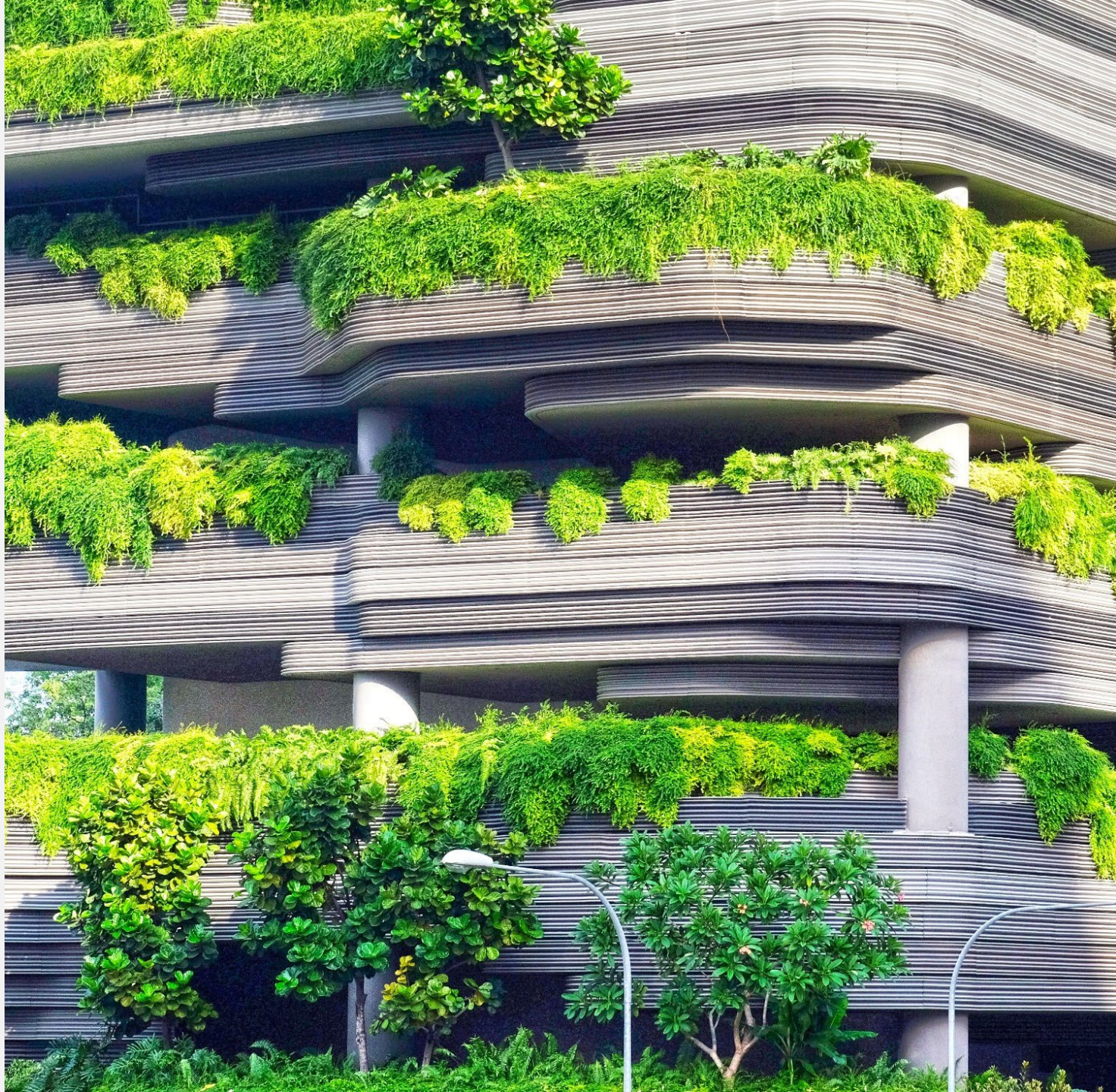
Carbon Utilization in Concrete Manufacturing

SOLIDIA®



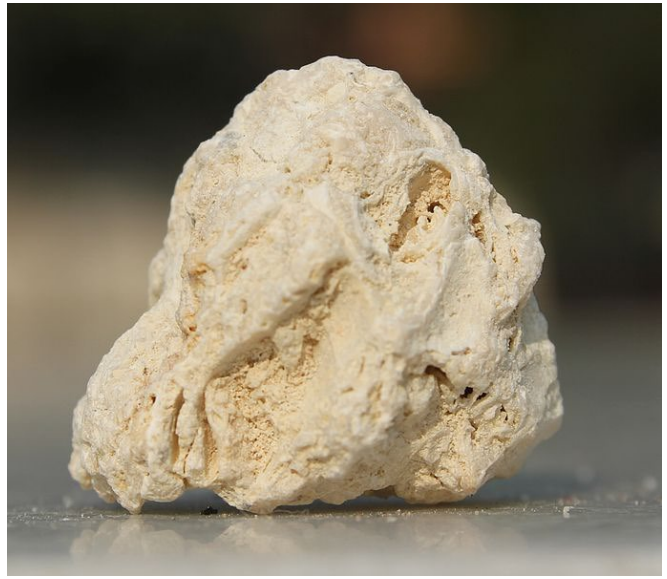
Overview

- Background on cement and concrete production
- Case study of Solidia Cement®
- Broader set of emerging carbon-utilizing concrete technologies

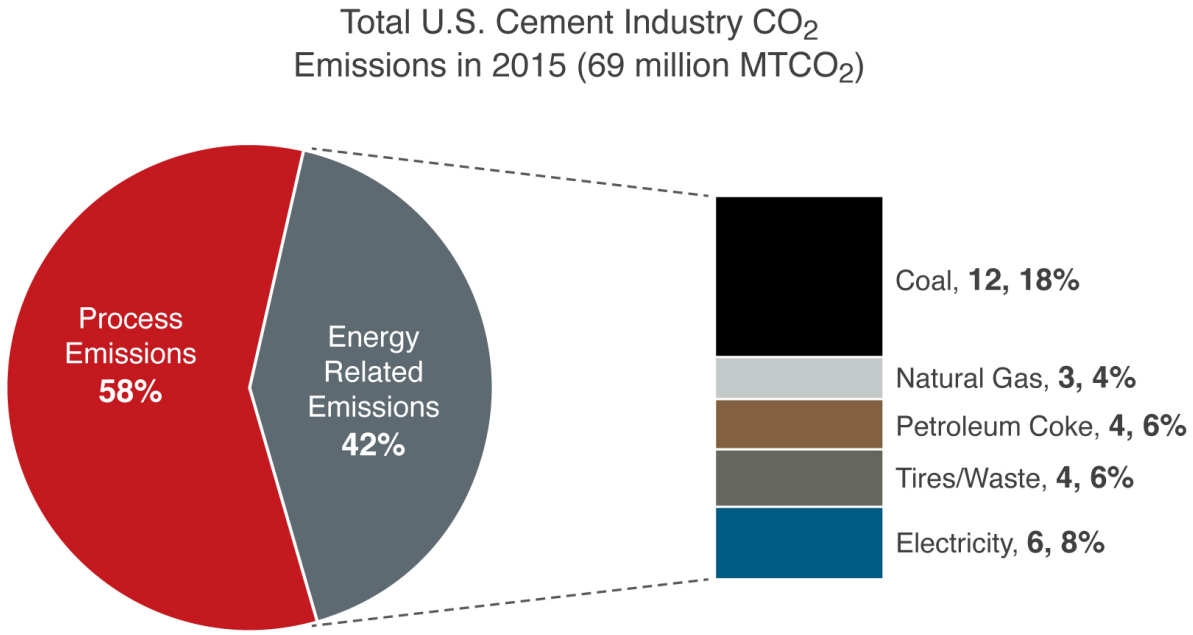
Background -- Portland cement production

Calcination and cement clinker formation

- Limestone and sand or clay heated to 1450 C
- $CaCO_3$ –> $CaO + CO_2$



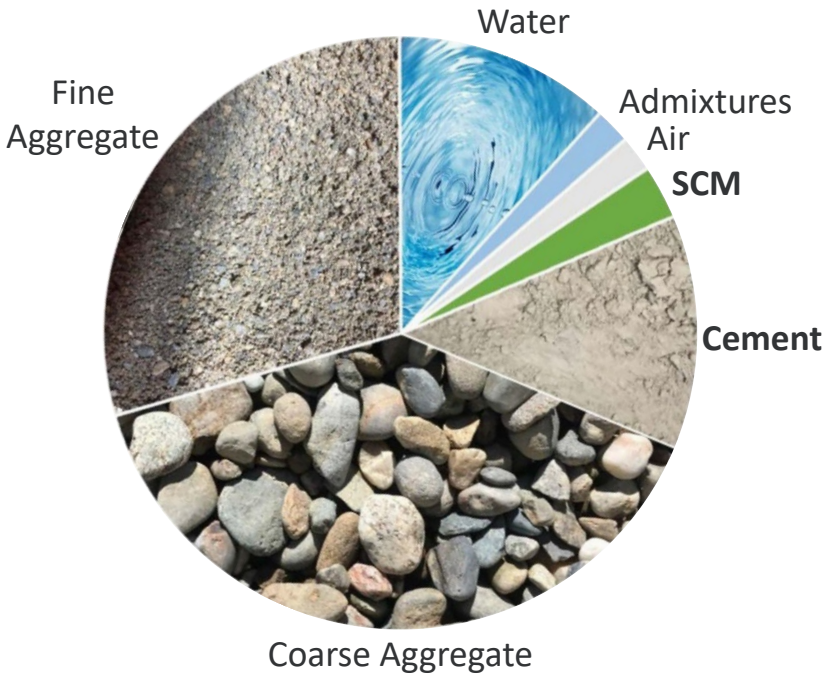
7% of global CO_2 emissions



DOE Industrial Decarbonization Roadmap

September 2022

Background – concrete is made with cement



Ready Mix
(80%)

Dry Cast
(20%)

Portland cement reacts with water

Cement is the primary source of concrete CO_2 emissions

Case study of Solidia Cement

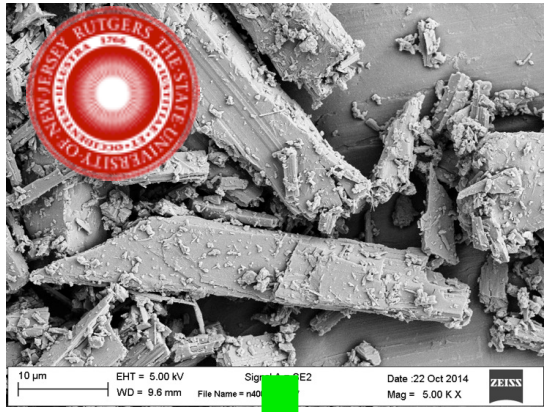
Development of Solidia Cement

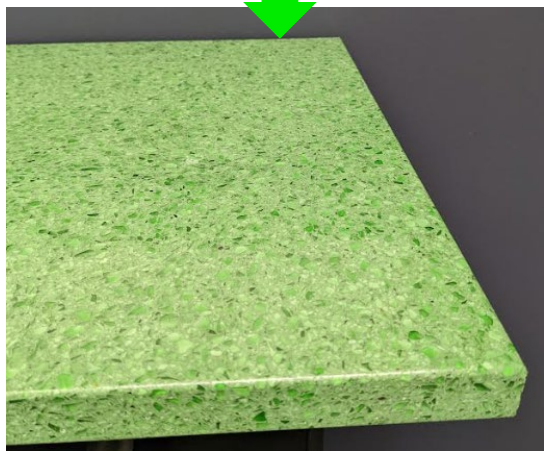
- Natural wollastonite
- Countertops, architectural panels

- Development of synthetic CCSC
- Pilot Kiln Production

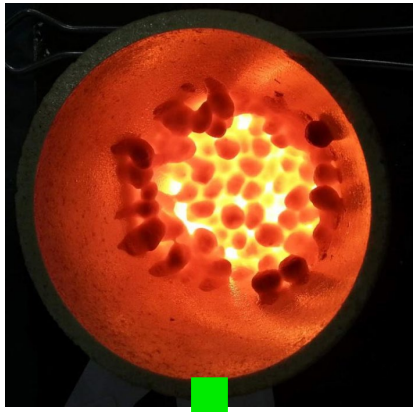
- Pilot & Commercial Clinker Productions
- >15,000t clinker produced

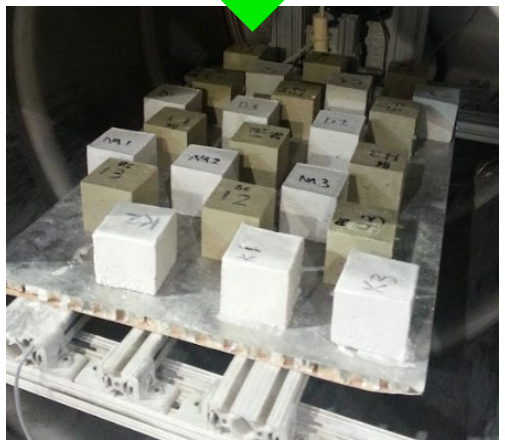
2007 - 2011





2012-2013



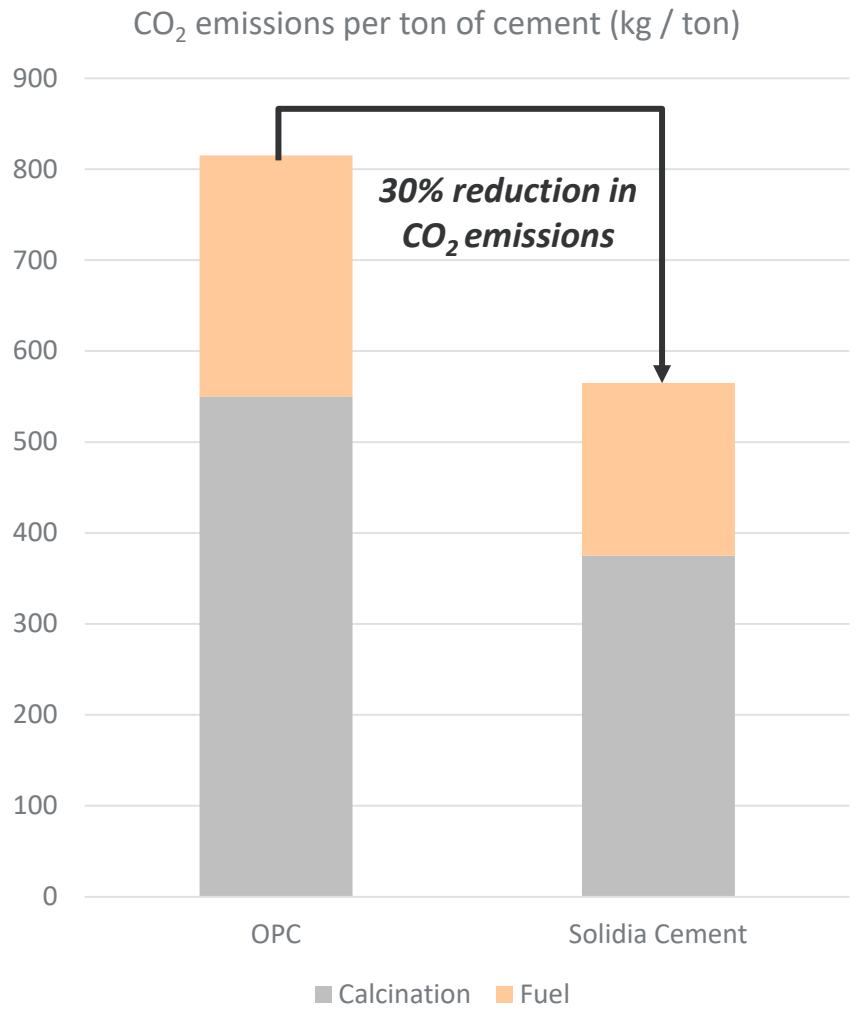


2014 - 2022

Solidia Cement

Less energy, lower CO_2 emissions, lower cost = **a better and more sustainable cement**

	Raw material mix	Kiln reaction	Clinker / Cement
OPC	$5\ CaCO_3 + 2\ SiO_2$	1450 °C	$Ca_3SiO_5 + Ca_2SiO_4 + 5CO_2$
	less limestone	*less energy*	*new chemistry*
Solidia	$CaCO_3 + SiO_2$	1200 °C	$CaSiO_3 + CO_2$
	=	=	=
Impact	***less CO_2 from raw material calcination***	***less CO_2 emission from fuel***	***more cement per ton of raw material***



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Use of Solidia Cement

Solidia Cement + CO_2 → **$CaCO_3$** + SiO_2

Solidia Cement does not react with water

Mineralizes at least 20% of the cement mass in CO_2

Solidia Technologies supply chain – dry cast concrete

Carbon Capture & Utilization Value Chain

Direct air capture

Industrial plant

CO_2

Low-carbon Cement & Concrete Value Chain

Cement plant

↓ calcination CO_2

↓ thermal CO_2

Solidia Cement

Non-hydraulic cement

Solidia Concrete™

Dry cast concrete plant

SOLIDIA®

Solidia Concrete for dry cast applications

S-CEM™ + CO_2 → **$CaCO_3$** + SiO_2

binder **amorphous**

- Reacts and hardens with CO_2 (vs. OPC with water)
- Process and product performance advantages
- Industrial CO_2 capture, utilization and storage (CCUS) opportunity
- Commercialized in NY tri-state region; expanding into TX triangle
- Completed 30+ trials with dry cast plants across 12 EU countries

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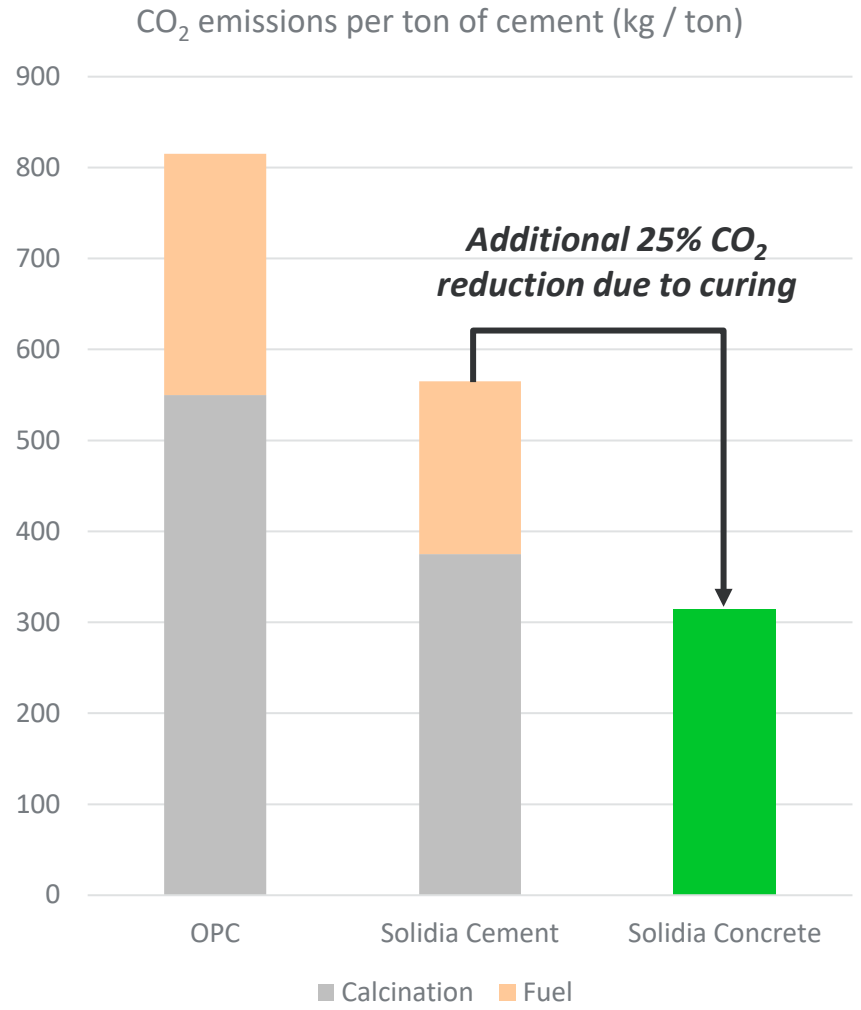
HOLCIM

EP HENRY

CO_2 delivery system at paver plant
Wrightstown, NJ

Solidia paver installation
Princeton, NJ



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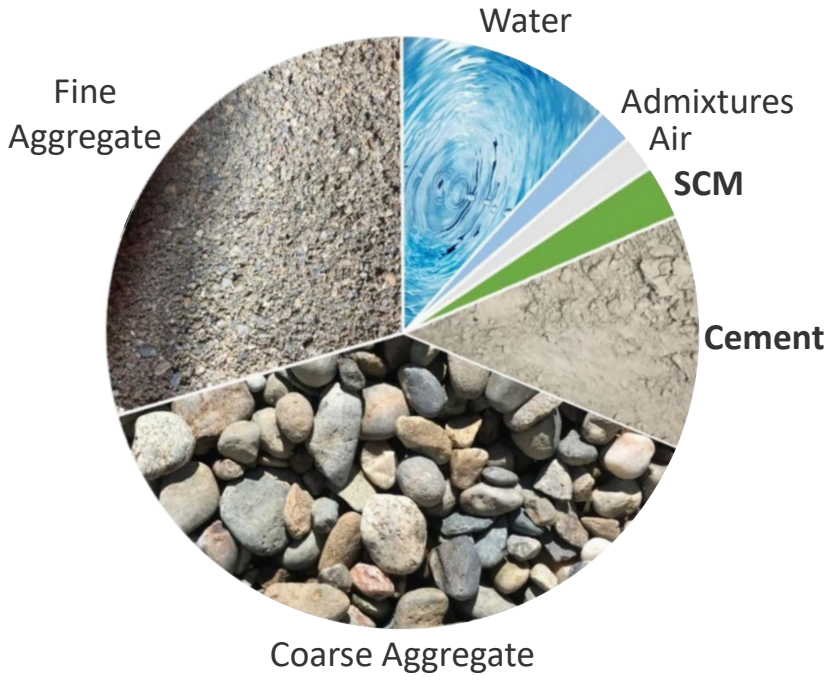
Background -- supplementary cementitious materials (SCM)

- Typically fly ash
- Enhance concrete function
- Reduce cement fraction of concrete
- Reduce CO_2 emissions associated with concrete



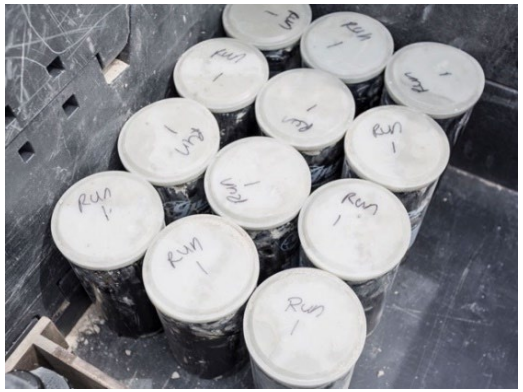
Solidia SCM™

Amorphous SiO_2 – reactive at room temperature with calcium hydroxide produced during OPC hydration

S-CEM™ + CO_2 → $CaCO_3$ + **SiO_2**

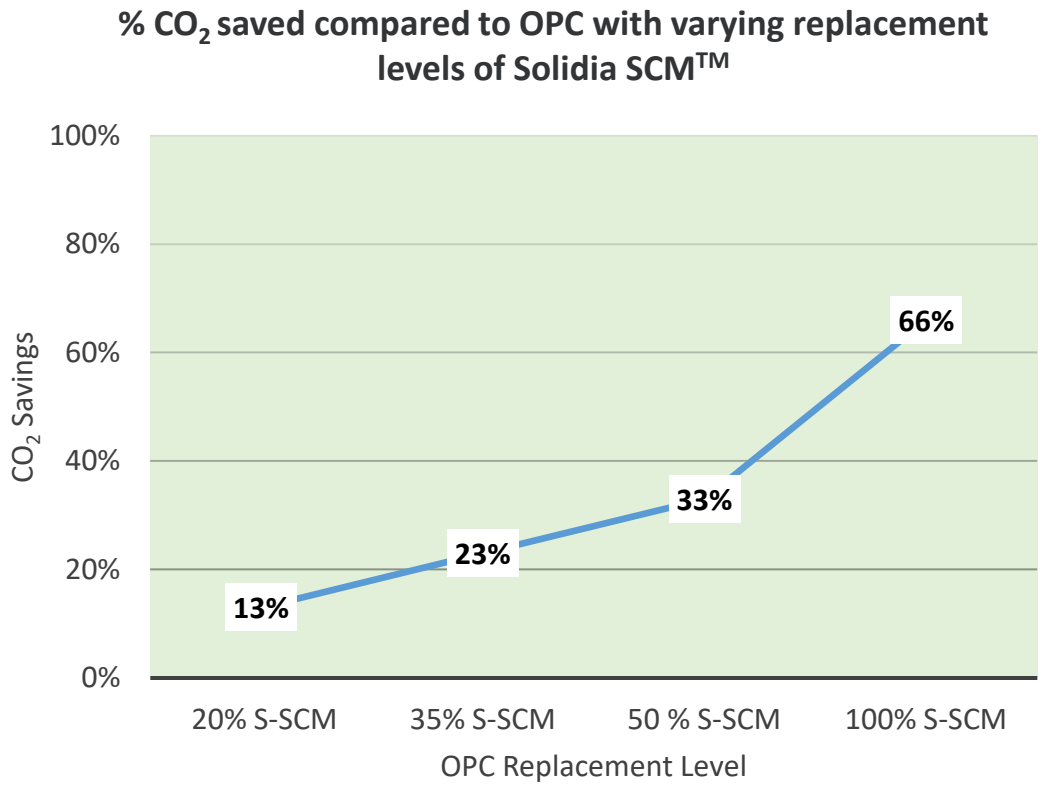
Solidia SCM™

- A functional filler for concrete
- Engineered to meet demand
- Blends with OPC; up to 35% replacement
- Product performance advantages
- Eliminates quality issues
- Can be manufactured locally anywhere



Sample cylinders for testing
Bethlehem, PA

Trial pour w/ 35% S-SCM replacement
Bethlehem, PA



*includes CO_2 emissions reduction at kiln + CO_2 mineralized during carbonation

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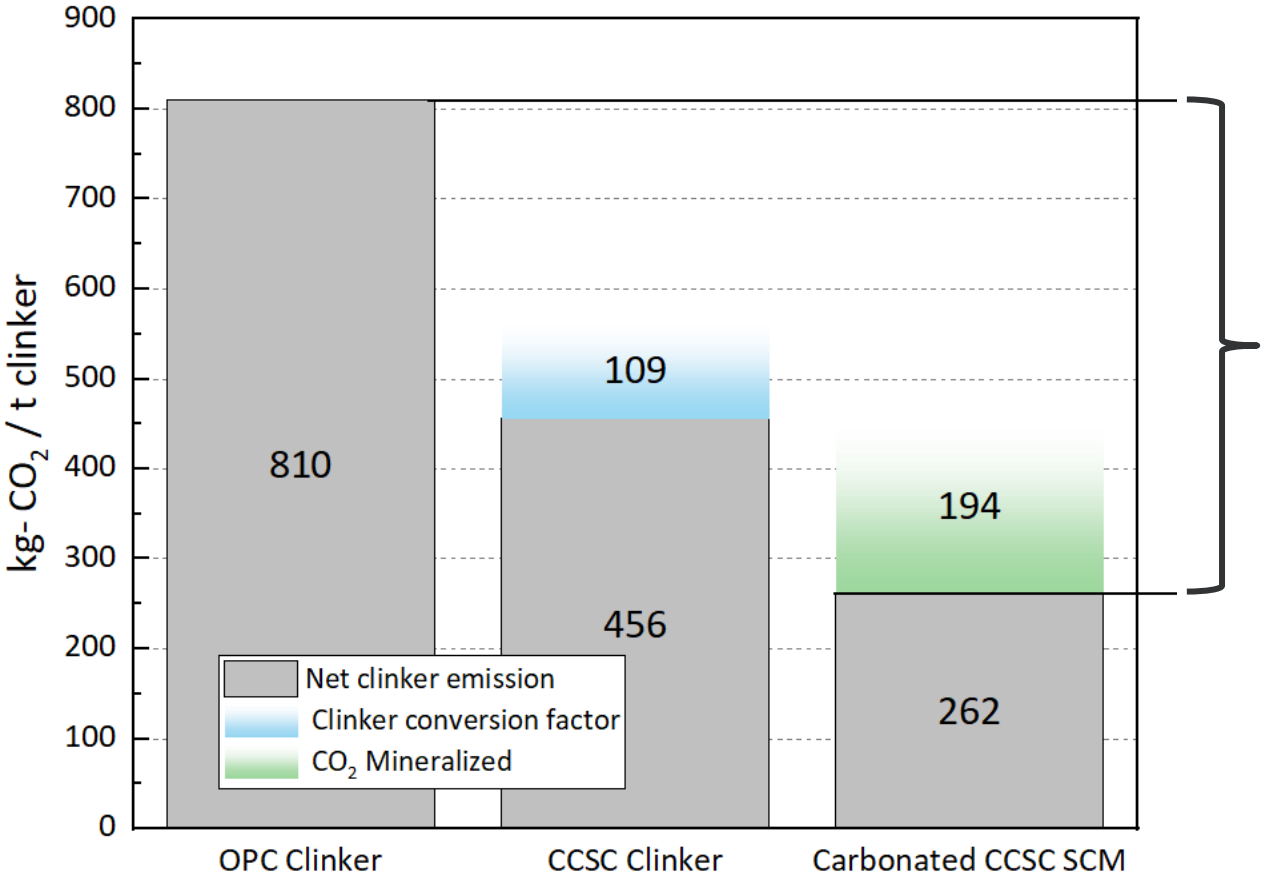
CO_2 impact in carbonated SCM

- Up to 68% reduction in footprint compared to OPC clinker
- High potential for use of waste gas, or direct utilization of flue gas



-511 kg-CO_2 / t clinker
(68% Reduction)

- **109 kg-CO_2 / t clinker Abated**
  - 0.81 t CCSC Clinker = 1.0t Carbonated CCSC SCM
- **194 kg-CO_2 / t clinker Mineralized**
  - >24% mass of CCSC mineralized

Solidia Technologies supply chain – Solidia SCM™

Low-carbon Cement & Concrete Value Chain

Cement plant

↓ calcination CO_2

↓ thermal CO_2

CO_2

Active functional, synthetic pozzolan

Solidia SCM™

Solidia Cement™

Non-hydraulic cement

Ready-mix concrete

SOLIDIA®

Solidia solutions

CO_2 abatement through emissions reduction and CCUS in cement and concrete manufacturing

Solidia Cement

Reduce CO_2 emissions

- ↓ process CO_2 (thermal)
- ↓ product CO_2 (calcination)

Solidia Concrete

Capture CO_2 gas

- mineralize and store CO_2 as calcium carbonate

Solidia SCM

Avoid high embodied CO_2

- replace Portland cement

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Current State of Development

Building commercial concrete plant

Solidia Technologies To Open Commercial Manufacturing Facility for Dry-Cast Concrete Products

53,000-square-foot plant will leverage Solidia's groundbreaking technology to produce pavers and concrete masonry units with premium performance capabilities compared to traditional materials.

SAN ANTONIO, TEXAS, May 16, 2023 — Solidia Technologies™, a leading provider of decarbonization technologies and sustainable, high-performance construction and building material solutions, has announced its first concrete products manufacturing plant. The plant will utilize an existing 53,000-square-foot building on rail-served acreage located at Alamo Junction in Elmendorf, Texas, near Solidia's headquarters in San Antonio. The wholly owned commercial dry-cast facility will manufacture pavers and concrete products using Solidia Cement®, a pioneering technology that solves crucial pain points for architects and contractors, including by providing greater strength and superior aesthetics, while dramatically reducing cement's carbon footprint.

1,000 ton/yr SCM pilot

Solidia Technologies Expands SCM Capabilities, Capacity at San Antonio, Texas, Headquarters

With increased production capabilities, the facility marks a crucial milestone in the company's progress with Supplementary Cementitious Materials from R&D to commercial venture.

SAN ANTONIO, TEXAS, March 21, 2023 — Solidia Technologies®, a leading provider of decarbonization technologies and sustainable solutions to the construction and building materials industries, is expanding production capacity of its proprietary Supplementary Cementitious Material (SCM), a key component used in concrete, at its headquarters in San Antonio, Texas. Solidia's high-performing, engineered SCM product improves the durability, workability, and overall properties of concrete while mineralizing captured CO_2 to reduce greenhouse gas emissions by 30% to 40%. With significantly more production capacity and proximity to key customers, suppliers, and partners, the expansion continues the company's move from research and development into commercialization.

ASTM specifications for Cements that Require Carbonation Curing

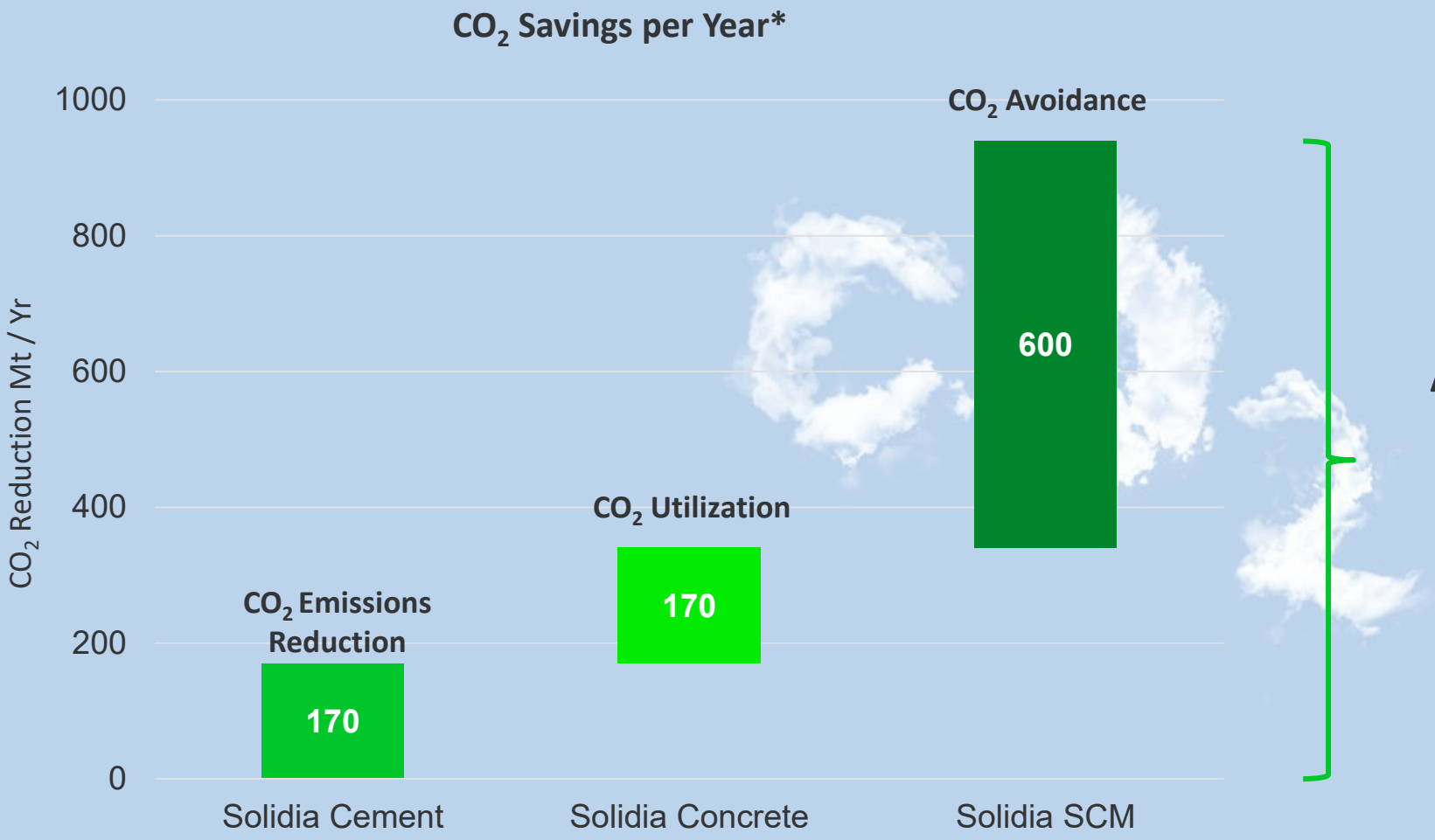
Designation: C1905/C1905M – 23

Standard Specification for
Cements that Require Carbonation Curing

Designation: C1910/C1910M – 23

Standard Test Methods for
Cements that Require Carbonation Curing

Solidia CO_2 impact on a global scale



At scale, the potential total CO_2 savings from Solidia technologies approaches 1 Gt each year*

**0.94 Gt assumes full-market conversion across the 2020 4Gt estimated global OPC market.*

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Technoeconomic analysis

- Production of Solidia Concrete from Solidia Cement and CO2 is market-proven to be profitable
- Solidia SCM production from Solidia Cement and CO2 from waste kiln flue gas is expected to be profitable
- General availability of incentives
  - 45Q tax credit of $60/Mt for capture of CO2 for utilization in a process that chemically converts to a compound in which such CO2 is securely stored
  - 48C tax credit for 30% of the cost to re-equip a facility with equipment that reduces GHG emissions by at least 20%
  - Federal Buy Clean Initiative
  - State incentives
  - Voluntary market for carbon removal

Broader set of emerging carbon-utilizing concrete technologies

Carbon utilization in concrete manufacturing

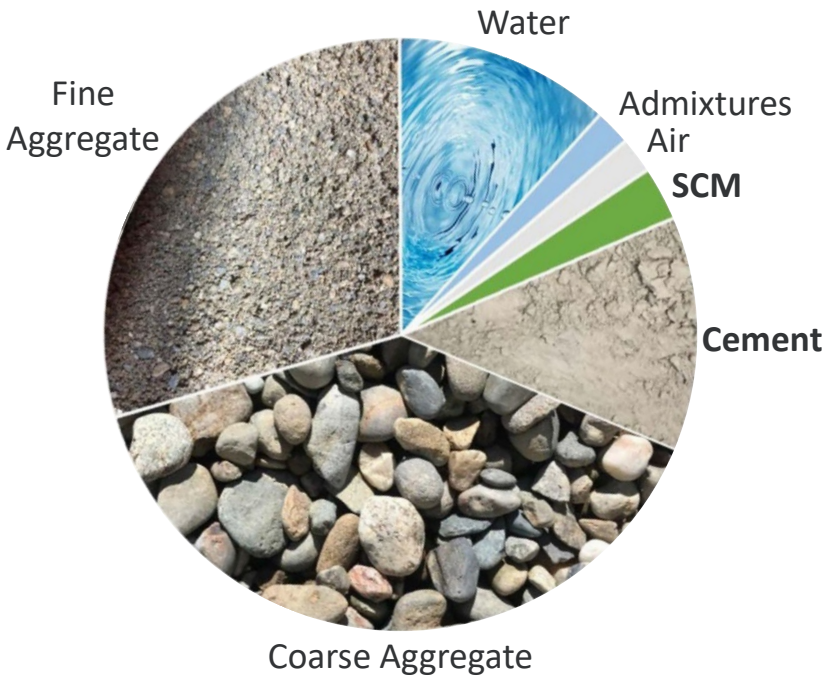
Many places to play/many participants

- Annual global concrete production ~ 34 billion MT
- Annual global CO2 emissions from energy combustion and industrial processes ~37 billion MT

carbon8

Blue Planet

HOLCIM



carbon upcycling

Heidelberg Materials

FORTERA

SOLIDIA®

CARBON CURE

CARBONBUILT

Solidia partners

Government

U.S. DOE
- SCM Development
- Five-year program on CO_2 storage
- Support for commercialization in US

U.S. Environmental Protection Agency (EPA)
- Incorporation of Solidia Cement and SCMs

U.S. Department of Transportation (DOT)
- Examine transportation infrastructure applications

Climate Change and Emissions Management Corporation (CCEMC)
- Support for commercialization in Alberta, Canada

EU Life
- Solid Life Project: Scaling and testing of Solidia Cement & Precast

Academia

Oregon State University
- Mechanisms of carbonation curing

Georgia Tech
- Solidia SCM™ performance

Purdue University
- Solidia Concrete™ microstructure & durability

University of South Florida
- Corrosions of steel rebar in Solidia Concrete

Ohio University
- Methods to passivate raw surface of steel rebar

Rutgers, The State University of New Jersey
- Solidia Concrete cast-in-place applications
- Solidia Cement™ synthesis