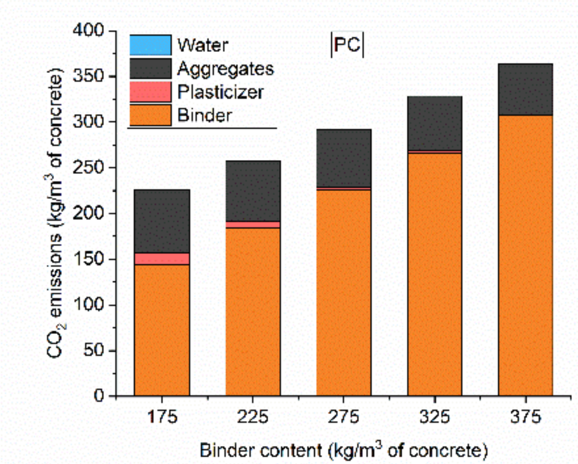
- Key is aggregate grading: existing models work well: Bolomey, DeLarrard, etc

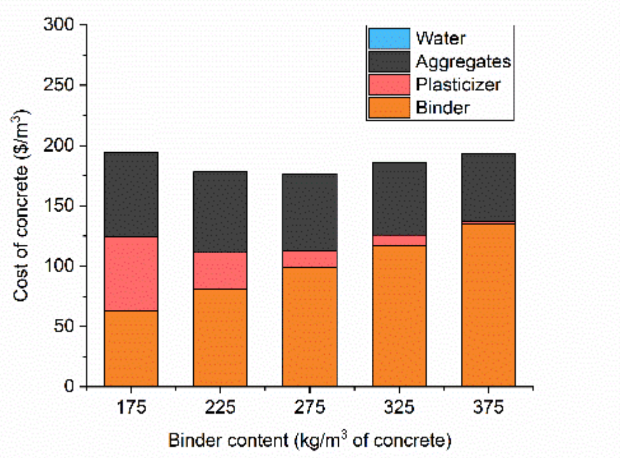
- See ROK&TOK with Doug Hooton

"Traditional" cement contents much higher than needed









Limitations in standards from days before admixtures!
But, at low cement contents concrete becomes "sticky" less robust

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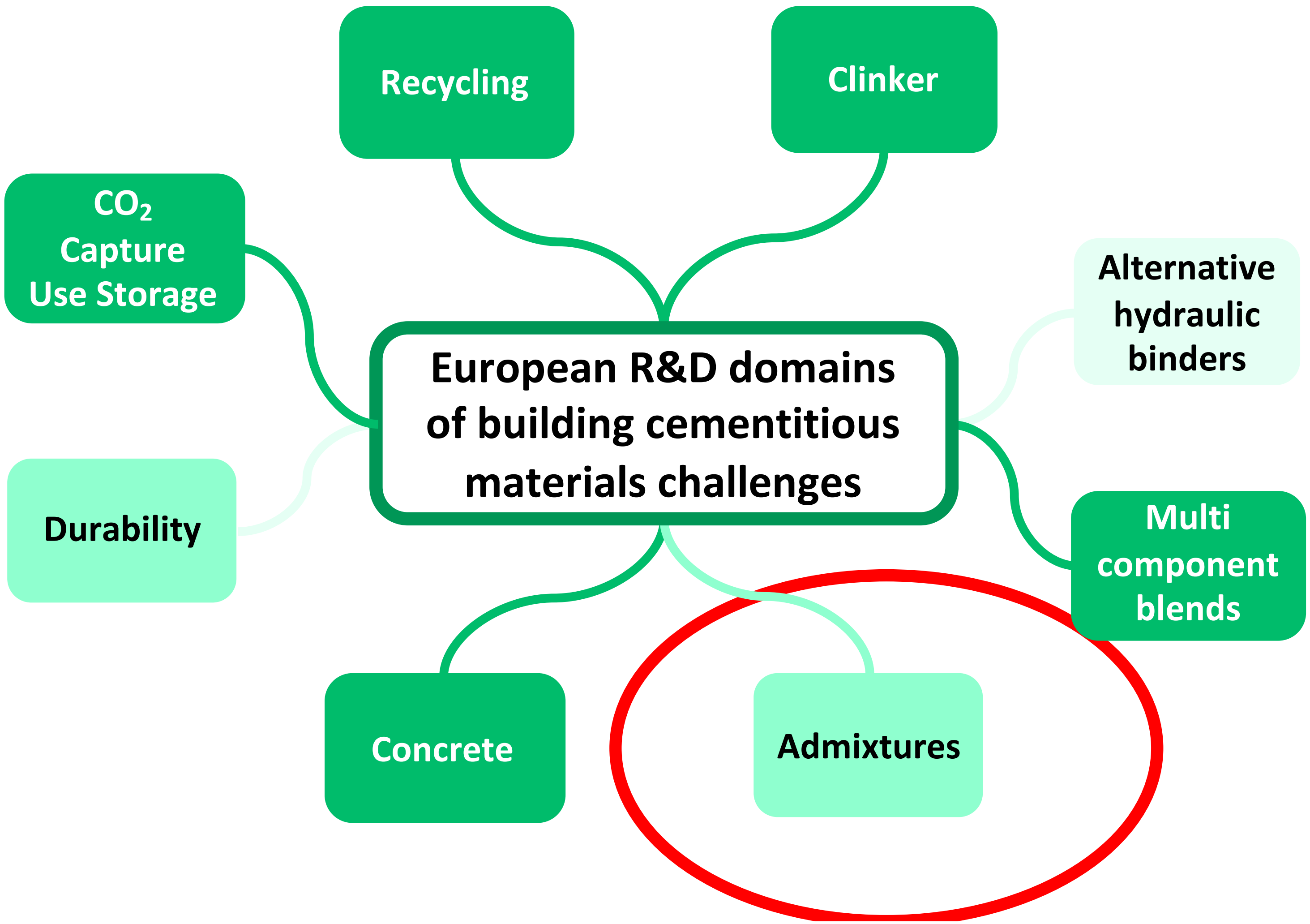
Concrete research priorities

Topics	N°	Key-questions to be solved thanks to new research
Low cement content	19	Develop mix-design methodologies for concrete with low cement or low paste content to improve workability and early-age strength robustness
Poor quality aggregates	20	Find ways to mitigate the effects of using poor quality sands, containing too many or not enough fine particles and/or clay.
Concrete digitalisation	21	Develop tools to improve concrete mix design methods, traceability, concrete production & field monitoring. For example sensors and Artificial Intelligence.
	22	Make Digital Fabrication carbon friendly: with low carbon binder, use of real concrete with coarse aggregates, 3D-shotcreting to embed reinforcement

Domains considered



Admixture research priorities

Topics	N°	Key-questions to be solved thanks to new research
SuperPlasticizers	15	Develop SP processes to control polydispersity
	16	Develop methods to determine spatial/temporal competitive absorption mechanisms, with phase specificity (including SCMs)
Accelerators & Strength enhancers	17	Improve early age strength of low CO_2 concretes without negative impact on workability or late strength evolution.
Air entrainment agents	18	Understand and improve air entrainment stability with SCMs and impurities

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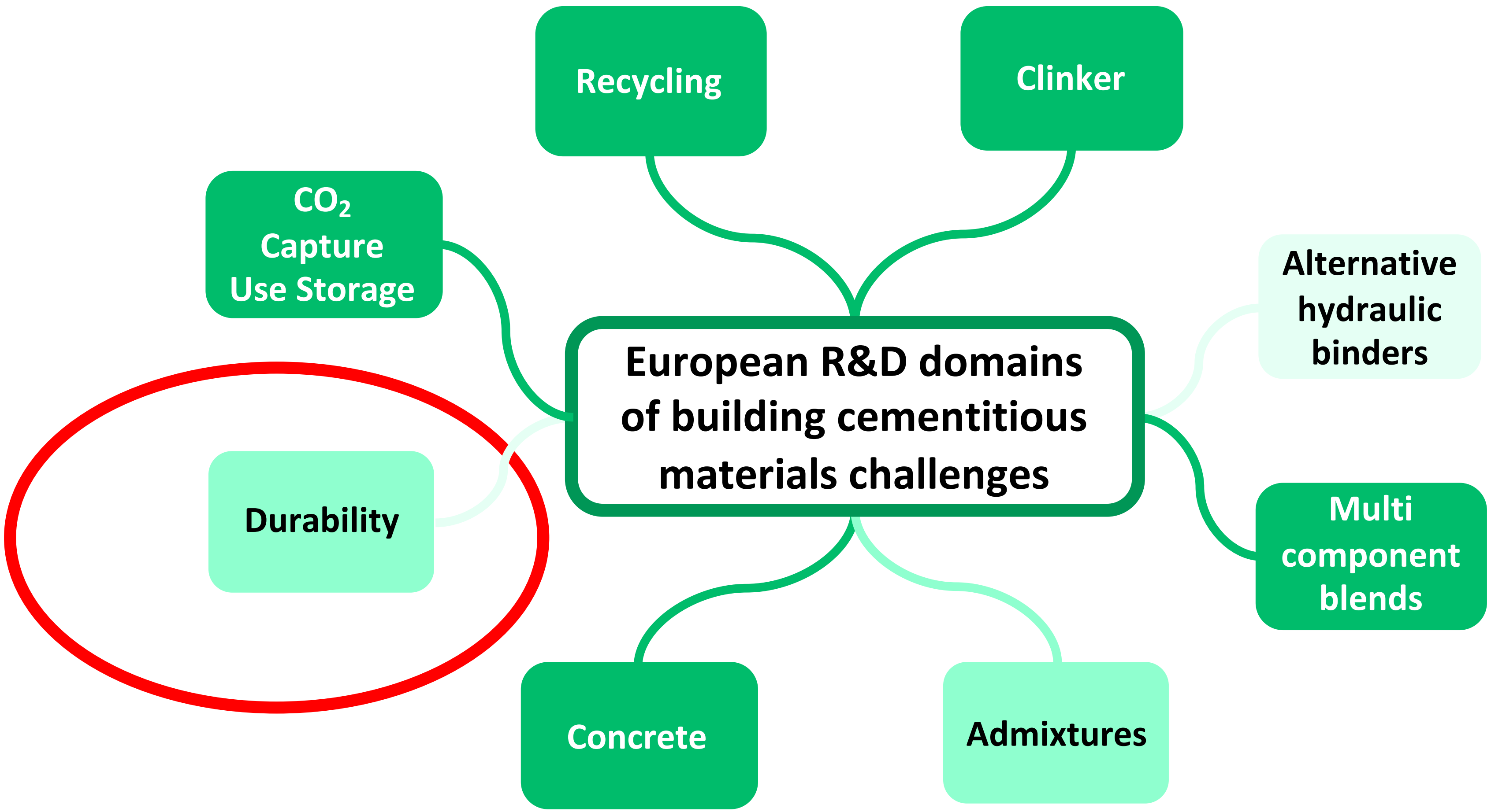
Domains considered



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Durability

- Carbonation
- Chloride
- Alkali Silica Reaction
- Freeze-Thaw
- Sulfates

} Generally improved by SCMs

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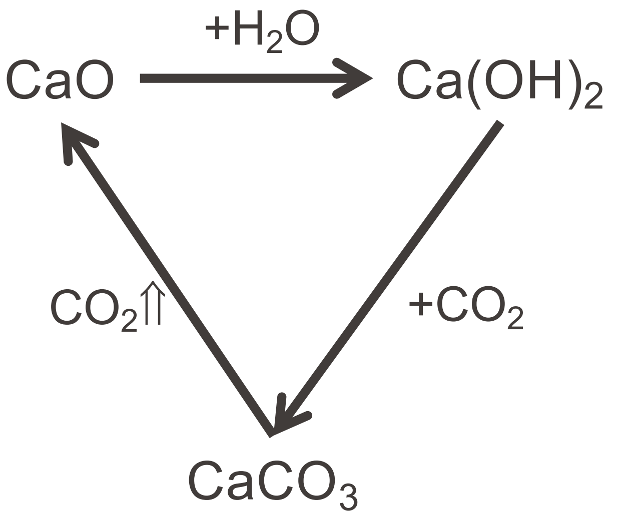
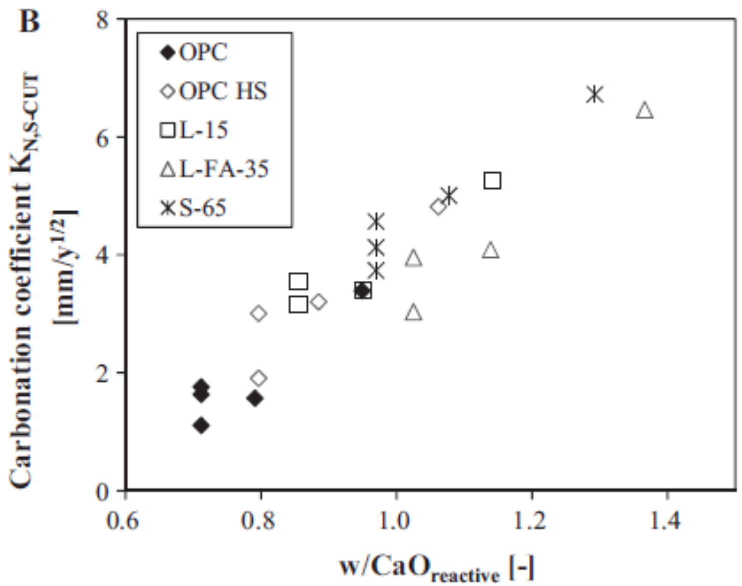
Durability: Carbonation is main limitation

Reducing calcium content; reduces buffer to carbonation
this is the same for all low carbon cements, fly ash, slag, calcined clay



All CaO content can react with CO_2, not just portlandite

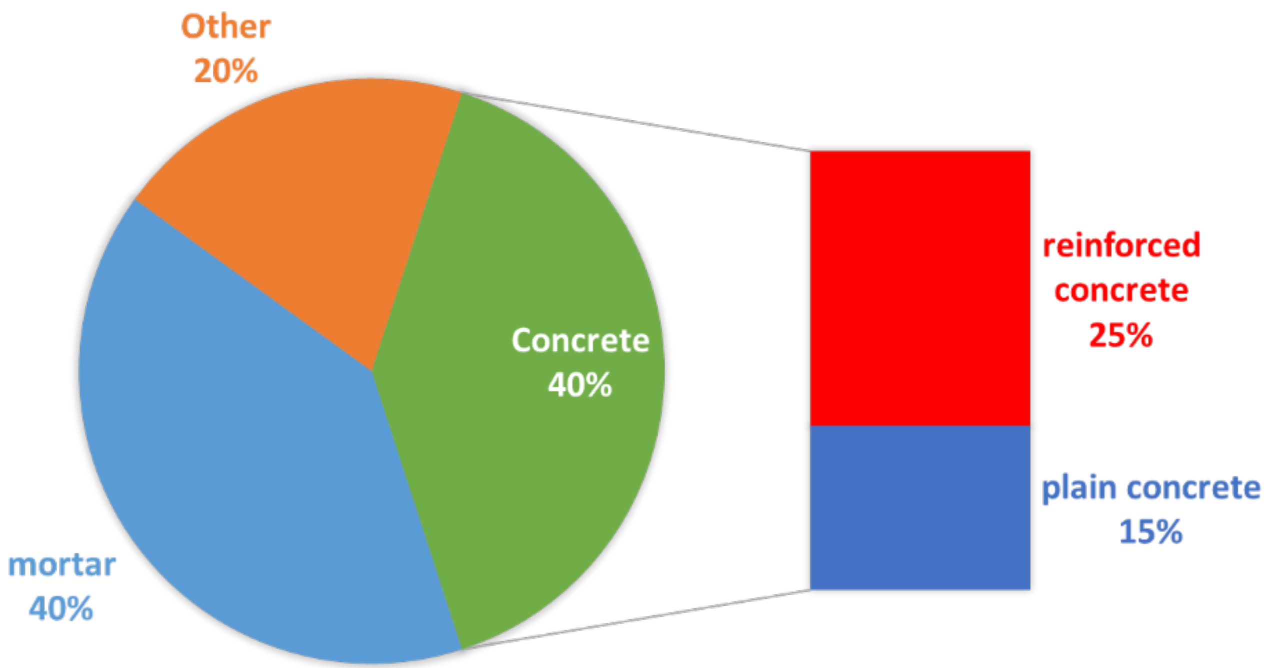


Leemann, et al(2015) :

How much concrete is susceptible to corrosion after carbonation

Where is cement used: Cement-based materials

Blocks
Tiles
Pavers
etc



Bricklaying
Renders

Breakdown for Brazil considered good world average
Source: Eco-efficient cements, Scrivener, John, Gartner, UNEP 2017

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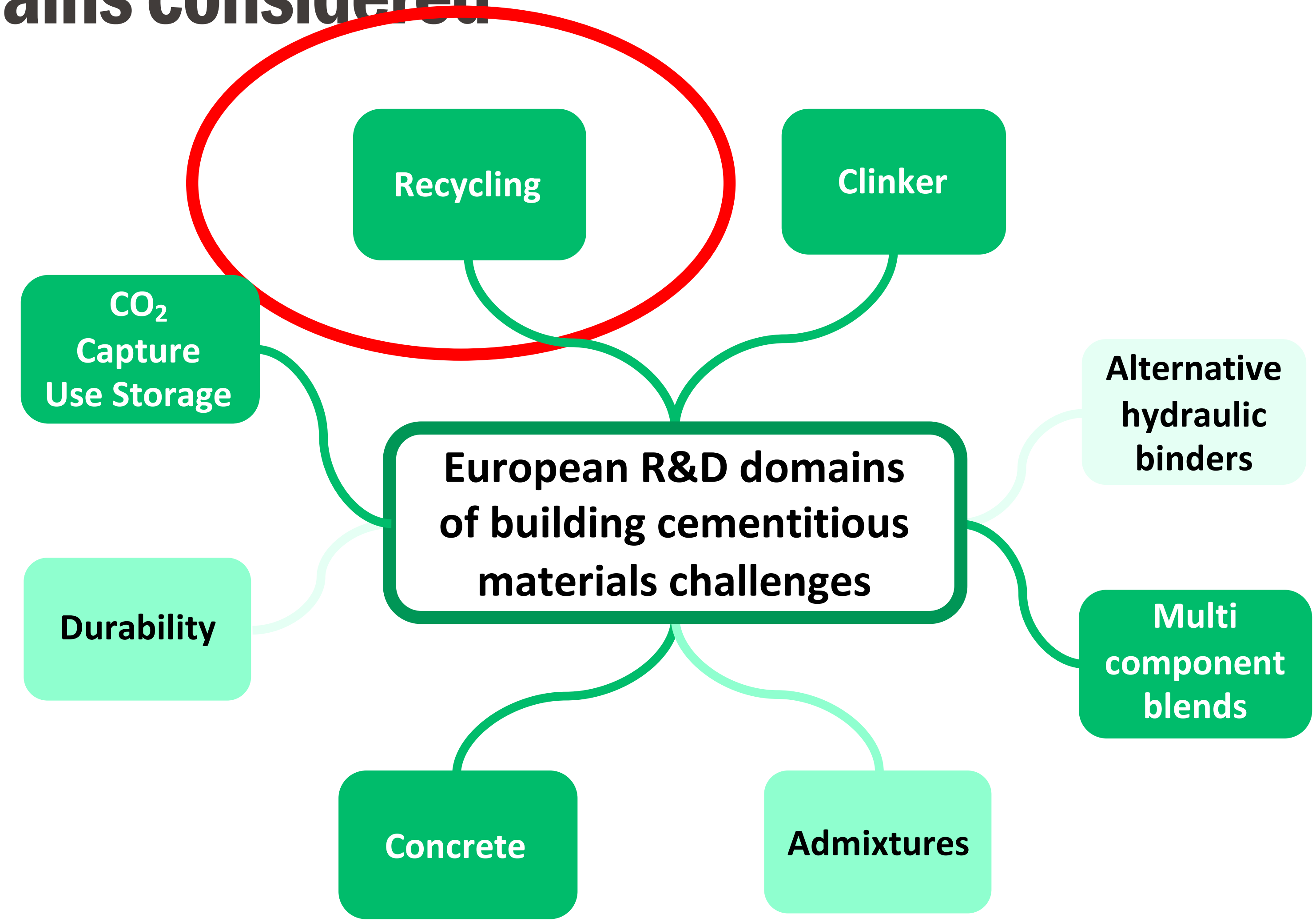
Durability: Research priorities

Topics	N°	Key-questions to be solved thanks to new research
Corrosion	23	Develop more relevant quick test methods and service life models to move from standards imposing minimum cement content to performance standards
Alkali-Silica reaction	24	Determine the SCM content optimum with quick relevant tests and address the risk of recycled aggregates
Frost	25	Develop a reliable scaling resistance test and establish a clear theory about scaling mechanisms

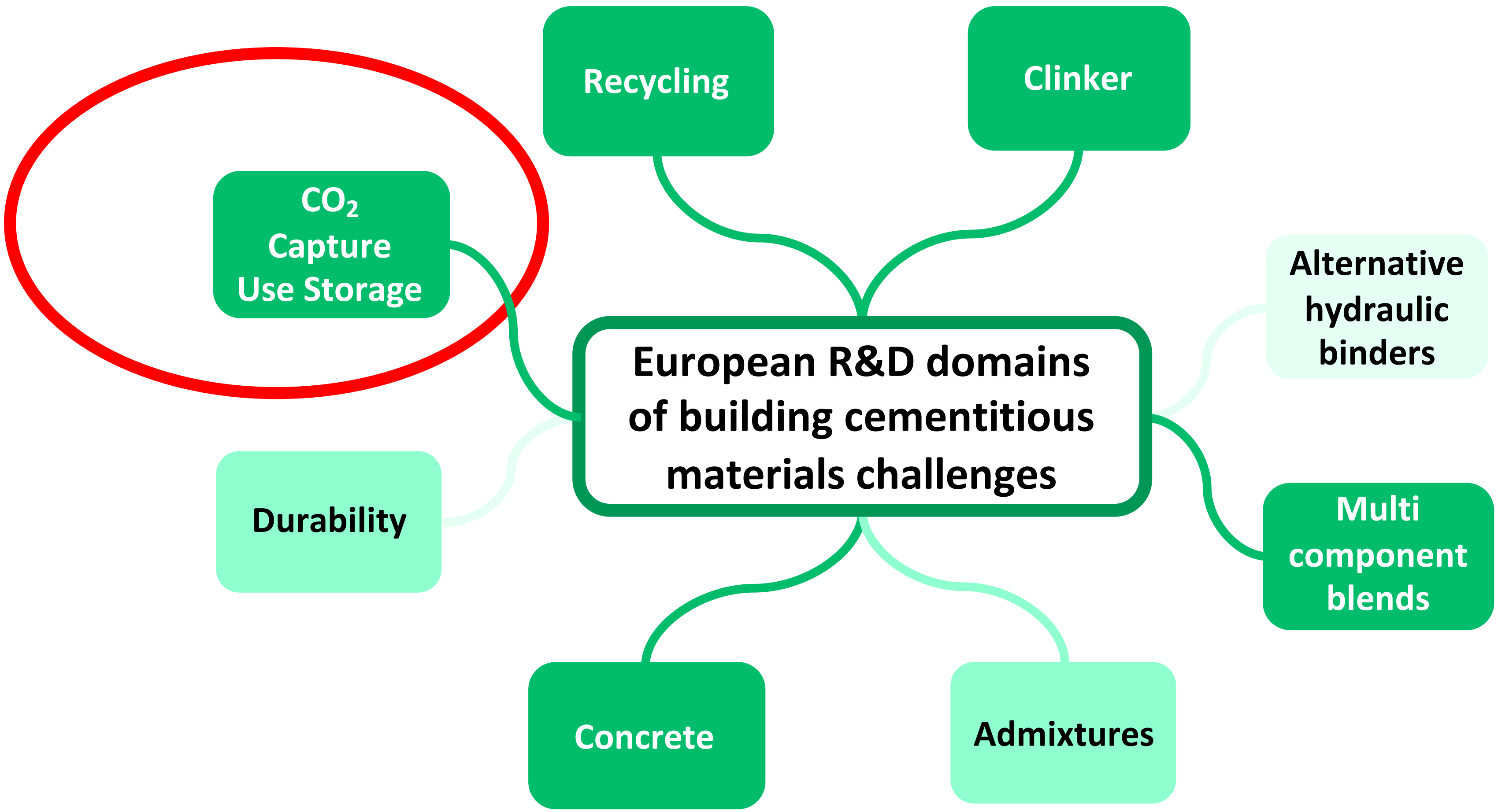
Domains considered



Recycling: research priorities

Topics	N°	Key-questions to be solved thanks to new research
Recycled concrete aggregates	28	Develop cost-efficient solutions to block their porosity and absorption
	29	Improve, accelerate and reduce the cost of treating recycled aggregates by carbonation
Recycled concrete fines	30	Determine the most efficient process to treat RCF in order to produce reactive SCMs

Domains considered



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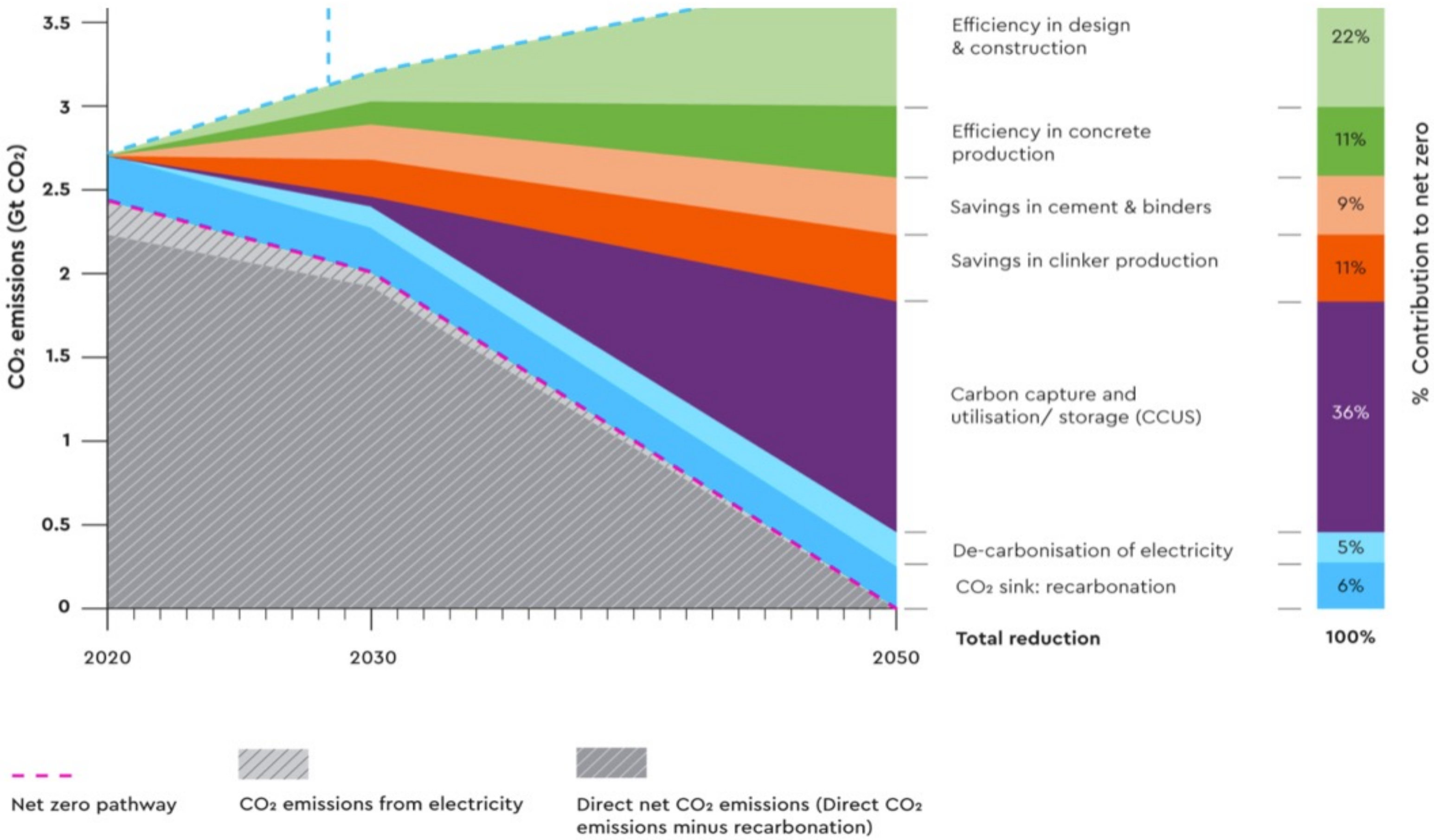
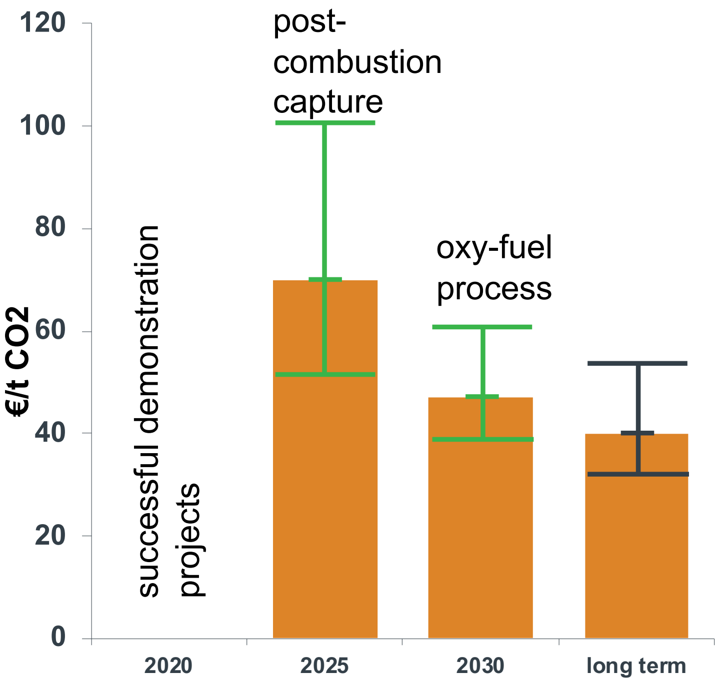
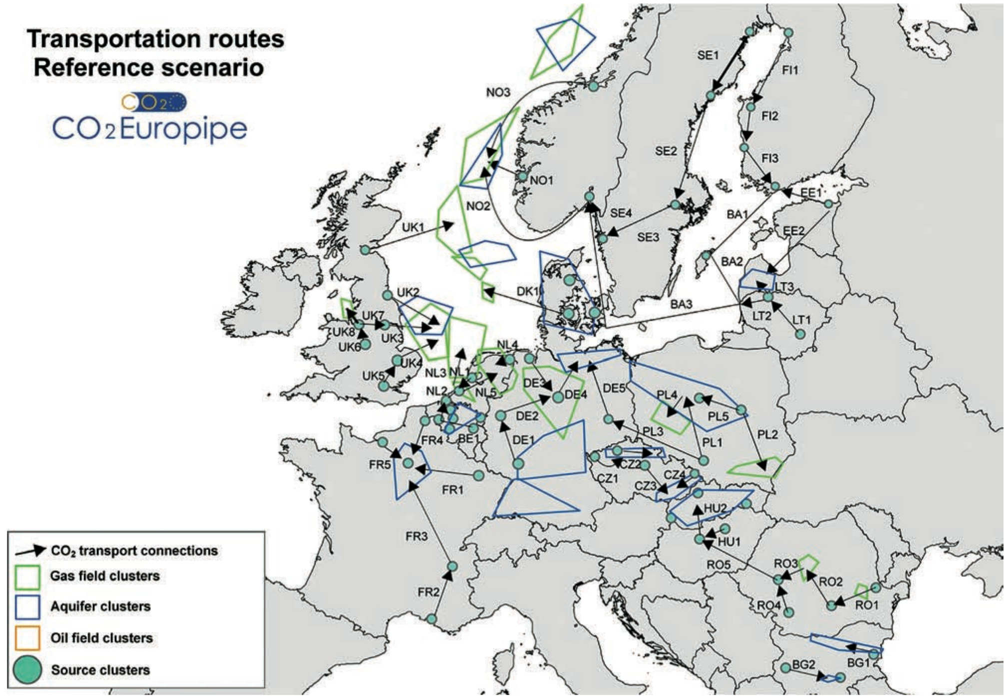
Global Cement and Concrete Association



Carbon Capture and Storage



At the very least it will be expensive
Reducing now will be a very sound investment



Scale of production >>> any “use” scenario
Need to build network to transport to storage sites

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CO2 capture storage: research priorities

Topics	N°	Key-questions to be solved thanks to new research
CO_2 capture	26	Understand and quantify the impact of process changes to facilitate CO2 capture, on clinker reactivity and on volatilization of minor elements
Mineralisation	27	Determine possible industrial wastes for carbonation, by the use of industrial non-treated CO2 flue gas

What capacity is there for products based on formation of $CaCO_3$?

RESEARCH ARTICLE | ENGINEERING

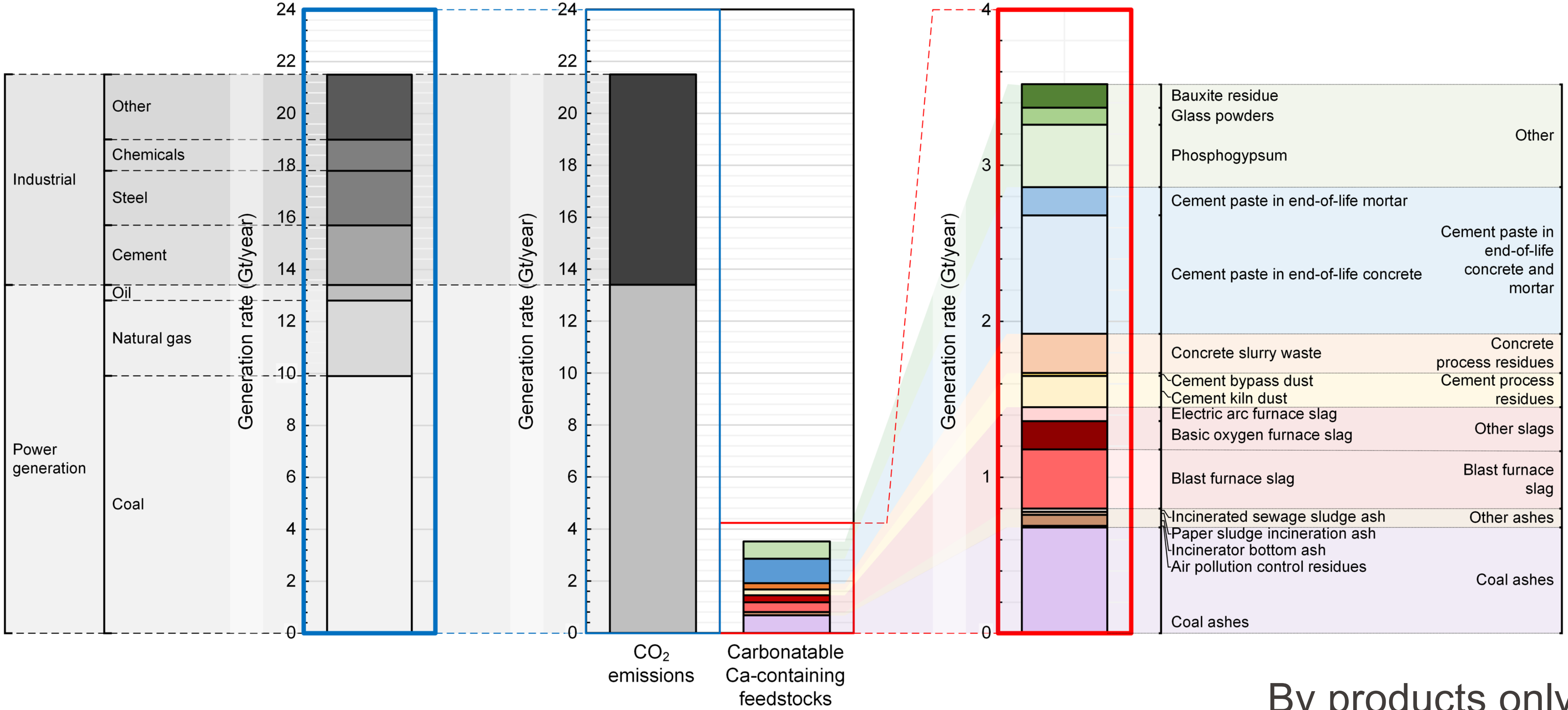
Global decarbonization potential of CO_2 mineralization in concrete materials

Justin G. Driver, Ellina Bernard, Piera Patrizio, +2, and Rupert J. Myers Authors Info & Affiliations

Edited by Eric Masanet, University of California at Santa Barbara, Santa Barbara, CA; received August 5, 2023; accepted May 23, 2024 by Editorial Board Member William C. Clark

July 8, 2024 | 121 (29) e2313475121 | https://doi.org/10.1073/pnas.2313475121

Carbonateable sources. Driver et al 2024



Gross over estimate: Slag already used, About 1/3 fly ash used

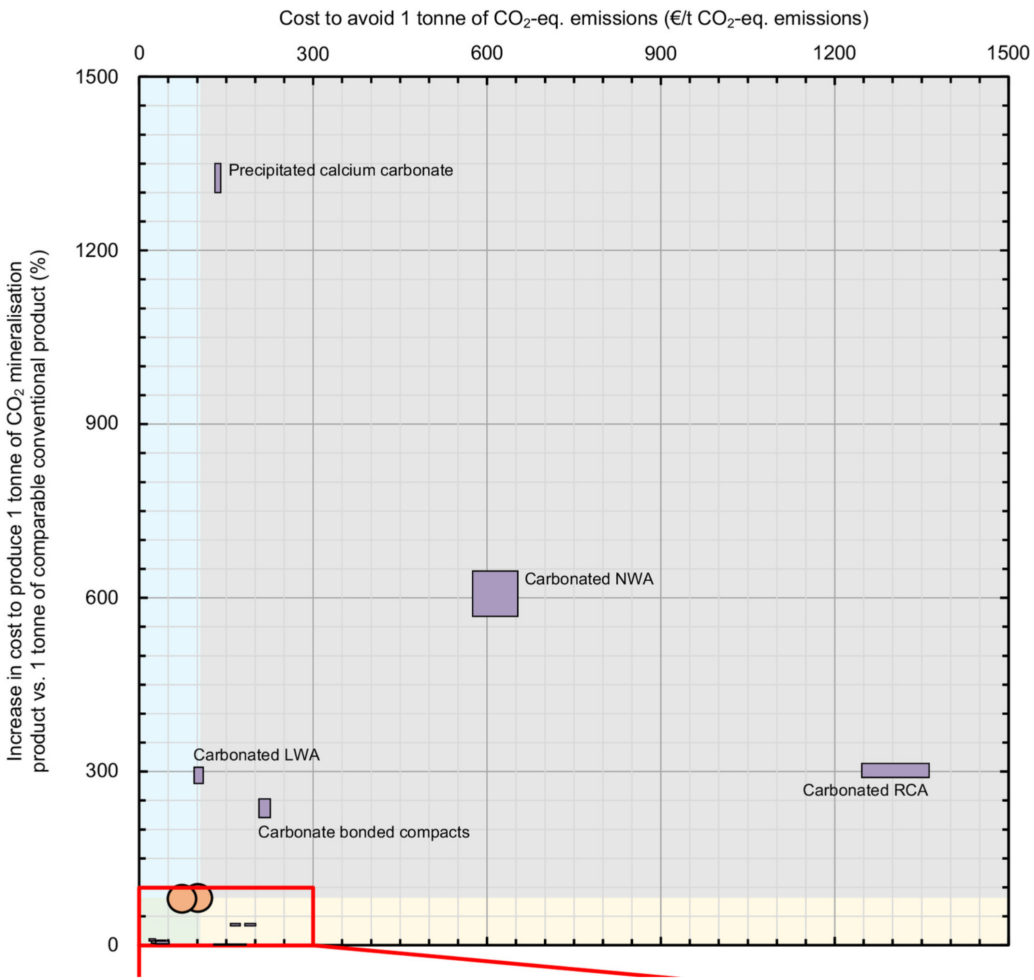
Maximum potential 0.39 Gt CO_2 eq (0.8% of total world emissions

By products only
Mine tailings and rocks are another source

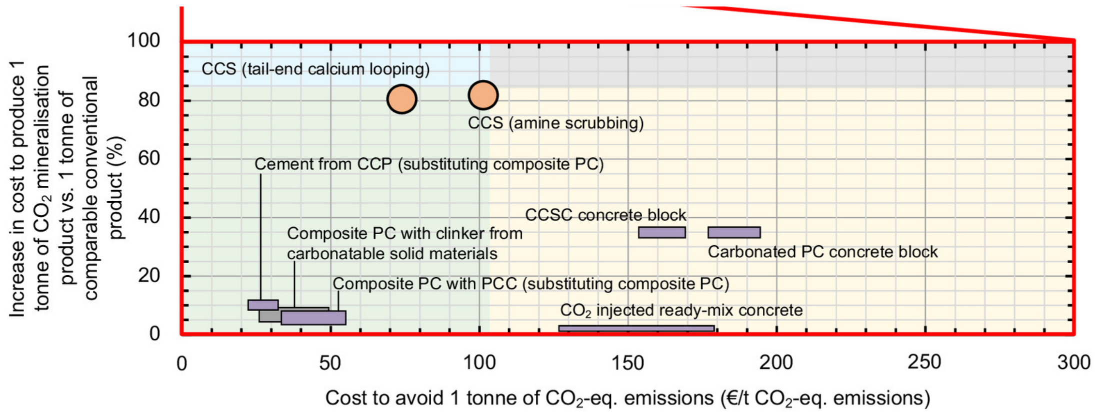
Karen Scrivener

Mineralised products: economics

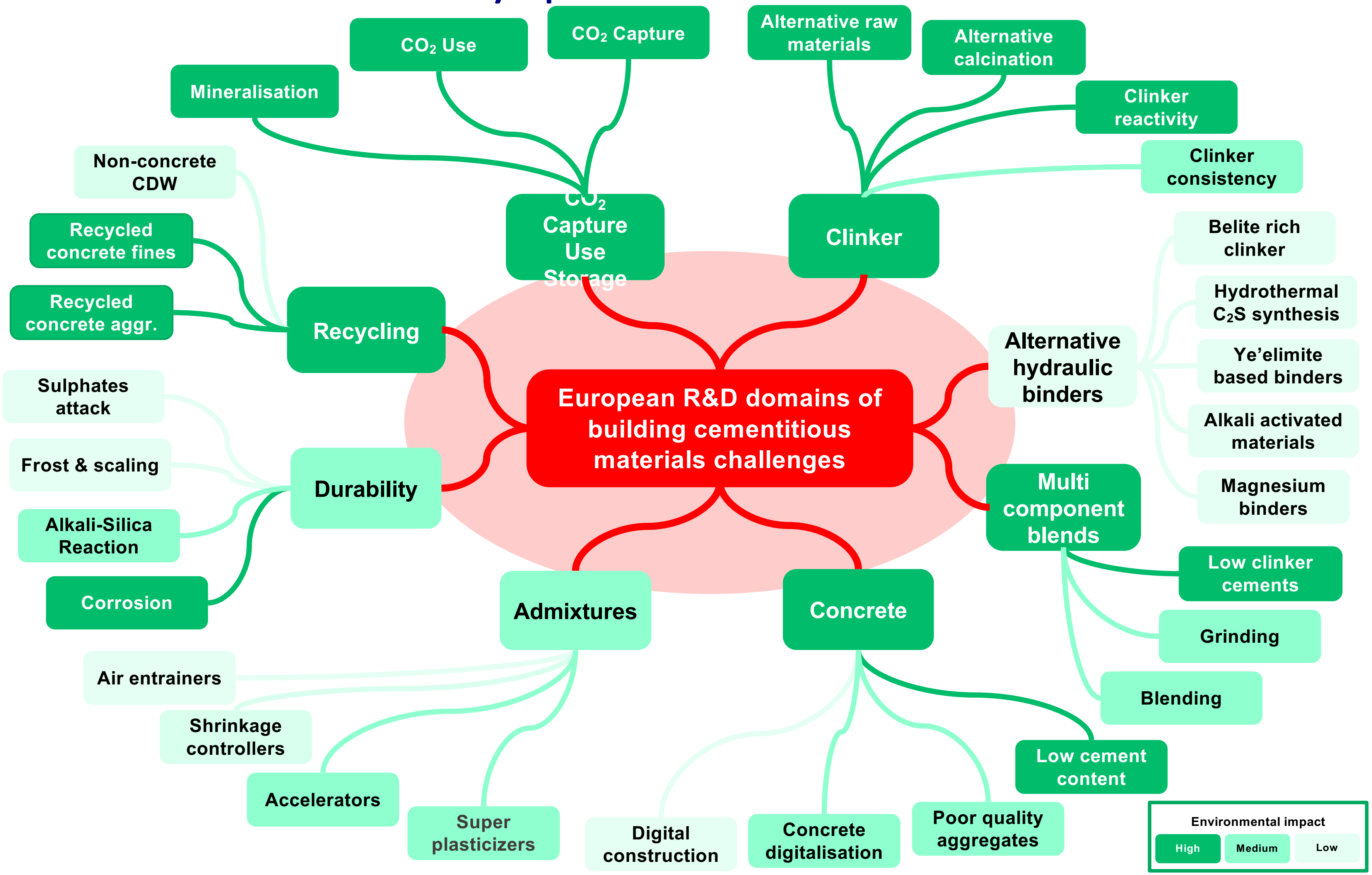
Karen Scrivener



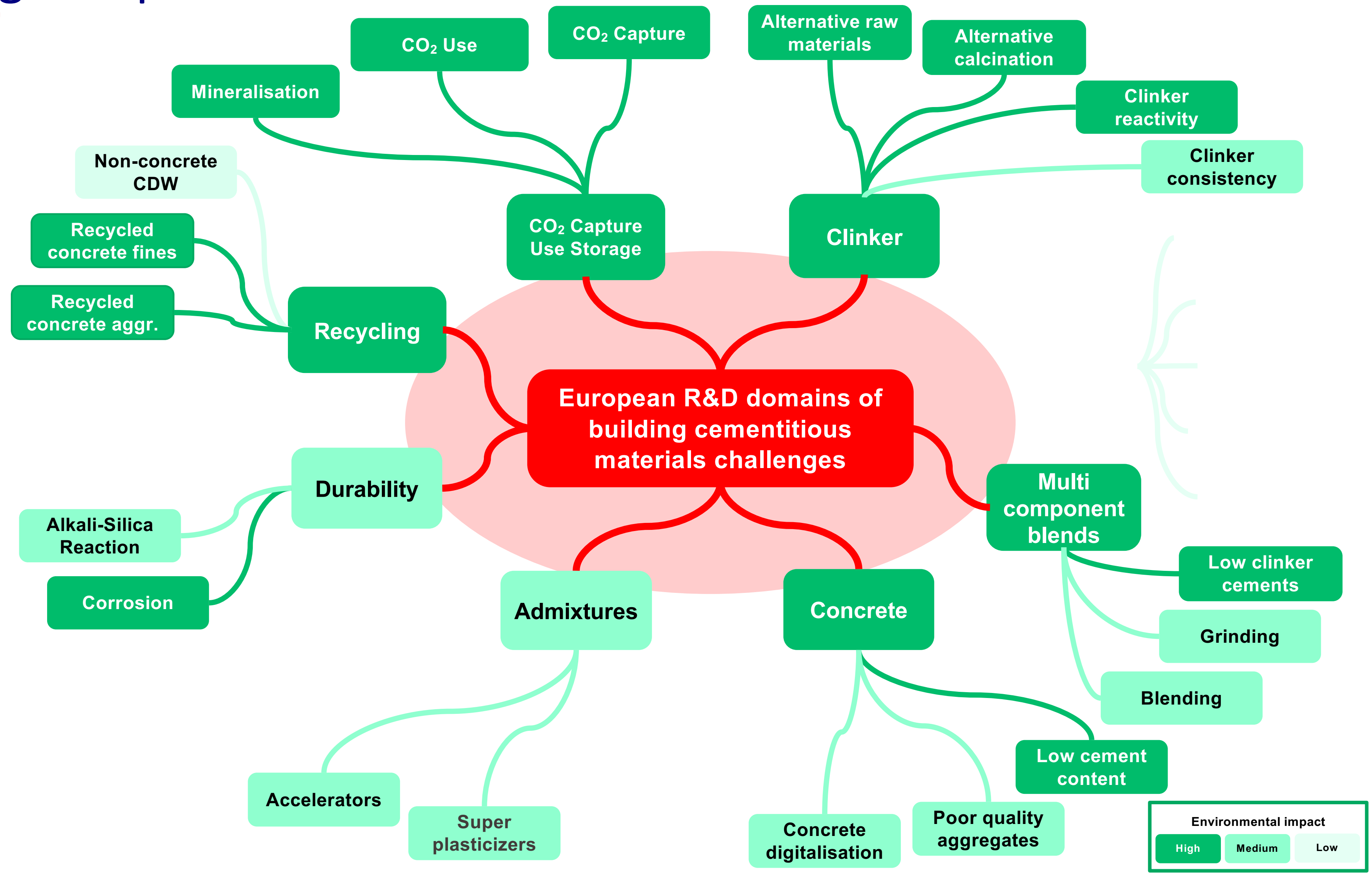
Most ideas are not economically feasible



Watermelon: and 30 key questions



Highest priorities



Need to breakdown the silos

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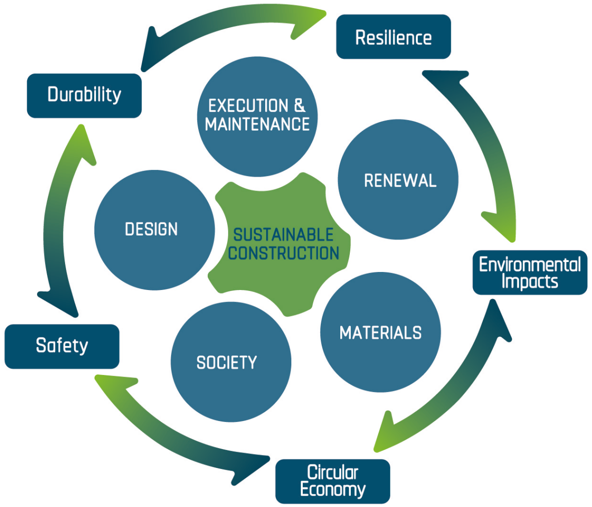
GLOBE

Global consensus on sustainability in the built environment

- High level policy advice
- More than 150 nations
- 5000+ experts
- 50+ years of expert networks
- Standards and guidelines
- Research and education
- Innovation



www.globe-consensus.com

See on-line presentation from COP28 for more details

rilem

fib CEB•FIP

cib

ECCS CECM EKS

IABSE

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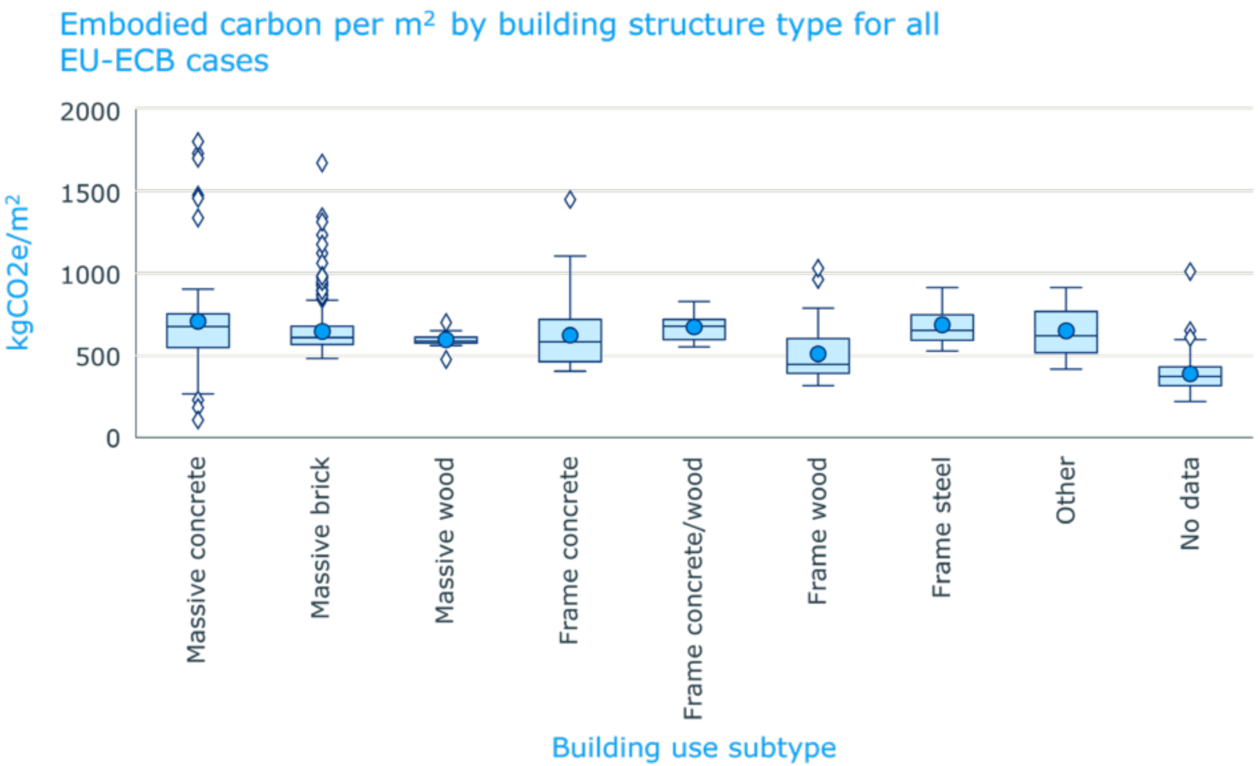
Need for metrics in application - Buildings



GLOBE

Global Building Data Initiative

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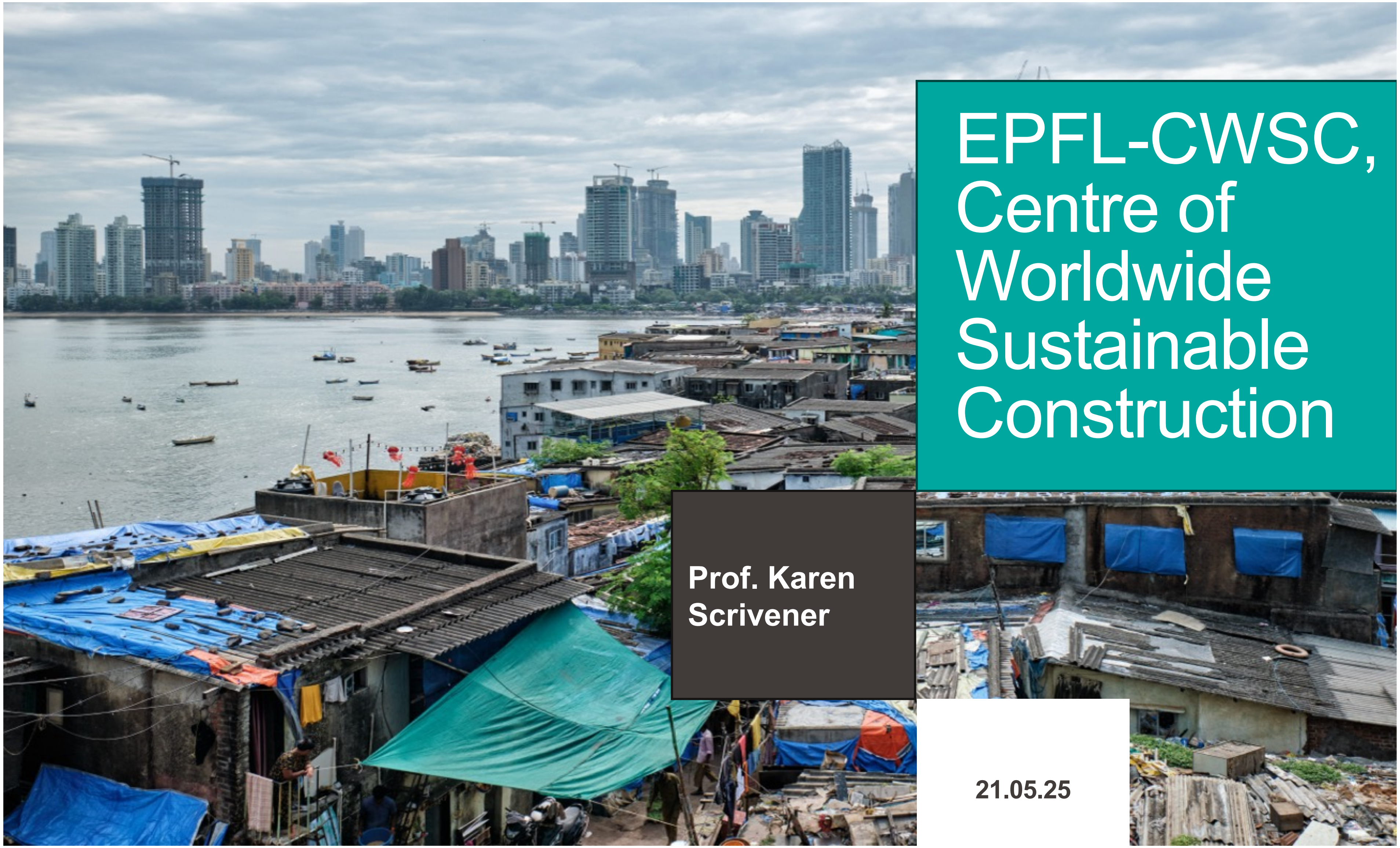


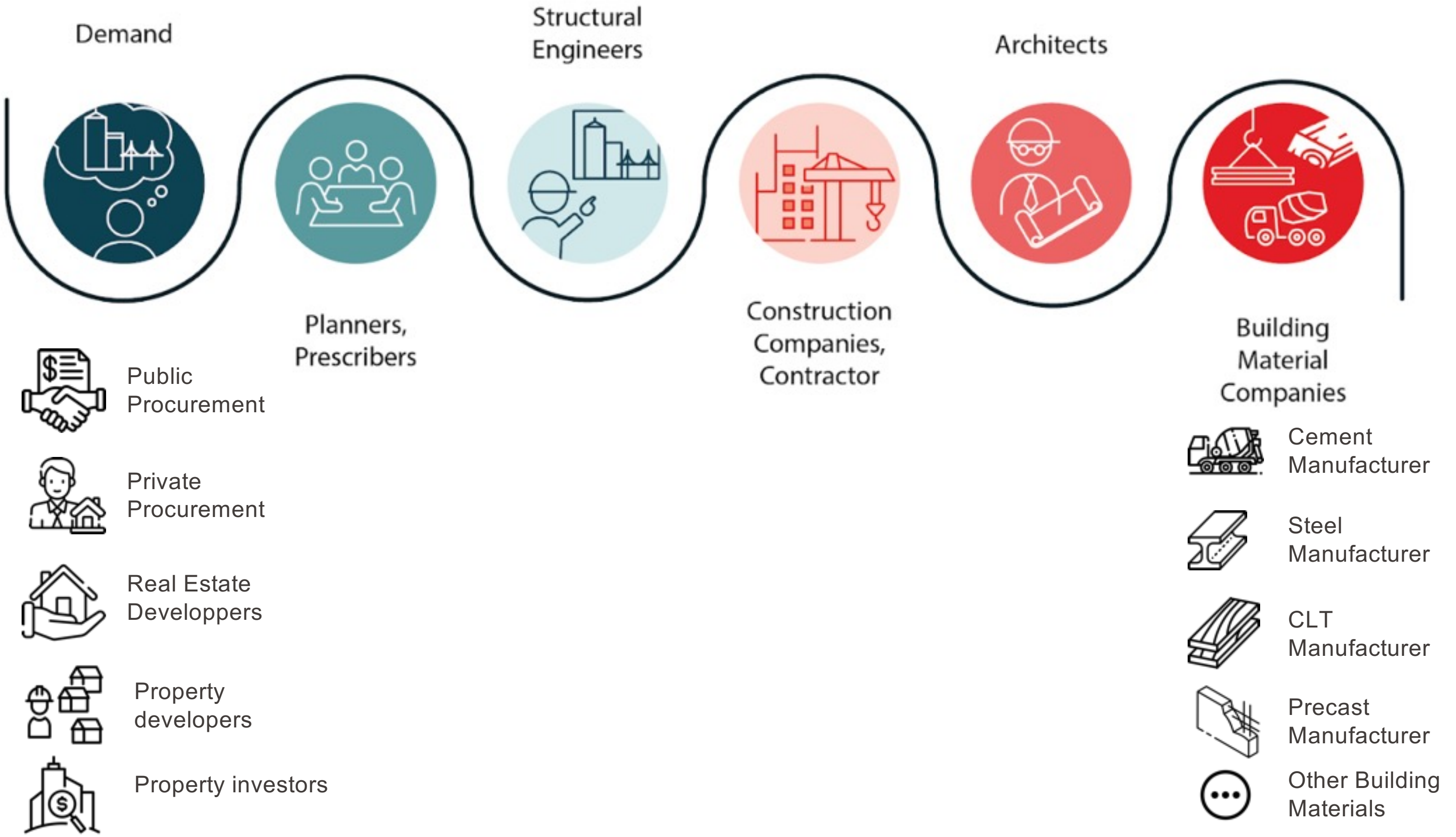
EPFL-CWSC, Centre of Worldwide Sustainable Construction

Prof. Karen Scrivener

21.05.25

École polytechnique fédérale de Lausanne

CWSC will cover the whole value chain



The aim is to break down disciplinary silos and favour different disciplines of construction working together

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Sustainable
Construction Summit
2026

Towards a Sustainable Built Environment

Bringing together Academia, Government, and Industry

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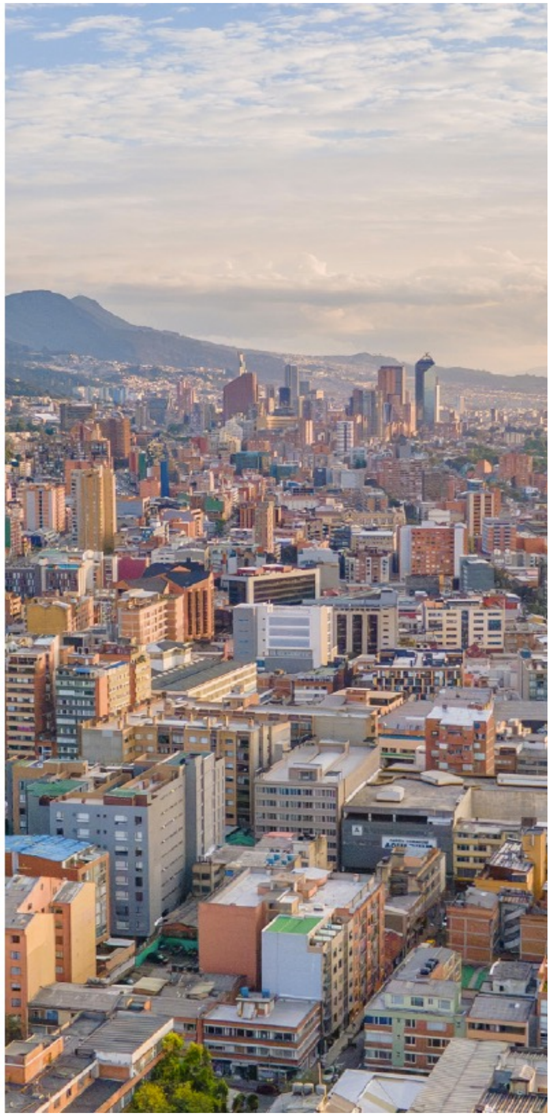
UN environment programme

Global Alliance for Buildings and Construction

Join us April 20-22, 2026,
at the SwissTech Convention Center,
EPFL, Lausanne, Switzerland



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Concluding remarks

- ✓ Stop wasting time on hype
- ✓ We have most of the solutions
- ✓ CO_2 is a *global* issue
- ✓ Speed and scale are essential
- ✓ Perfect should not be the enemy of the good
- ✓ Still a lot of research needs

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Thank You

Karen Scrivener

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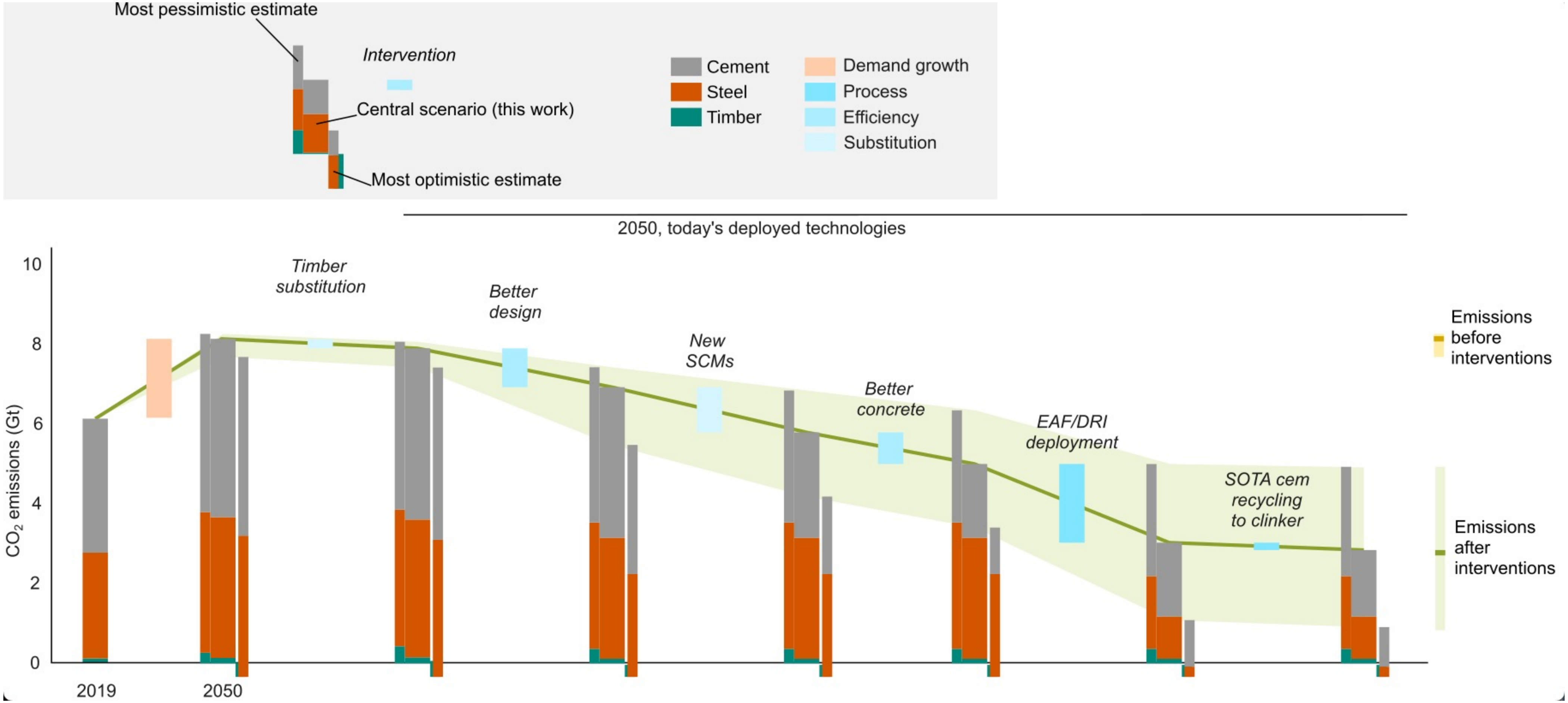
polytechnique
fédérale
de Lausanne



Most pessimistic estimate
Intervention
Central scenario (this work)
Most optimistic estimate
Cement
Steel
Timber
Demand growth
Process
Efficiency
Substitution
2050, today's deployed technologies
10
8
6
4
2
0
CO_2 emissions (Gt)
Timber substitution
Better design
New SCMs
Better concrete
EAF/DRI deployment
SOTA cem recycling to clinker
2019
2050
Emissions before interventions
Emissions after interventions

EPFL

Potential for growth AND CO_2 reductions