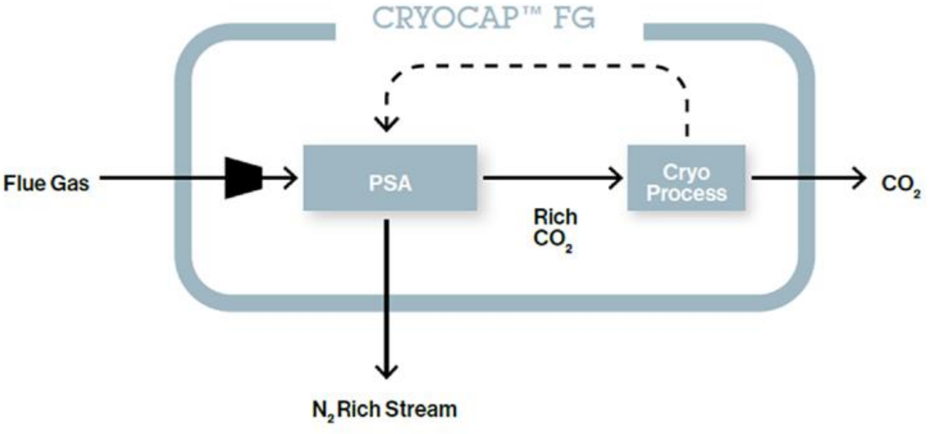
Industrial Carbon Capture from a Cement Facility Using the Cryocap™ FG Process

(DE-FE0032136)



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U.S. Department of Energy, National Energy Technology Laboratory
Carbon Management Project Review Meeting
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Project Overview & Objectives

- **Cooperative Agreement No**. DE-FE0032136
- **Total Funding**: $4,999,585
  - DOE: $3,999,585
  - Non-DOE: $1,000,000
  - Cost Share: 20%

- Performance Period:
  April 1, 2022–September 30, 2023
  18 months, 1 Budget Period

- **Main objective**: To execute and complete a front-end engineering and design (FEED) study for a commercial-scale, carbon capture system that separates 95% of the total CO2 emissions at Holcim Ste Genevieve Cement Plant using Air Liquide's Pressure Swing Adsorption (PSA) assisted Cryocap™ FG technology

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TECHNOLOGY BACKGROUND

Cryocap™

A complete product range to capture and/or liquefy CO_2 from industrial gas streams

A world premiere

Cryocap™ is a technological innovation for CO_2 capture that is unique in the world, using a cryogenic process (involving low temperatures to separate gases). Cryocap™ can be adapted to specific applications combining a variety of Air Liquide technologies.

CRYOCAP™ H_2

Hydrogen production

CRYOCAP™ FG

> 15% flue gas
(Cement, Refineries, H_2)

CRYOCAP™ Oxy

Oxycombustion

CRYOCAP™ Steel

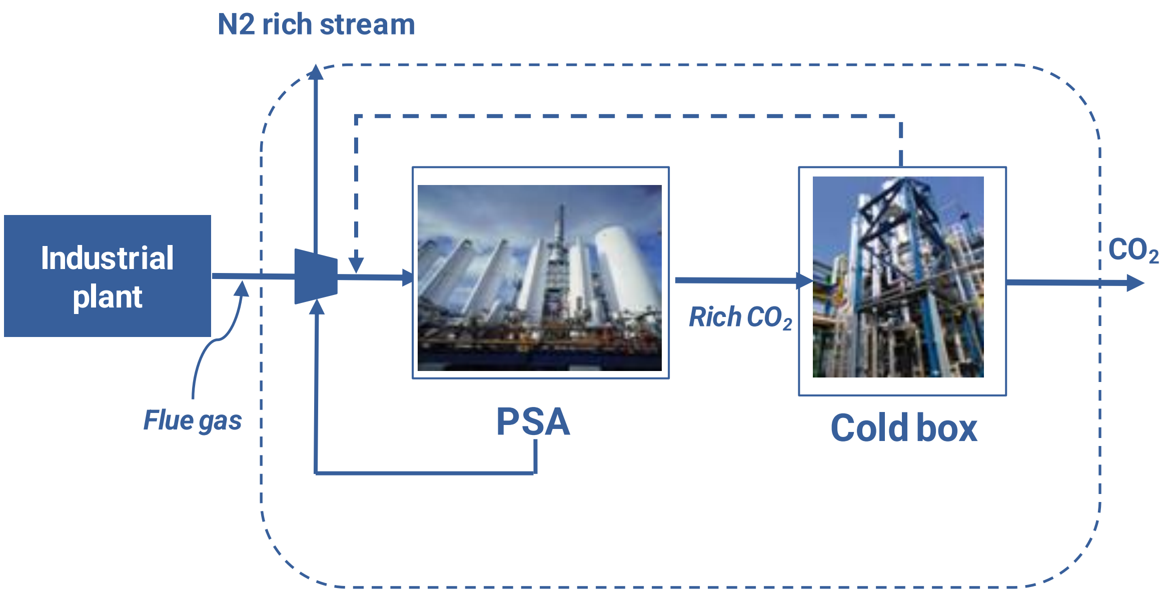
Steel production

CRYOCAP™ XLL

CO_2 liquefaction

Cryocap™ FG: CO_2 Capture from Flue Gas

- Suitable for Cement, Lime, SMR (flue gas), FCC, …
- PSA as a preconcentration brick
- HSE friendly (no chemicals and no flammables)
- Electricity powered (no steam needed)
- Compact & Flexible footprint: Compressors, PSA and Coldbox can be located in 3 different plots
- NO_x Smart Management
- Gaseous or liquid CO_2
- CO_2 capture rate: 95%+



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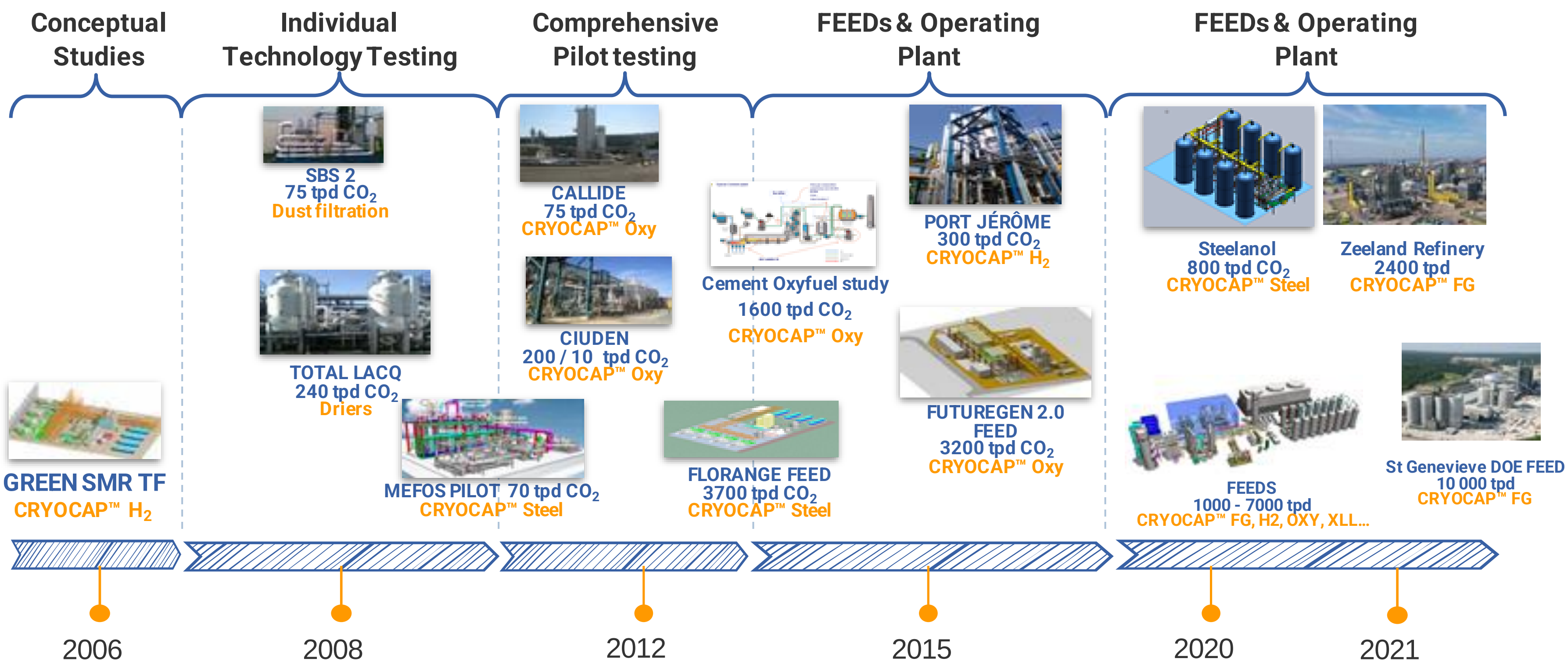
Cryocap™: 15+ years of legacy



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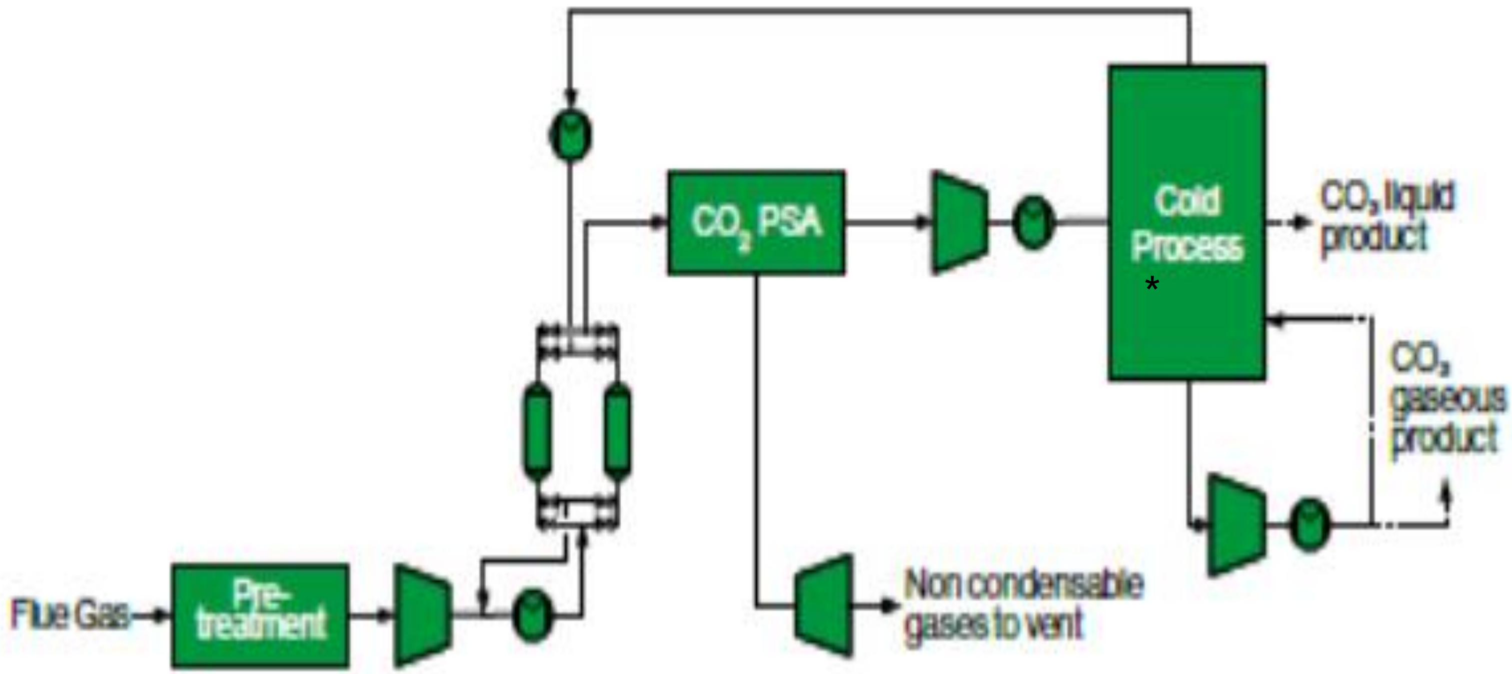
Typical block Flow Diagram of Process



*Liquid product not being produced for project design

Industrial Carbon Capture from a Cement Facility Using the Cryocap^{TM} FG Process

HOST SITE

Holcim Ste. Genevieve Cement Plant

Part of Holcim's focus on reducing carbon footprint

- Located in Bloomsdale, Missouri
- The largest single cement kiln in the world, commissioned in 2009
- Annual cement production capacity of 4.5 million metric tons
- A 4,000-acre site contains more than 100 years of limestone supply, in addition to 2,000 acres conservation area

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Excellent Host Site for Industrial Carbon Capture

World's largest single kiln cement plant

- Approximately 2.9 million tonne CO_2/yr
- Close to potential geological storage locations, i.e. the Illinois Corridor, where CarbonSAFE has highlighted significant storage potential
- Site is ~ 35 miles SW of Prairie State Generating Company (PSGC) site — a focus for geological storage as part of Phase III CarbonSAFE project

Possible Location of Capture Unit

Source: Google Earth

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PROJECT MANAGEMENT

Management Structure

Designed to enable transition to build/operate

ILLINOIS
PRIME CONTRACTOR
University of Illinois (UIUC)
Dr. Kevin C OBrien, PI
Dr. Hafiz Salih, Project Manager

HOLCIM
Holcim (US) Inc.
Derick Dreyer
Host Site

Advisory Board
CarbonSAFE-Illinois (FE-0029381)
Prairie State Energy Campus, Marissa, IL (Host Site FE0031841)

SUBAWARDEE
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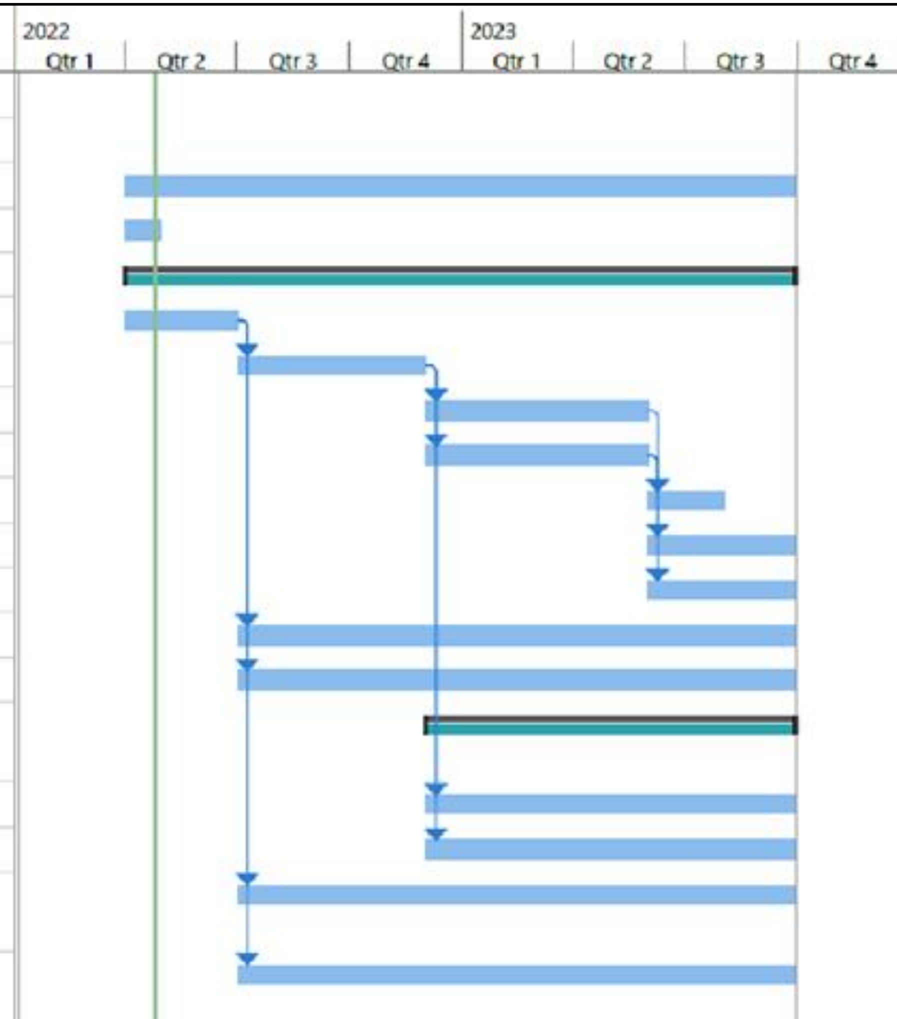
Air Liquide US Inc.
Andrew Clarridge
ISBL design and costing

SUBAWARDEE
Visage Energy CLEAN ENERGY CONSULTING
Daryl-Lynn Roberts
Social Justice Analysis,
Market Analysis

Kiewit
Kiewit Corporation
Bob Slettehaugh
Bryan Lofgreen, Alan Donovan
OSBL Design and Costing

Project Timeline

Task Name	Start	Finish
1.0 Overall Project Management	**Fri 4/1/22**	**Fri 9/29/23**
1.1. Project Management Plan	Fri 4/1/22	Fri 4/29/22
2.0 Initial Engineering Design	**Fri 4/1/22**	**Fri 9/29/23**
2.1 Design Basis	Fri 4/1/22	Thu 6/30/22
2.2 Preliminary Engineering	Fri 7/1/22	Thu 12/1/22
2.3 ISBL Engineering	Fri 12/2/22	Wed 5/31/23
2.4 OSBL Detailed Engineering	Fri 12/2/22	Wed 5/31/23
2.5 HAZOP Review	Thu 6/1/23	Wed 8/2/23
2.6 Constructability Review	Thu 6/1/23	Fri 9/29/23
2.7 Cost Assessment	Thu 6/1/23	Fri 9/29/23
3.0 Business Case Analysis	Fri 7/1/22	Fri 9/29/23
4.0 Technology EH&S Risk Assessment	Fri 7/1/22	Fri 9/29/23
5.0 Techno-Economic Analysis (TEA) and Life Cycle Analysis (LCA)	**Fri 12/2/22**	**Fri 9/29/23**
5.1 TEA Analysis	Fri 12/2/22	Fri 9/29/23
5.2 LCA Analysis	Fri 12/2/22	Fri 9/29/23
6.0 Preliminary Environmental Justice Analysis	**Fri 7/1/22**	**Fri 9/29/23**
7.0 Preliminary Economic Revitalization and Job Creation Outcomes Analysis	**Fri 7/1/22**	**Fri 9/29/23**



Deliverables and Milestones

Budget Period	Task or Subtask Number	Milestone Title & Description	Planned Completion Date	Actual Completion Date	Verification Method
1	1.0	Updated Project Management Plan	Within 30 days after award	4/27/2022	Project Management Plan file
1	2.1	Project Design Basis Completed	6/30/2022	6/30/20	Topical Report File
1	2.5	HAZOP Completed	8/2/2023		Topical Report File
1	2.6	Constructability Review Complete	9/29/2023		Topical Report File
1	2.7	Project Cost Assessment	9/29/2023		Topical Report File
1	3.0	Business Case Analysis Completed	Within 90 days of project completion		Topical Report File
1	4.0	EH&S Analysis	Within 90 days of project completion		Topical Report File
1	5.0	TEA and LCA	Within 90 days of project completion		Topical Report File
1	6.0	Environmental Justice Analysis	Within 90 days of project completion		Topical Report File
1	7.0	Economic Revitalization and Job Creation Outcomes Analysis	Within 90 days of project completion		Topical Report File

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Perceived Risk	Risk Rating: L, M, H Probability	Impact	Overall	Mitigation and Response Strategy
Financial				
Cost share for project not obtained or insufficient	L	H	L	• Cost share commitment letters obtained. • All entities providing cost share are financially sound.
Cost/Schedule				
Project costs and/or schedule overruns	L	H	L	• Team has previous experience conducting DOE projects on budget and on time.
Tasks require significantly more time than expected	L	H	M	• Experience from prior/ongoing projects were used to develop timelines that would meet DOE requirements.
Technical / Scope				
Challenges in meeting required quality of CO_2 for intended transport and storage	L	H	M	• Following first discussion on the Basis of Design between Air Liquide and Lafarge, no showstoppers have been identified to meet the typical NETL guidelines for sequestration ("Conceptual design for saline reservoir sequestration" of NETL CO2 impurity design parameters document from January 2012) • Design of the purification equipment following capitalization on various Air Liquide demonstration and commercial plants (Callide, Ciuden, Port Jerome, etc..)
Challenges in meeting 95% capture for total emissions	L	M	L	• Design of the PSA and the cryogenic section optimized for high CO2 recovery with adequate process margin to meet the recovery requirement • Potential CO2 losses in the carbon capture system to be tracked, including compressor seal losses for example
Availability of energy supply (i.e. sufficient waste heat from existing host site)	L	H	M	• Selection Process launched early in collaboration with partners. • Waste heat integration with cement plant limited (full electrical as a base case) but will be studied early during the FEED
Challenge in the design and manufacturing of large modules/equipment (9000tpd+ CO2 capture)	L	H	L	• Modularization strategy to be defined at the beginning of the FEED considering constructability, maximum shipping windows and manufacturers capabilities • Considering several equipment in parallel vs one very large
Delayed supply of equipment offers for estimate	L	M	M	• Procurement review started in a timely manner allowing for some delays in response time without affecting critical part of project. • Active dialogue with key suppliers to ensure that timeline is kept.

	Risk Rating: L, M, H			
Perceived Risk	Probability	Impact	Overall	Mitigation and Response Strategy
Management, Planning, and Oversight				
Unrealistic planning base/assumptions in project schedule may result in delays of project implementation	L	M	M	• Clear and carefully planned timeline created in collaboration with designers and engineers. • Scenario-based planning, using conservative assumptions and adequate contingency time for activities on the critical path of the project. • Bottom-up planning of individual activities.
Deficient project management may result in inefficiencies and delays	L	M	M	• Integrated, holistic project management set up. • Adequate allocation of experienced/qualified personnel to project management. • Detailed milestone planning. • Structured meeting, monitoring, and reporting structure to ensure real-time transparency. • Defined decision-making structures and processes.
Availability of key personnel for project	L	M	L	• Commitment received from partner organizations.
Uncertainty of permitting agencies and timelines	L	L	L	• Agencies and timelines known based on previous experience with FEED studies at host site.
EH&S				
Management of emissions	L	M	L	• Capture subsystem provider has previously design systems to mitigate these issues. • Leverage experience from previous projects to meet strict permit requirements.
External Factor				
Issues related to COVID-19 delay execution	M	H	M	• Team has worked virtually for months. • Communication process currently in place that uses remote work tools, e.g. Microsoft Teams.
Negative Stakeholder response to proposed capture system/study	M	M	M	• Discussions with elected officials on similar projects have received positive support.

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DESIGN BASIS

Design Basis Summary

Factor	Result
Captured CO_2 product Specification	Established through review with CarbonSAFE team
Flue gas measurements	Measured under various operating conditions
Desulfurization approach	Integrated DCC system that uses caustic soda
Waste streams (volumes and types)	Identified and will review with regulators to determine permitting timeline and strategy
Electric sourcing for capture plant	Purchased from the grid
Transportation of components to the host site	Determined routes for shipping relevant equipment to the site

Environmental Justice Analysis

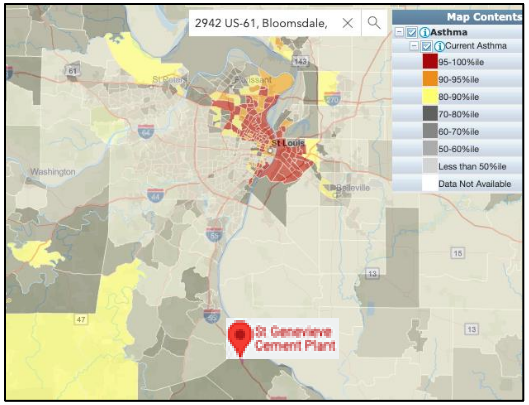
- Objective: Analyze the impact of proposed CCS retrofit improvements to the existing industrial facility on the local/surrounding communities and assess the potential distribution of anticipated Justice40 benefits.

- Identified local communities that have been disproportionately impacted through Stakeholder Mapping process.
  - Primary focus is on St. Louis as the nearest large Disadvantaged Community (DAC) that has been traditionally marginalized/underserved.
  - After further analysis, other DAC communities, to the west of the host site, have now been included as well (Franklin, Madison, and Washington Counties).

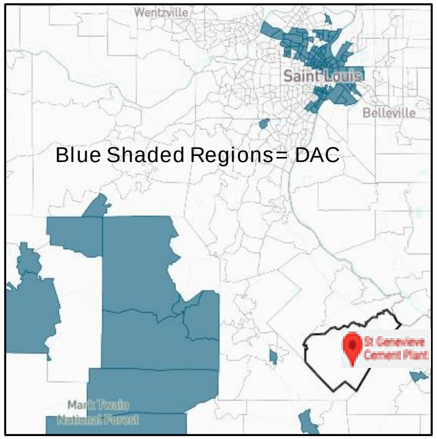
- Performing social characterization of the surrounding counties.
  - Each have different metrics which should be distinctly analyzed.
  - Example: Several of the DAC counties have varying unemployment and energy burden metrics (5% vs. 10%).

- Facilitating the involvement of surrounding communities by encouraging information exchanges and mixture of engagement techniques (e.g. focus groups, small discussions, and educational workshops).
  - Engaging local community-based organizations that are focused on EJ issues from a granular level in the different counties and assessing current EJ community-based initiatives underway.

EJ characteristics surrounding Facility



Source: EPA EJSCREEN mapping tool



Source: Energy Justice Mapping Tool - Disadvantaged Communities Reporter

Summary

- Industrial capture FEED on track and on budget
- Design basis complete
- Moving into preliminary engineering
- Beginning Environmental Justice outreach

Acknowledgements

Name	Organization
Andy O'Palko, Jodi Collins	National Energy Technology Laboratory / U.S. Department of Energy
Vinod Patel, Jim Dexter, Stephanie Brownstein, Jason Dietsch, Melanie Keuhn, Scott Prause, Bajio Varghese Kaleeckal, Sebastiano Giardinella, Margaret Morrison	University of Illinois
Derick Dreyer, Erin Watson, Suhail Akhtar, Alessandro Ferrari, Fathesha Sheikh	Holcim Cement
Andrew Clarridge, Michelle Jones, Lindsey Turney, Ademola Oladinni, Abigail Bonifacio, Timothy Henderson, Pierre-Philippe Guerif	Air Liquide
Will Johnson, Daryl-Lynn Roberts	Visage Energy
Bryan Lofgreen, Alan Donovan, Bob Slettehaugh, Theresa Shin	Kiewit

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