Carbon Uptake: Establishing the Baseline

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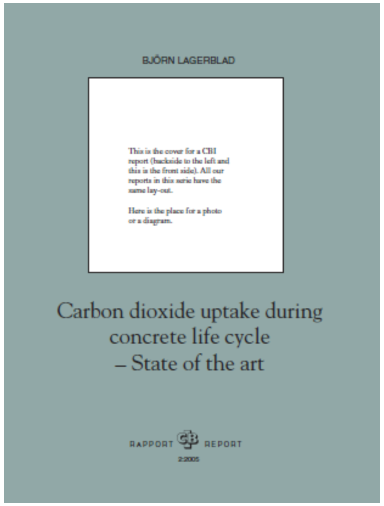
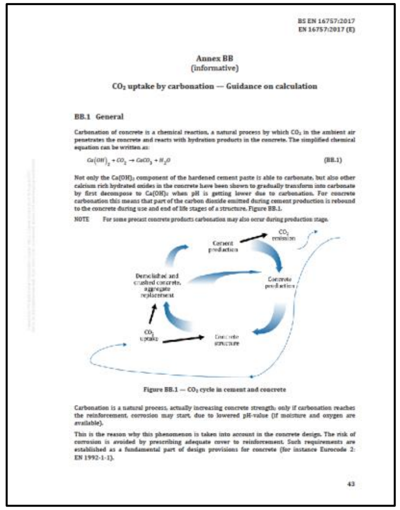
Jamie Farny
Director, Environmental Measurement & Metrics
Portland Cement Association

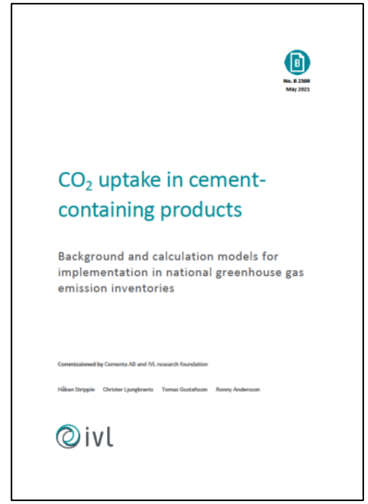
Outline

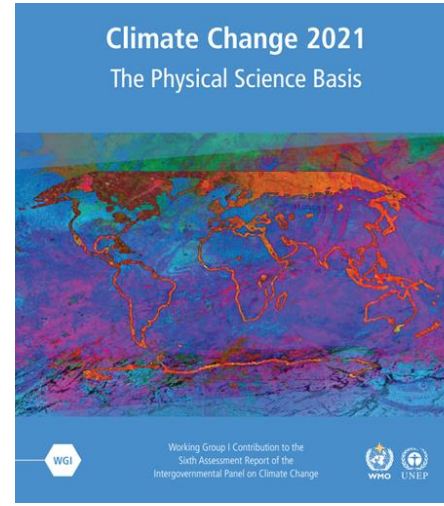
- Carbon uptake – recognition, chemistry, contribution to carbon neutrality
- Importance of baseline for measurement, reporting
- Quantifying carbon uptake at project level, country level
- Current data gaps, potential research, data needs
- NIST Low Carbon Cements and Concretes Consortium
- PCA policy priorities

Some Key Resources





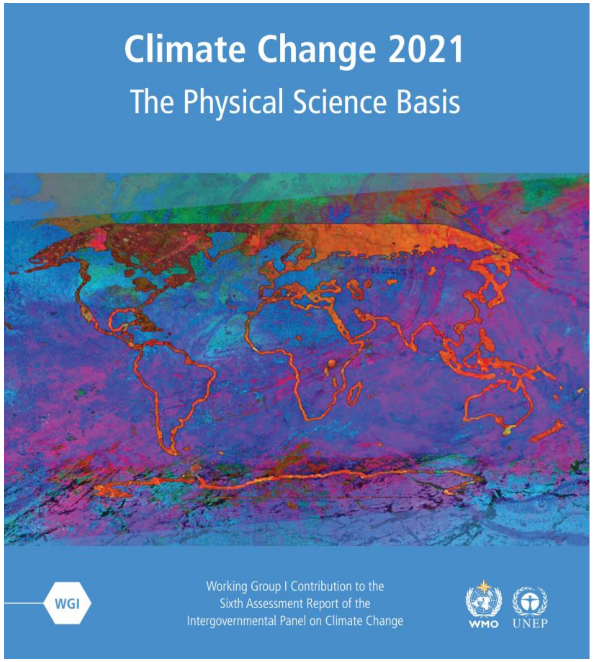




2005 – Lagerblad	**2017 – BS EN 16757 Annex BB**	**2021 – IVL Report B 2309**	**2021 – IPCC AR6**
CO_2 uptake during concrete life cycle	EPDs and PCRs for concrete/elements	CO_2 uptake in cement-containing products	Comprehensive assessment report on climate change
Provide documentation of concrete carbonation during service life and secondary use (Swedish Cement and Concrete Research Institute)	Guidance on calculation of CO_2 uptake (British Standard)	Background and calculation models for implementation in national greenhouse gas emission inventories (IVL Swedish Environmental Research Institute)	Calls for rapid and far-reaching transitions across all sectors and systems to achieve deep and sustained emissions reductions (IPCC)

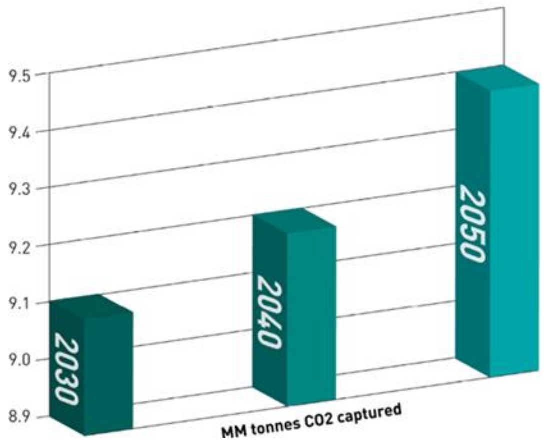
Intergovernmental Panel on Climate Change

- IPCC Sixth Assessment Report
- Carbonation recognized:
  - CO_2 emissions from carbonates in cement production are around 4% of total fossil CO_2 emissions.
  - CO_2 uptake in cement infrastructure (carbonation) offsets a significant portion of the carbonate emissions from current cement production (Friedlingstein et al., 2020).

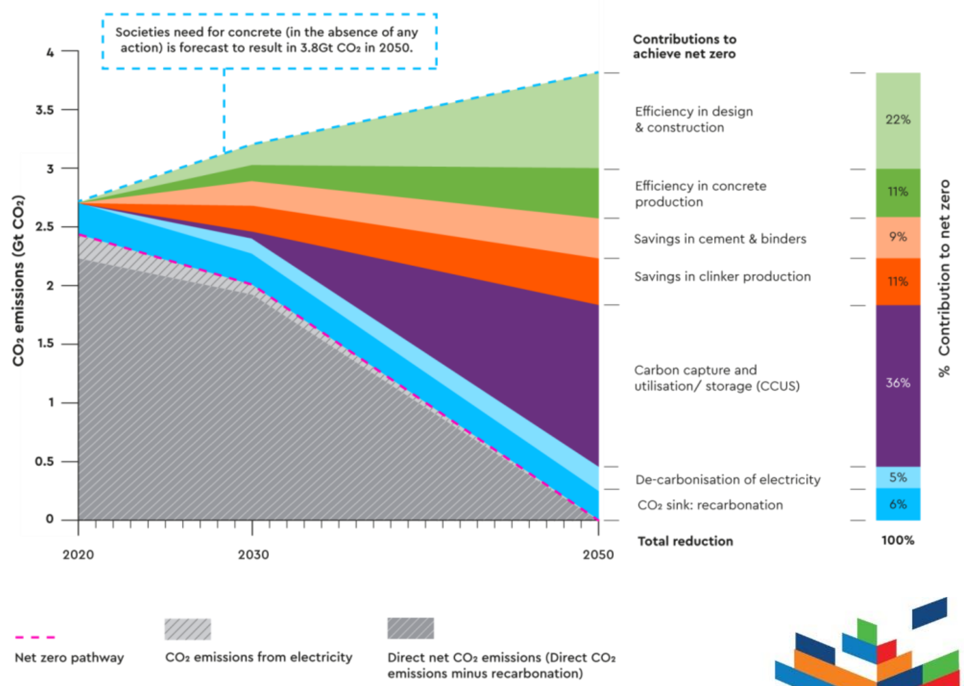


PCA & GCCA Roadmaps & Carbonation (promote recognition of carbon uptake)

Concrete as a carbon sink: Capturing CO_2

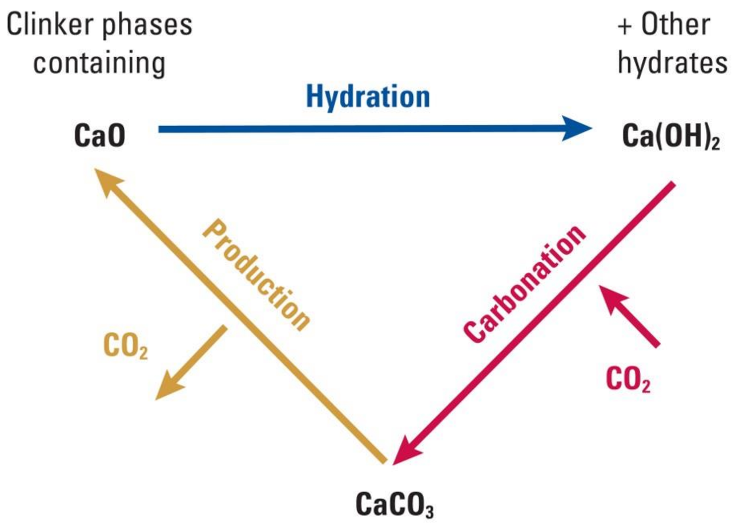


GETTING TO NET ZERO



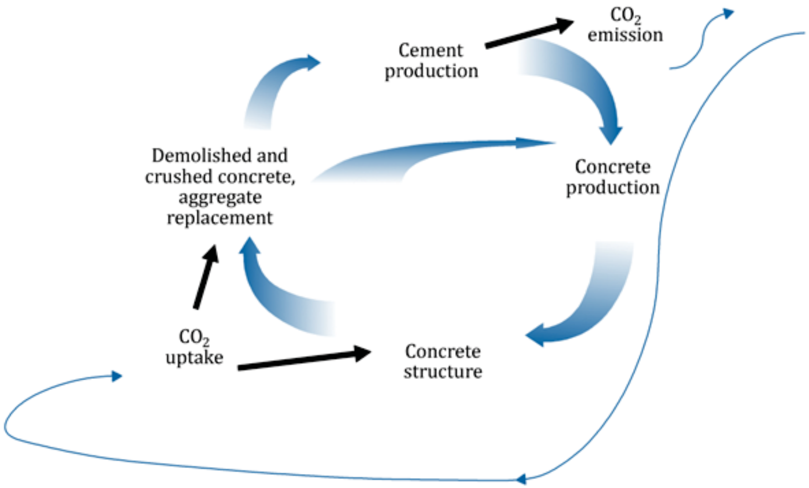
Cement Manufacture, Carbon Uptake

- Manufacture: $CaCO_3 \rightarrow CaO + CO_2$
- Hydration: $CaO + H_2O \rightarrow Ca(OH)_2$
- Uptake: $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$



Micro: chemical reactions

EN 17657 Annex BB



Macro: carbon cycle

Baseline for Carbonation is Clinker Production

CLINKER
Key chemically
reactive ingredient

- Clinker production generates CO_2
- Fuel emissions are not offset by carbonation
- Calcination emissions ~60% of cement plant CO_2 emissions = the theoretical maximum uptake
- Multiple levers to reduce or offset CO_2 emissions:
  - Reduce clinker factor from ~0.91 current to 2050 target = 0.75
  - Decarbonated raw feed
  - Lower clinkering temperatures
  - Promote recognition of carbon uptake

Project-Level Carbonation MIT Calculator Factors that Affect Carbon Uptake

- Time (life cycle)
- Geometric, locational
- Mix design
- Cement and concrete practices vary by country
- Annex BB, IVL, Lagerblad, etc.

Use phase Carbon Uptake

Input name	Value (Please fill out all the yellow cells)
1. General	
Analysis period (years)	100
2. Geometric and locational characteristics	
Concrete volume (m3)	10
Surface area (1) (m2)	0
Exposure condition (1)	Indoor (without cover)
Surface area (2) (m2)	0
Exposure condition (2)	Indoor (without cover)
3. Mix design characteristics	
Compressive strength (MPa)	25-35 MPa
Portland cement content (kg/m3)	350
Slag content (kg/m3)	0
Fly ash content (kg/m3)	0
Limestone content (kg/m3)	0
Use phase Carbon uptake (kg CO2)	0

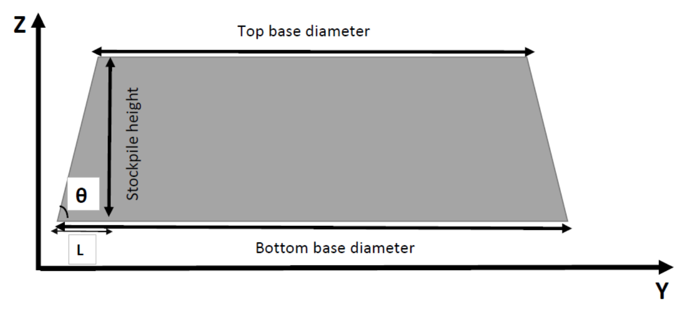
Total Carbon uptake (kg CO_2)	195

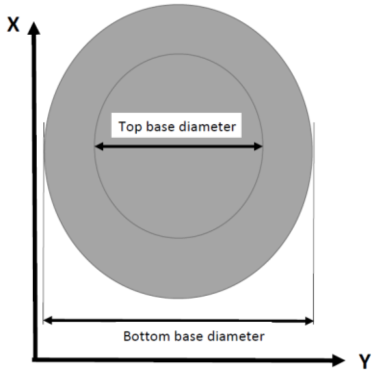
Project-Level Carbonation
MIT Calculator
Factors that Affect Carbon Uptake

- EOL storage conditions affect carbonation
- Size of aggregate pile
- Aggregate grading
- Exposure

End-of-life Carbon Uptake*

Input name	Value (Please fill out all the yellow cells)
Top base diameter (m)	3.4
Bottom base diameter (m)	6.2
Stockpile height (m)	1
Crushed concrete grading	Fine (particles less than 16 mm)
Stockpiling time period (years)	1.5
Slope - θ (degrees)	20
Sheltered from rain?	No
Mass of crushed concrete* (metric ton)	21.15
End-of-life Carbon uptake (kg CO_2)	195

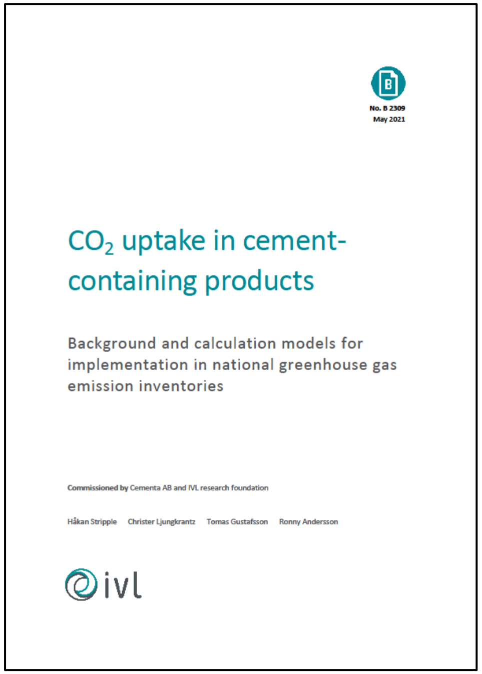




Country-Level Carbonation

CO_2 uptake in cement-containing products

- IVL Report No. B 2309 – Swedish Research Institute, May 2021
- 3 methodologies: Tier 1, Tier 2, Tier 3
- Tier 1 is called "simplified methodology"
- Tiers 2 and 3 require greater effort – more data, analysis, specificity


No. B 2309
May 2021

CO_2 uptake in cement-containing products

Background and calculation models for implementation in national greenhouse gas emission inventories

Commissioned by Cementa AB and IVL research foundation

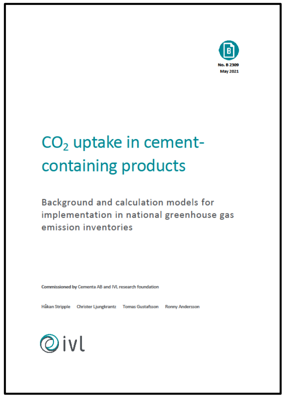
Håkan Stripple Christer Ljungkrantz Tomas Gustafsson Ronny Andersson

ivl

Country-Level Carbonation

CO_2 uptake in cement-containing products

- Tier 1 is used as first estimate
- Provides (conservative) estimates for:
  - – Use stage (existing structures)
  - – End-of-life stage (demo, crushing, stockpiling)
  - – Secondary use (recycling)
- Uptake values related to calcination emissions from annual clinker consumption
  - – (production – export + import)


CO_2 uptake in cement-containing products

Background and calculation models for implementation in national greenhouse gas emission inventories

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B 2309 Tier 1 approach

- CO_2 uptake for existing concrete structures, national basis
- Use annual clinker consumption (20-year average)
- Portland cement maximum theoretical CO_2 uptake = 0.49 kg CO_2/kg cement (BB EN 16757)
- ***Use stage*** estimates 20% uptake (alternative A):
  - 0.20 x (calcination emissions)
- ***EOL and secondary use*** estimate 2% and 1% uptake, respectively:
  - (0.02 + 0.01) x (calcination emissions)

B 2309 Tier 1 approach

- For 10,000,000 metric tons (10 MMT) portland cement production:
  - 0.49 kg CO_2/kg cement (BB EN 16757)
  - 10,000,000 x (0.49) = 4,900,000 kg CO_2
- Use stage (alternative A):
  - 0.20 x (calcination emissions) = 0.20 x 4,900,000 = 980,000 kg CO_2
- EOL and secondary use (3%) = (0.02 + 0.01) x (calcination emissions):
  - 0.03 x 4,900,000 = 147,000 kg CO_2
- 10 MMT of cement absorbs 980,000 + 147,000 = 1,127,000 = 1.13 MMT CO_2
- Or about 11.3% of the calcination emissions *over the life of the concrete made with this amount of cement*

Ongoing/Suggested Research, Data Gaps

- CMHA research will better quantify rate of reaction and total uptake for CMU
- Similar research could benefit other cement-based materials
- As for test methods to quantify uptake, NIST is busy…

Set 6
4 Week

Set 6
13 Week

Set 6
26 Week

NIST LCCCC Work on Carbonation

- Low Carbon Cements and Concretes Consortium, 2022
- Develop traceable & accurate measurement techniques
- Standardized techniques to measure carbon(ate) in cement-based materials
- Inform guides, standards, specifications
- 4 Work Groups:
- WG Quantifying Carbonates
- WG Specifications
- WG Carbon Accounting
- WG Novel Materials, Products, and Processes

Some Current & Potential Test Methods to Quantify Uptake

- Thermogravimetric analysis (TGA)
- Infrared analysis (IR)
- Mass spectrometry of gas liberated
- X-ray diffraction (XRD or XRD + TGA)
- Phenolphthalien (qualitative)
- Furnace or combustion methods
- Fourier transform infrared spectroscopy (FTIR)
- Chemical methods
- X-ray fluorescence (XRF)
- Others

PCA Policy Priorities for Carbonation

- Recognition and validation
  - Establish an accepted method for calculating CO_2 uptake
- Life cycle consideration
  - Recognize and quantify carbonation in whole-life LCAs and sustainable procurement policy
- Research the life cycle carbonation benefits of concrete materials
  - Include end-of-life recycling/treatment

Thank you!

Jamie Farny
Portland Cement Association
jfarny@cement.org