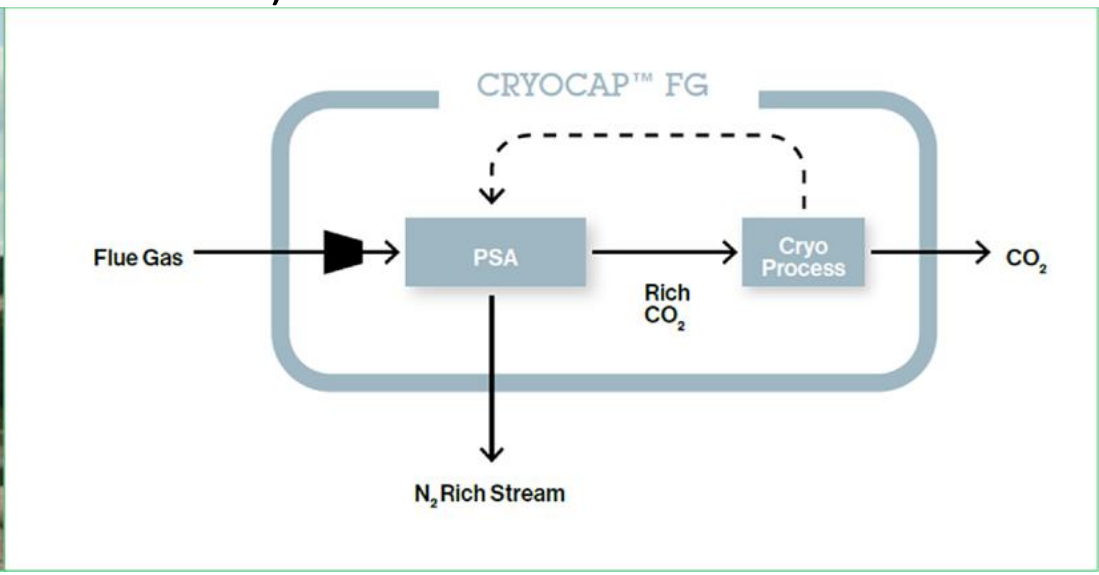
Industrial Carbon Capture from a Cement Facility Using the Cryocap™ FG Process

(DE-FE0032136)



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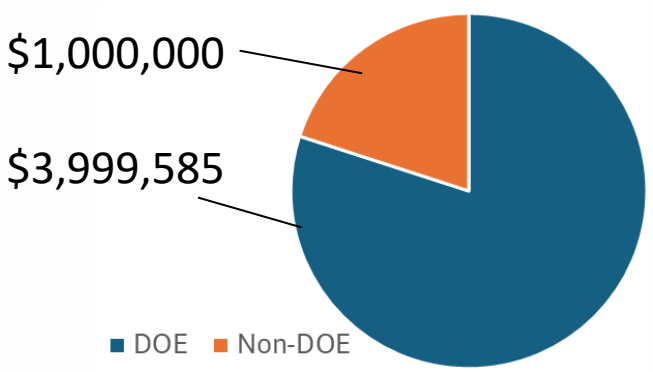
2024 FECM / NETL Carbon Management Research Project Review Meeting
August 5-9, 2024

Prairie Research Institute | NET ZERO Center of Excellence | HOLCIM | Air Liquide Engineering & Construction | Visage Energy Clean Energy Consulting | Kiewit | U.S. Department of Energy | NETL National Energy Technology Laboratory

Disclaimer

Project Overview

- **Cooperative Agreement No**. DE-FE0032136
- **Total Funding**: $4,999,585



- Performance Period:

2022			2023				2024		
Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Budget Period 1 (24 months)									

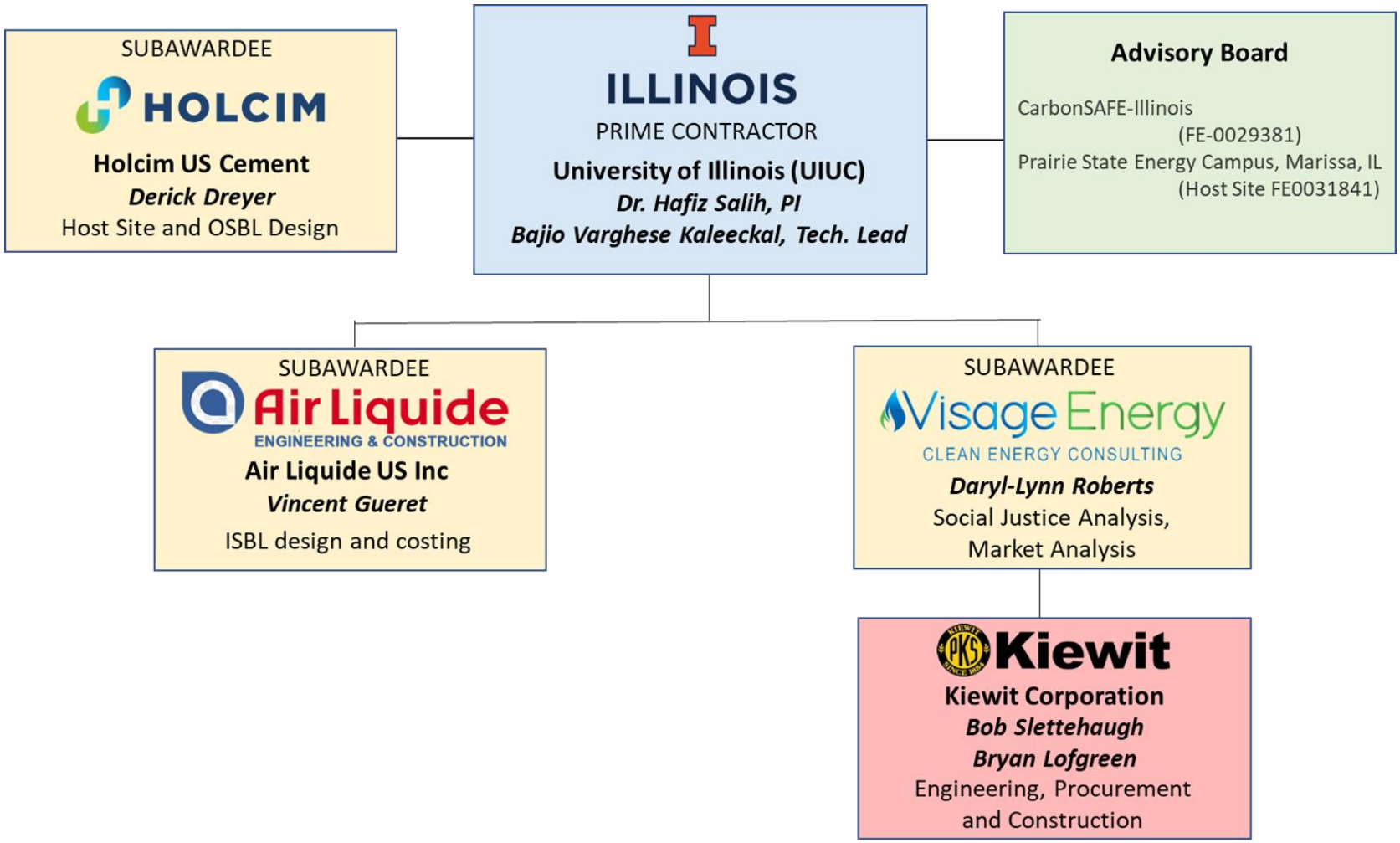
Start 4/1/2022

Official End 5/31/2024

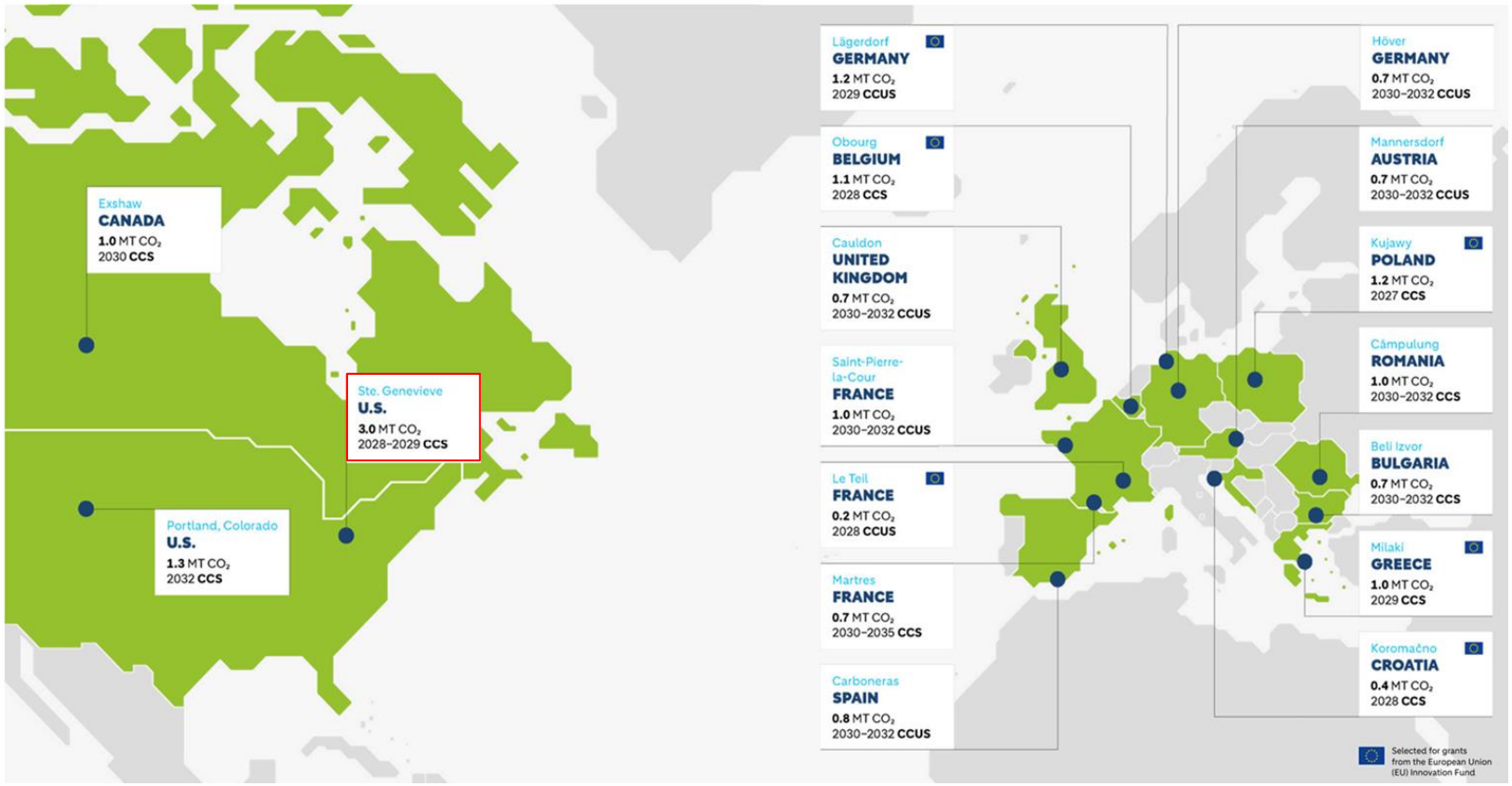
- **<u>Main objective</u>**:

  To complete a front-end engineering and design (FEED) study for a commercial-scale, carbon capture system that separates 95% of the total CO_2 emissions at Holcim Ste Genevieve Cement Plant using Air Liquide's Pressure Swing Adsorption (PSA) assisted Cryocap™ FG technology

Project Organization Structure

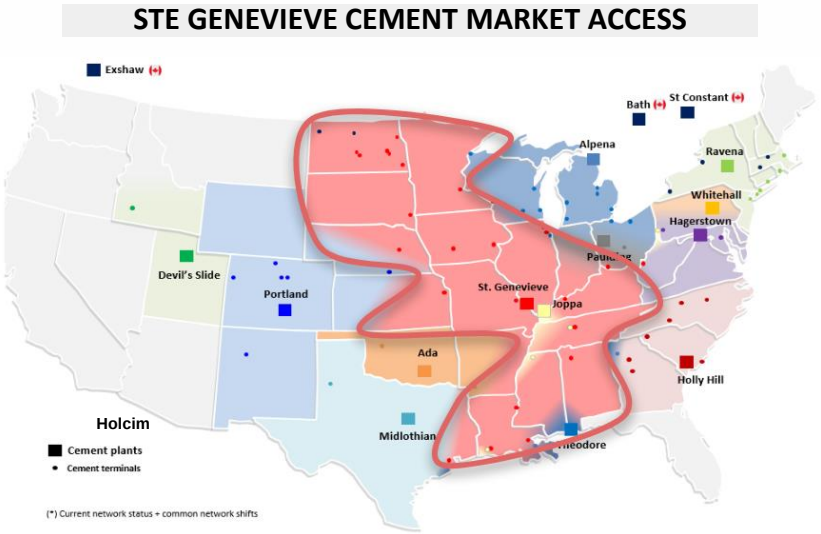


Holcim's Global CCUS Portfolio



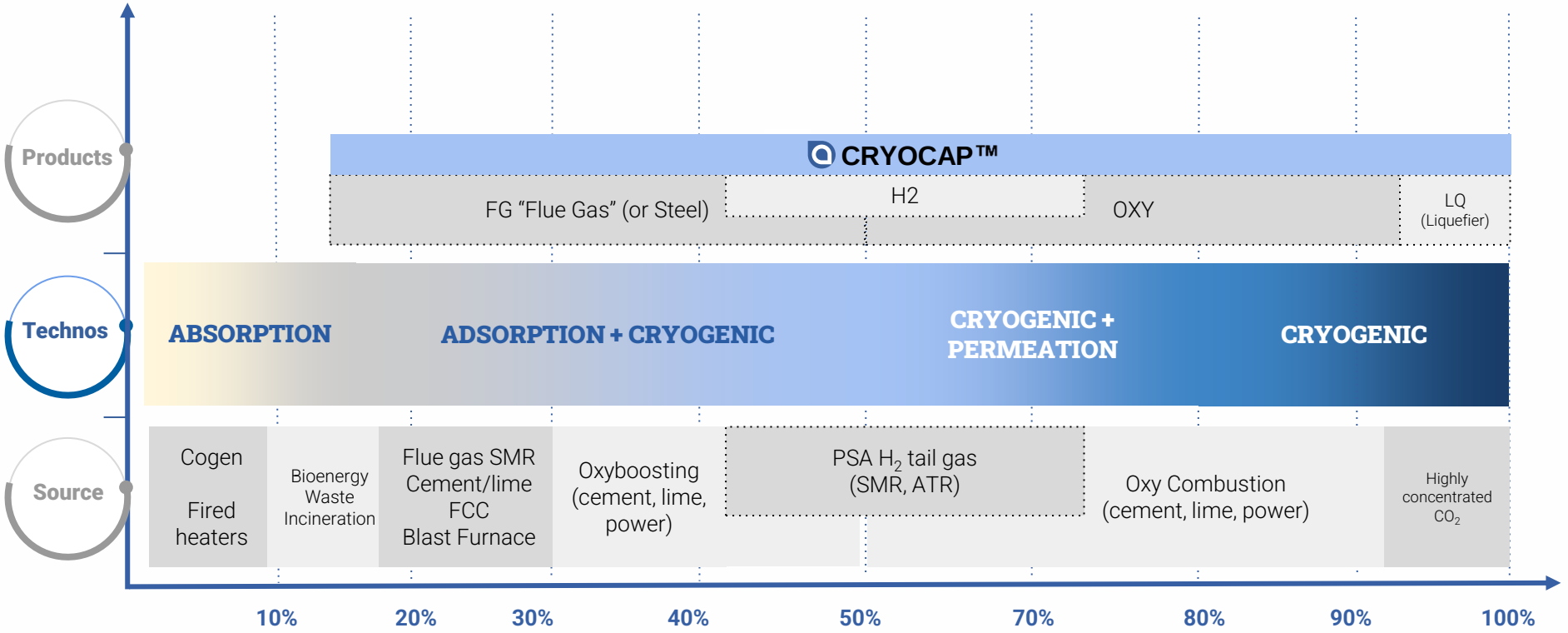
Holcim has a large portfolio of large scale projects in various stages of development

Ste Genevieve - Holcim's Flagship Cement Facility



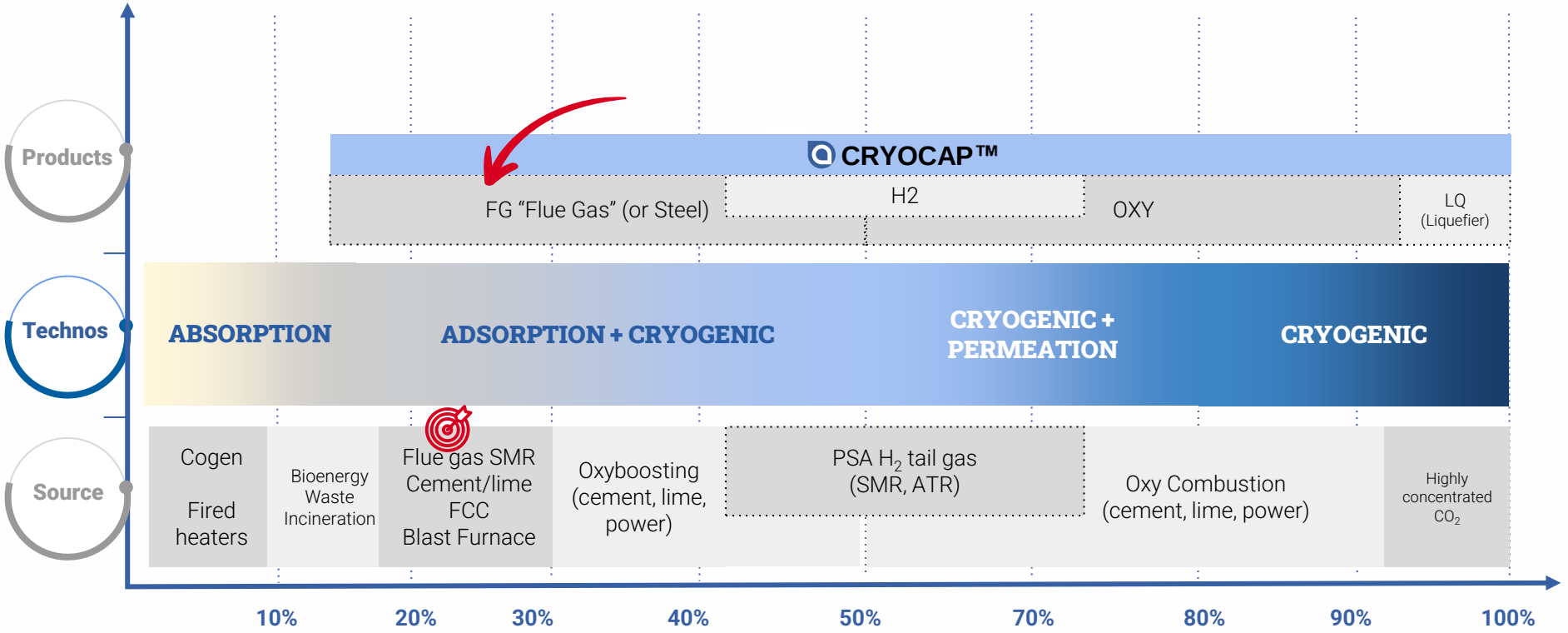
- Largest single-line cement plant in the world. Modern, efficient & state of the art facility, with high degree of automation and utilization (on stream factor)
- More than 100 years of limestone supply & 2,000 acres conservation area.
- Annual cement production capacity of 4.5 million metric tons. Investment of $100 million underway to further increase the capacity to 5.3 million metric tons, with no increase to CO_2 absolute emissions.
- Pivotal CCS project with a potential to decarbonize ~25% of Holcim US' and ~5% of US' cement production
- Potential to provide net zero cement to the largest geographic market in the US due to its logistic strengths.

Cryocap™ overall technology mapping



CO_2 Content in Feed Gas (dry basis)

Cryocap™ overall technology mapping



Site Data & Basis of Design Documents

Flue Gas Specification

		Nominal
Temperature	F (C)	302 (150)
Pressure	psia (bara)	16.1 (1.11)
Flue Gas Total Mole flow	MMSCFD(70) (wet)	1087
Carbon Dioxide (CO_2)	mole% wet	20.3
Water (H_2O)	mole% wet	12.3
Nitrogen (N_2)	mole% wet	58.1
Oxygen (O_2)	mole% wet	8.5
Argon (Ar)	mole% wet	0.8

CO_2 Product Specification

- Pressure: 2,215 psia (153 bara)
- Temperature: <120F (<49C)
- Purity: >95%
- Impurities: as per potential pipeline and storage operator specifications

Cryocap™ application to Holcim Ste Genevieve set-up

Key Design Considerations
- Application to specific flue gas characteristics
- Process integration
- 2 Parallel Trains

2 **Decarbonated gas**

Flow: 800 kNm³/h (dry basis)
1% CO_2

3 **Supercritical CO_2 Product**

Flow: 225⁺ kNm³/h (3.9 Mtpy CO_2)
100% CO_2
95%⁺ CO_2 recovery

Flue Gas Pre-Conditioning

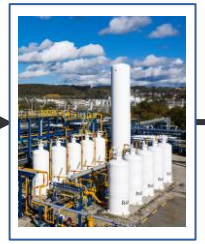
Gas Separation & Purification

1 **Cement Flue Gas**

Flow: 1,190 kNm³/h
20% CO_2

Pretreatment

Flue Gas Compression



PSA

Rich CO_2

Tail Gas Compression

Rich CO_2

Cryogenic Processing

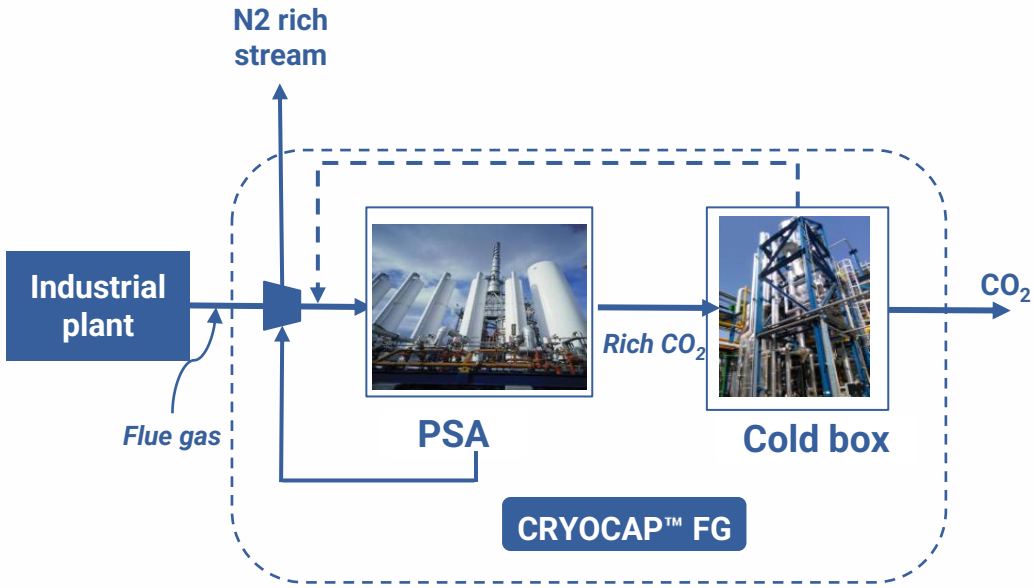
Pure CO_2

Process condensates to water treatment

* rounded figures, for the purpose of the presentation only

Cryocap™ FG: CO_2 Capture from Flue Gas
(~15% to 40% dry mol CO_2)

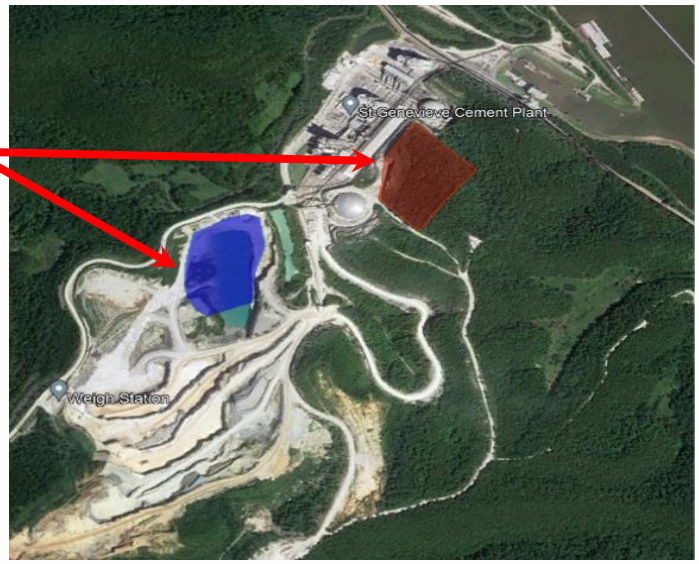
- Modular & mature technology bricks
- PSA as a preconcentration brick
- HSE friendly (no chemicals and no flammables)
- Electricity powered (no steam needed)
- Compact & Flexible footprint: Compressors, PSA and Coldbox can be located in 3 different plots
- NO_x Smart Management
- Gaseous or liquid CO_2
- CO_2 capture rate: 95%+



Site Specific Evaluations

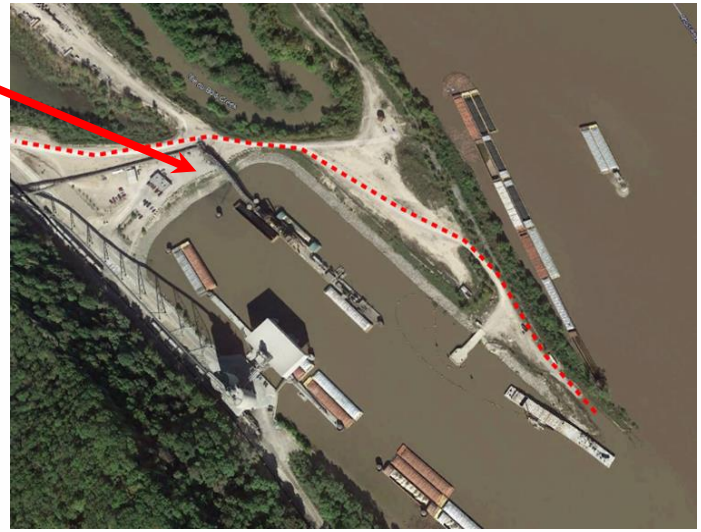
Selection of Site Location (25 acres):

- *Two options evaluated, base of mine selected*
- *Considered mine planning, constructability i.e. laydown, labor access, construction (craneage), ground vibrations from blasting, etc.*



Transportation & Constructability Review:

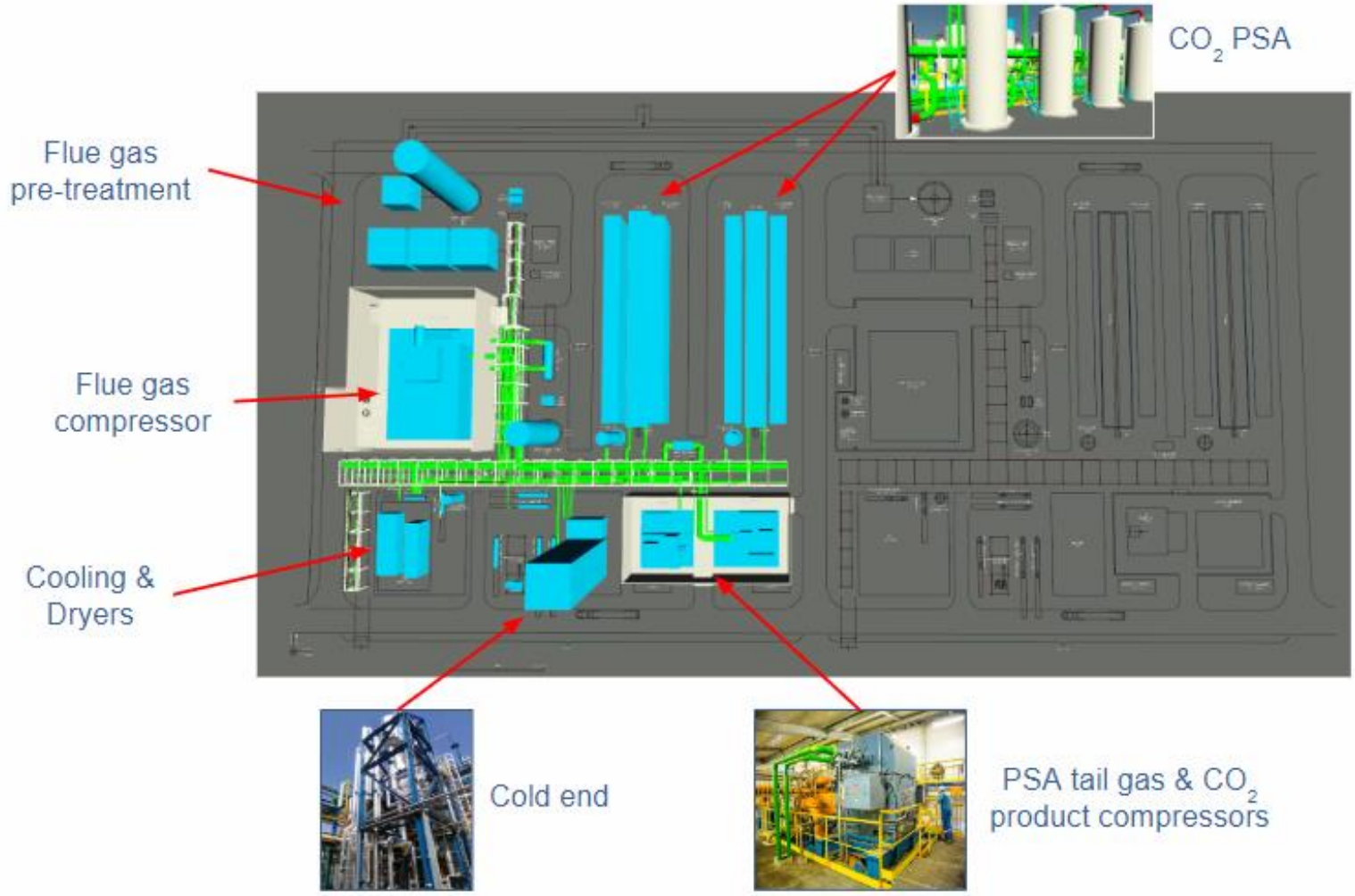
- *Ideal Site for modularization & off-site fabrication*
- Preliminary Heavy Haul/Lift Planning
- *Transportation not limiting factor*



Cooling Method Evaluation:

- *Water sources (sample analysis)*
- *Evaporative Cooling w/ZLD*
- *Minimize water consumption*

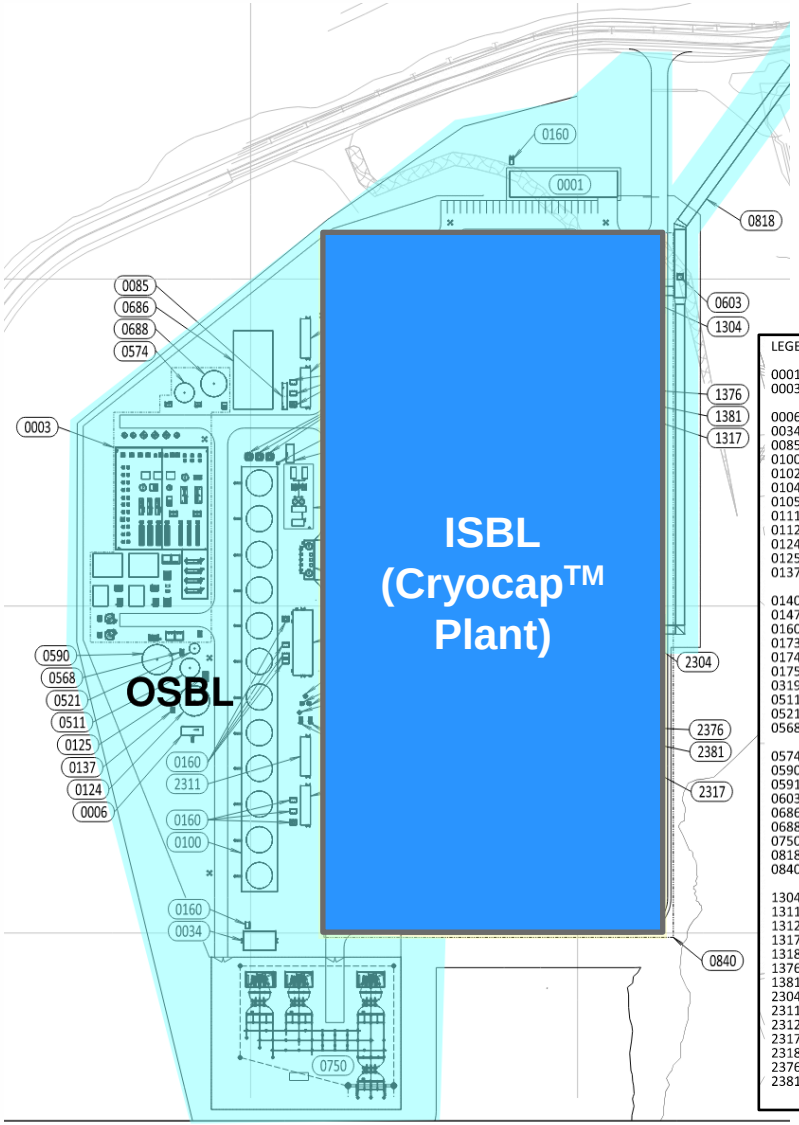
ISBL Detailed Engineering - Plant Layout (1 Train)



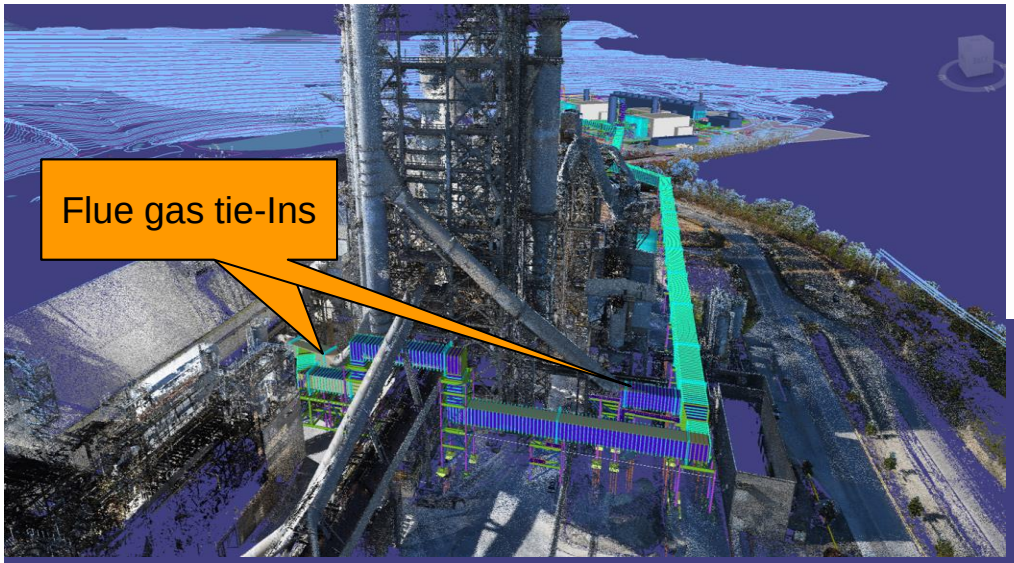
OSBL Detailed Engineering - Plot Plan

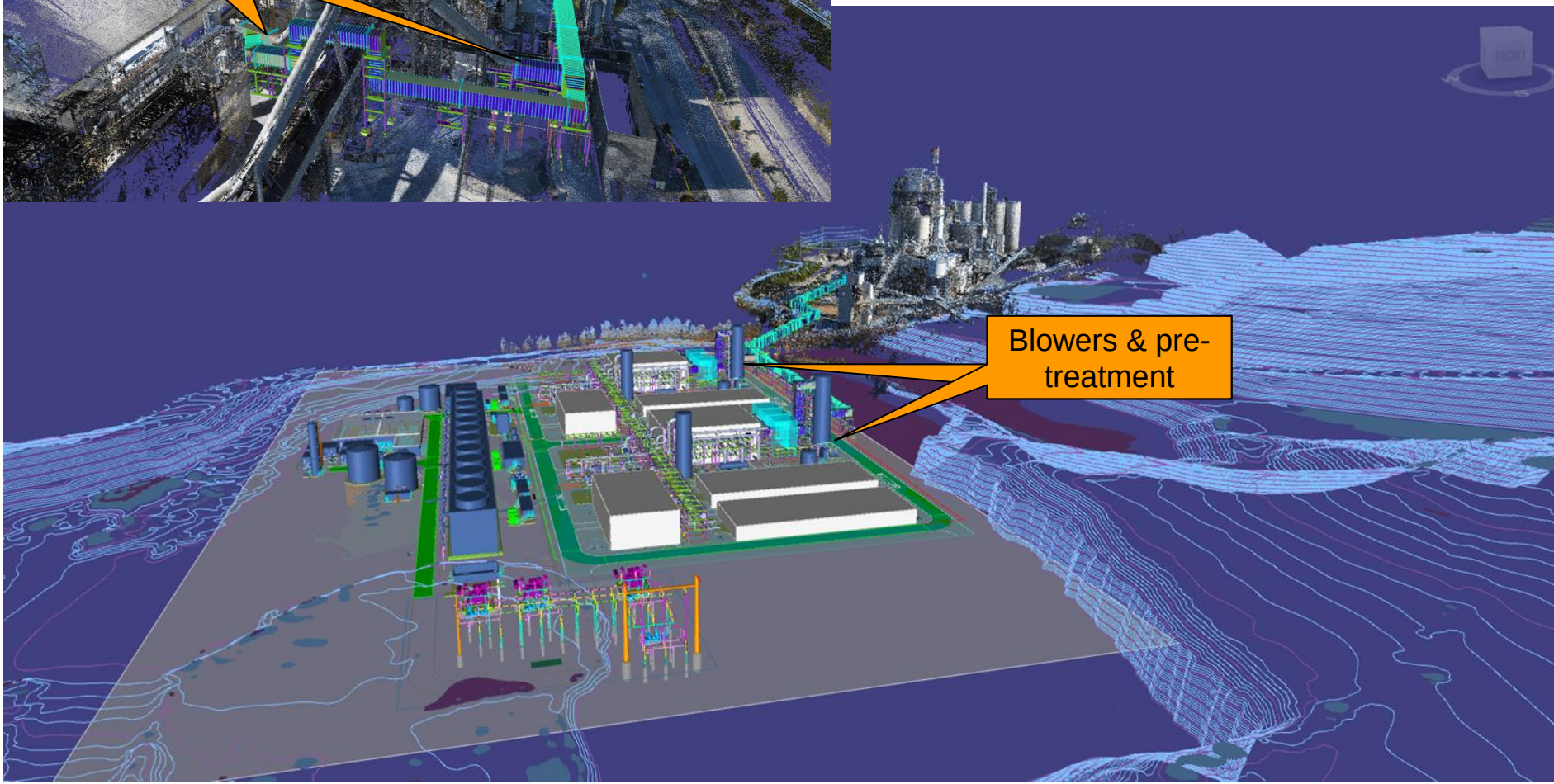
- Cooling Tower & Pumps
- Flue Gas Duct, Fans, & Dampers
- **Water Treatment (ZLD)**
- All Buildings
- Nitrogen Generation System
- Caustic Storage / Forwarding
- Field Erected Tanks
- Admin Building & DCS
- Collector Well & Pump House
- Other Balance of Plant Systems and Equipment (Air, Water, Drains, etc)
- Power Distribution to OSBL & ISBL
- Main Power Transformers
- Electrical Enclosures
- DC/UPS
- SUS Transformers
- ISBL Compressor Drives
- Substation Equipment
- All Civil

Provided vendor quotes as part of project deliverables.



OSBL Detailed Engineering – 3D Models - Flue Gas Duct Tie-ins & Capture Plant Layout





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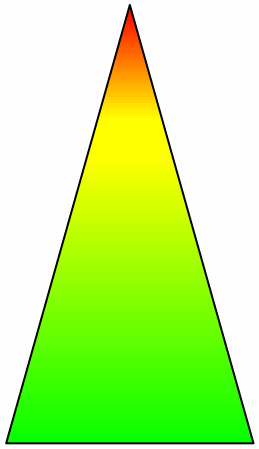
Risk Assessment

- A **Hazard Identification** (HAZID) review of the ISBL and **Hazard and Operability** (HAZOP) review of the ISBL interconnections were performed at site with plant operations.
  - ❑ Interdisciplinary process
  - ❑ Process (flow, pressure, temperature, composition, etc.) and system interconnections & interdependencies evaluated
    - ❑ Plant to OSBL
    - ❑ OSBL to ISBL
- Mitigations & controls identified, without major concerns



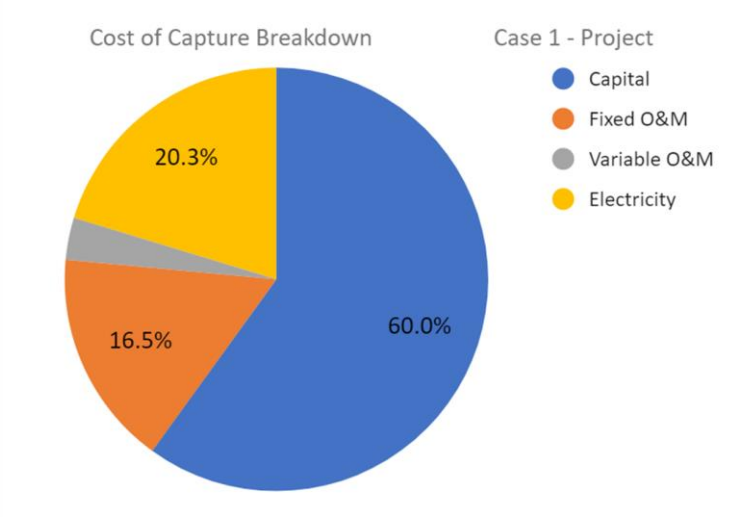
0 roadblocks

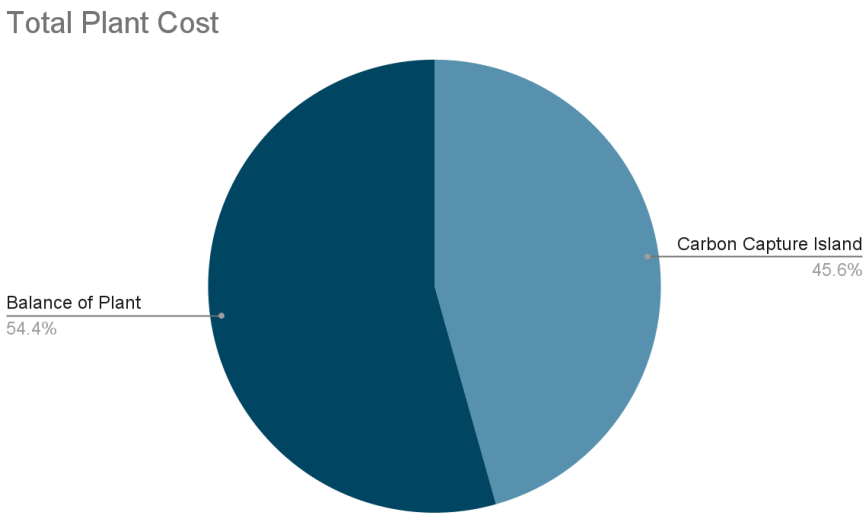
84 recommendations for EPC phase

24 std op. procedures for EPC phase

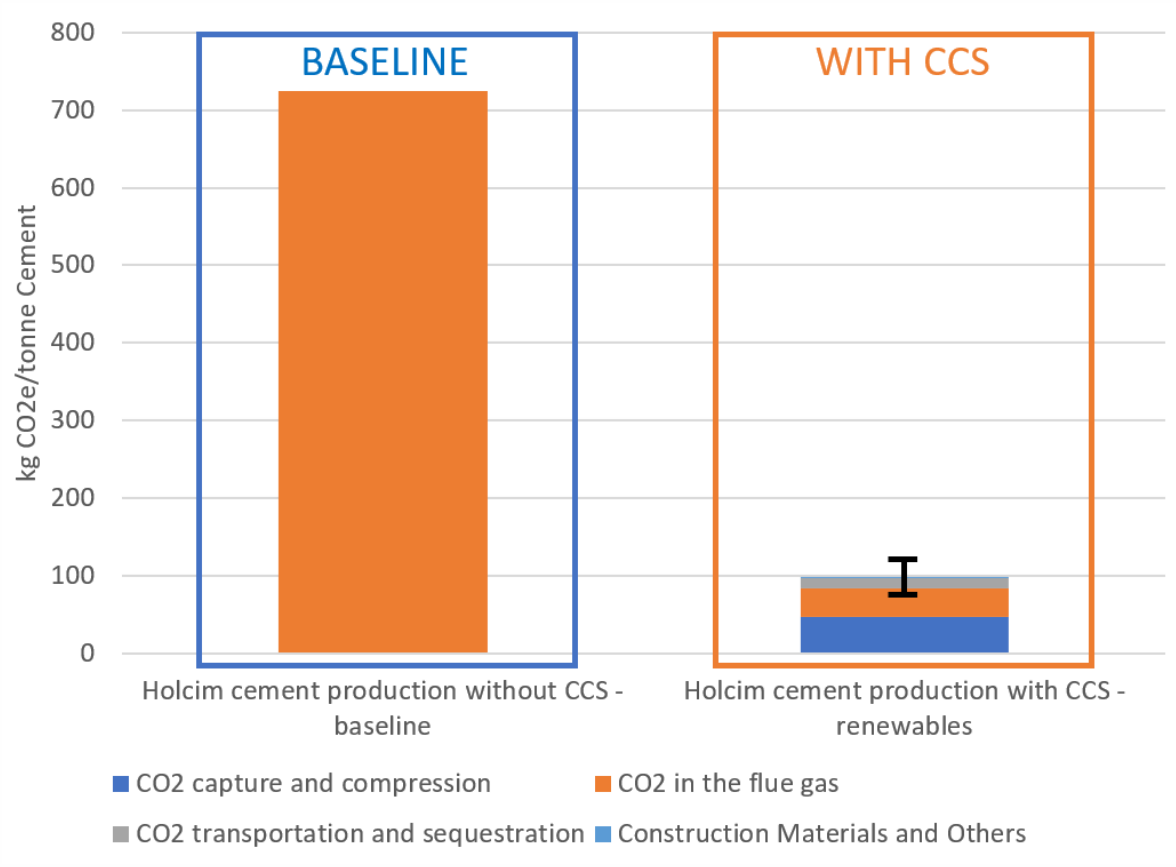
Techno Economic Analysis

- 2023 NETL method with project-specific data and assumptions
- Operational Period: 30 years
- Commercial Rates for ROI, loan
- Class 3 Cost Estimate
  - Includes site improvements, ZLD, buildings
- Direct, Indirect and Owners Costs Included





Life Cycle Analysis (GWP)



Scope: cradle to gate
Functional unit: 1 tonne cement
Method: TRACI 2.1 (NETL)
Electricity: U.S. Renewables
Region: Midwest
Baseline: Holcim Ste Genevieve LCA (2021)

Environmental Justice Analysis

- Identified local communities that have traditionally been marginalized and disproportionately impacted through a stakeholder mapping process
- Assessed involvement strategies of communities by information exchanges and engagement techniques
- Holcim held community engagement meetings sharing with the community potential project benefits and impacts.

Economic Revitalization & Job Creation

	Jobs	Economic Impact	Tax Revenue
Construction	>15,000 work-years	~$2.5B	>$240M
Operation	> 8,600 work-years	~$7.3B	>$220M

Conclusions & Lessons Learned

- Strong, motivated teams are essential for constructive project FEED development
- Project development & technology selection is site specific (flue gas, layout, energy/ utility provisions require study work and trade-off analysis)
- Cooling evaluation is key for cement plants, based on atmospheric conditions, cooling demand, water source (volume & quality)
- Water treatment and effluent disposal can have significant impacts both in terms of cost and overall freshwater withdrawal, with cement plant integration opportunities
- Pre-treatment and flue gas conditioning is critical to deliver a successful project integration to the cement industry
- PSA + Cryogenic technologies has HSE advantages translating to benefits in integration (e.g. utility requirements) & community benefits
- Effective capacity to consider cement plant variations, MTBF/ MTTR vs ramp up / ramp down and turndown

Acknowledgements

Name	Organization
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Q & A

Cryocap™: 18+ years of legacy