PROJECT DELTA [DE-FE0032149]

Front-End Engineering and Design for a CO2 Capture System at Calpine's Delta Energy Center

Andrew Awtry, Ph.D.

ION CLEAN ENERGY – DELTA

AUG 5, 2024

PROJECT OBJECTIVE

Project Period of Performance:

February 1, 2022 – October 31, 2024*

**No Cost Extension Pending to February 28, 2025*

Funding:

Federal Share:	$6,983,840
Cost Share:	$1,745,961

Objective:

Complete a FEED for a commercial-scale carbon dioxide (CO_2) capture facility retrofitted onto an existing natural gas combined cycle (NGCC) power station. The project team has designed and costed a CO_2 capture facility retrofitted onto Delta Energy Center (DEC), an 857 MW facility in Calpine's fleet.

ION TECHNOLOGY

Proprietary Solvent

- Liquid amine-based capture
- Low aqueous
- WW Patents

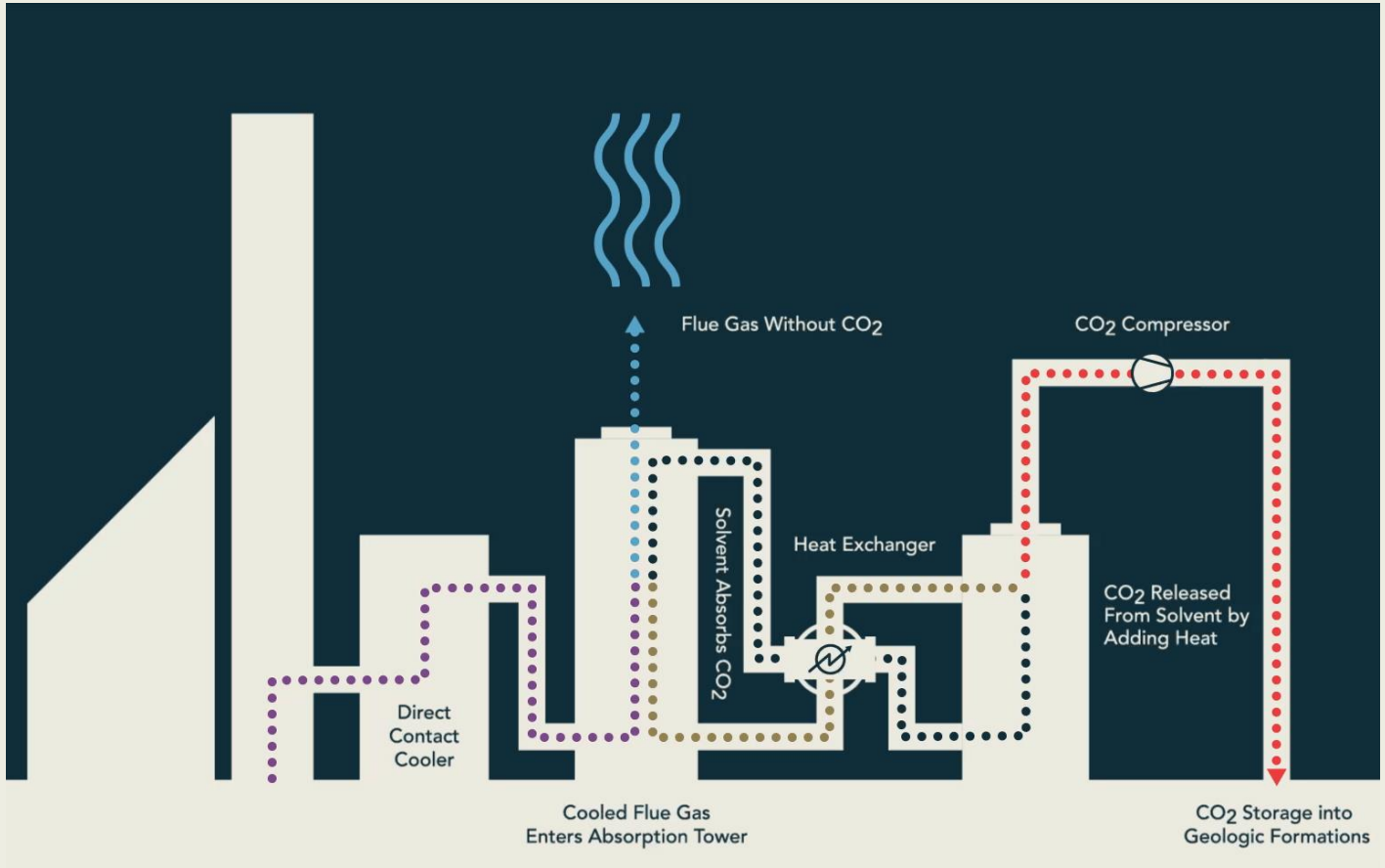
Reduced CAPEX & OPEX

- Smaller columns, HXs and footprint
- Lower energy requirements

Established Engineering Process

Pilot Performance Metrics

- Low Regeneration Energy
  - Fast kinetics
  - Working capacity
  - Low heat capacity
- Low Tendency for Corrosion
- Low Degradation Rate



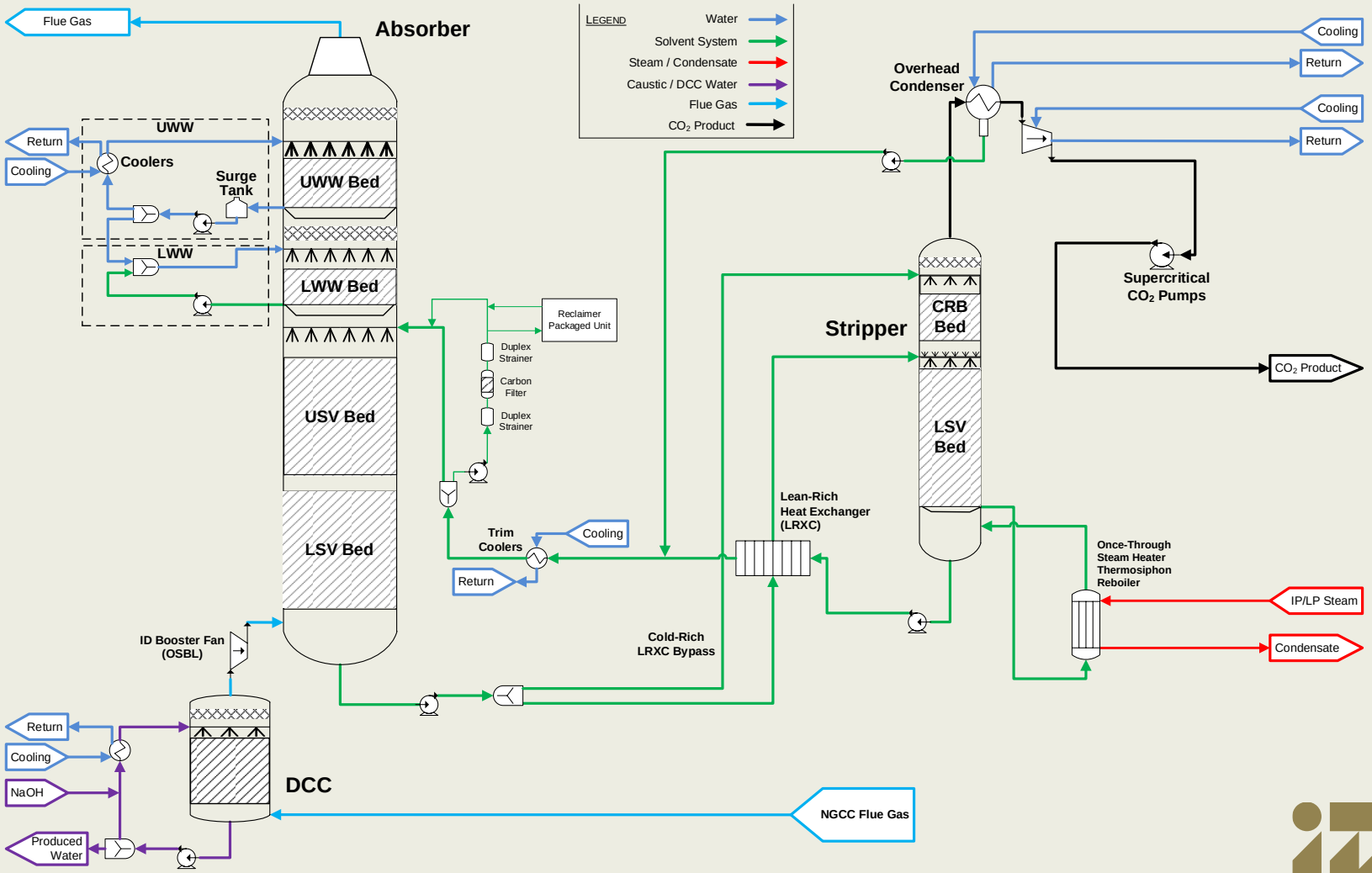
PROTREAT PROCESS MODEL

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
- Utilize heat integration from compression to lower energy requirements

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



3/1/2022

PROJECT TEAM MEMBERS

ION Clean Energy
- Award Recipient
- Technology Provider
- Process Design and Project Management

Calpine
- Host Site & Subrecipient
- Power Generation Engineering, Operational and Financial Expertise

Sargent and Lundy
- Capture Island Process Oversight, Engineering & Costing
- Balance of Plant Engineering & Costing
- Overall Cost Estimate Development
- Engineering Studies Lead

Koch Engineered Solutions (KES)
- Gas/Liquid Contactor Vendor
- Contactor Design & Costing Support

Siemens Energy
- Compressor Technology Provider
- CO_2 Compressor Design & Costing – Including Heat Integration

Kiewit
- Owners Engineer
- Document Review

Toshiba America Energy System (TAES)
- Steam Turbine OEM
- Evaluation of Steam Extraction

Deltak
- HRSG OEM
- Evaluation of Flue Gas Duct Tie-in

STATEMENT OF PROJECT OBJECTIVES

Task 1 – Project Management

Task 2 – Overall Project Design Basis

- Subtask 2.1 – CCS Design Basis
  - CCS Design Basis/Design Criteria
  - Carbon Capture System Requirements Document
- Subtask 2.2 – System Design Description
  - System Design Description including BOP

Task 3 – Process Design – CO_2 Capture Island

- Subtask 3.1 – Preliminary Design of the Carbon Capture Island
  - Process Flow Diagrams, Heat and Material Balance, Utility Summary, Preliminary Equipment List, a Theory of Operation, and a refined set of requirements with support from performance models and system analyses.
- Subtask 3.2 – Detailed Design of the Carbon Capture Island
  - Detailed Equipment List supported by vendor data sheets, Controls Description, Emissions and Effluent List, Capture System P&IDs and an Equipment Layout Plan

STATEMENT OF PROJECT OBJECTIVES

Task 4 – Engineering and Design

- Subtask 4.1 – BOP Systems Design
  - Design work supporting Site Plan, Foundation, Ductwork, Structural Steel, Steam Turbine Tie-In, Heat Rejection System, Pipe Racks, Building/Architecture, Electrical Systems, General Arrangement Drawings and a Preliminary 3D Model
- Subtask 4.2 – System Level Engineering
  - System level engineering packages including the system level Heat and Water Balances, P&ID's and resulting Equipment, Piping, Instrument and Electrical Load Lists

Task 5 – Supplemental Studies and Investigations

- Including
  - Steam and Power Sourcing Study
  - Cooling Water and Optimization Study
  - Reliability, Availability and Maintainability (RAM) Analysis
  - Hazard and Operability Review (HAZOP)
  - Constructability Review

STATEMENT OF PROJECT OBJECTIVES

Task 6 – Cost Estimating

- Subtask 6.1 – CO_2 Capture Island and BOP Capital Costs
- Subtask 6.2 – Operating & Maintenance Costs
- Subtask 6.3 – Overall Cost Estimate and Cost of Capture

Task 7 – Final Reporting & DOE Deliverables

- Subtask 7.1 – FEED Study
- Subtask 7.2 – Additional Required DOE Deliverables:
  - Life Cycle Analysis
  - Business Case Analysis
  - Techno-Economic Analysis
  - Economic Revitalization and Job Creation Outcomes Analysis
  - Environmental Justice Analysis

KEY MILESTONES

#	Corresponding Task	Title/Description	Target/Actual Completion Date	Verification Method
M1	1.0	DOE Kickoff Meeting	**06/13/2022**	Presentation Slides
M2	1.0	Updated PMP	**02/28/2022**	PMP Transmitted to DOE FPM
M3	2.0	Basis of Design for Project Finalized	**05/31/2022**	Meeting Held w/ Results Project SharePoint Site; Completion Memo to DOE
M4	3.0	Preliminary Design Review Complete	**05/10/2022**	Meeting Held w/ Results Project SharePoint Site; Completion Memo to DOE
M5	4.0	Critical Design Review Complete	**09/13/2022**	Meeting Held w/ Results Project SharePoint Site; Completion Memo to DOE
M7	5.4	HAZOP Complete	**11/29/2022**	HAZOP Report Completed
M8	6.0	Overall Cost Estimate and Cost of Capture	**08/31/2023**	Meeting Held w/ Results Project SharePoint Site; Completion Memo to DOE
M9	7.0	Front-End Engineering Design (FEED) Report	10/31/2024	Report Delivered to DOE/NETL
M10	7.0	Final DOE Report & Presentation	10/31/2024	Report Delivered to DOE/NETL

DELTA ENERGY CENTER

Location:

- Pittsburg, CA

Facility Type:

- 3 x 1 NGCC
- Siemens W501F CTs
- Deltak HRSGs
- Toshiba ST

Additional Site Information

- Evaluating terraced uplands on adjacent property SW of Delta as potential capture location
- Land south of the facility is currently not available for Carbon Capture System
- DDSD provides makeup water to base plant

SYSTEM DESIGN

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 to match full DEC load and support the desired DEC turndown
- Designed for 95% capture of CO_2; resulting in up to 98% capture at turndown
- CO_2 product at expected Capacity Factor: 2.4M tonnes of CO_2/yr

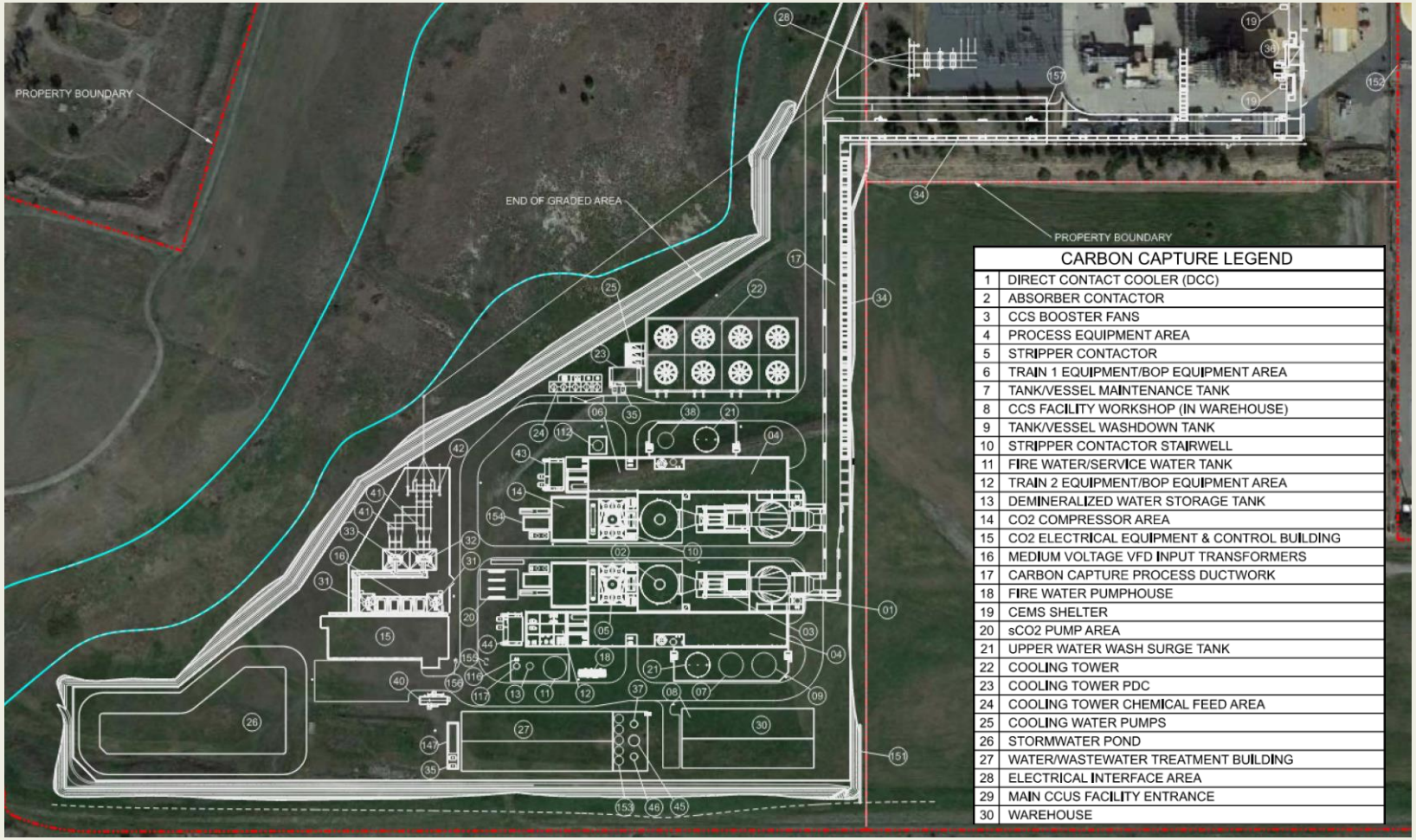
SYSTEM DESIGN

CO_2 Capture Plant: BOP Design

- Steam Sourcing
  - Worked with the Steam Turbine vendor to optimize and evaluate consequences of extraction at various locations
- Heat Rejection System
  - Utilize consumptive water available from DDSD and DCC blowdown
  - Sufficient water available for fully evaporative cooling system
  - 2% Summer occurrence temperature was used for the basis for design
- Flue Gas Tie-in
  - Worked with vendor (Deltak) to design tie-in point and consolidate HRSG stack flows

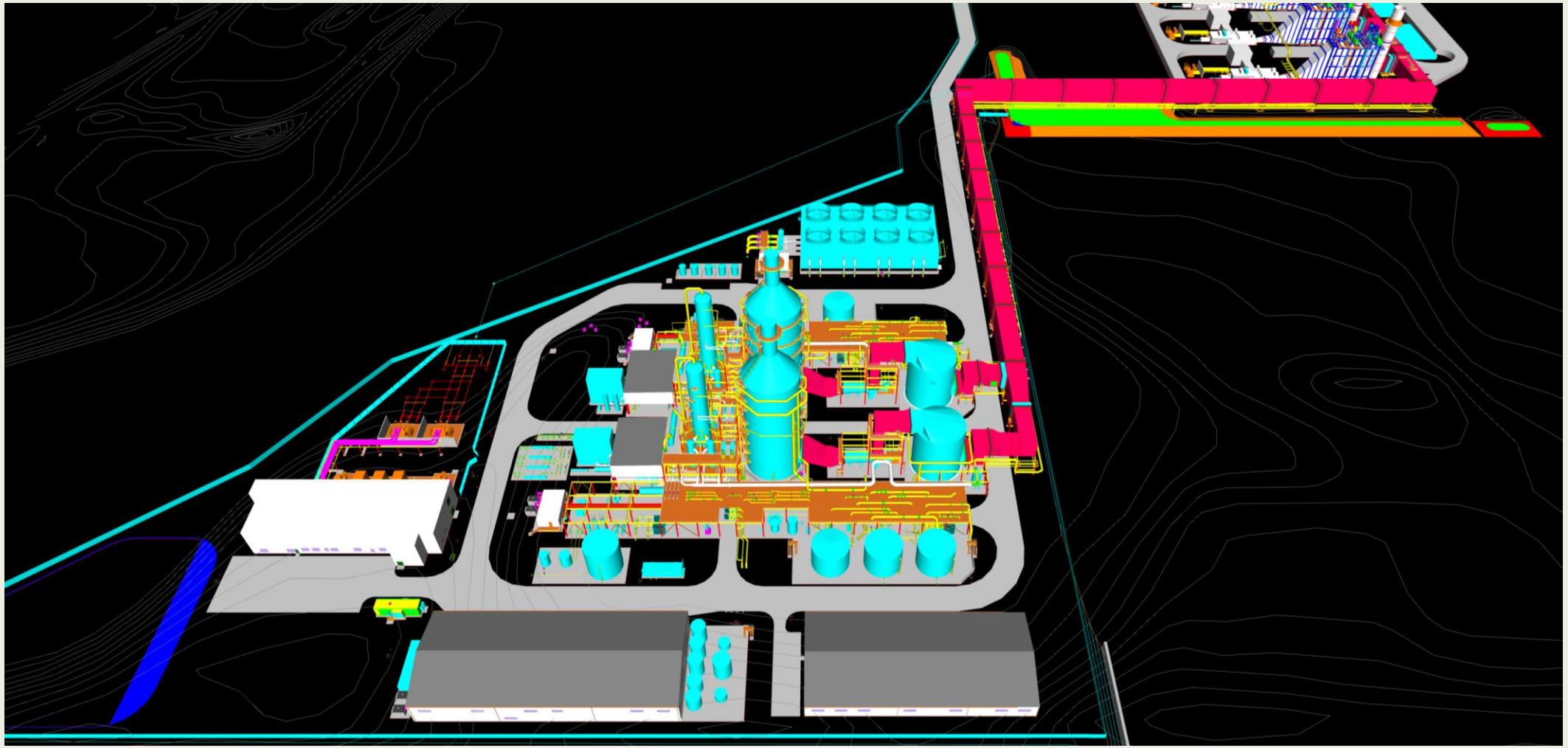
CARBON CAPTURE SYSTEM

Plot Plan – General Arrangement



CARBON CAPTURE LEGEND	
1	DIRECT CONTACT COOLER (DCC)
2	ABSORBER CONTACTOR
3	CCS BOOSTER FANS
4	PROCESS EQUIPMENT AREA
5	STRIPPER CONTACTOR
6	TRAIN 1 EQUIPMENT/BOP EQUIPMENT AREA
7	TANK/VESSEL MAINTENANCE TANK
8	CCS FACILITY WORKSHOP (IN WAREHOUSE)
9	TANK/VESSEL WASHDOWN TANK
10	STRIPPER CONTACTOR STAIRWELL
11	FIRE WATER/SERVICE WATER TANK
12	TRAIN 2 EQUIPMENT/BOP EQUIPMENT AREA
13	DEMINERALIZED WATER STORAGE TANK
14	CO2 COMPRESSOR AREA
15	CO2 ELECTRICAL EQUIPMENT & CONTROL BUILDING
16	MEDIUM VOLTAGE VFD INPUT TRANSFORMERS
17	CARBON CAPTURE PROCESS DUCTWORK
18	FIRE WATER PUMPHOUSE
19	CEMS SHELTER
20	sCO2 PUMP AREA
21	UPPER WATER WASH SURGE TANK
22	COOLING TOWER
23	COOLING TOWER PDC
24	COOLING TOWER CHEMICAL FEED AREA
25	COOLING WATER PUMPS
26	STORMWATER POND
27	WATER/WASTEWATER TREATMENT BUILDING
28	ELECTRICAL INTERFACE AREA
29	MAIN CCUS FACILITY ENTRANCE
30	WAREHOUSE

CARBON CAPTURE SYSTEM



CARBON CAPTURE SYSTEM

CARBON CAPTURE SYSTEM

COST ESTIMATE BASIS

CAPEX in 2023 USD

- Vendor Budgetary Quotes for all major pieces of equipment
- Labor wages: Prevailing wages for Sacramento, CA with a Regional Labor Productivity of 1.15
- Include Additional Labor Indirect costs (labor supervision, show up time, cost of overtime, per diem, insurance)
- Includes Site Overhead costs (construction management, field office, craft support, pre-op testing, site services, safety, temp facilities and utilities, mobilization/demobilization and legal expenses)
- Includes Construction Indirect costs (small tools and consumables, scaffolding, freight on equipment, freight on materials, sales tax)
- Includes Project Indirect Costs (EPC engineering services, EPC CM support, Startup and spare parts, EPC G&A, EPC Risk and Profit, Initial Fills)
- Includes Contingency: 15% on all categories (Labor, Equipment, Materials, Subcontracts, Construction Equipment, and Indirect Costs)

COST ESTIMATE BASIS

OPEX in 2023 USD

- Variable OPEX:
  - Power costed at $30/MWh
  - Steam costed as lost electricity to the grid (de-rate)
- Fixed OPEX:
  - 26 Operators and support staff required
  - 40-hr work week for 52 wks/yr
  - Maintenance Material and Labor Costs estimated using 2.5% of the sum of equipment, materials and 60% subcontract costs

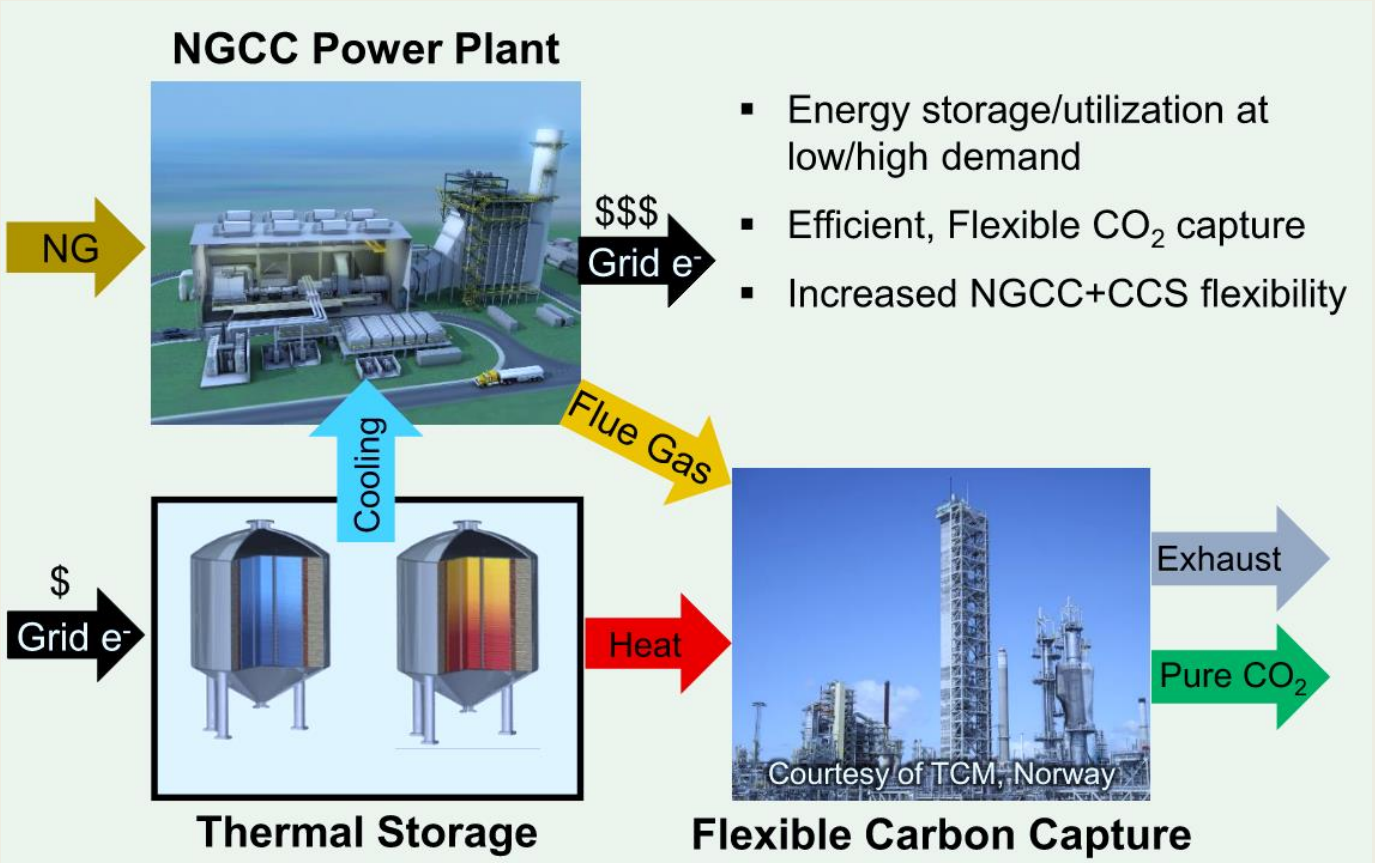
DELTA ENERGY CENTER FEED WRAP-UP

- **Cost Estimate:**
  - CAPEX - $1,500,000,000
  - OPEX - $61,600,000/yr
- **Completed the Required Analyses:**
  - Life Cycle Analysis
  - Business Case Analysis
  - Revitalization and Job Creation Outcomes Analysis
  - Environmental Justice Analysis
- **Techno-Economic Analysis**
  - Completed as required by the FOA directions using the NGCC case (Case 31) but,…
  - Sized at 500,000 tpa, which does not allow for comparison to Case 31B.
  - Using TEA from the Enterprise Project, we get the following comparison to 31B in 2019 USD:
    - 27% reduction in CAPEX
    - 12% reduction in O&M
    - Cost of Capture is 28% lower than case 31B

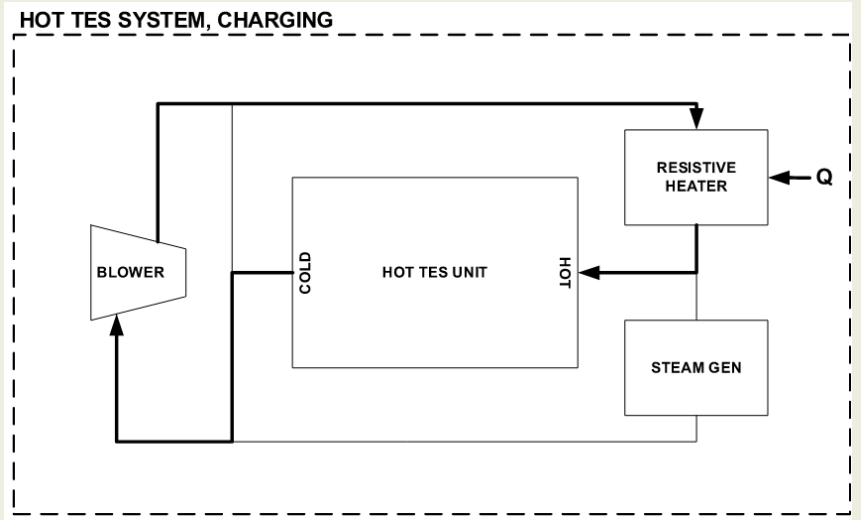
THERMAL STORAGE IMPLEMENTATION STUDY

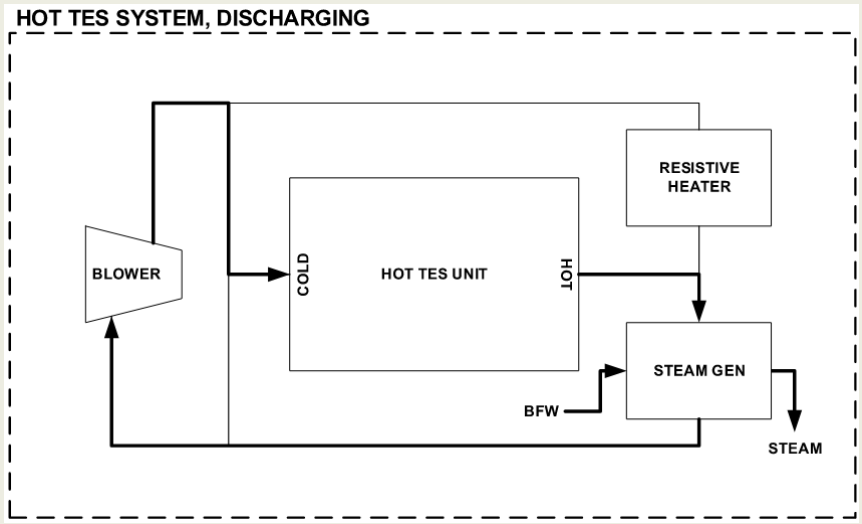
AUG 28, 2023

THERMAL ENERGY STORAGE (TES) MODIFICATION



- Energy storage/utilization at low/high demand
- Efficient, Flexible CO_2 capture
- Increased NGCC+CCS flexibility





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- Power Generation Engineering, Operational and Financial Expertise

Sargent and Lundy

- Capture Island Process Oversight, Engineering & Costing
- Balance of Plant Engineering & Costing
- Overall Cost Estimate Development
- Engineering Studies Lead

Colorado State University

- Subrecipient
- Net Present Value Evaluation of Thermal Storage Implementation
- Detailed Modeling of Thermal Storage impact on CCI Availability and Base Plant Dispatch profiles

Storworks Power

- Thermal Storage Technology Developer
- Engineering and Costing of Thermal Storage process

THERMAL ENERGY STORAGE (TES) MODIFICATION

Task 2: Modeling and Optimization

- ION evaluated higher capture rates with fixed and optimal absorber heights.
- S&L scaled capture island design down to two CT/HRSG feeding one ST for the base facility.
- CSU leveraged modeling tools to recommend an optimized TES configuration for DEC, based on historical grid price and any operating expectations provided by Calpine.

Task 3: TES Component Level FEED

- Storworks conducted FEED level engineering design and cost estimation for all TES system components.
- Storworks performed detailed thermal modeling of TES module to determine relevant time constraints and performance metrics.
- CSU updated the optimization model

THERMAL ENERGY STORAGE (TES) MODIFICATION

Task Descriptions	Q1			Q2			Q3
	April	May	June	July	Aug	Sept	Oct
DEC TES Modeling and Optimization							
TES Component Level FEED							
TES System Integration							
Cost Estimating							
NGCC-SWITCC Performance Modeling							
Sensitivity Analysis							

Tasks	Date	Resources
Task 1: Project Management	**April 2024**	ION & All
Task 2: DEC TES Modeling, Optimization	**June 2024**	CSU, ION, S&L
Task 3: TES Component-level FEED	**June 2024**	Storworks
Task 4: TES System Integration FEED	Aug 2024	ION, Storworks, S&L
Task 5: Cost Estimating	Sept 2024	S&L
Task 6: SWITCC Performance Modeling	Oct 2024	CSU
Task 7: Sensitivity Analysis	Oct 2024	CSU & All
Final Project Report	Oct 2024*	ION

*There is currently a NCTE Request through February, 2025 to allow for adequate review time for the Final FEED Reporting.

ACKNOWLEDGEMENT & DISCLAIMER

Acknowledgement

This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under cooperative award number DE-FE0032149.

Disclaimer

THANK YOU

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U.S. DEPARTMENT OF ENERGY

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