U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

AMMTO & IEDO JOINT PEER REVIEW

May 16th-18th, 2023

Washington, D.C.

An Innovative Process for the Direct Utilization of CO_2 in Solid Synthetic Pozzolan Production | IEDO

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Project Overview

- A scalable process to manufacture an engineered, low-carbon pozzolan that can be used as a partial Portland cement replacement in concrete to reduce the U.S. cement industry's massive CO_2 footprint

Energy, Emissions, & Environment:

- Reduce CO_2 footprint associated with Portland cement production and use by 60% or more
- Use and store anthropogenic CO_2

Cost & Competitiveness:

- Lower cost to produce than Portland cement
- Target price between fly ash (coal power plant by-product) and slag (iron & steel-making by-product)
- Comparable / superior performance to traditional SCMs

Technical & Scientific:

- At least 15 wt% CO_2 uptake in under 12 hours
- Meet basic concrete performance per ASTM tests (e.g., strength activity index, water demand, ASR)
- No meaningful effects of CO_2 concentration and impurities on process and SCM performance

Other Impacts:

- Leverage existing supply chain (e.g., feedstock), assets (e.g., cement kiln), and waste streams (e.g., cement kiln flue gas)
- Minimal disruption to cement plant operations and raw material change cost

Project Outline

Innovation: An innovative process for direct utilization of CO_2 in solid synthetic pozzolan production

Project Lead: Solidia Technologies, Inc.

Timeline: July 1, 2021 - March 31, 2023 (100% complete)

Budget:

	Budget Period 1			Budget Period 2				Total Planned Funding
	FY21	FY22				FY23		
	Jul - Sep	*Oct - Dec*	*Jan - Mar*	*Apr - Jun*	*Jul - Sep*	*Oct - Dec*	*Jan - Mar*	
DOE Funded	$ 249,415	$ 133,582	$ 266,803	$ 215,777	$ 587,731	$ 345,459	$ 268,391	$ 2,100,000
Solidia Cost Share	$ 63,135	$ 33,814	$ 67,537	$ 54,620	$ 148,774	$ 87,447	$ 67,939	$ 532,626

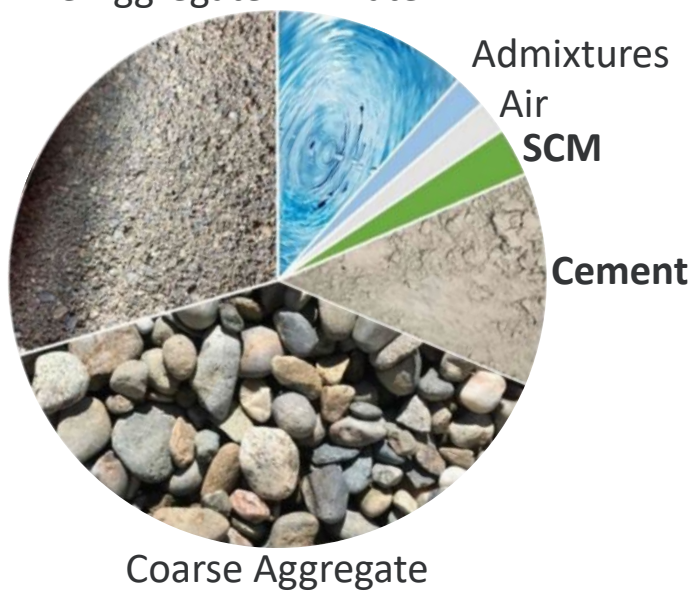
End Project Goal:

1. Develop a process for producing a solid synthetic pozzolan through direct capture, utilization, and storage of CO_2 from the flue gas stream of an operating cement plant through reaction with Solidia Cement®, a non-hydraulic cement, without any disruption to the clinker production process
2. Use the carbonated Solidia Cement as a supplementary cementitious material (SCM) in concrete with comparable or superior performance to concrete with traditional SCMs such as fly ash and slag cement

Background

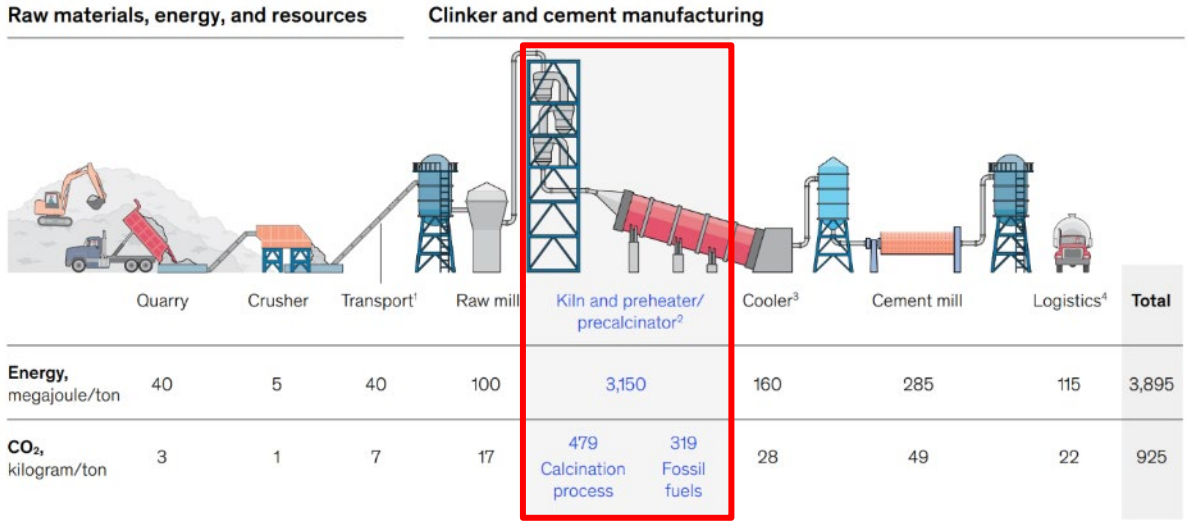
Concrete is the most consumed man-made material

>85% of CO_2 emissions from manufacturing



Ready Mix
(80%)

Dry Cast
(20%)



[1]Assumed with 1kWh/t/100m.
[2]Assumed global average, data from the Global Cement and Concrete Association, Getting the Numbers Right 2017.
[3]Assumed reciprocating grate cooler with 5kWh/t clinker.
[4]Assumed lorry transportation for average 200km.

8% of global CO_2 emissions

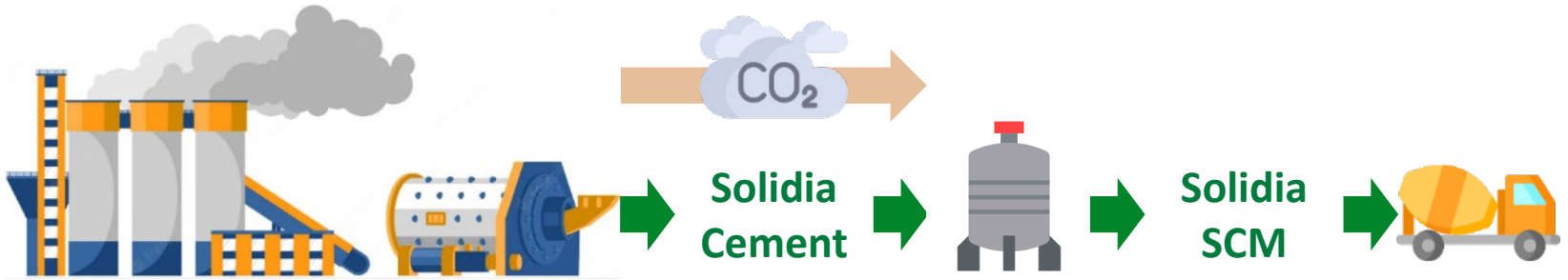
Sources: McKinsey & Company, CleanTechnica, ClimateWatch, Global Cement and Concrete Association

Strategic Approach

REDUCE CO_2 Emissions

USE & STORE Waste CO_2

AVOID high embodied CO_2



Cement Plant

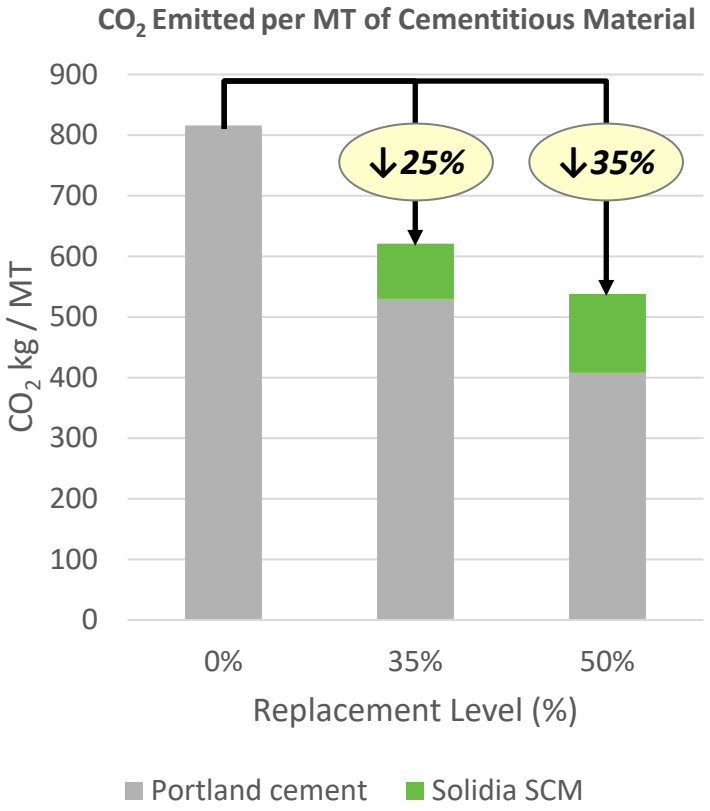
↓ *calcination* CO_2

↓ *thermal* CO_2

SCM Processing

Active functional, synthetic pozzolan

Concrete



Strategic Approach

Fundamental Process Development

Carbonation

- Examined 7 methods for maximum CO_2 uptake with minimum residence time
- Used scanning electron microscope (SEM) to characterize composition and microstructure
- Determined effect of composition, microstructure, and CO_2 uptake on pozzolanic activity

Flue Gas Utilization

- Used thermodynamic computations (e.g., OLI, PHREEQC) to determine effects of impurities in cement kiln flue gas
- Studied effects of CO_2 and SO_2 concentration with simulated flue gas

Product Performance Validation (per ASTM)

Workability

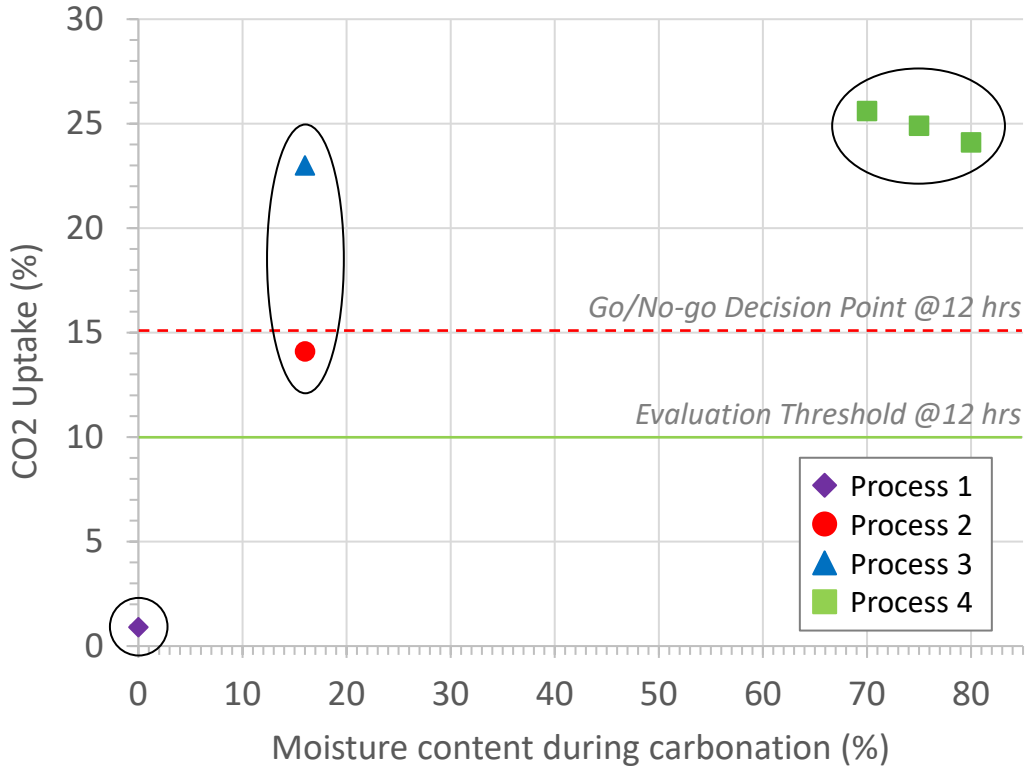
- Third-party lab mortar and concrete tests with varying concrete mix design and replacement levels to evaluate:
  - Slump and slump loss
  - Water demand for placement

Strength & Durability

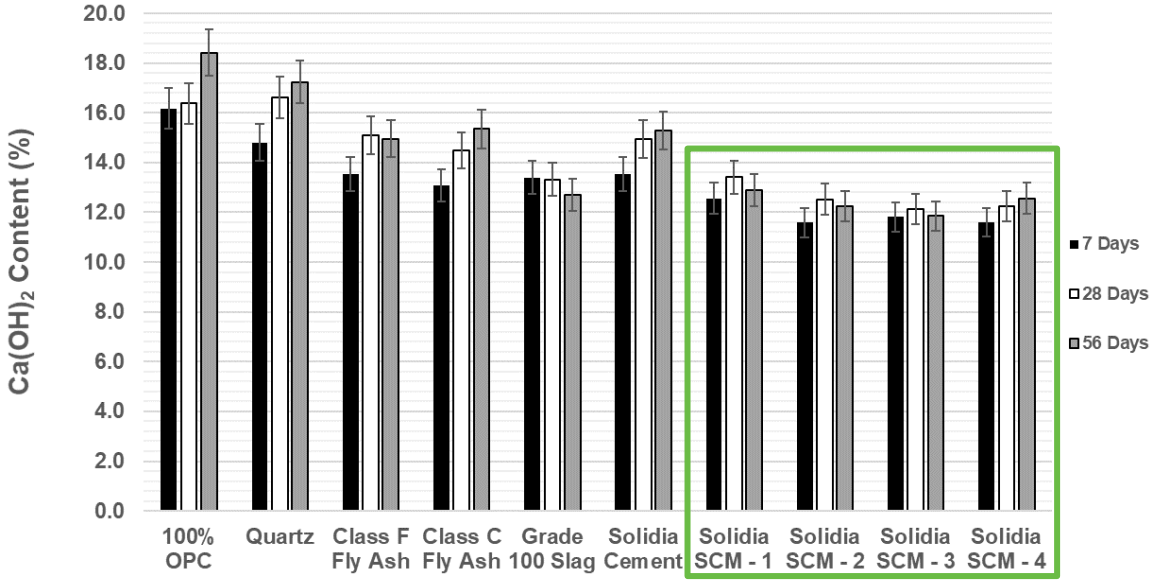
- Third-party lab mortar and concrete tests with varying concrete mix design and replacement levels to evaluate:
  - Compressive strength
  - Strength activity index (SAI)
  - Alkali silica reactivity (ASR)

Results and Achievements

Two methods meet CO_2 uptake and time thresholds



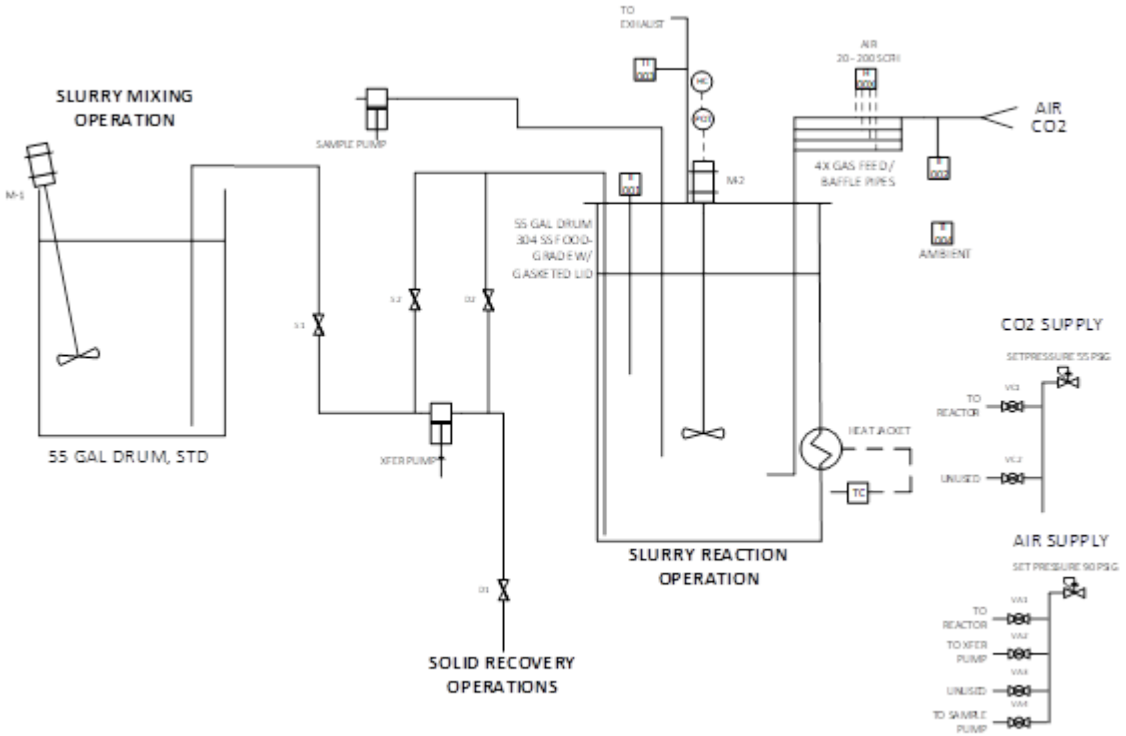
The resulting product has high pozzolanic activity



Lower $Ca(OH)_2$ content = higher consumption

Results and Achievements

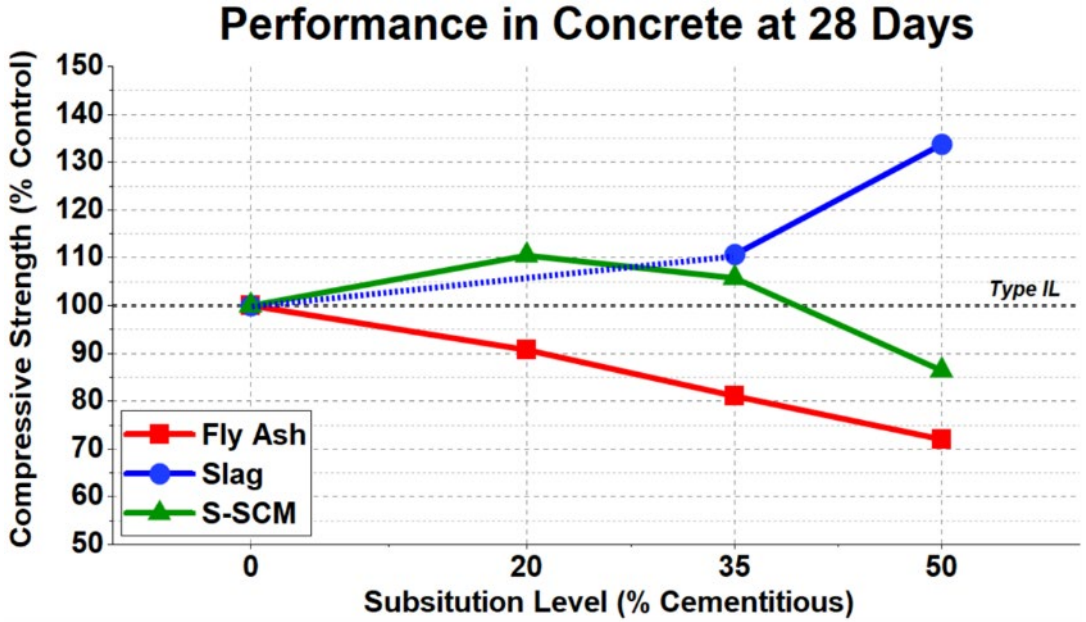
Designed a slurry reactor



Built the batch reactor

Results and Achievements

Comparable performance to traditional SCMs



Type IL Cement
Lean mix 460 lbs/yd^3
Concrete W/C = 0.45
Slump target 6 ± 1 inch

Compressive Strength of Control
1 day : 2500 psi
7 days: 4390 psi
28 days 4860 psi

Confidence following suite of ASTM tests

- ASTM C1567: Alkali-Silica Reactivity (ASR) ☑
- ASTM C1202: Chloride Permeability ☑
- ASTM C1157 & C595: Sulfate Expansion ☑

Future Work, Technology Transfer, & Impact

Future Work:

- Commission large lab line at HQ to produce 1,000 MT per year of Solidia SCM to seed market (material qualification and trial pours with DOTs and ready-mix producers)

Technology Transfer:

- Build pilot line at a cement kiln for direct utilization of flue gas CO_2 to produce and deliver Solidia SCM into the market
- Extend technology application to waste streams to reduce CO_2 footprint and expand market access (remove supply chain constraints)

Impact:

- Grant provided access to critical resources (people, equipment, labs) necessary to conduct experiments, measure impact, and develop repeatable process and product
- Accelerated development to prove viability and instilled confidence in next phases of investment

Questions?

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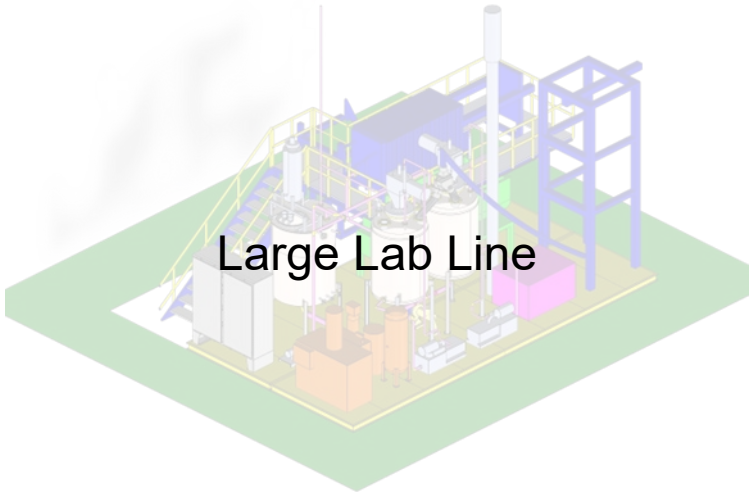

Pilot Line