Design and costing of ION's CO_2 capture plant retrofitted to a 700 MW coal-fired power plant

2020 NETL CO_2 Capture Technology Project Review Meeting

August 18, 2020

Project: Commercial Carbon Capture Design and Costing: Part 2 (C3DC2) - DE-FE0031840

Andy Awtry, Ph.D. – VP Engineering

ION Clean Energy, Boulder, CO, USA

ION's CO_2 Capture Technology Development

Accelerated development path leveraging existing research facilities

2010

ION Engineering Lab-pilot
0.001 MWe
Boulder, CO, USA

2012

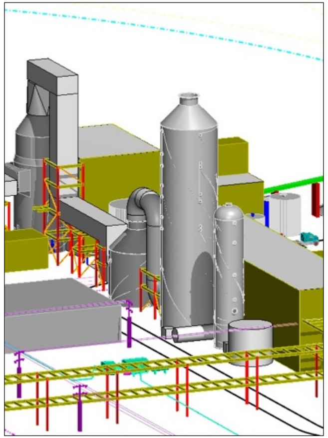
Univ. of N. Dakota EERC
0.05 MWe
Grand Forks, ND, USA

2015

National Carbon Capture Center
0.5 MWe
Wilsonville, AL, USA

2016 - 2017

CO_2 Technology Centre Mongstad
12 MWe
Mongstad, Norway

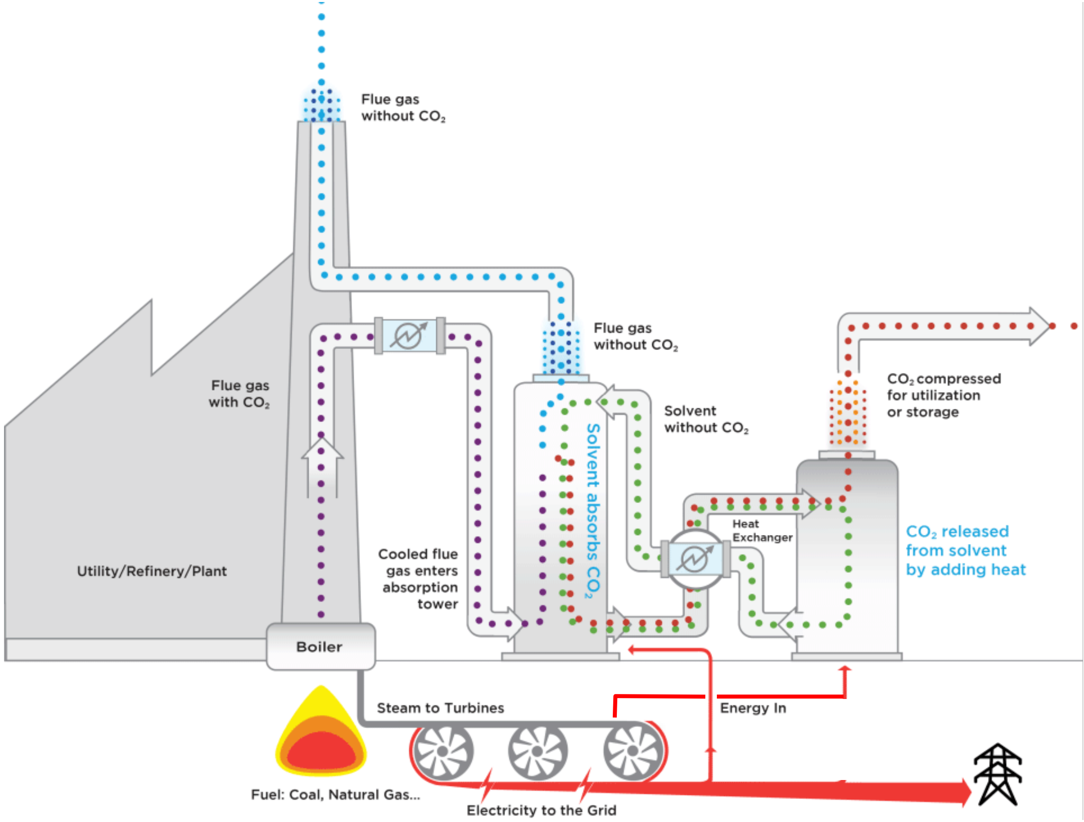


2018 - 2021

Design & Costing Commercial Retrofit
300 & 700 MWe
Sutherland, NE, USA

ION Technology Overview

- Proprietary Solvent-based Technology
  - Liquid absorbent-based capture
  - Low aqueous
  - Worldwide Patents
- Established Engineering Process
  - Learnings from Boundary Dam
  - Learnings from Petra Nova
- Basis of Performance
  - Fast kinetics (on par or faster than MEA)
  - Working capacity (higher than MEA)
  - Low heat capacity (much lower than MEA)
  - < 1,090 Btu/lb CO_2 (2.5 MJ/kg CO_2)



ION Technology Overview

Value Added

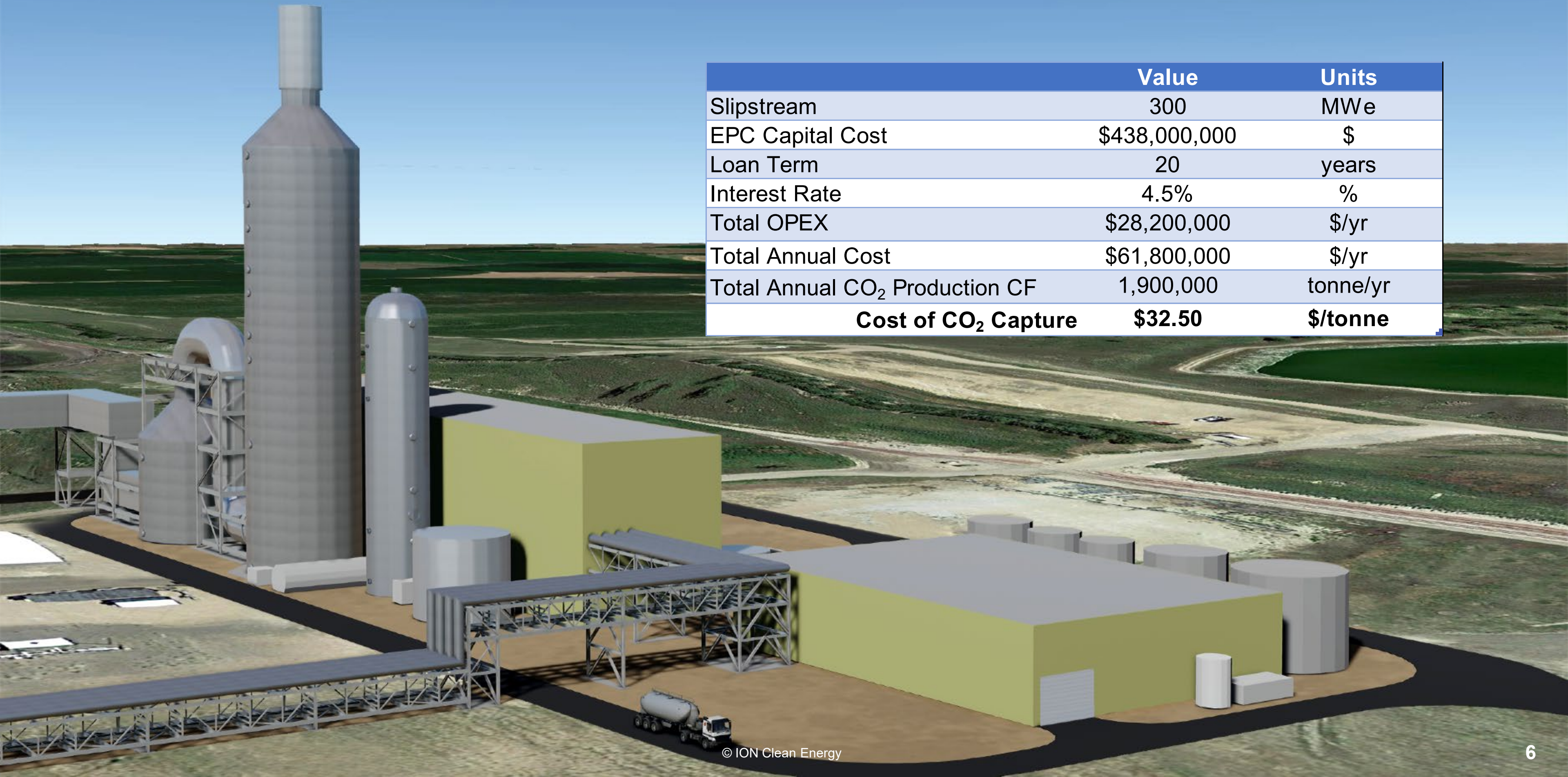
- High Capture Efficiency
  - Up to 96% CO_2 Capture
- Design System for CAPEX/OPEX savings
  - Smaller absorber column(s) vs higher carrying capacity
  - Pumps/HEXs are smaller due to lower liquid flow rates
- Low regeneration energy requirement
  - Low parasitic load
  - Low steam demand – reduction in plant de-rate if integrated into the steam cycle
- Demonstrated lower corrosion rates than MEA
- Demonstrated lower total emission rates than MEA

Commercial Carbon Capture Design & Costing

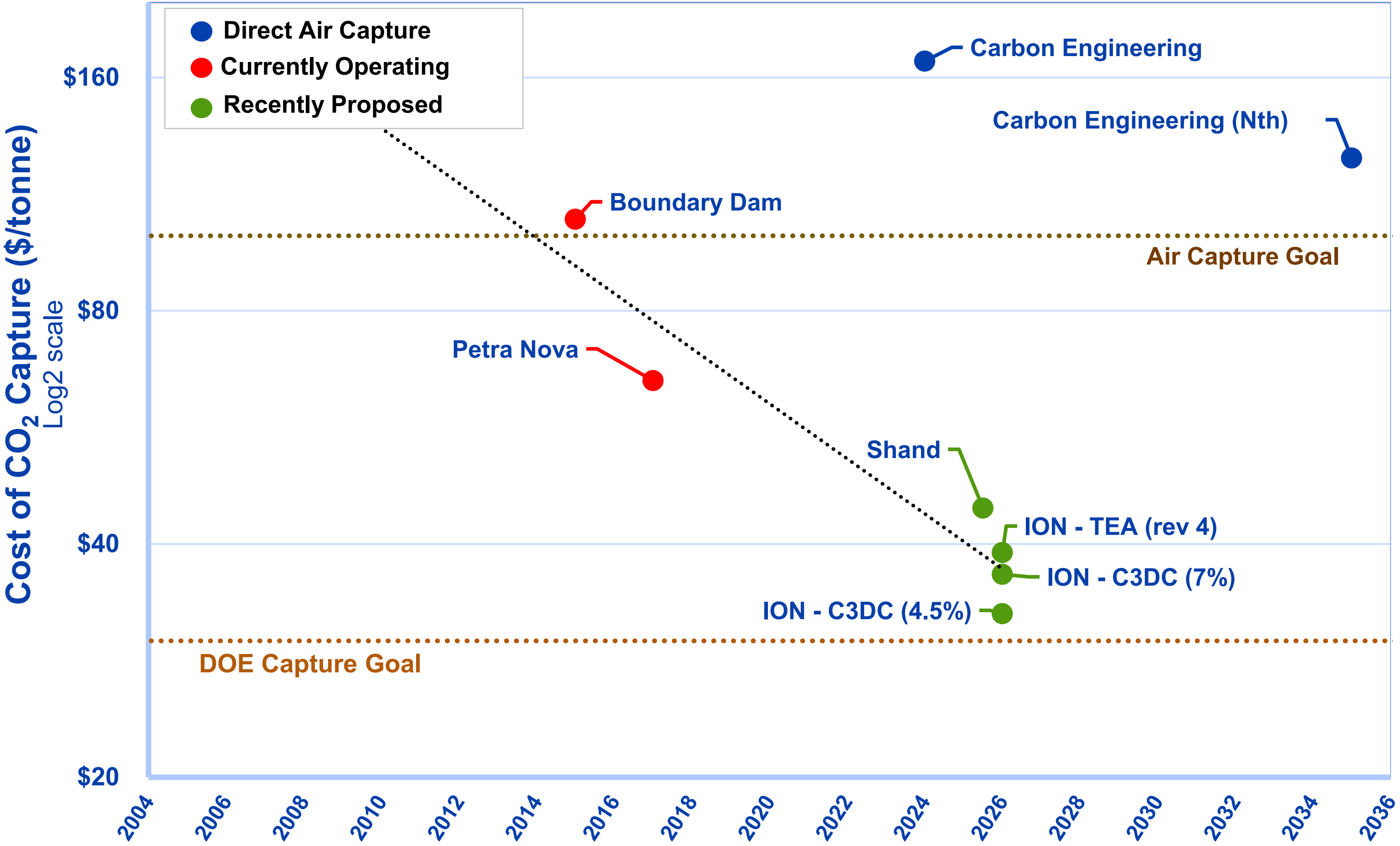
(C3DC) DE-FE0031595 – Previous Award, Completed Q4 2019

- Objective: Retrofit a Carbon Capture System at a power station
  - Nebraska Public Power District's (NPPD) Gerald Gentleman Station (GGS)
  - 300 MWe Slipstream for carbon capture
  - Ownership model: NPPD owns and operates the capture island
  - Design Basis: CO_2 product for enhanced oil recovery (not regulatory driven)
- Class 3 (AACE) Cost Estimate
  - Cost Estimate is -20% to +30%
  - Completed about 20% of Engineering Effort
- Completed 18mo Project in Q4 of 2019

Commercial Carbon Capture Design & Costing Study



	Value	Units
Slipstream	300	MWe
EPC Capital Cost	$438,000,000	$
Loan Term	20	years
Interest Rate	4.5%	%
Total OPEX	$28,200,000	$/yr
Total Annual Cost	$61,800,000	$/yr
Total Annual CO_2 Production CF	1,900,000	tonne/yr
Cost of CO_2 Capture	**$32.50**	**$/tonne**



Direct Air Capture
Currently Operating
Recently Proposed
Cost of CO_2 Capture ($/tonne)
Log2 scale
$160
$80
$40
$20
Carbon Engineering
Carbon Engineering (Nth)
Boundary Dam
Air Capture Goal
Petra Nova
Shand
ION - TEA (rev 4)
ION - C3DC (7%)
ION - C3DC (4.5%)
DOE Capture Goal
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036

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COMMERCIAL CARBON CAPTURE DESIGN & COSTING STUDY: PART 2

DE-FE0031840

Nebraska Public Power District

Host Site – Gerald Gentleman Station

- Located in Sutherland, Nebraska
- Largest generating station in Nebraska
- Two units with total capacity of 1,365 MW
  - Unit 1 – 1979 – 665 MW
  - Unit 2 – 1982 – 700 MW
- Burns Powder River Basin Coal

Commercial Carbon Capture Design & Costing Study: Part 2

(C3DC2) DE-FE0031840

- Retrofit a Carbon Capture System at an existing power station
  - Nebraska Public Power District's (NPPD) Gerald Gentleman Station (GGS)
  - **700 MWe carbon capture system (2x 350 MWe trains)**
  - **Ownership model: Capture System is 3rd Party Owned and Operated**
  - Design Basis: CO_2 product for EOR (not regulatory driven)
- **Class 2 (AACE)** Capital Cost Estimate
  - Estimate Accuracy Range: **-15% to +20%**
  - Complete about **50-60%** of Engineering Effort
- 18-month project; to be completed in Q1 of 2021
- $5.8M project budget
  - $4.6M DOE-NETL
  - $1.2M ION & Partners

C3DC2 Study

Project Team and Roles

ION Clean Energy

- Technology Developer
- Process Design and Project Management

Nebraska Public Power District

- Host Site (GGS)
- Power Generation Engineering, Operational and Financial Expertise

Sargent and Lundy

- Balance of Plant (BOP) Engineering
- Overall Cost Estimate Development
- Constructability Review
- Construction Cost Estimating

Koch Modular Process System

- Carbon Capture pilot experience and expertise
- Capture Process Oversight, Design and Costing

Siemens

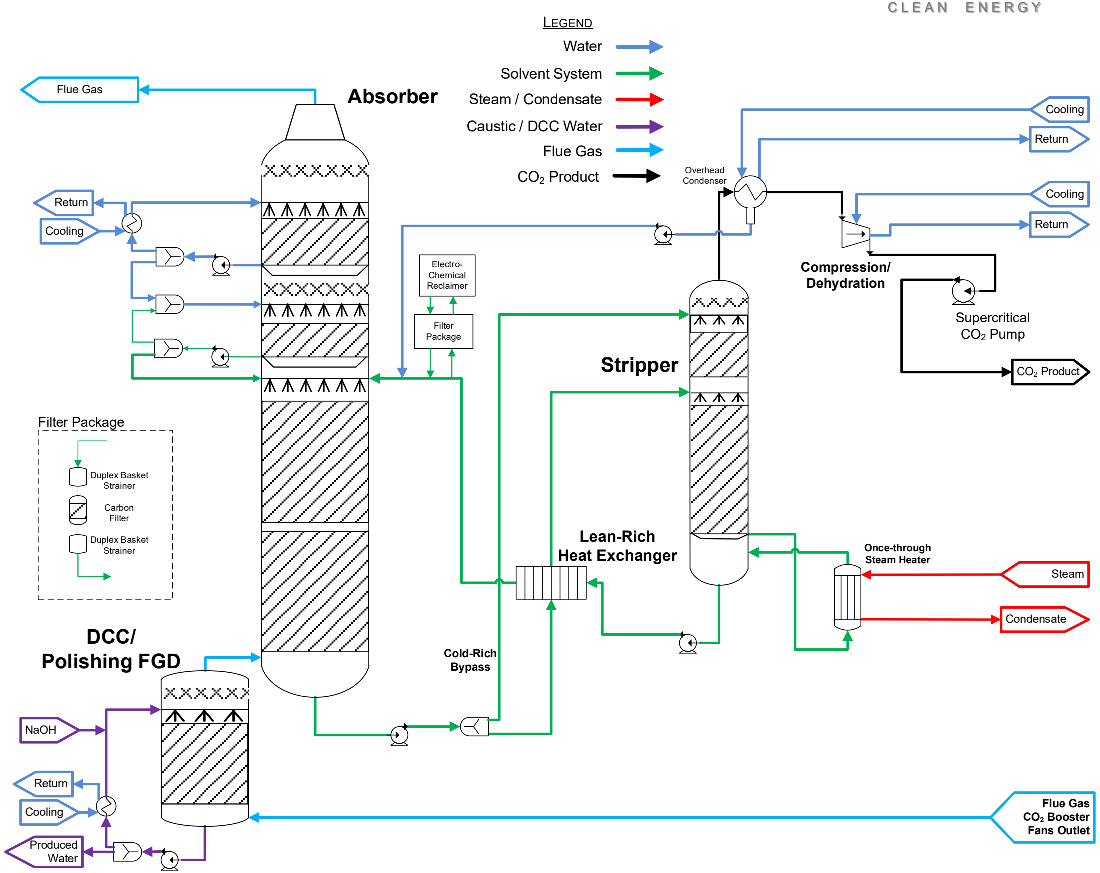
- Compressor Vendor

ProTreat® Process Model

ION CO_2 Capture Process

Key features of ION process compared to ‘common’ MEA-designed plant

- Cold-Rich By-pass
- Optimized lean rich cross exchanger (LRXC) design
- Caustic addition to DCC to act as SO_x Polishing Scrubber
- Compressor Selection



ProTreat output provides stream tables, key performance indices, and steam, cooling and electrical duties

System Design

700MWe CO_2 Capture Plant

- Capture System Design
  - 2x 50% trains for the Capture Island
  - 2x 50% on major pieces of equipment to assist in turndown and provide some risk mitigation
  - Designed for operation at full load, and track plant load to maximum turndown
  - Designed for 90% capture of CO_2; it is a load following plant so >95% capture at turndown
  - CO_2 product at historic plant CF (2018-2019): 4.3M tonnes of CO_2/yr
- BOP Design
  - Steam sourcing from GGS2 steam cycle
  - Cooling water from a hybrid system

C3DC2 Study
Design Basis

	% Complete	Task Name	Ownership
1	50%	C3DC2 Project - FEED Study	
2	64%	1.0 Project Management and Planning	
19	80%	2.0 Overall Project Design Basis	
20	100%	M3: Overall Project Design Basis	ION, S&L, KMPS, Siemens
26	65%	Design Criteria (Mechanical, Electrical, I&C, and Structural)	S&L
32	82%	Operating Philosophy	ION
38	100%	Overall Process Flow Diagrams	S&L
44	0%	BOP System Design Description	S&L

C3DC2 Study

CO_2 Capture System Design

	% Complete	Task Name	Ownership
50	70%	3.0 Process Design - CO2 Capture Island Design	
51	99%	Preliminary Design - CO2 Capture Island	
52	100%	Process Design Basis	ION, KMPS, Siemens
59	100%	ION Process Model	ION
64	100%	Process Flow Diagram	ION
68	100%	System Design Description	ION
72	95%	Heat and Mass Balance	ION, KMPS, Siemens
78	100%	Utility Requirements	ION, KMPS, Siemens
82	100%	Process Equipment List	ION, KMPS, Siemens
86	99%	Data Sheets for Process Equipment	KMPS, Siemens
102	100%	M4: Preliminary Design Review	ALL
103	52%	Detailed Design - CO2 Capture Island	
104	100%	CO2 Island Process Control Description	ION, KMPS, Siemens
108	64%	CO2 Capture System P&IDs	KMPS, Siemens
115	25%	CO2 Capture System Lists	ION, KMPS
122	0%	Compression/Dehydration System Lists	ION, Siemens
129	100%	CO2 Equipment Arrangement Drawings	KMPS, S&L, Siemens
130	70%	Support Efforts	ION
131	92%	3D Model Development for Carbon Capture Island	KMPS, Siemens

C3DC2 Study

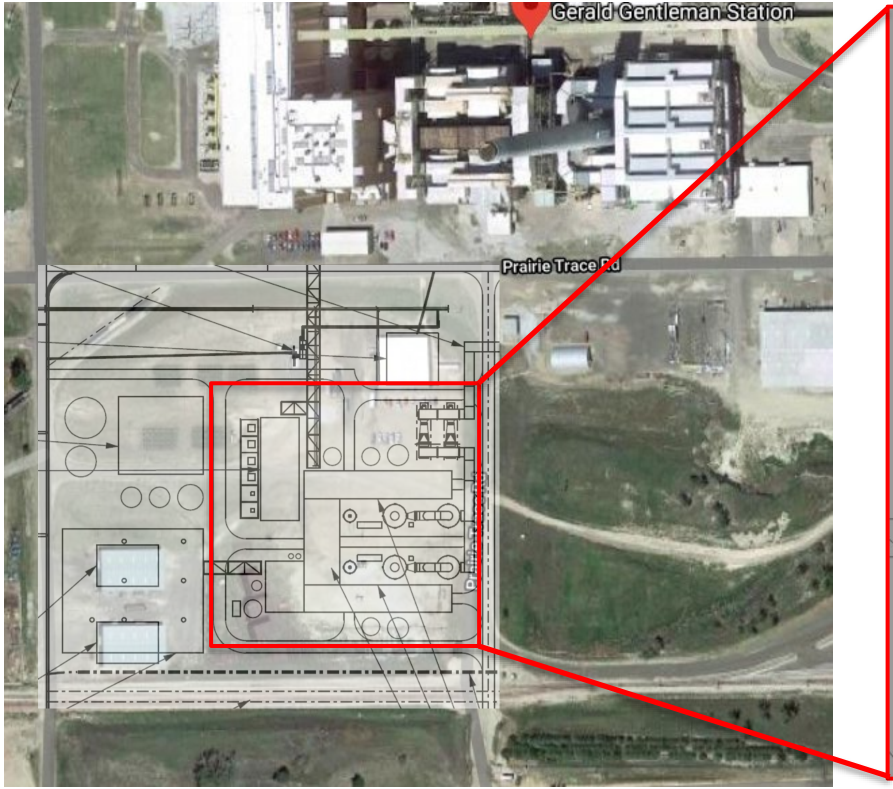
Balance of Plant Engineering and Design – S&L w/ NPPD support

	% Complete	Task Name
135	41%	4.0 Engineering & Design - Integration and BOP
136	41%	Detailed Design - Integration and BOP
137	47%	Mechanical Design
138	100%	Overall Mass Balance
144	89%	Overall Heat Balance
150	100%	Overall Water Balance
156	30%	3D Model
161	66%	Site Plan
167	66%	Overall General Arrangement Drawing
173	65%	BOP P&IDs
179	44%	BOP Piping Line List
185	44%	BOP Valve List
191	43%	Terminal Point List
197	53%	Mechanical Equipment List
203	0%	BOP Mechanical Equipment Specs
209	0%	BOP Underground Piping Plan
215	5%	Piping Isometric and Layout Drawings
221	0%	Piping and Utility Relocation Drawings
227	0%	Demolition Drawings
233	5%	Cooling System Specification
239	0%	Fire Protection System Specification
245	0%	HVAC Specification
251	54%	Civil Sitework Design
252	0%	Spill/Containment Plan

	% Complete	Task Name
258	0%	Stormwater Runoff Plan
264	88%	Grade Elevation Study
270	100%	Geotechnical Study and Evaluation
276	20%	Structural Design
277	24%	Foundation Drawings
283	67%	Ductwork Drawings
289	0%	Utility Rack Drawings
295	0%	Architectural Drawings
301	21%	Electrical Design
302	86%	Project Load List
308	67%	One Line Diagrams
314	0%	Cable and Cable Tray Layouts
320	0%	Lighting Drawings
326	0%	BOP Electrical Equipment Specifications
332	26%	I&C Design
333	86%	Project Instrument List
339	84%	Controls Architecture Diagram
345	9%	Control Description
351	0%	Control System Equipment List
357	0%	Control System Specification
363	0%	Communications Infrastructure Specification
369	0%	Cable Block Diagrams by Loop
375	0%	Building and Facility Security Plan
381	54%	ION Technical Oversight of Integration & BOP Design
382	0%	M5: Critical Design Review

C3DC2 Study

General Arrangement Drawing



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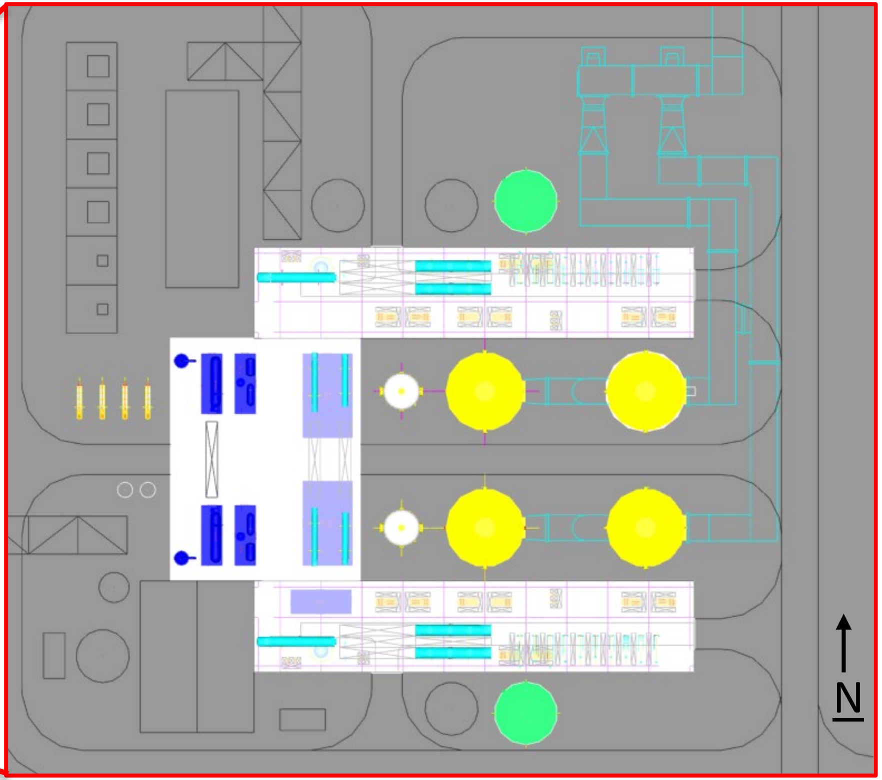
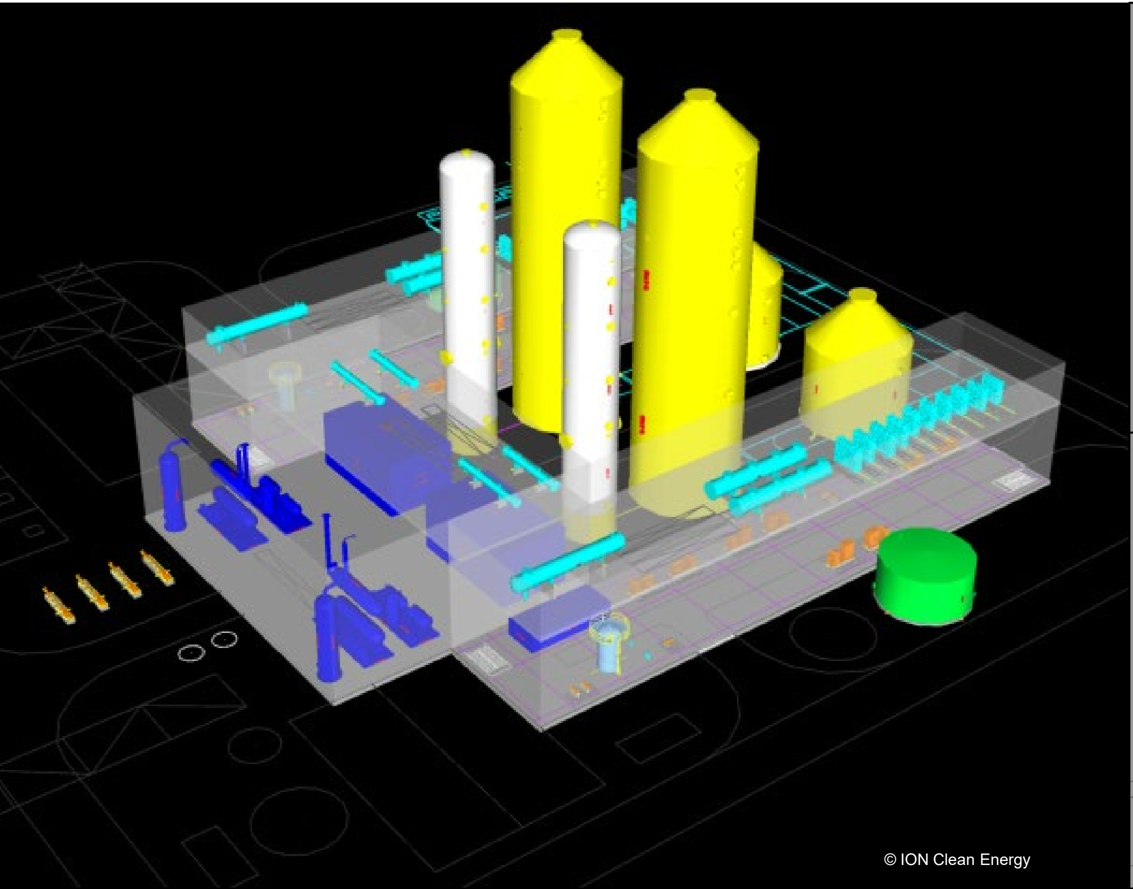
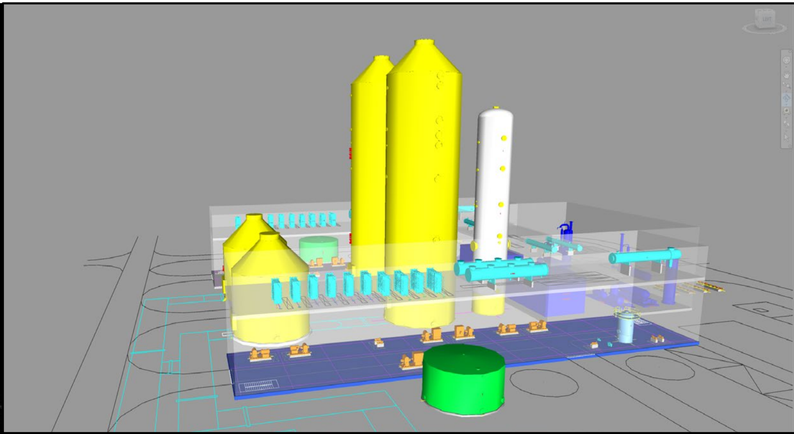
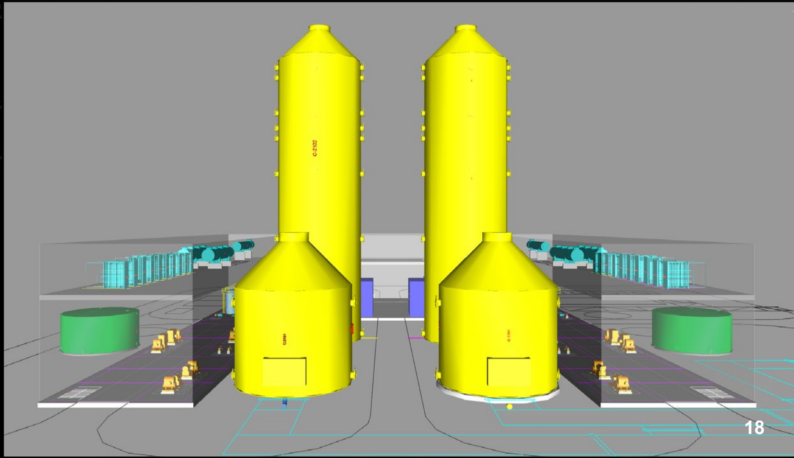


C3DC2 Study

Preliminary 3D Model – Carbon Capture System







C3DC2 Study

Studies and Investigations

	% Complete	Task Name
383	51%	5.0 Studies and Investigation
384	88%	Steam Sourcing Study
392	81%	Cooling Water System Study
400	88%	Solvent Materials Compatibility Study
407	75%	Wastewater Treatment Study
413	86%	Permitting and Regulatory Review
422	0%	Draft Permit Applications
430	47%	Selective Catalytic Reduction Costing Study
436	60%	Reagent Handling Study
442	0%	M6: HAZOP Review
454	3%	Constructability Review
462	0%	Overpressure Relief Study
466	0%	Project Execution & Operations Management Planning
491	57%	ION Technical Oversight of Studies

C3DC2 Study

Cost Estimate and Reporting Tasks

	% Complete	Task Name
492	7%	6.0 Cost Estimate
493	10%	CO2 Capture Equipment Pricing
501	0%	BOP Equipment Pricing
504	0%	BOP Commodity Input
507	0%	Commodity and Construction Costs
510	0%	Operating & Maintenance Costs
516	0%	M7: Overall Cost Estimate and Cost of Capture
522	10%	ION Technical Oversight of Cost Estimate
523	0%	7.0 Reporting
524	0%	M8: Front-End Engineering Design (FEED) Report
531	0%	M9: Final DOE Project Report

Cost of CO_2 Capture

Costing Basis

- Costing Efforts to begin in September 2020
- 3rd party owned and operated
  - Grid prices for power
  - Independent cooling water system
- Designed the CO_2 Capture Island to produce a reliable CO_2 product stream for EOR/Sequestration; Not regulation driven CO_2 capture
- Used historical data for the load-following unit to model cumulative captured CO_2 based on observed power plant load factor, capture plant uptime, and ambient conditions
- Calculate the cost with and without the additional flue gas pre-conditioning to isolate the cost of CO_2 capture for comparison to sites that may already have this equipment

Commercial Carbon Capture Design & Costing Study: Part 2

(C3DC2) DE-FE0031840

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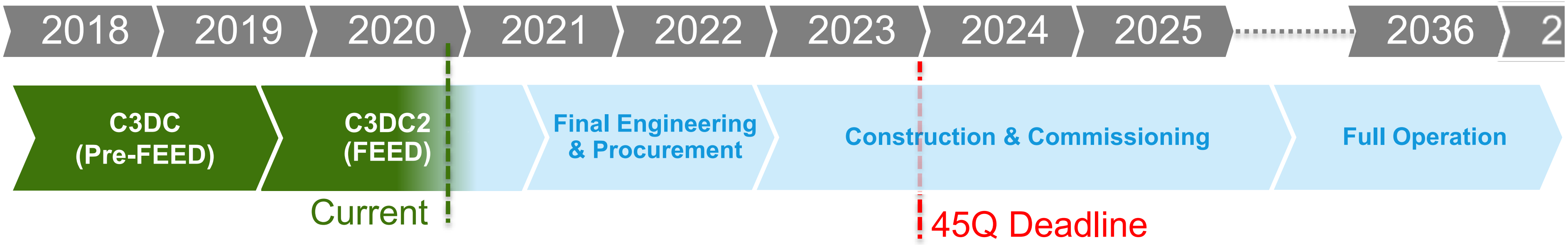
#	Milestone Title / Description	Projected Completion Date	Actual Completion Date	Comments
M1	DOE Kickoff Meeting	12/5/2019	12/5/2019	
M2	Updated PMP	10/31/2019	11/7/2019	Version 1.1
M3	Basis of Design for Project Finalized	1/10/2020	2/25/2020	Rev B of Basis of Design issued in February 2020
M4	Preliminary Design Review Complete	3/30/2020	5/6/2020	
M5	Critical Design Review Complete	8/31/2020		
M6	HAZOP Complete	11/24/2020		HAZOP meeting scheduled for Mid-Oct
M7	Overall Cost Estimate & Cost of Capture	1/12/2021		
M8	Front-End Engineering Design (FEED) Report	3/15/2021		
M9	Final DOE Report & Presentation	3/31/2021		

Path Forward



- 45Q changed the landscape for deploying carbon capture
  - Currently on track to qualify for 45Q tax credits
- 2021 Q1 Completion of C3DC2 Project (FEED)
  - Outcome of project will provide key learnings and necessary details for evaluation of deployment of CO_2 capture
    - Resource needs
    - Plant specific challenges (steam, cooling water and permitting)
    - Provide accurate costs (-15% to +20%) to feed a business model
    - Provide comparison between ownership models

Acknowledgement and Disclaimer

Acknowledgement

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Thanks

C3DC2 Team:

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KMPS: Paul Jaipersaud, Stan Lam, Tom Schafer
Siemens: Joseph Williams, Robert Bailie

Department of Energy:

Katy Daniels, Jose Figueroa, Lynn Brickett, Bethan Young

Commercial Carbon Capture Design & Costing Study: Part 2

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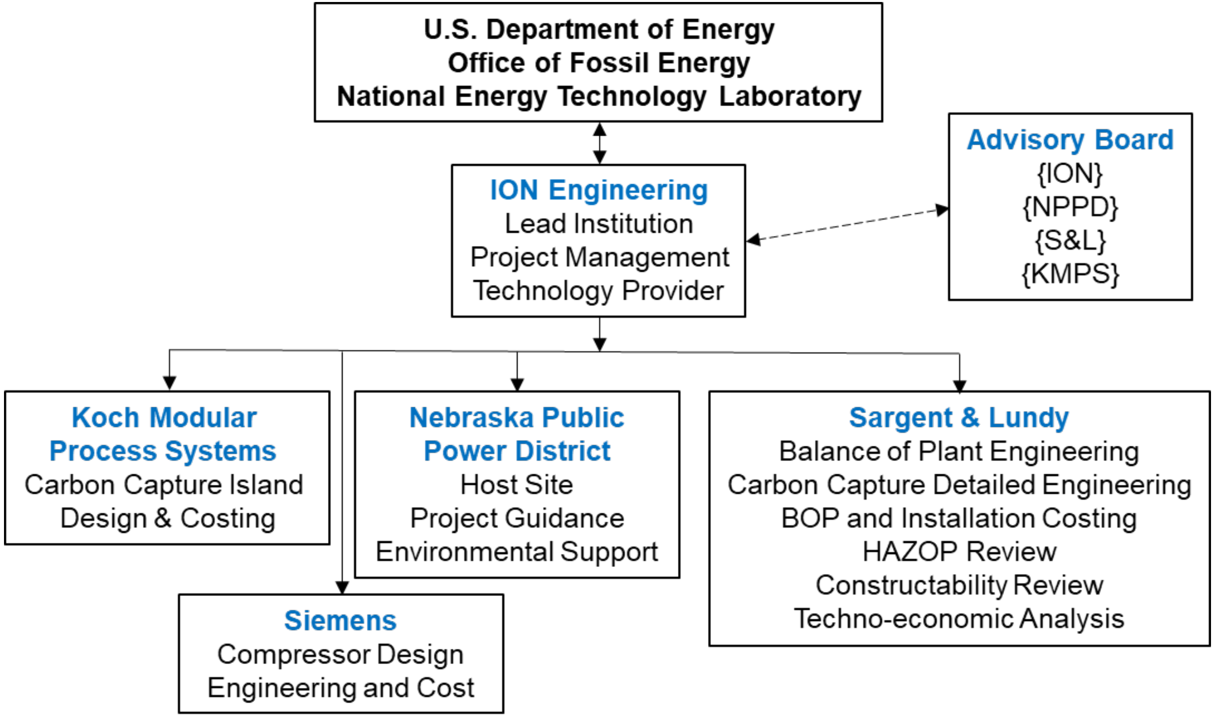

Commercial Carbon Capture Design & Costing Study: Part 2

(C3DC2) DE-FE0031840

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	Task Name	Duration	Start
1	C3DC2 Project - FEED Study	443 days	Mon 9/2/19
2	1.0 Project Management and Planning	395 days	Mon 9/2/19
19	2.0 Overall Project Design Basis	289 days	Thu 10/31/19
50	3.0 Process Design - CO2 Capture Island Design	257 days	Mon 9/30/19
51	Preliminary Design - CO2 Capture Island	229 days	Mon 9/30/19
102	M4: Preliminary Design Review	0 days	Fri 4/24/20
103	Detailed Design - CO2 Capture Island	126 days	Thu 4/16/20
135	4.0 Engineering & Design - Integration and BOP	286 days	Fri 12/20/19
136	Detailed Design - Integration and BOP	286 days	Fri 12/20/19
382	M5: Critical Design Review	0 days	Wed 9/16/20
383	5.0 Studies and Investigation	281 days	Tue 12/3/19
492	6.0 Cost Estimate	170 days	Tue 7/21/20
523	7.0 Reporting	75 days	Tue 2/23/21