Resource Assessment of Industrial Wastes for CO_2 Mineralization

FECM 24 (08/08/2024)

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UNIVERSITY OF NORTH DAKOTA
COLLEGE OF ENGINEERING & MINES

PROJECT PARTICIPANTS

University of North Dakota

- College of Engineering and Mines Research Center
- Dept. of Civil Engineering
- Dept. of Geography
- Dept. of Chemical Engineering

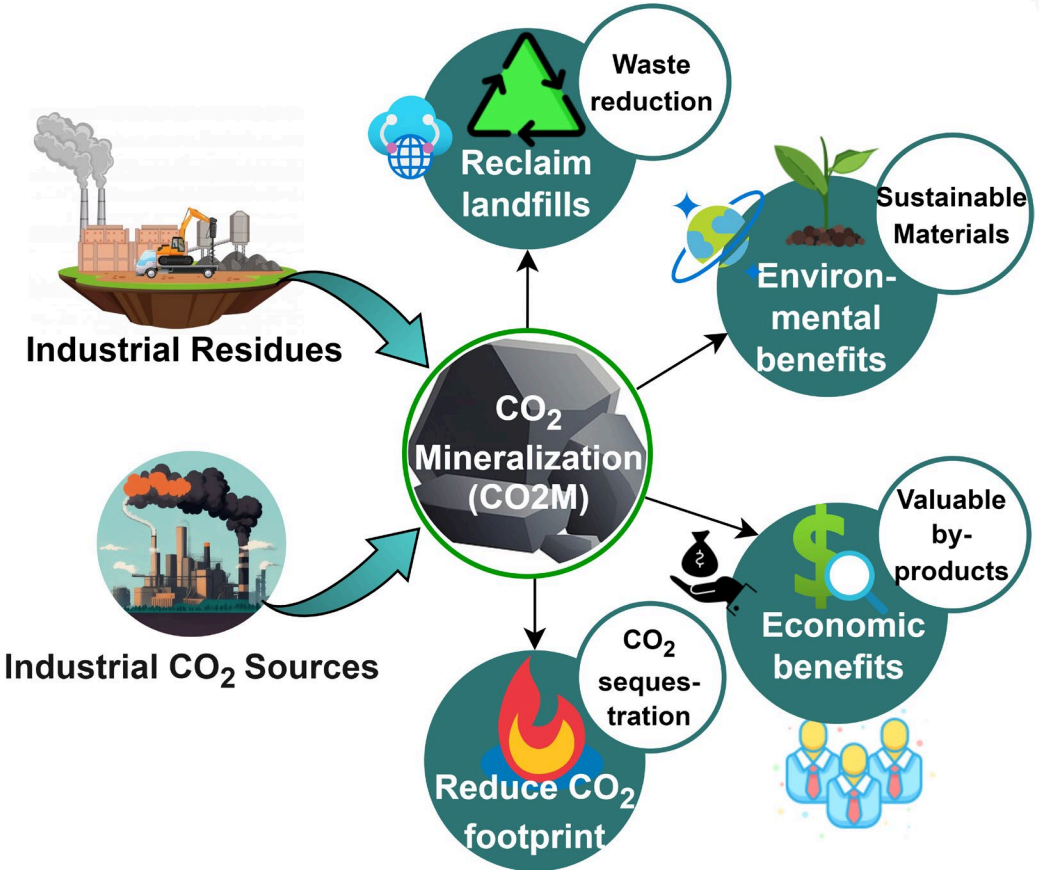
Envergex, LLC (Sub-recipient)

Industry Supporters – Residue Providers

PROJECT OBJECTIVES

Identify & quantify usable resources for CO_2 capture

- Map resource locations
- Develop CO_2 Mineralization (CO2M) processes
- Tap into existing infrastructure (CO_2 resources)
- Beneficiate residues to products (identify users)
- Quantify process viability environmental & economic benefits/disadvantages



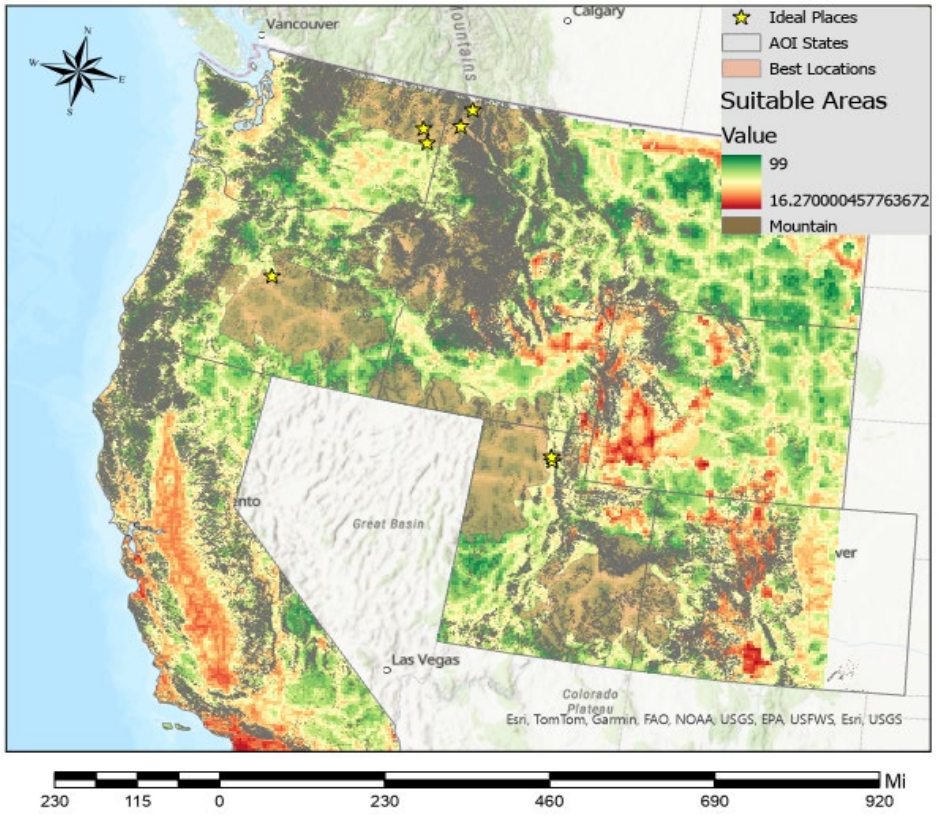
ASSESSING CO2M VIABILITY, BENEFITS & DISADVANTAGES

Analogy: Integrating Spatial, Network & Suitability Analysis to find an idyllic town in Western U.S.

- Suitability parameters and criteria
  - Climate 28%
  - Light Pollution 13%
  - Earthquakes 10%
  - Mountains 16%
  - Hospitals 15%
  - Roads 18%
- Adjustable weighting

Similarly – assess best U.S. CO2M opportunities

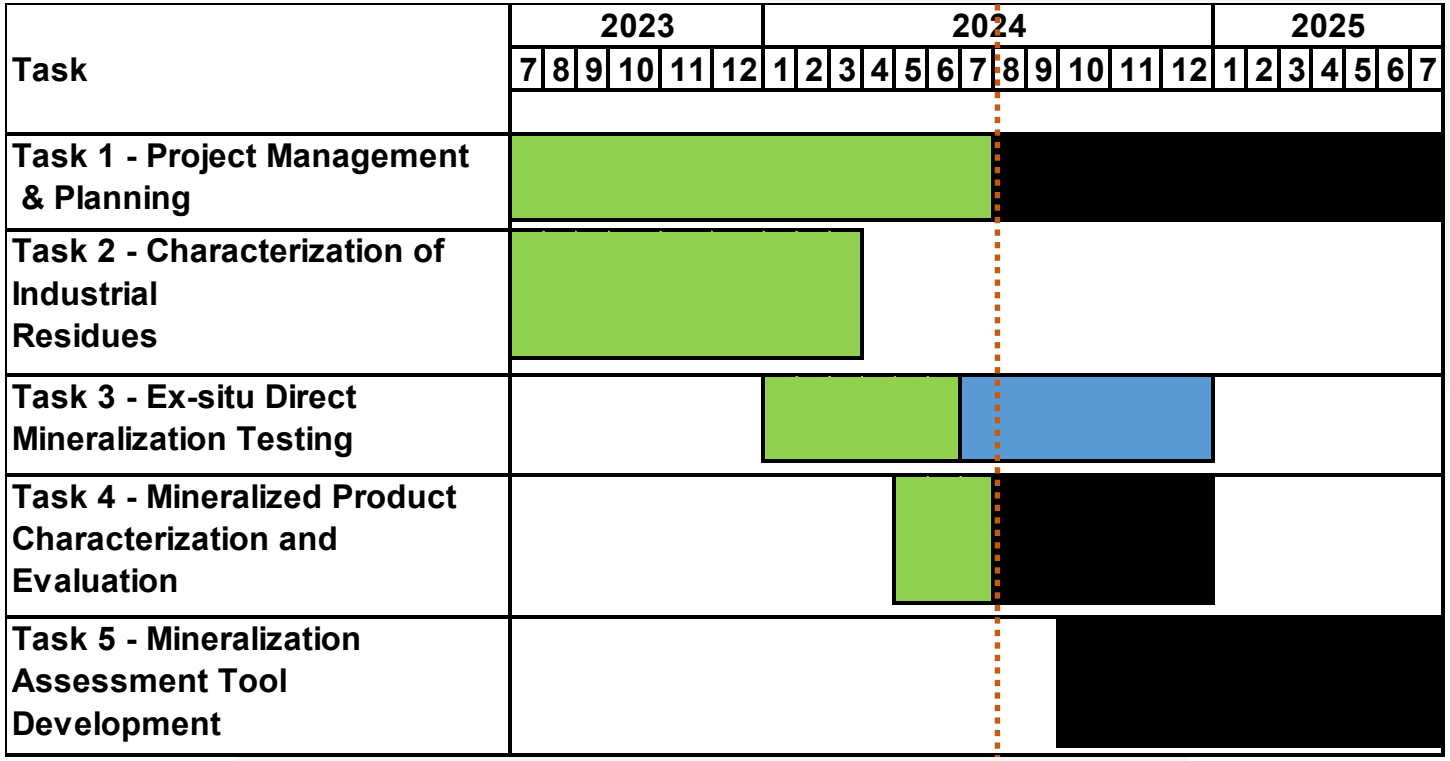
- Base on: resources, quantities, CO_2 capacity, sociodemographic factors, infrastructure, etc.



Example: Map of beautiful places in Western U.S.

PROJECT PERFORMANCE DATES

- Milestones & deliverables for each task
- Project update reports through quarterlies and final project report
- Current progress:
  - Task 3/4 in progress



Task/Subtask No.	Deliverable Title
1.1	Project Management Plan
1.2	Community Benefits Plan
4	Mineralization Results Report & Data
5	Resource Assessment Tool & User Manual

FUNDING SUMMARY

- DOE & North Dakota Industrial Commission (NDIC) Project
- DOE Funding & NDIC Cost Share
- NDIC: “Assessment of Lignite-Based Industrial Residues for Value-Added Product Creation through CO_2 Mineralization”
- National- & State-wide focus

Project	DOE	NDIC
Objective	Assess viability of using industrial wastes for CO_2 mineralization	Assess viability of beneficiating lignite-based residues using mineralization
Goal	Identify & quantify industrial residues applicable for CO_2 capture	Identify & quantify as well as remove contaminants hindering residue use as construction replacement material
Duration	• 24-months	
Budget	$ 1,000,000	$ 250,000 (cost-share)

ADVANCING DOE PROGRAM GOALS

Enabling CO_2 Mineralization using Industrial Residues

- CO_2 Mineralization Potential
  - No single sufficient resource
  - Funding opportunity goal: 20 MMT CO_2 capture/y
  - Industrial residues → Potential reactive minerals
  - Can reduce residues & liabilities
  - Enhancing material value

BACKGROUND

Heterogeneity Challenge

- Variability in properties, locations, & availability of residues
- Necessitates database & assessment tool/benchmark
- No two processes alike

Industry Needs

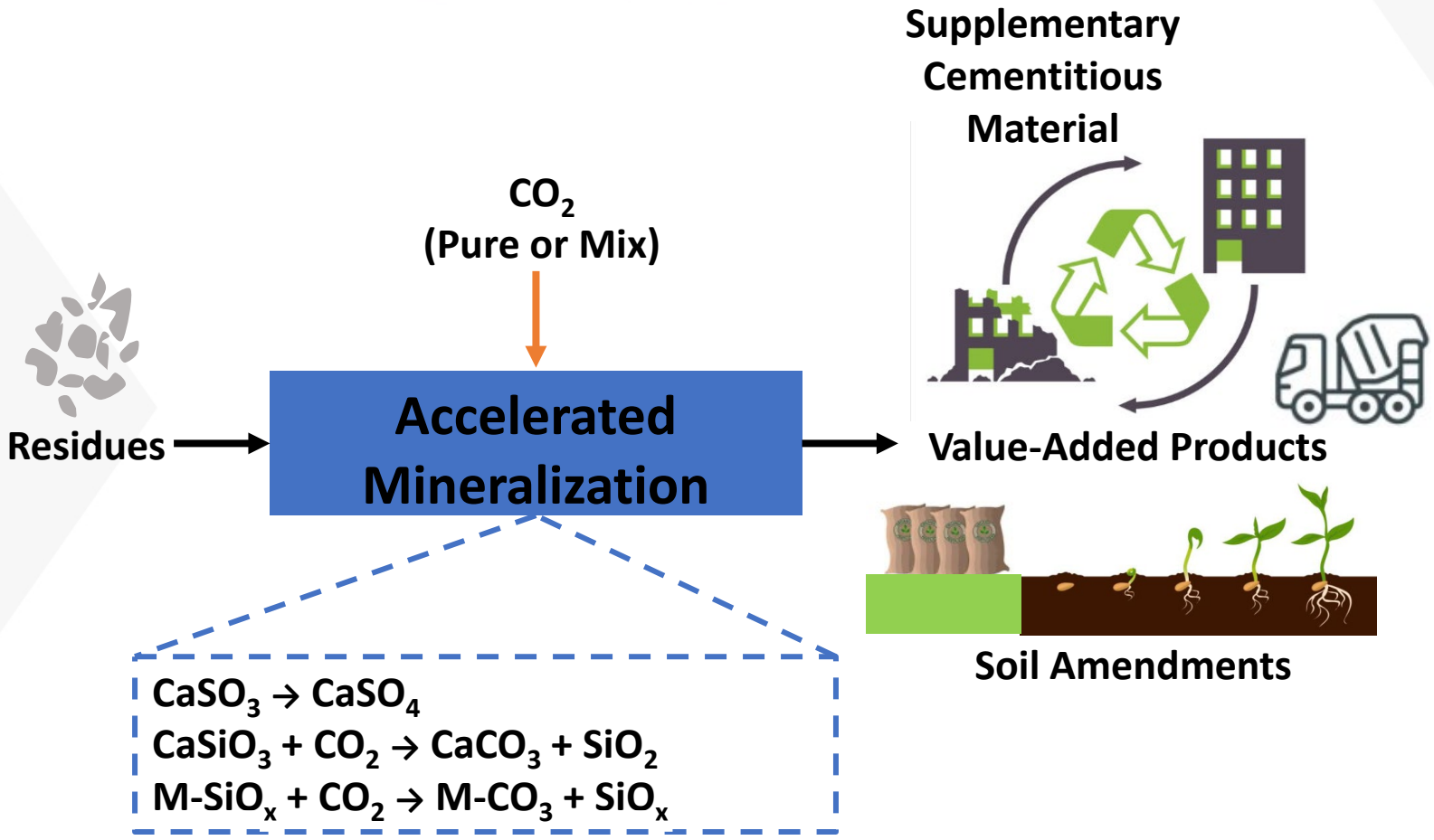
- R&D tools
- CO_2 mineralization strategies
  - When and where to use

Studied Residues

TECHNICAL APPROACH

CO_2 Mineralization (CO2M)

- Carbonation advantage: Captured CO_2 does not require deep geologic disposal
- Nature's example: Weathering reactions
- But, kinetic & mass transfer limitations
- Processes impractical for ex-situ point-source capture



PROJECT STRUCTURE

Task 1.0 - Project Management and Planning

- Subtask 1.1 - Project management plan (PMP)
- Subtask 1.2 - Community benefits plan (CBP)

Task 2.0 - Characterization of Industrial Residues

- Subtask 2.1 - Residue Procurement
- Subtask 2.2 - Residue Characterization

Task 3.0 - Ex-situ Direct Mineralization Testing

PROJECT STRUCTURE

Task 4.0 - Mineralized Product Characterization and Evaluation

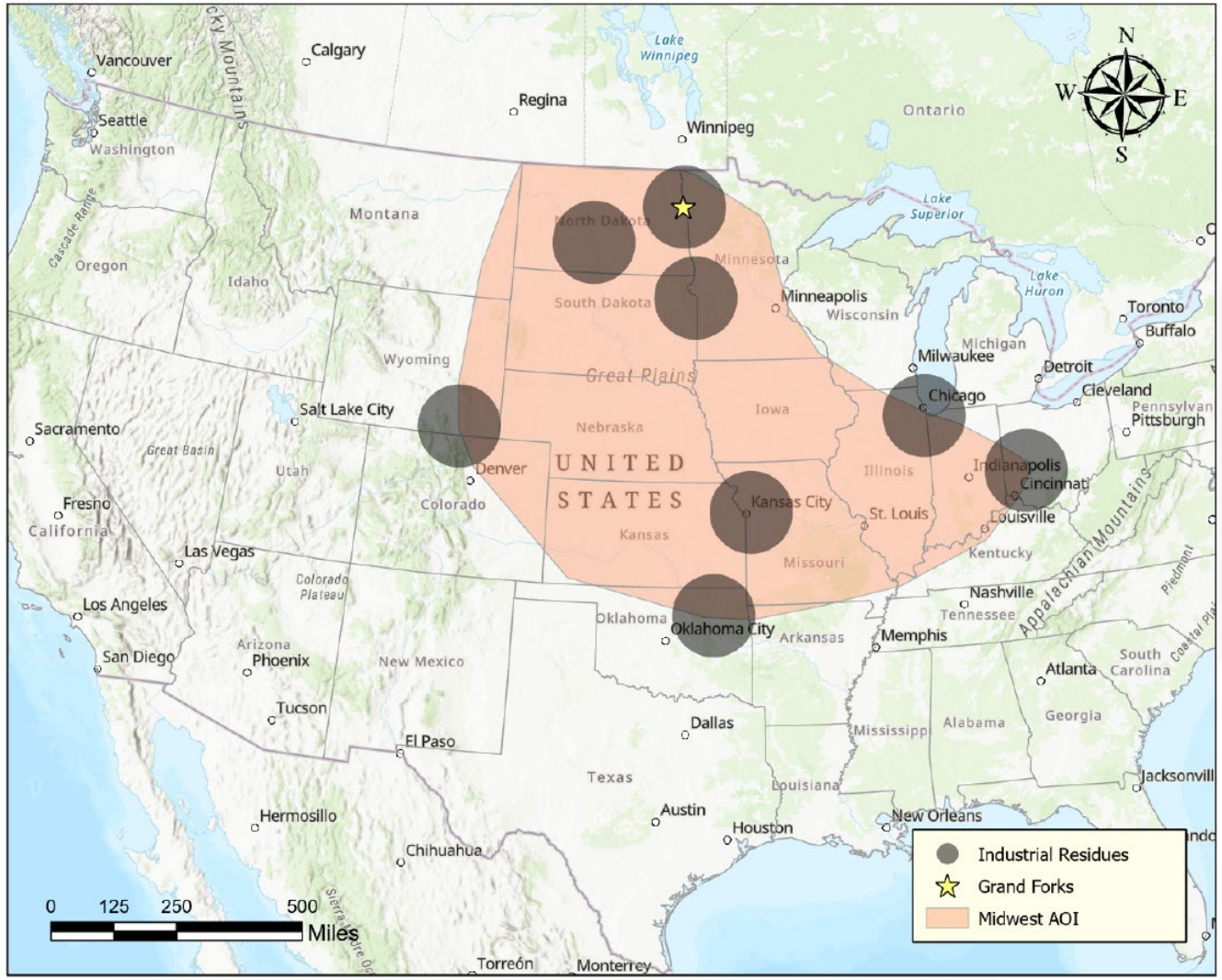
- Subtask 4.1 - Product Characterization
- Subtask 4.2 - Product Performance Testing

Task 5.0 - Mineralization Assessment Tool Development

- Subtask 5.1 – Lifecycle Assessment for CO_2 Mineralization
- Subtask 5.2 – Geographical Information System (GIS) Model
- Subtask 5.3 – Develop Alternative-Processing Schemes
- Subtask 5.4 – Develop Process Flow Diagrams
- Subtask 5.5 – Technical and Economic Analysis

CURRENT PROJECT STATUS

TASK 2.0 – CHARACTERIZATION OF INDUSTRIAL RESIDUES



- Residue procurement and initial characterization complete
- *15 samples from 5 industries* in the Midwest
- <u>Residues of focus also available beyond Midwest</u>

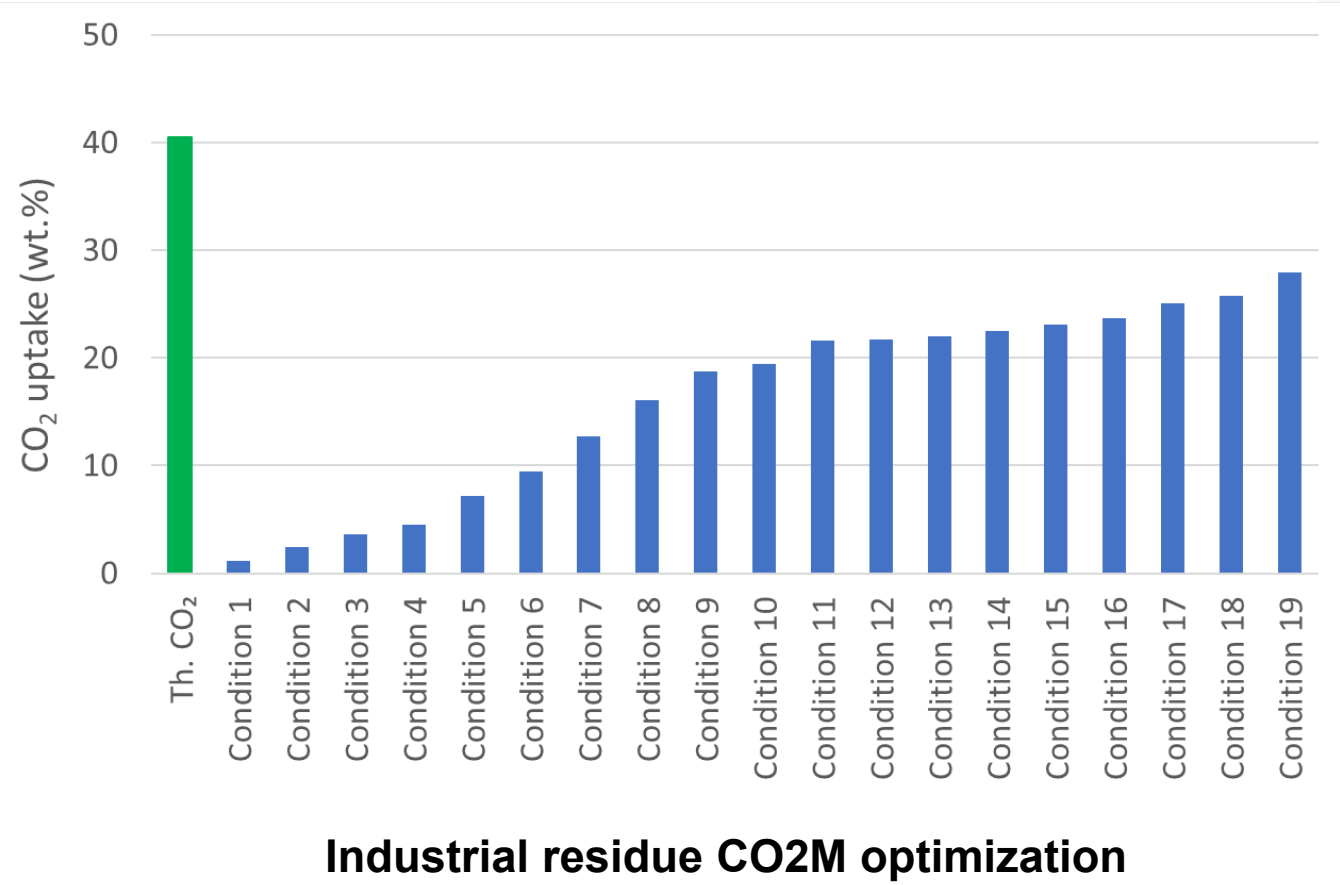
TASK 3.0 - EX-SITU DIRECT MINERALIZATION TESTING

CO2M Experiments

- Lab scale: Semi-batch testing
- Theoretical vs. actual carbonation
- Parametric study

Mineralization example

- Enhancement changes performance
- Other parameters: temperature, moisture, pressure, enhancers



Industrial residue CO2M optimization

TASK 3.0 - EX-SITU DIRECT MINERALIZATION TESTING

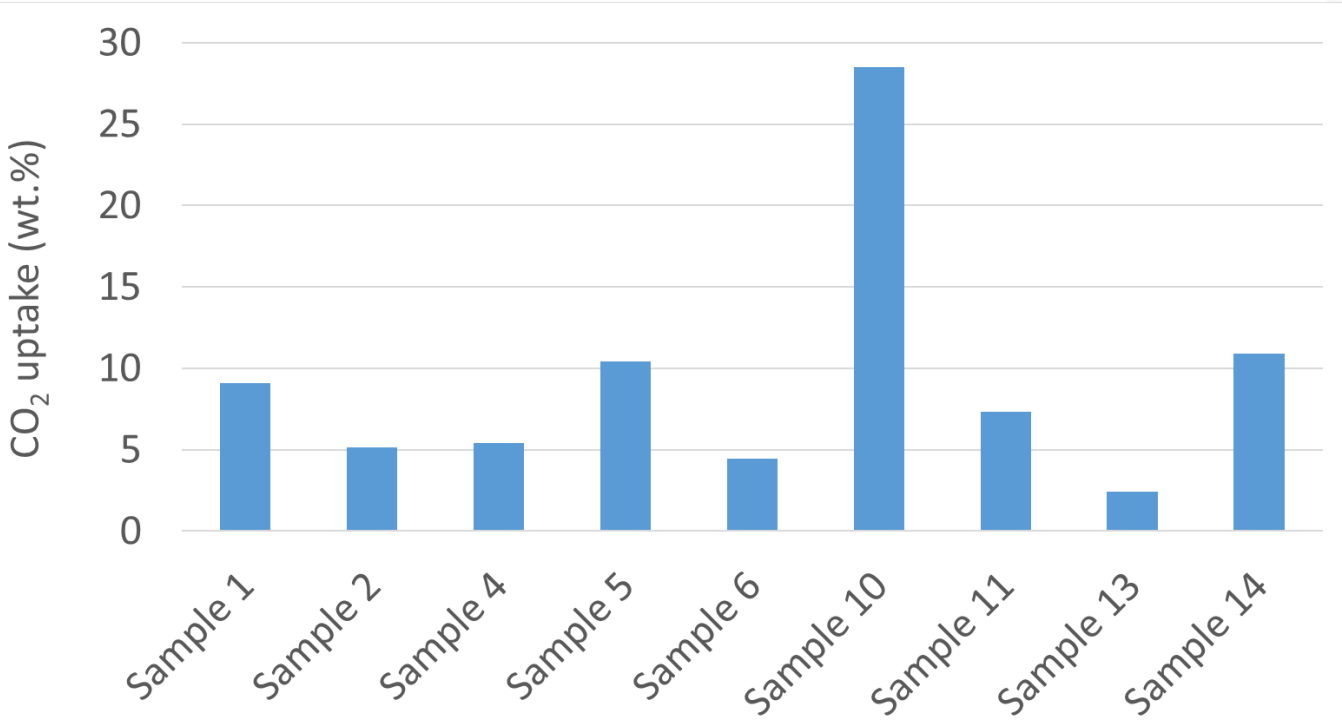
Residues Testing

Nine samples tested to date

- Each sample requires unique evaluation

4-5 MMT CO_2/y capture possible in U.S.

- Using <u>five</u> industrial residues
- Currently produced and mostly landfilled
- Legacy landfilled material also available



Residue CO2M comparison

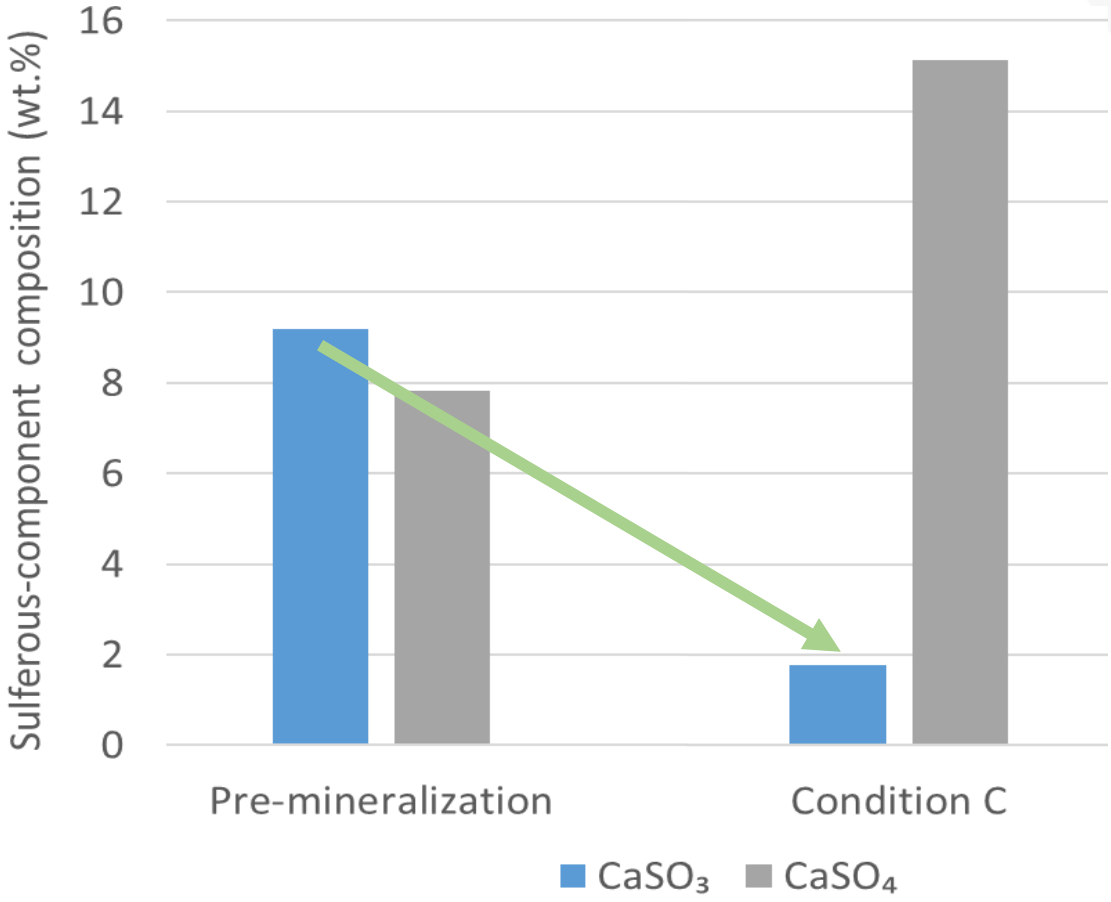
TASK 3.0 - EX-SITU DIRECT MINERALIZATION TESTING

Most important finding

- Modified CO2M shows improvement in coal combustion residue quality
  - $CaSO_3$ converted to $CaSO_4$
  - $SO_3 \rightarrow SO_4$ results in fly ash/gypsum mixture
  - With admixtures (e.g., ash, fine limestone) obtain materials for SCM application

Current process

- Up to 90% SO_3 conversion into SO_4
- Confirmed via wet chemistry/XRD methods

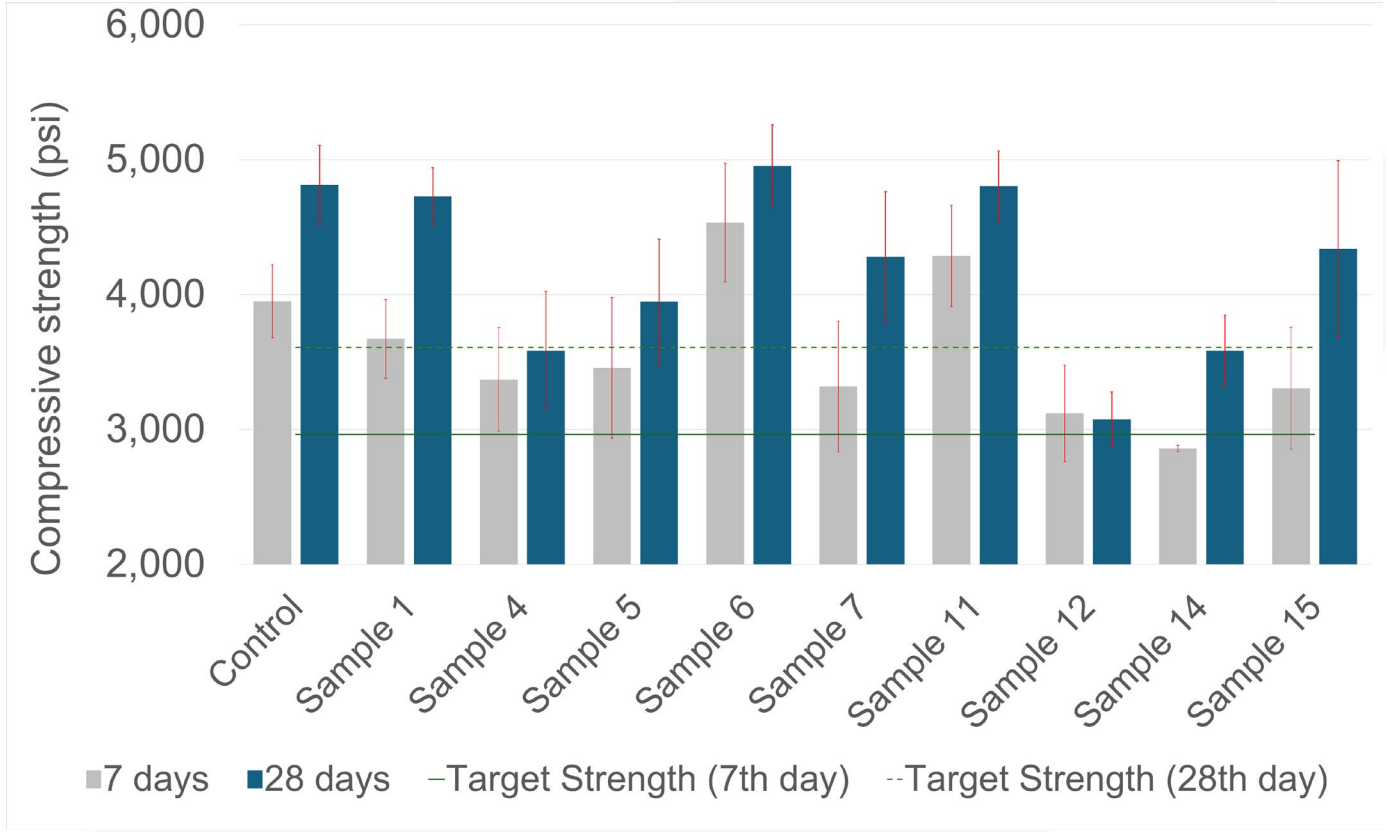


SO_3 conversion via modified CO2M process

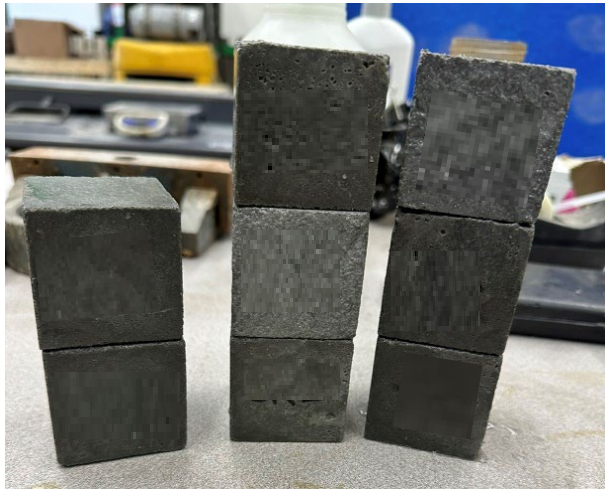
TASK 4.0 - MINERALIZED PRODUCT CHARACTERIZATION AND EVALUATION

Baseline Strength Activity Index evaluation of select residues

- Establish baseline (shown)
  - 20% cement substitution with as-received residues



Compressive strength testing



Test cubes

RISKS AND CHALLENGES

Challenges

- Variety of residues
  - Differing resources, locations and industries
  - Even multiple residues at one source
  - Variations in residue handling and disposal
- CO2M process
  - Several parameters
  - Require tailored approach
- Mitigation
  - Work closely with residue suppliers & end-users

PROGRESS TOWARDS SMART MILESTONES

Goal 1: Increasing Representation in STEM

- Partnered with programs to support underrepresented groups in applying for research positions
- Provided training, mentorship, and education on CO2M technology

Goal 2: Equitable Site and Material Selection

- Identified materials and linking to Environmental Justice considerations
- Ultimately identify communities that can benefit most from CO2M

Goal 3: STEM Outreach

- Engaged in career fairs, public presentations, and local events
- Collaborated with the Citizens' Climate Lobby and TRIO Upward Bound Program
- Utilized NSF’s Research Experience for Undergraduates (REU) to give students exposure to CO2M

COMMUNITY BENEFITS AND IMPACTS

Highlight – future collaboration

- UND's TRIO Programs & CEM Research Institute
  - Letter of support for UND TRIO Programs' 2025-2030 Student Support Services grant cycle
  - Work on student placement (hourly positions etc.)
  - Lab tours for high school learners

Link: UND TRIO

Highlight – Outreach

- Presentations to area students
  - Highlighting importance and excitement of STEM studies
  - Inform about addressing real-world challenges through engineering research

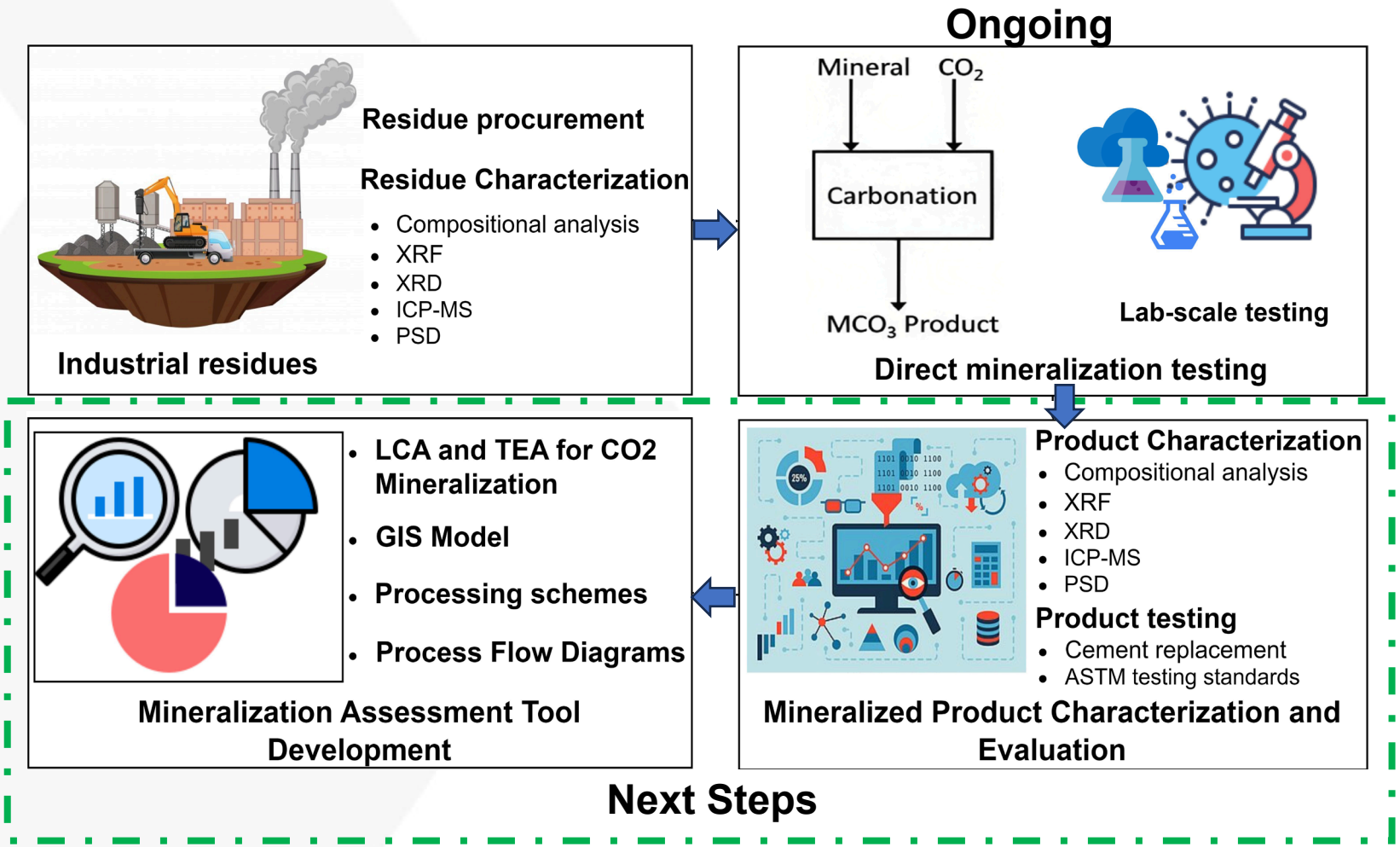
Student Outreach

NEXT STEPS

Continue CO2M testing with procured residues

Begin characterization for mineralized product

- Cement replacement performance evaluation



DOE ACKNOWLEDGEMENT & DISCLAIMER

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END

- Thank you
- Questions?
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