

UNDUNIVERSITY OF NORTH DAKOTA

Resource Assessment of Industrial Wastes for CO₂ Mineralization

FECM 23 (08/29/2023) Award No: FE0032244 Project Period of Performance: 07/01/2023 - 07/31/2025 PI: Dr. Johannes van der Watt (University of North Dakota) Project Manager: Johnathan Moore



PROJECT PARTICIPANTS

University of North Dakota

- Energy and Minerals Innovation Center (EMIC)
- Dept. of Civil Engineering
- Dept. of Geography

• Dept. of Chemical Engineering

Envergex, LLC (Sub-awardee)

Industry Supporters – Residue Providers





PROJECT SUMMARY

Opportunity: Industrial residues often underutilized – potential for use other than disposal

Goal: Use residues to capture CO_2 – beneficially alter composition for value-added secondary use

Solution approach:

- Identify industrial residues with carbonation potential
- Characterize chemical and physical properties
- Test CO₂ Mineralization
- Assess benefits of treatment
- Quantify environmental/economic performance

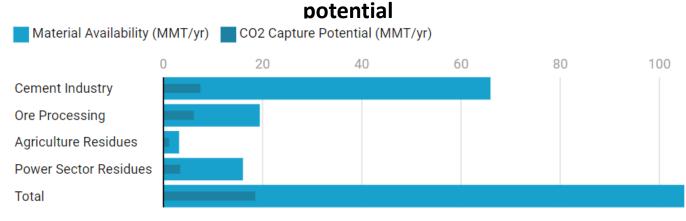
Waste reduction Reclaim Sustainable landfills Materials Environmental Industrial Residues benefits CO2 Mineralization (CO2M) Valuable byproducts **Economic** CO2 Industrial CO₂ Sources benefits sequestration Reduce CO footprin

BACKGROUND

Enabling CO₂ Mineralization using Industrial Residues

- CO₂ Mineralization Potential
 - No single resource available for DOE's 20 MMT CO₂ capture goal
 - Industrial residues = Potential reactive minerals
 - Can reduce residues & liabilities
 - Enhancing material value

Enhance commercial potential



U.S. industrial residue production and CO_2 mineralization

BACKGROUND

Heterogeneity Challenge

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

Industry Needs

- Guidelines for CO₂ mineralization technologies
- R&D tools



PROJECT OBJECTIVES

Identify & quantify usable resources for CO₂ capture

Map resource locations

- Develop CO₂ Mineralization (CO2M) processes
- Tap into existing infrastructure (CO₂ resources)
- Beneficiate residues (identify users)
- Quantify process viability environmental & economic benefits/disadvantages

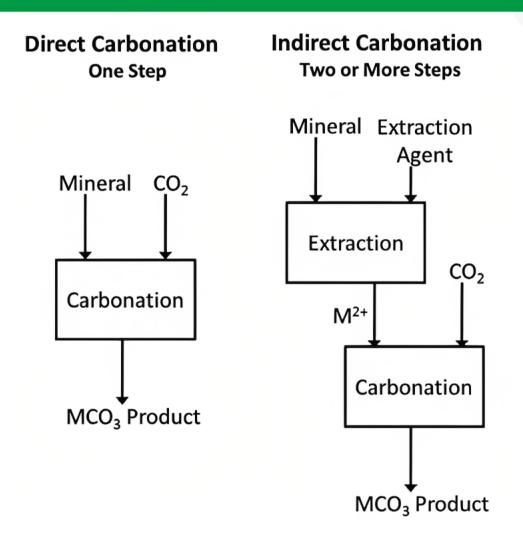


TECHNICAL APPROACH

CO₂ Mineralization (CO2M)

- E.g. Wollastonite reaction with CO₂:
- $CaSiO_3 + CO_2 = CaCO_3 + SiO_2$

- Carbonation advantage: Captured CO₂ does not require deep geologic disposal
- Nature's example: Weathering reactions
- But, kinetic & mass transfer limitations
- Processes impractical for ex-situ point-source capture
- Key approach: Proprietary enhancement orders of magnitude improvement



TECHNICAL APPROACH



• Reiterative approach Mineral CO₂ • Collect, **Residue procurement** Characterize **Residue Characterization** Carbonation • Test Compositional analysis • XRF Characterize • XRD ICP-MS Lab-scale testing MCO₃ Product Refine PSD Industrial residues **Direct mineralization testing** Select promising routes **Product Characterization** LCA and TEA for CO2 Compositional analysis Evaluate feasibility **Mineralization** XRF XRD **GIS Model** • ICP-MS PSD Processing schemes **Product testing** Cement replacement Process Flow Diagrams • ASTM testing standards Mineralization Assessment Tool **Mineralized Product Characterization and** 8 **Development Evaluation**

Task 1.0 - Project Management and Planning

- Project management plan (PMP)
- Community benefits plan (CBP)

Task 2.0 - Characterization of Industrial Residues

- Subtask 2.1 Residue Procurement
- Subtask 2.2 Residue Characterization
 - Compositional analysis: Ash, Moisture, LOI, and pH
 - Elemental analysis
 - Mineralogy
 - Particle Size Distribution
 - Grindability



Industrial residues

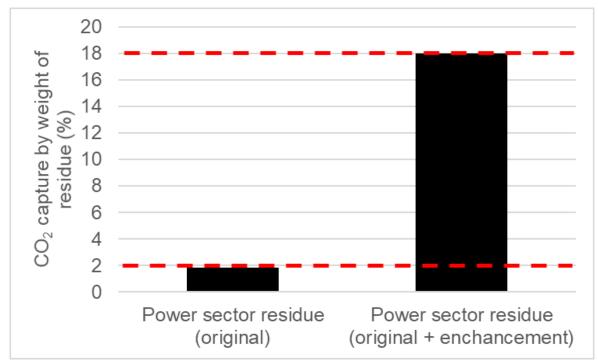


Task 3.0 - Ex-situ Direct Mineralization Testing

- Lab scale: Semi-batch testing
- CO₂ uptake
- Theoretical vs actual carbonation
- Parametric study

Mineralization example

- Example: Power sector residues
- Enhancement changes performance
- High carbonation potential



Power Sector Residue Mineralization

Task 4.0 - Mineralized Product Characterization and Evaluation

- Subtask 4.1 Product Characterization
 - Compositional analysis: Ash, Moisture, LOI & pH
 - Mineralogy & Microstructure
 - Leachability (landfilled material better/worse)
- Subtask 4.2 Product Performance Testing
 - E.g., ASTM C618 and ASTM C989 standard specification
 - Perform screening analyses
 - E.g., aggregate/cement replacement

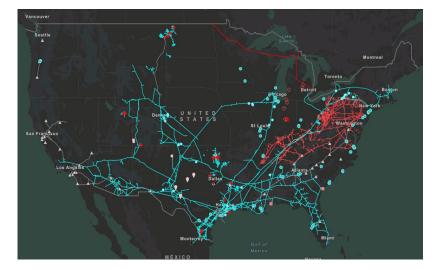


Task 5.0 - Mineralization Assessment Tool Development

- Subtask 5.1 Lifecycle Assessment for CO₂
 Mineralization
 - LCA will follow ISO 14040-14044
 - SimaPro 9.1 software

- Subtask 5.2 Geographical Information System (GIS) Model
 - Model will be designed using GIS software package ArcGIS Pro



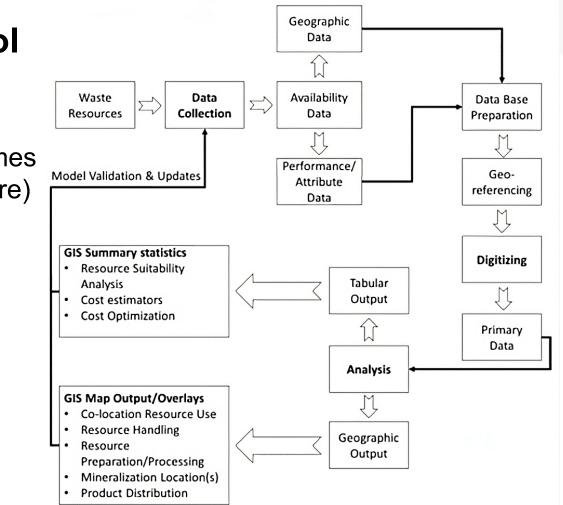


Task 5.0 - Mineralization Assessment Tool Development

 Subtask 5.3 – Develop Alternative-Processing Schemes –Develop processing schemes (modeling software)

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- Subtask 5.4 Develop Process Flow Diagrams
 Coordinate with project supporters
- Subtask 5.5 Technical and Economic Analysis
 Class V Concept Screening (AACE Int.)



PROJECT SCHEDULE

- Milestones & deliverables for each task
- Project update reports through quarterlies and final project report

Task/Subtask/Milestone Description		23		20)24		20)25
		Q2	Q3	Q4	Q5	Q6	Q7	Q8
Fask 1 - Project Management & Planning								
Fask 2 - Characterization of Industrial Residues				-	-			-
Subtask 2.1 - Residue Procurement			-					
Subtask 2.2 - Residue Characterization								
Milestones/Deliverables			•					
Procure and prepare residues		\diamond						
Procure, prepare, characterize residue materials			\diamond					
Task 3 - Ex-situ Direct Mineralization Testing								
Milestones/Deliverables					-			
Evaluate performance of residues in lab scale system					\diamond			
Task 4 - Mineralized Product Characterization & Evaluation Subtask 4.1 - Reaction Product Characterization								
Subtask 4.2 - Product Performance Testing								
Milestones/Deliverables							-	
Description of residue and byproduct properties						\diamond		
Summary of product performance							\diamond	
Mineralization Results Report & Data							\diamond	
Task 5 - Mineralization Assessment Tool Development								
Subtask 5.1 - LCA for CO2 Mineralization								
Subtask 5.2 - GIS for CO2 Mineralization								
Subtask 5.3 - Develop Alternative-Processing Schemes								
Subtask 5.4 - Develop Process FlowDiagrams								
Subtask 5.5 - TEA								
Milestones/Deliverables								
Complete carbon lifecycle assessment							\diamond	
Developed GIS model								\diamond
Developed alternative-processing schemes, process flow diagrams and								
technical-economic analysis Resource assessment tool & user manual								

PROJECT MANAGEMENT PLAN & RISK MANAGEMENT PLAN

 Project Management Plan Overview Project scope, objectives, & timeline Organization 	U.S. Department of I	Dire Minerals Principal J Johannes v Research Assi	Daniel Laud ctor, Energy Innovation Notestigator an der Watt, stant Profess	& Center	North Dakota Industrial Commission – Lignite Research, Marketing and Development Program (NDIC-LRP)			
 Roles, responsibilities, & communication structure 	Envergex Sparking innovations Env		Program Resource Manager		urce			
 Scope, Schedule, Cost 								
 Scope definition, change control, detailed schedule, & budgeting 	Task 1 Project Management and Planning	Task 2 Characterization Proposed Industri			Task 4 Mineralized Product Characterization and		Task 5 Mineralization Assessment Tool	
 Quality and Communication 	and I mining	Residues	Tes	Testing		ation	Assessment Iooi	
Quality standards, assurance, & stakeholder communication	Van der Watt (Lead) Laudal (Support) Srinivasachar (Co-lead) 15	Van der Watt (Lea Srinivasachar (Co Graduate Student	-lead) Van der Watt (Co-lead)		Van der Watt (Lead) Srinivasachar (Co-lead) Graduate Students		Van der Watt (Lead) Klemetsrud (5.1 Co-lead) Vandeberg (5.2 Co-lead) Srinivasachar (5.3, 5.4 & 5.5 Co-lead) Graduate Students	

PROJECT MANAGEMENT PLAN & RISK MANAGEMENT PLAN

Risk Management Plan

- Assessment and Prioritization
 - Evaluating risks likelihood & impact
- Mitigation and Contingency
 - Strategies to reduce risks, contingency plans
- Monitoring and Reporting
 - Ongoing risk tracking, communication, & reporting
- Documentation and Lessons Learned
 - Maintaining risk register, learning from outcomes

PROJECT BUDGET

- 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 CO₂ 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)			

DOE ACKNOWLEDGEMENT & DISCLAIMER

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- Thank you
- Questions?
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