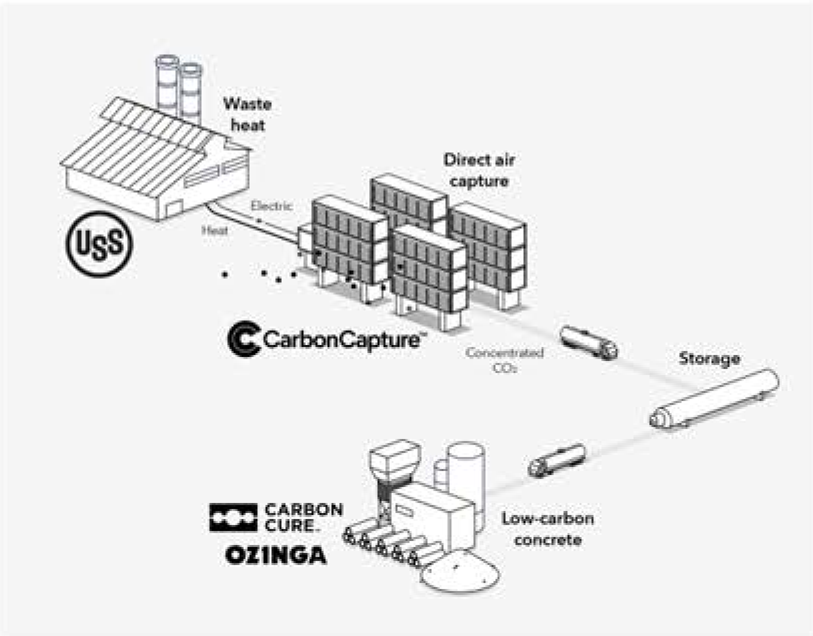
FEED Study of CarbonCapture Inc. DAC and CarbonCure Utilization Technologies Using United States Steel's Gary Works Plant Waste Heat (DE-FE0032154)



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Illinois Sustainable Technology Center
Net Zero Center of Excellence

2024 FECM/NETL Carbon Management Research Project Review Meeting

August 7, 2024

Disclaimer

Acknowledgement

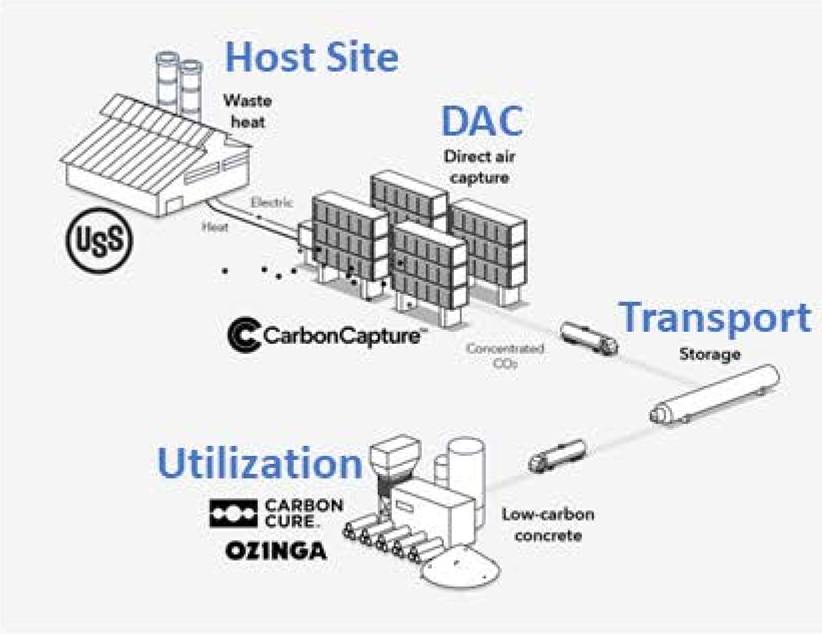
This material is based upon work supported by the Department of Energy under Award Number DE-FE0032154.

Project Overview

Project Overview

OBJECTIVES

- FEED study for DACU (DAC + Utilization)
- Capture 5,000+ tonnes/yr net CO_2 from air
- Utilize CO_2 in concrete and reduce cement production emissions
- Utilize waste heat from U. S. Steel in Gary, IN
- Demonstrate potential for full CO_2 value chain
- Illustrate the project impacts job creation, regional economic development, and environmental justice

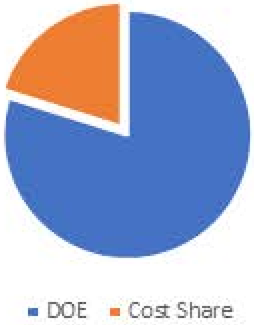


OVERVIEW

DOE: $3,459,554

Cost Share: $874,868

Work Period: 24 months



TIMELINE

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

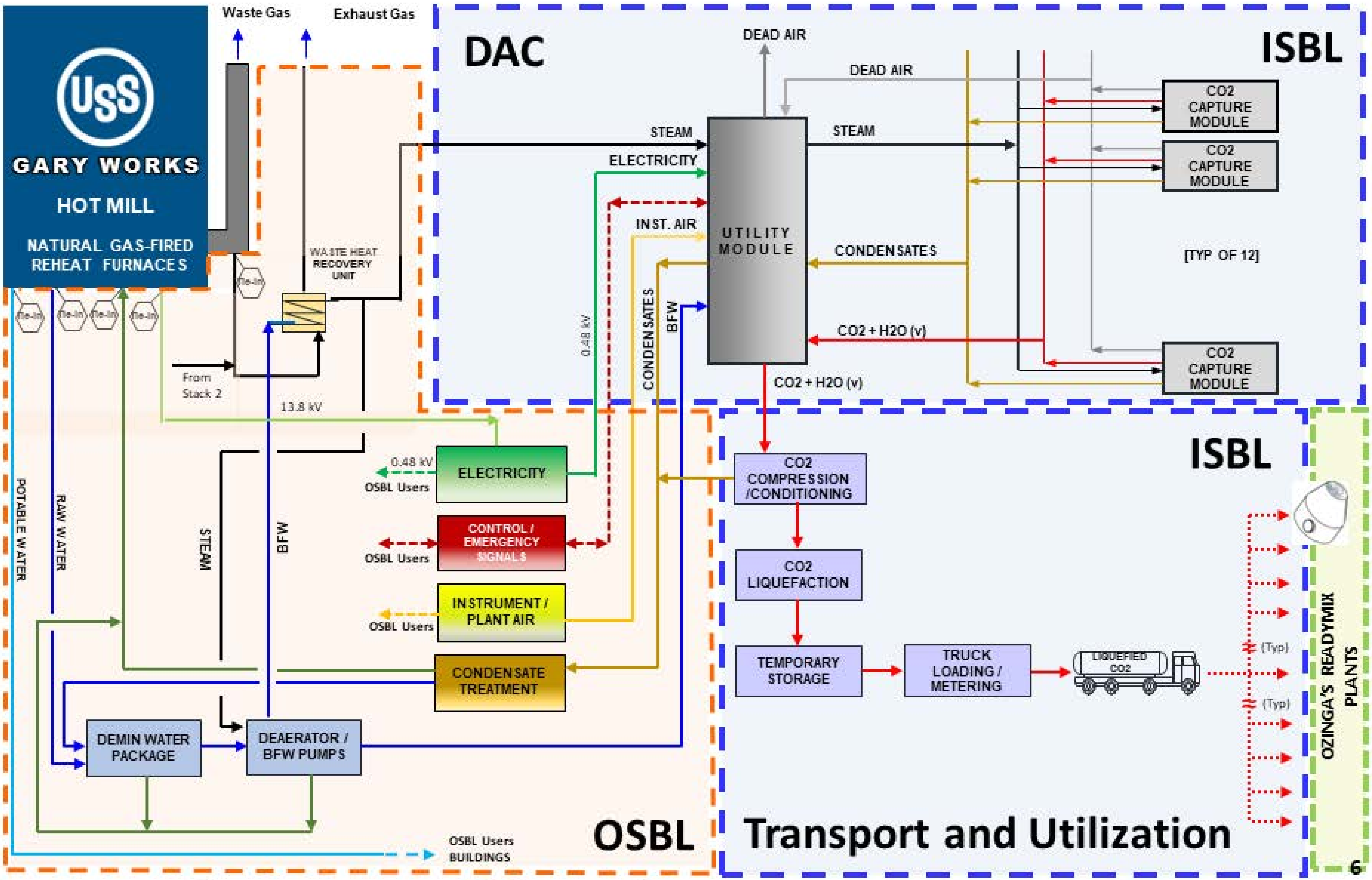
Start 10/1/2022

End 9/30/2024

Milestones Completed

Budget Period	Task or Subtask Number	Milestone Title & Description	Planned Completion Date	Actual Completion Date	Verification Method
1	1.1	Updated Project Management Plan	10/30/2022	10/30/2022	Deliverable to NETL
1	1.2	Technology Maturation Plan (TMP)	12/30/2022	12/30/2022	Deliverable to NETL
1	1.3	Initial Workforce Readiness Plan	9/30/2023	9/29/2023	Deliverable to NETL
1	1.3	Final Workforce Readiness Plan	6/30/2024	6/29/2024	Deliverable to NETL
1	2.0	Front-End Engineering Design (FEED) Study	6/30/2024	3/31/2024	Deliverable to NETL
1	2.1	Project Design Basis Completed	12/29/2022	12/29/2022	Indicated in Monthly Report, Delivered by 9/30/2024
1	2.5	HAZOP Completed	6/1/2023	8/25/2023	Indicated in Monthly Report, Delivered by 9/30/2024
1	2.6	Constructability Review Complete	6/30/2024	4/19/2024	Indicated in Monthly Report, Delivered by 9/30/2024
1	3.0	Project Cost Assessment	6/30/2024	6/29/2024	Deliverable to NETL
1	4.0	Logistics Analysis of CO_2 Transportation to the Utilization Site	6/30/2024	6/29/2024	Deliverable to NETL
1	5.0	Business Case Analysis(BCA)	6/30/2024	6/29/2024	Deliverable to NETL
1	6.0	Life Cycle Analysis (LCA)	6/30/2024	6/29/2024	Deliverable to NETL
1	7.0	Environmental Health and Safety (EH&S) Analysis	6/30/2024	6/29/2024	Deliverable to NETL
1	8.0	Environmental Justice Analysis	6/30/2024	6/29/2024	Deliverable to NETL
1	9.0	Economic Revitalization and Job Creation Outcomes Analysis	6/30/2024	6/29/2024	Deliverable to NETL

Block Flow Diagram



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Technology Background

- DAC
- Utilization

Technology Background

- Direct Air Capture

CarbonCapture Inc.

DAC Provider

CarbonCapture™

What we do

We develop and deploy DAC machines.

- Founded in 2019
- Based in Los Angeles, team of 65+
- Unveiled first DAC module this past June capable of removing 500 tons/year CO_2
- Presold $27M in removal credits to top tier customers Google, Microsoft, Facebook, McKinsey, BCG, Stripe, H&M, JPMorgan Chase, etc.
- Raised over $90M in funding

NET ZERO CENTER of EXCELLENCE

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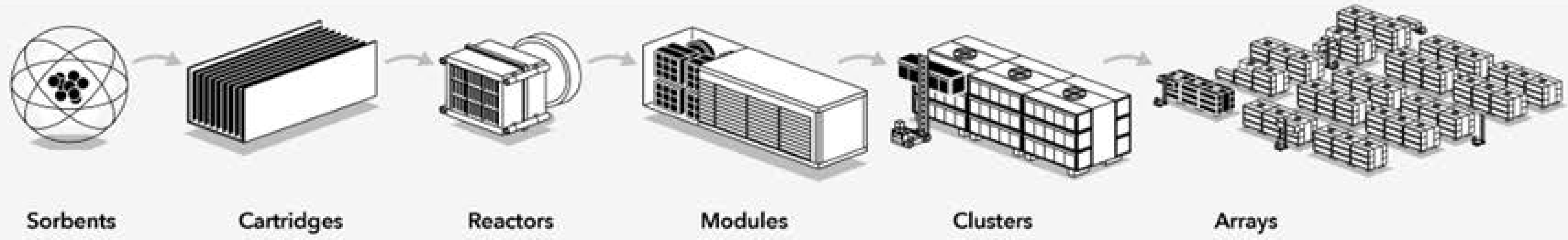
DAC Technology, DAC Plant Location & CO_2 Utilization Sites



Advantages:

- **Modularity:** modular, stackable components, capable of accepting multiple types of solid sorbents
- **Go-to-market sorbent:** amine in a hydrophobic structure
- **Low temperature:** relatively low desorption heat of 100°C
- **Site:** centrally located in industrial area

Approx. location of the DAC system

Tie-in to Waste Heat

Ozinga Plant Locations

U. S. Steel DAC Site Location

Storage Tank Location

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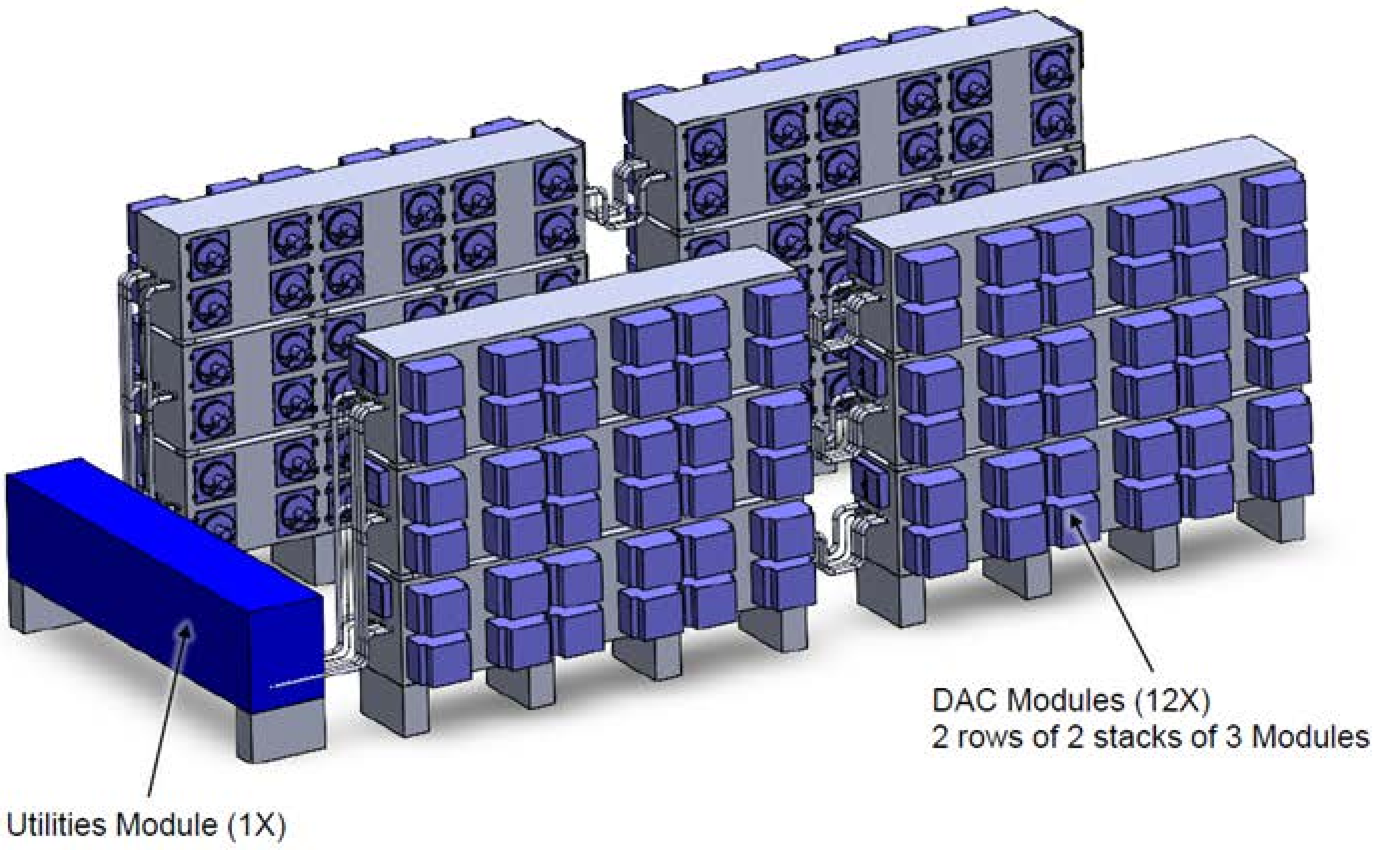
3-D Model of DAC Cluster



Technology Development

Direct Air Capture module from CarbonCapture Inc. Photo: CarbonCapture Inc.

- 1st commercial scale reactor with structured sorbent, Los Angeles, Single reactor (35 tons/year) – 2022
- 1st commercial scale module with structured sorbent, Los Angeles, Multi-reactor module (500 tons/year) – 2024
- Commercial pilot, Multi-module cluster (2000 tons/year) – planned for construction in 2025
- Note: design influenced from FEED Study

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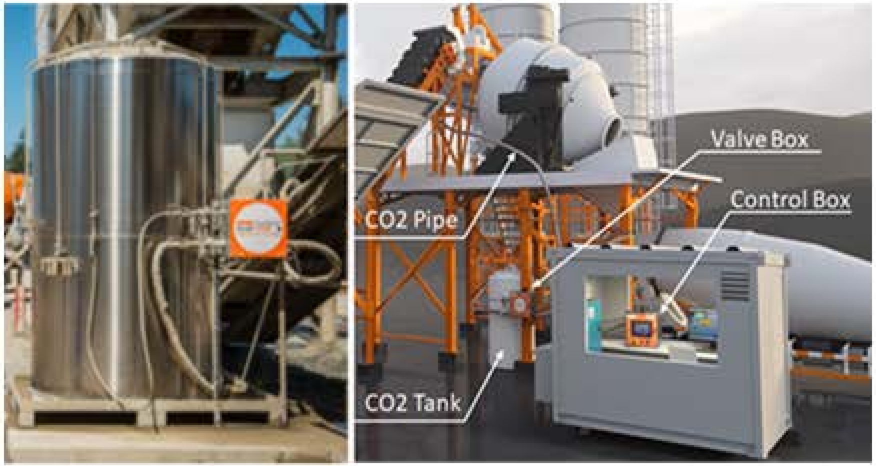
Technology Background

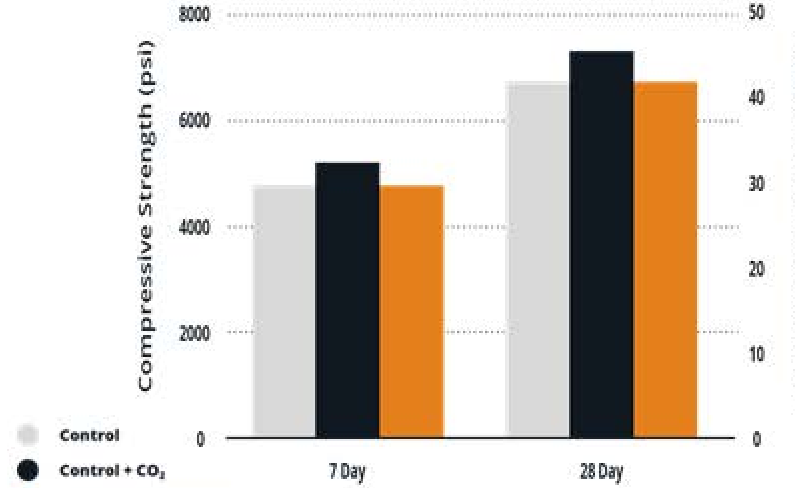
- Utilization

CarbonCure

CarbonCure Cement Carbonization Technology



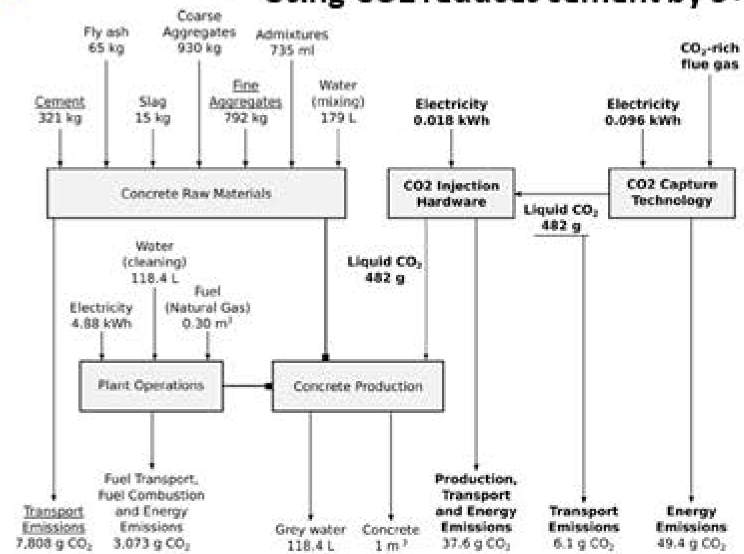
CarbonCure's retrofitted equipment into concrete plants



Using CO2 reduces cement by 3+%

Table 6
Summary of the Environmental Impact on 1 cubic meter of concrete.

Factor	g CO_2/m^3 concrete
Emissions – CO_2 from gas processing	49.4
Emissions – CO_2 from gas transport	6.1
Emissions – CO_2 from equipment production	0.1
Emissions – CO_2 from equipment transport	0.0
Emissions – CO_2 from equipment operation	9.2
Emissions – Avoided CO_2 from materials transport	–123.6
CO2AB: CO_2 absorbed	–289.1
CO2AV: Avoided CO_2 emissions from cement	–17584.8
Total CO_2 avoided and absorbed	–17997.4
CO2EM: Total CO2 produced	64.7
Net CO_2 reduction	–17932.7



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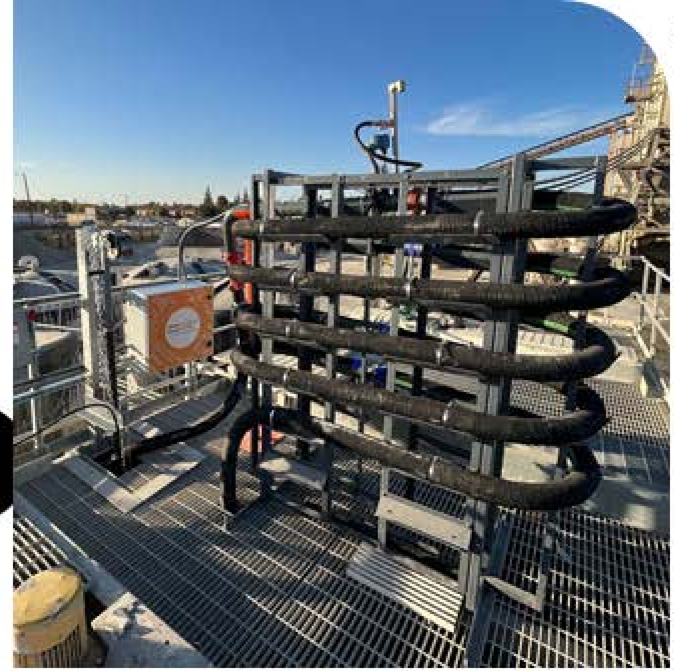
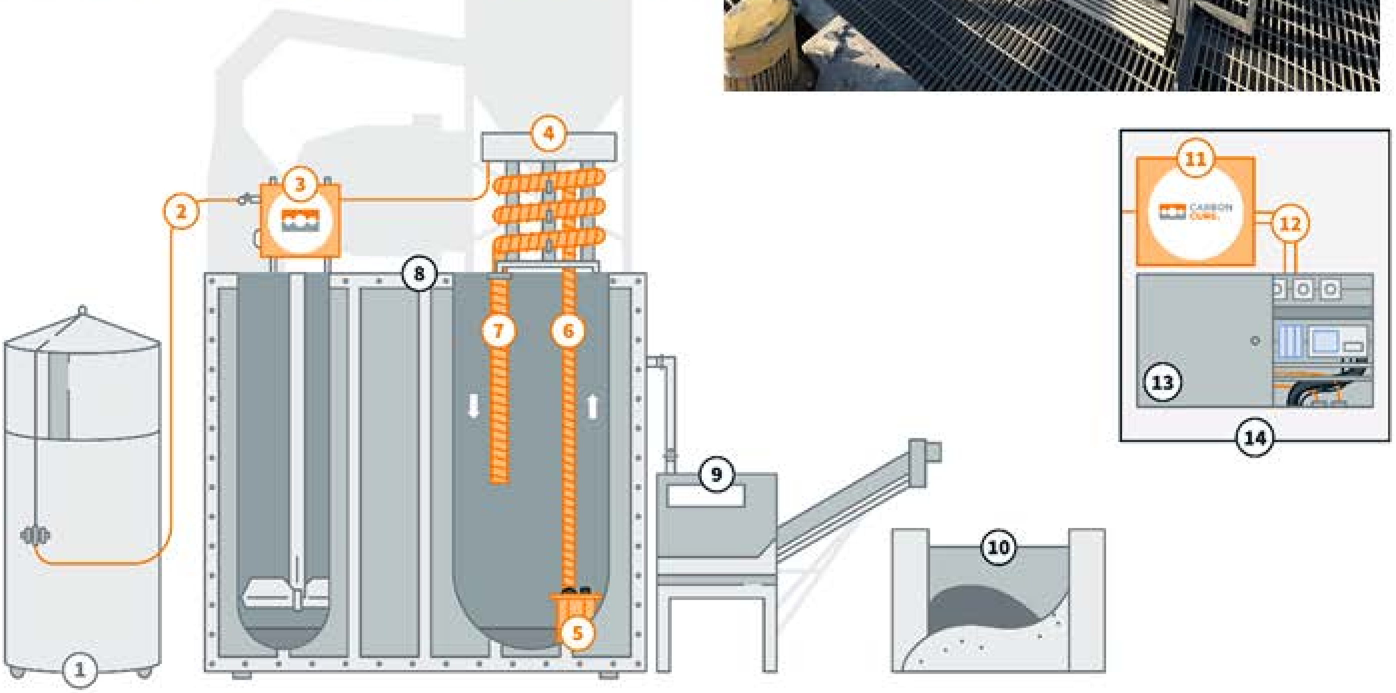
Previous literature indicated significant CO2 reduction by curing concrete with captured CO2

S. Monkman, M. MacDonald / Journal of Cleaner Production 167 (2017) 365-375



Reclaimed Water Technology

- Approx. 3% concrete is unused
- Reclaimers recover aggregates and recover cementitious slurry (Reclaimed Water)
- Using this process reduces the cement required by 3%.
- The 2 processes are additive.



Orange: Supplied by CarbonCure
Black: Supplied by Concrete Producer
Grey: Supplied by CO_2 Supplier

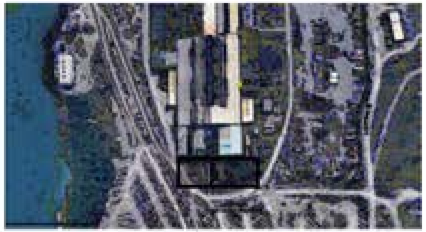
Legend

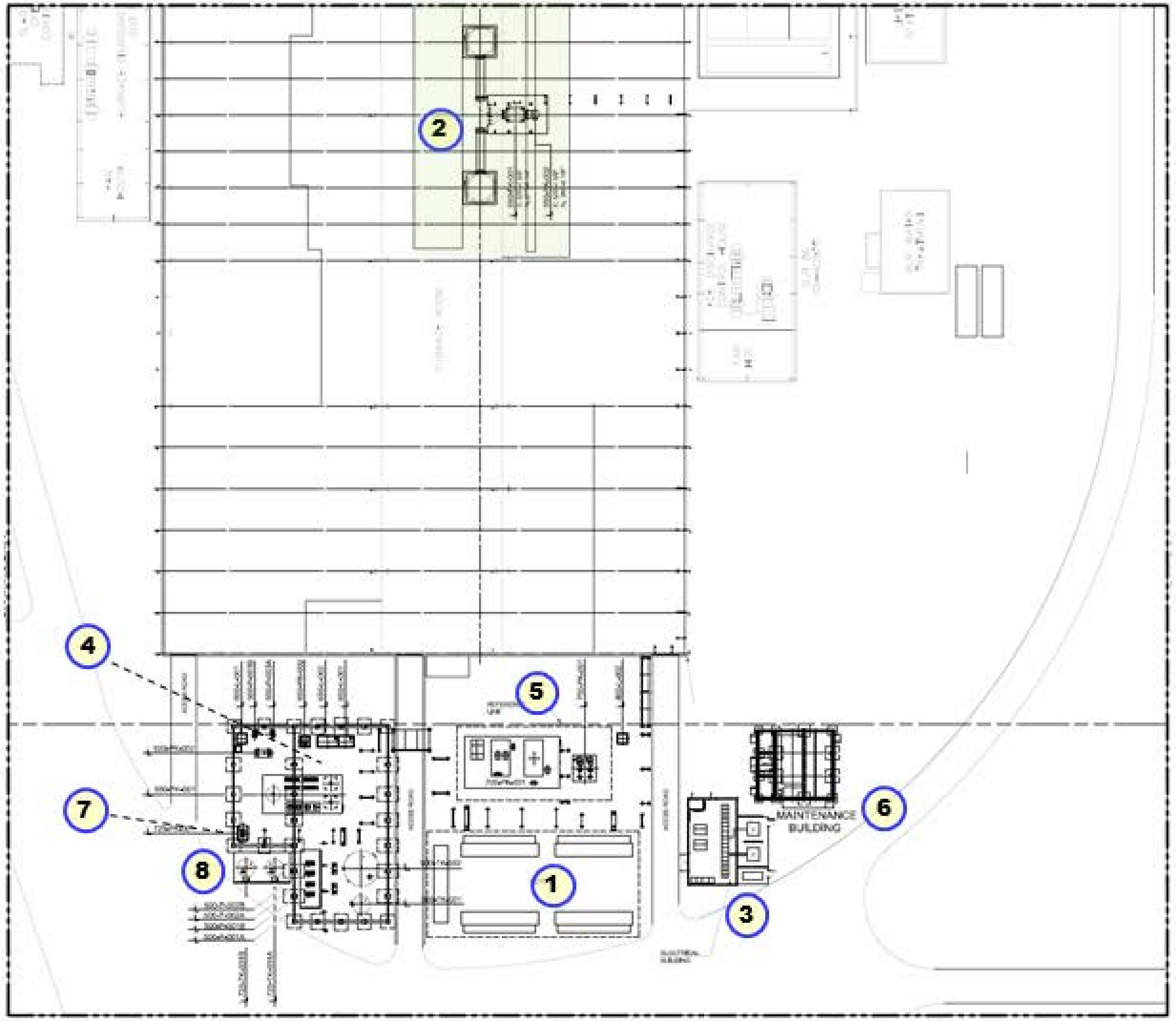
1. CO_2 Tank – Sized according to anticipated CO_2 usage
2. Gas CO2 Transfer Line
3. CarbonCure Valve Box
4. Reclaimed Water Treatment System
5. Slurry Pump
6. Slurry Infeed Pipe
7. Treated Slurry Return
8. Reclaimed Water Slurry Tank
9. Aggregate Reclaimer
10. Reclaimed Aggregate
11. CarbonCure Control Box
12. Process Monitoring Sensors
13. Reclaimer Control Panel
14. Reclaimer Control Room

CARBON CURE.

OSBL Systems

Plant Layout

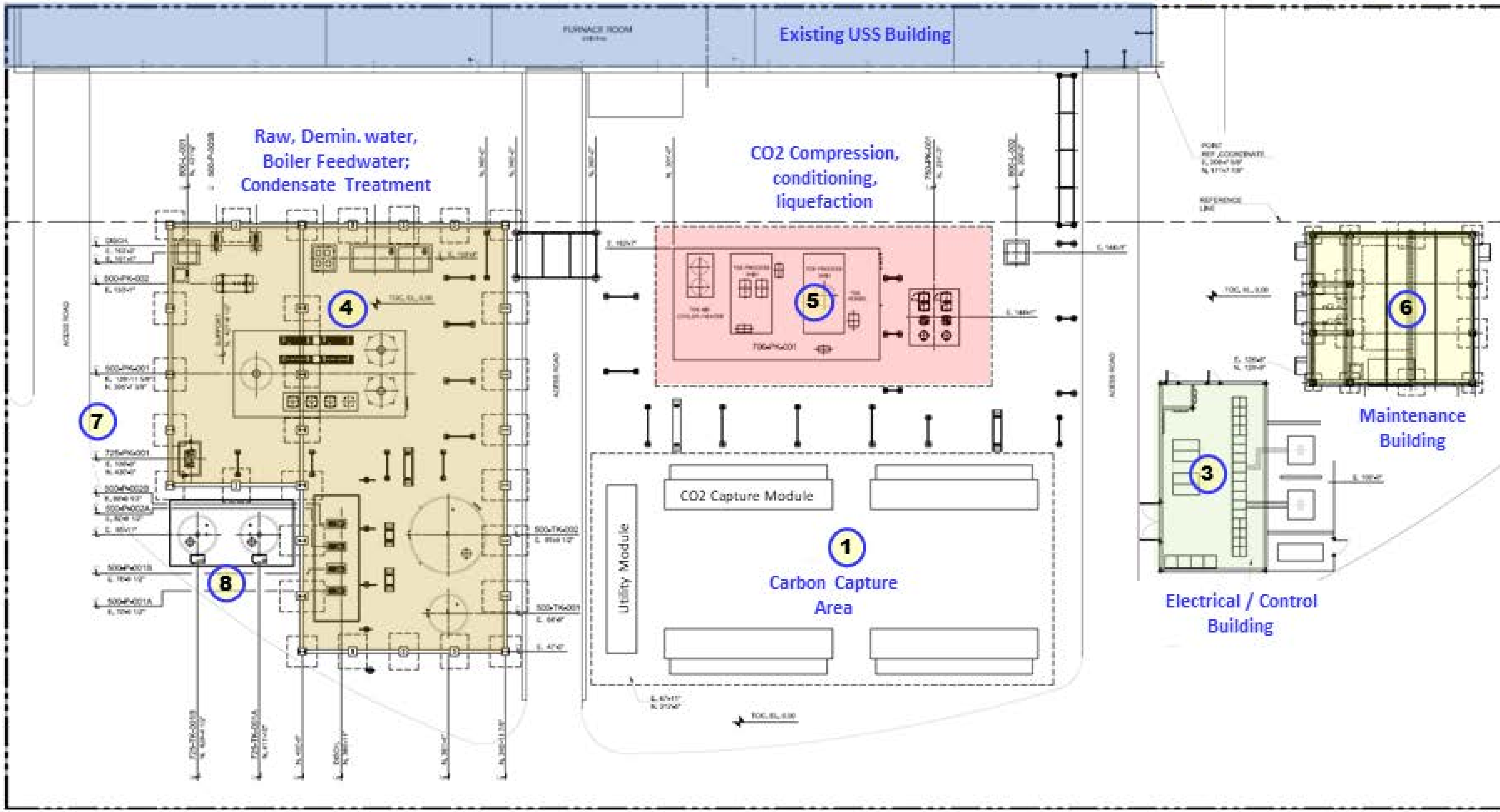




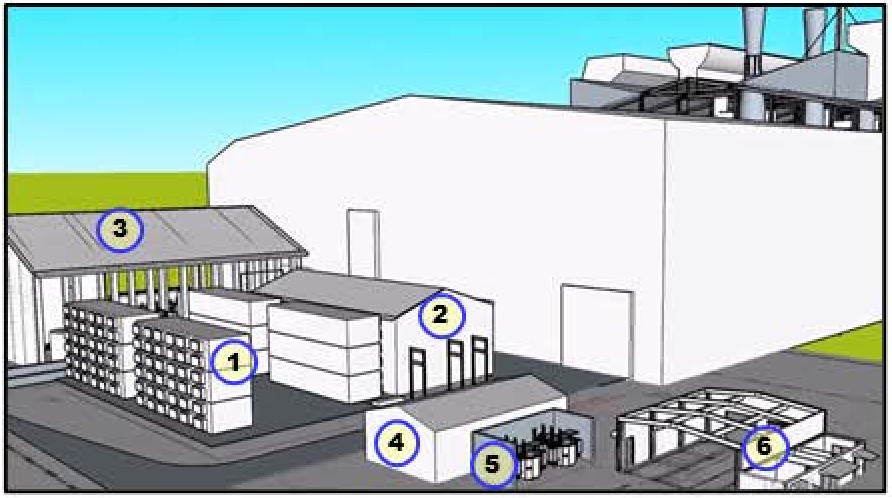
LEGEND

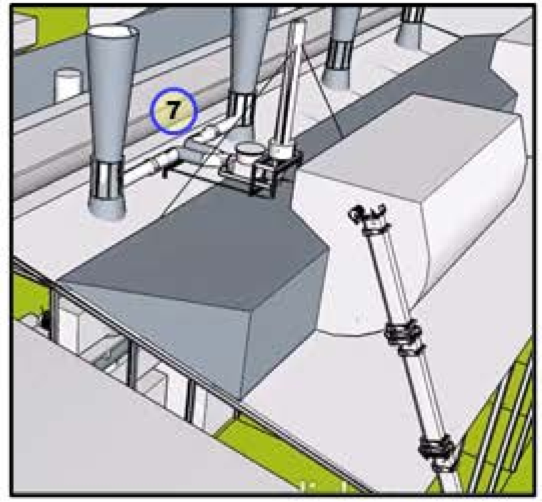
1	Carbon Capture Modules
2	Waste Heat Recovery Unit
3	Electrical / Control Room Area
4	Raw, Demin, Boiler feed water
5	CO2 Compression, Conditioning, Liquefaction
6	Maintenance / Office Building
7	Liquid CO2 Unloading
8	Liquid CO2 Storage

Plant Buildings



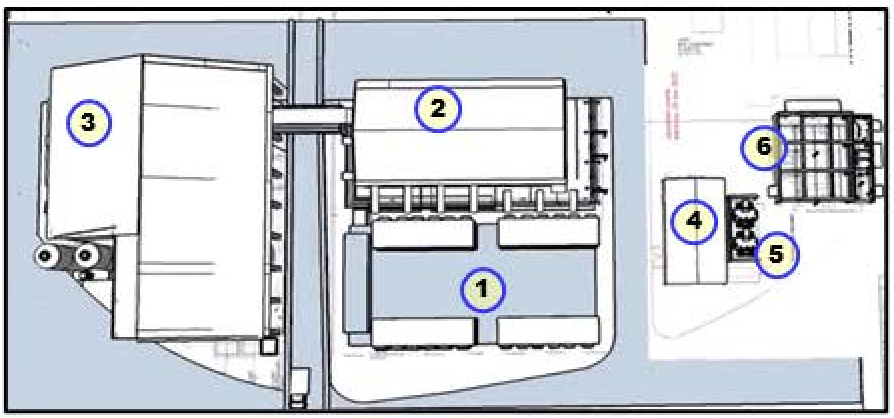
General Views

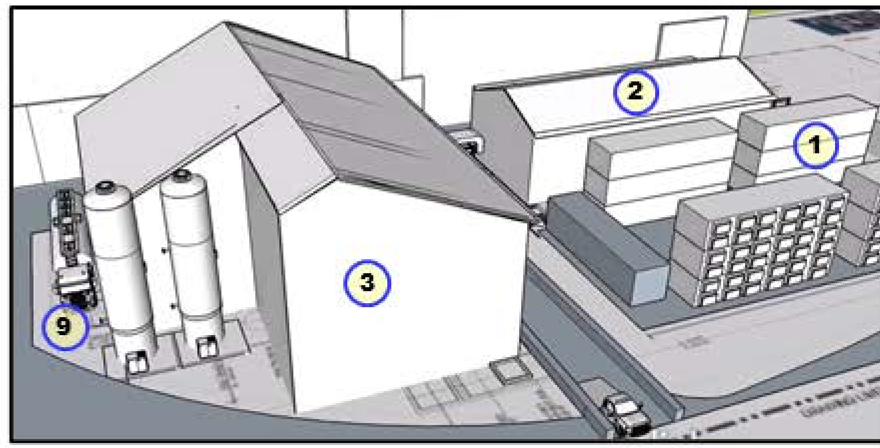




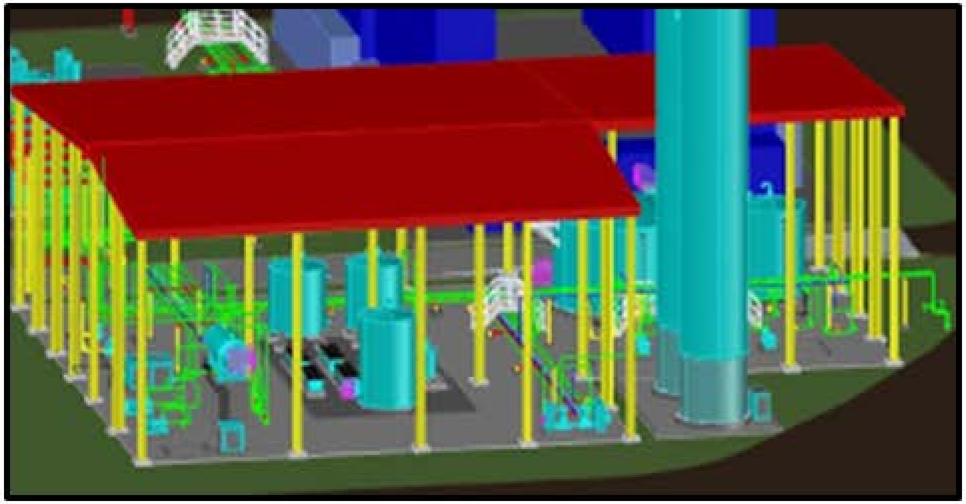
LEGEND

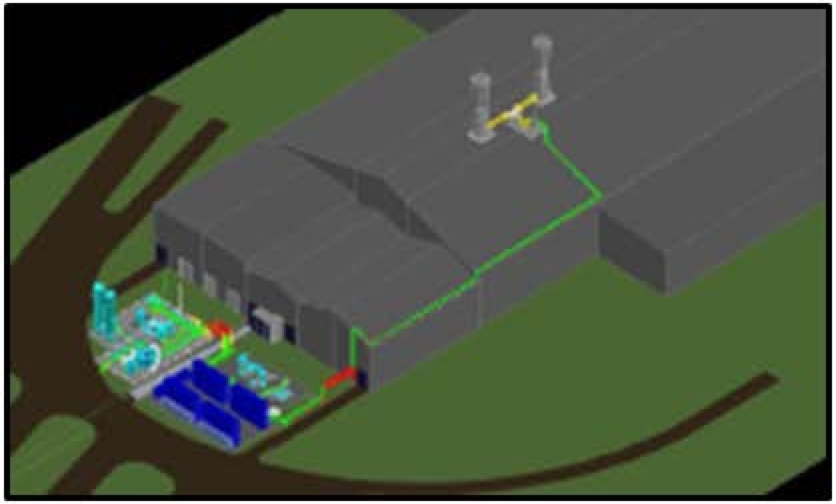
1. Carbon Capture Modules
2. CO2 Comp., Liquefaction
3. Raw, Demin., BFD, waste-water
4. Electrical / Control Bldg.
5. Power Transformers
6. Maintenance Bldg.
7. WHRU
8. Liq. CO2 Storage Tanks
9. Liq. CO2 Loading

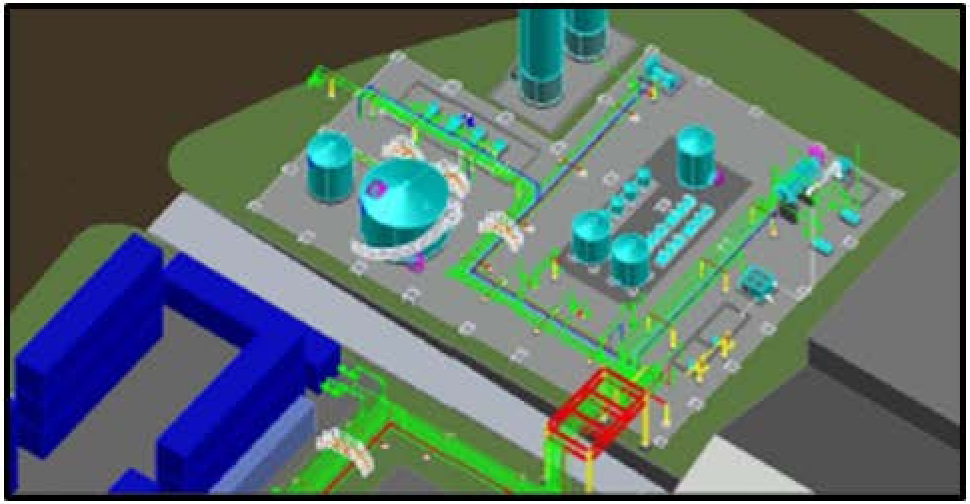


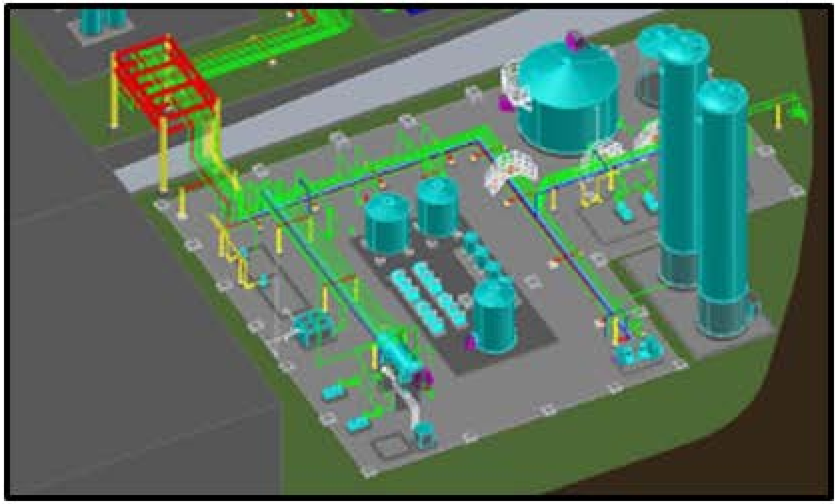


General Views







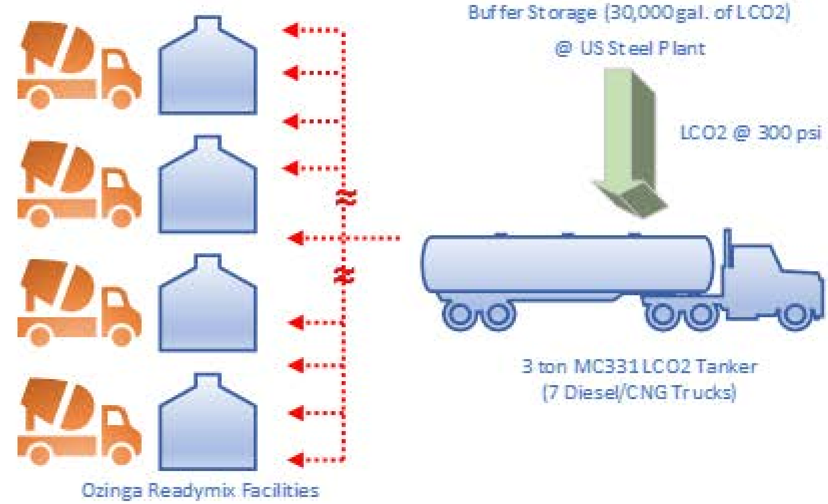


CO2 Logistic analysis

- Transport

CO_2 Logistics Analysis

- Analyzed 3 Different Scenarios:-
  - Scenario 1: Central Buffer Storage at US Steel Plant + Trucking
  - Scenario 2: Pipeline to Ozinga Central Storage @ Gary + Trucking
  - Scenario 3: CO2 Barge to Ozinga Central Storage in Chicago + Trucking
- Scenario 1 was selected as the best option for this project, due to:
  - Low annual CO_2 production Volume (~5,000 tonne/yr)
  - 55+ CO_2 Utilization sites spread across 3 states
  - Lowest Levelized cost of transport (LCOT)



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Trucks and Storage Tanks

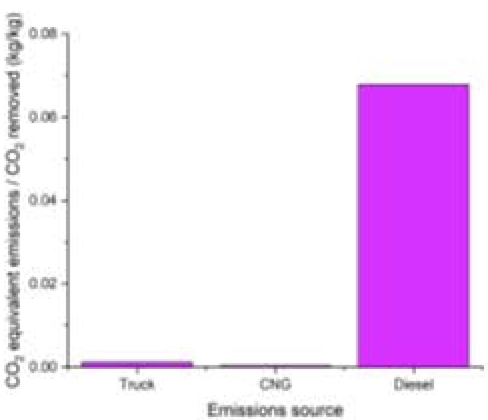
Tanker and Vertical Storage Tank

Bobtail truck w/ MC331 LCO2 Tank

Ozinga CNG Trucks at Ozinga RNG Gas Hub Location

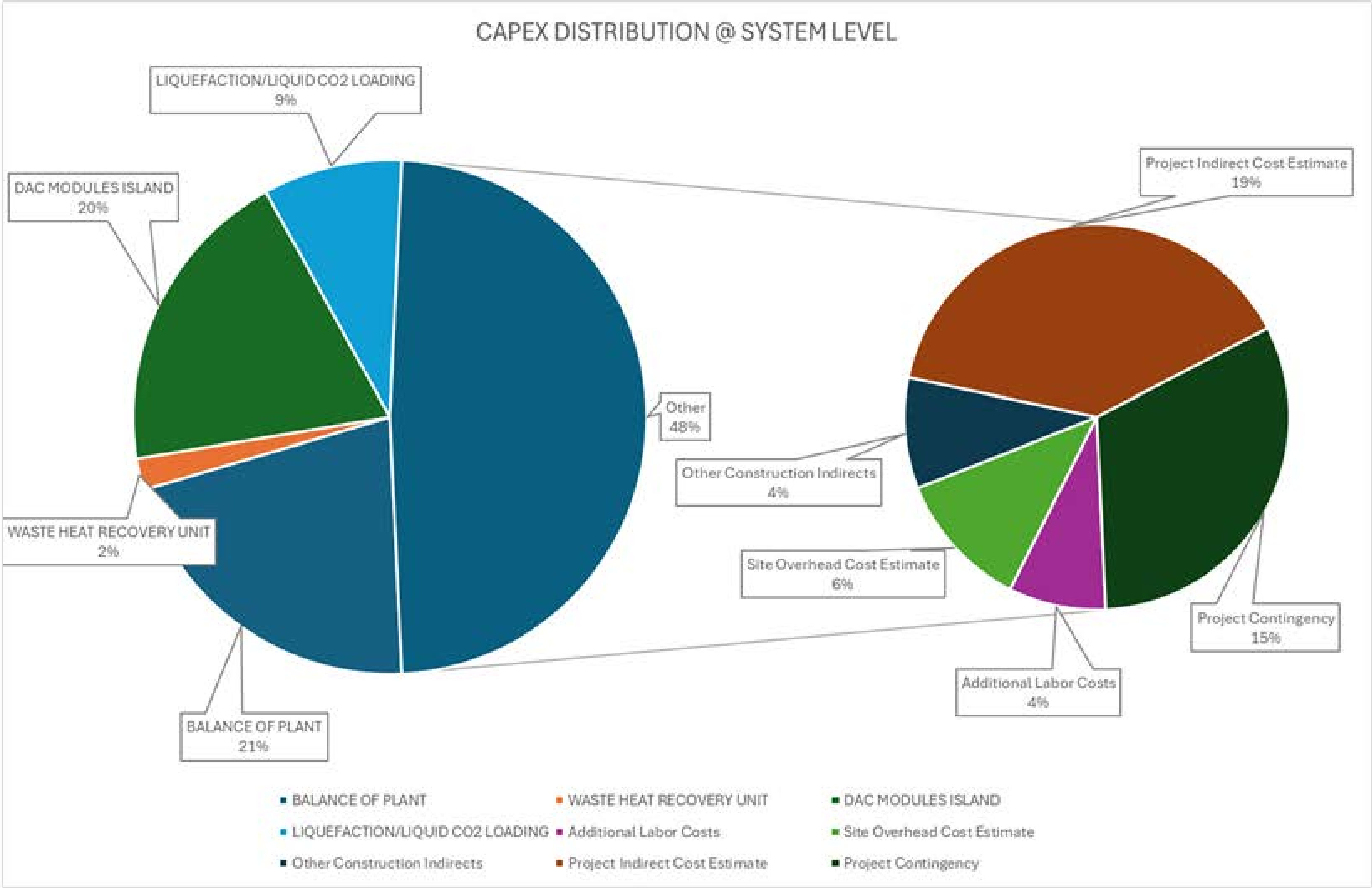
CO_2 Logistics Analysis

- Two strategies considered:
  - Investor owned & operated fleet of seven class-6 CO_2 Trucks (diesel/CNG) skid-mounted with 3-ton MC-331 LCO_2 Tanks
  - Using an existing 3rd party gas supplier in Chicago region as a Transport-partner (Food-grade certification required)
- CO_2 Storage:
  - 6-day buffer storage onsite at DAC plant facility in US Steel, Gary
  - 3-day buffer storage at a central Ozinga facility in Chicago
  - Micro bulk LCO_2 storage tanks at each Utilization site
- CNG Trucks increases LCOT by ~1-2% as compared to diesel trucks, but reduces GHG emissions significantly

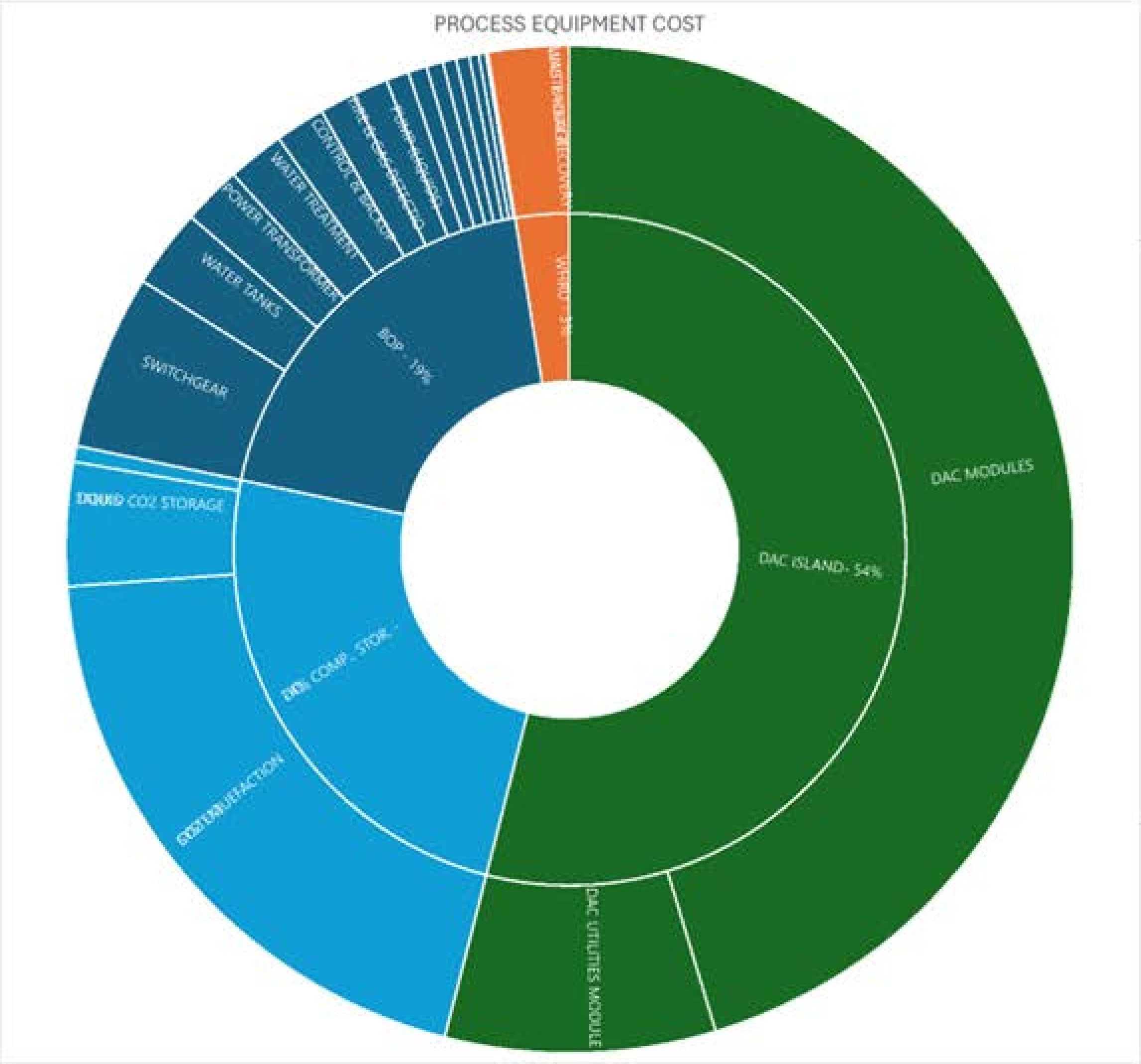


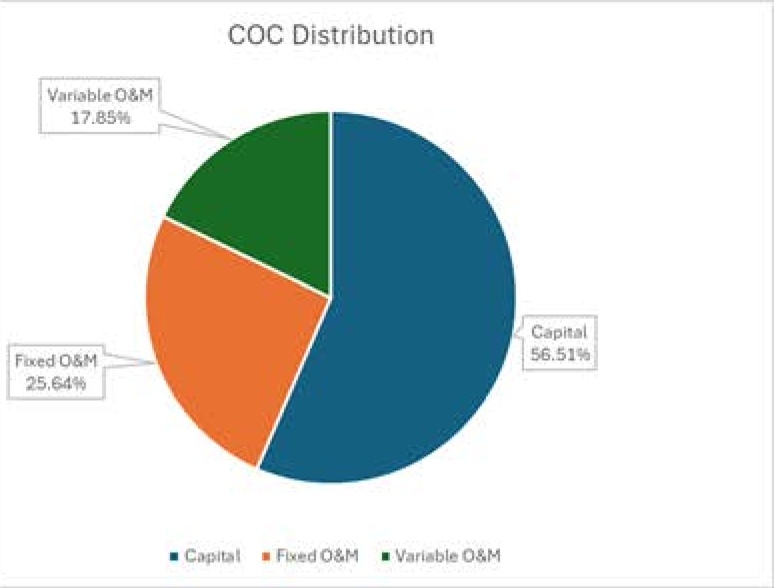
Economic Assessment

CAPEX at System Level – DAC, Storage & Loading Terminal



Process Equipment & COC Distribution





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Community Benefits

Environmental Justice Analysis Task

- **Objective**: Analyze the impact of proposed project on local communities and assess potential distribution of Justice40 benefits and disbenefits.
- Assessment of communities potentially impacted from the proposed DACU project was performed using the following mapping tools:
  - ArcGIS Justice40 Tracts map
  - Energy Justice Mapping tool
  - Climate and Economic Justice Screening Tool (CEJST)

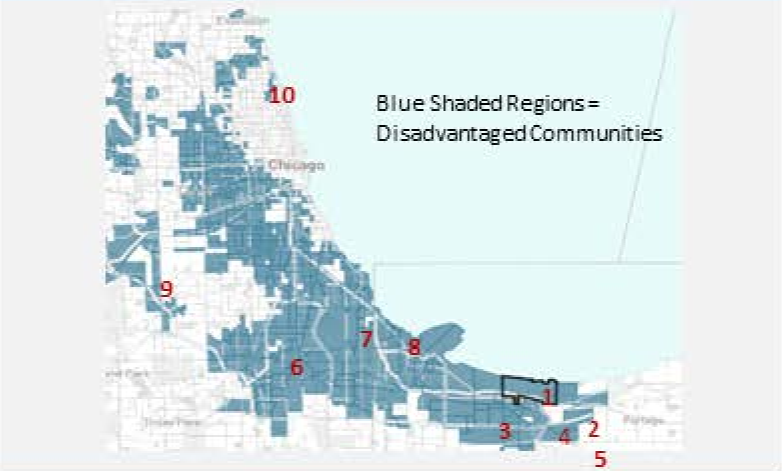
Analysis highlights census tracts with higher disadvantaged community profiles in the areas immediately adjacent to and surrounding project region

Generally, various mapping tools concur regarding Justice40 parameters. Analysis highlights discrepancies across various tools, with CEJST being the overarching tool for identifying disadvantaged communities

Social Characterization of Justice40 Communities

- Identified disproportionally impacted communities through Stakeholder Mapping.
- Focus on Disadvantaged Communities near both **Gary Indiana** U. S. Steel host site and Ozinga utilization sites in **Chicagoland region** with given unique socioeconomic and environmental challenges faced by these populations**.**
- Table serves as representative of varying environmental and socioeconomic impacts on surrounding communities.

EJ Characteristics Surrounding the Facility



EJ Profile of Surrounding Communities

	Census Tracts	City	DAC	Water Discharge	Climate Hazards Loss of Life estimate	RMP Proximity	Job Access	Less high school Education	Low Income Population	Outage Duration
1	18089010205	Gary	1	67.54584742	24.79550173	4.14556	-7.8	0.10983264	0.6339286	0
2	18089011500	Gary	0	5.347620509	23.23925267	0.4134	-6.2	0.07897664	0.4355401	0
3	18089021800	Hammond	1	8.79048E-06	30.50083174	0.43947	-6.6	0.18703704	0.4664804	0
4	18089041700	Lake Station	1	0.021150634	44.50844801	0.17284	-5.3	0.16077044	0.4762955	0
5	18089042100	Hobart	0	0.010867705	44.95112663	0.16714	-5.3	0.1795825	0.1704918	0
6	17031820202	Hodgkins Village	1	24.47545198	52.36668087	3.86801	-8.3	0.20405465	0.3304094	4487
7	17031838800	Chicago	1	0.005783617	50.95478354	3.50506	-8	0.25687104	0.6737589	4487
8	18089040200	Whiting	1	8.46733E-05	28.37542446	5.41235	-6.5	0.16851228	0.2092352	0
9	17043845803	Bridgeview village	1	0.115776886	65.8697535	1.1047	-7	0.07834101	0.2456286	4487
10	17031810200	Evanston	1	15.43014316	45.79249096	1.08785	-9.2	0.14474865	0.3082251	4487

Economic Revitalization and Job Creation Outcomes

	Jobs*	Economic Impact*	Tax Revenue*
Construction	>650 work-years	>$100M	>$12M
Operation & Utilization	> 2,800 work-years (~25 direct FTEs created)	~$1.6B	>$100M

*Total Impacts = Direct + Indirect + Induced

Lessons Learned

Lessons Learned

- **Waste Heat Recovery:**
  - Waste heat recovery is a viable solution to reduce overall energy needs. Challenges include matching temperatures/flowrates and operating profiles with the DAC unit's operation regime.

- **CO_2 Transportation:**
  - Third-party transportation supplier could be a solution to reduce CAPEX associated with CO_2 transport systems, provided that the CO_2 can be treated/certified to food-grade to match trucking and storage specifications. However, food-grade CO_2 certification requirements are costly.
    - Further exploration of industrial-grade CO2 transportation is necessary.

- **Life Cycle Impacts:**
  - The overall largest contributor to the systems Global Warming Potential are emissions associated with electricity, with CO_2 transportation being a nearly negligible contributor. Cleaner sources of electricity have the largest impact on reducing overall GWP.
  - All GWP contributors are dwarfed by the CO2 avoid by reducing cement in concrete batch.

Future Study

- Determine ownership structure
- Demonstrate technology
- Refine design and practices to reduce cost of carbon capture
- Sorbent Evolution

Acknowledgements

Name	Organization
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Brenda Petrilena, James Hoppe	U. S. Steel Corporation
Kevin Cail	CarbonCure
Ryan Cialdella	Ozinga
Alberto Baumeister, Claudio Mazzei	Ecotek
Paula Guletsky, John Lawlor, Clint Watters	Sargent & Lundy
Daryl-Lynn Roberts, Will Johnson	Visage Energy
Elliot Roth, Mike Bergen, Mariah Young	National Energy Technology Laboratory / US Department of Energy

Questions?