FECM Annual Project Review

Deer Park Energy Center NGCC Carbon Capture System FEED Study
Agreement No. DE-FE0032137

Acknowledgement : This material is based upon work supported by the Department of Energy under Award Number DE-FE-0032137

DOE Support Acknowledgement

Calpine appreciates the opportunity to partner with DOE on this analysis.

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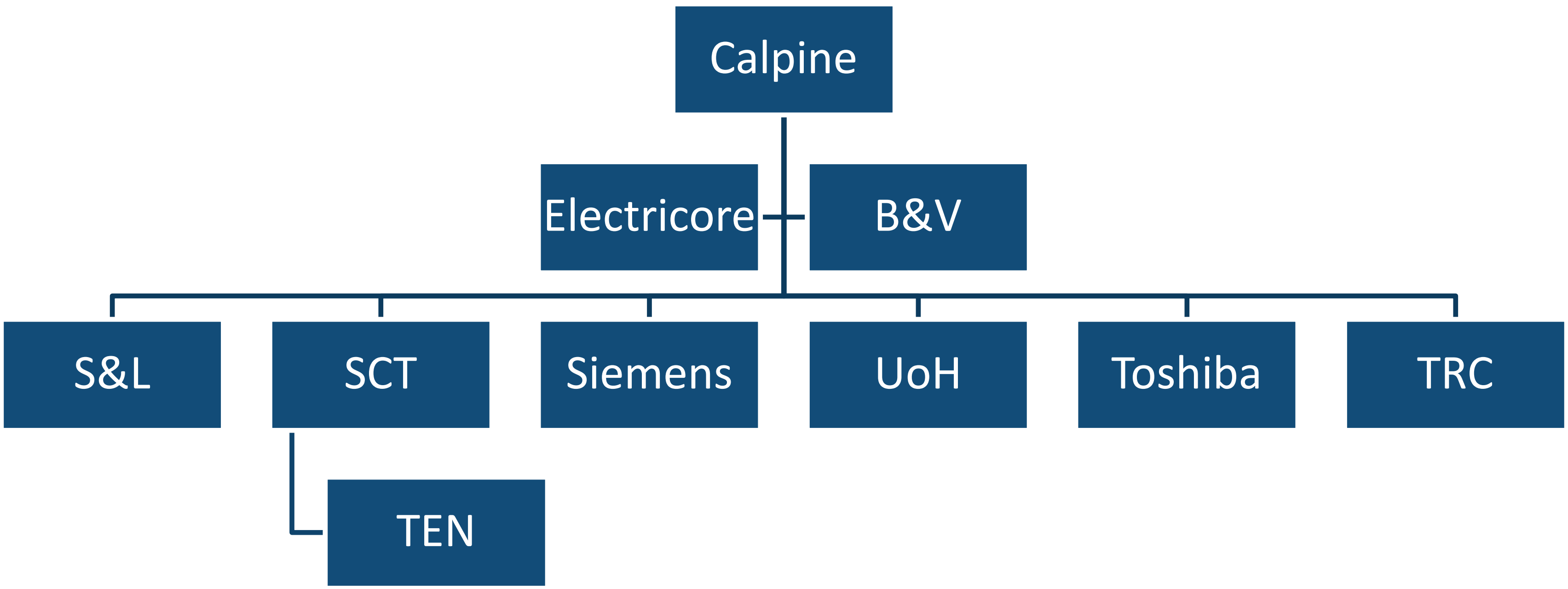
Project Team

- Sponsor: U.S. Department of Energy, Office of Fossil Energy and Carbon Management
  - Program Manager: Nicole Shamitko-Klingensmith
  - Award Administrator: Rueben Kerns
  - Contracting Officer: Jeffrey Kooser
- Project Participants
  - Prime: Calpine Texas CCUS Holdings, LLC
  - Technology: Shell Catalysts & Technologies
  - Engineer: Sargent & Lundy, LLC
  - Administrator: Electricore, Inc.
  - Technical Support: Toshiba, Siemens, B&V

Project Team

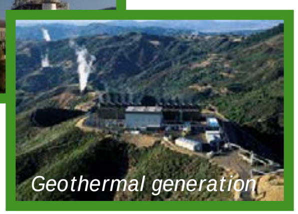


1 – Black & Veatch; 2 – Sargent & Lundy; 4 – Shell Catalysts & Technologies; 5 – Technip Energies; 6 – University of Houston; 7 – The Resource Company

Calpine at a Glance

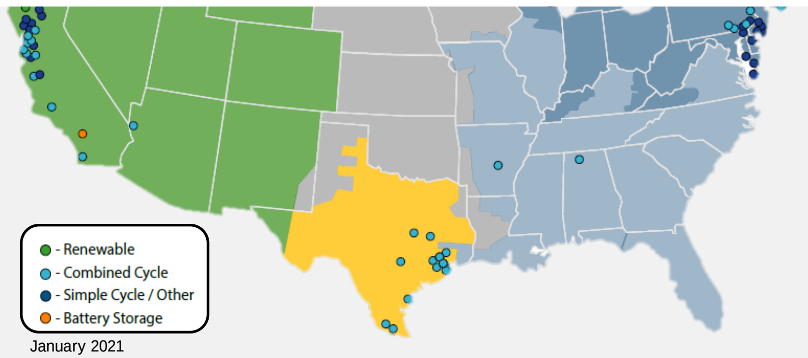
National generation portfolio of approximately 26,000 MW with complementary services platform

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY


Geothermal generation

INFRASTRUCTURE DEVELOPMENT

Energy storage pipeline; since 2000, constructed more MW in CA than any other entity

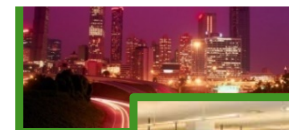


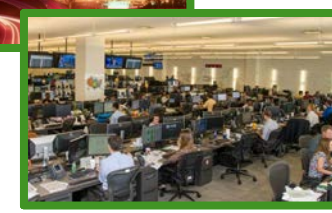
Serve customers in **23 states**, Canada and Mexico

Largest **geothermal** power producer in the world

More than **2,300** employees

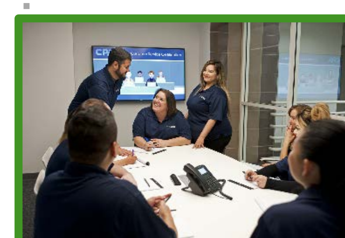
CHAMPION ENERGY SERVICES® | CALPINE ENERGY SOLUTIONS | North American Power®





CCA DATA MANAGEMENT & CUSTOMER SERVICE

Data management and call center services

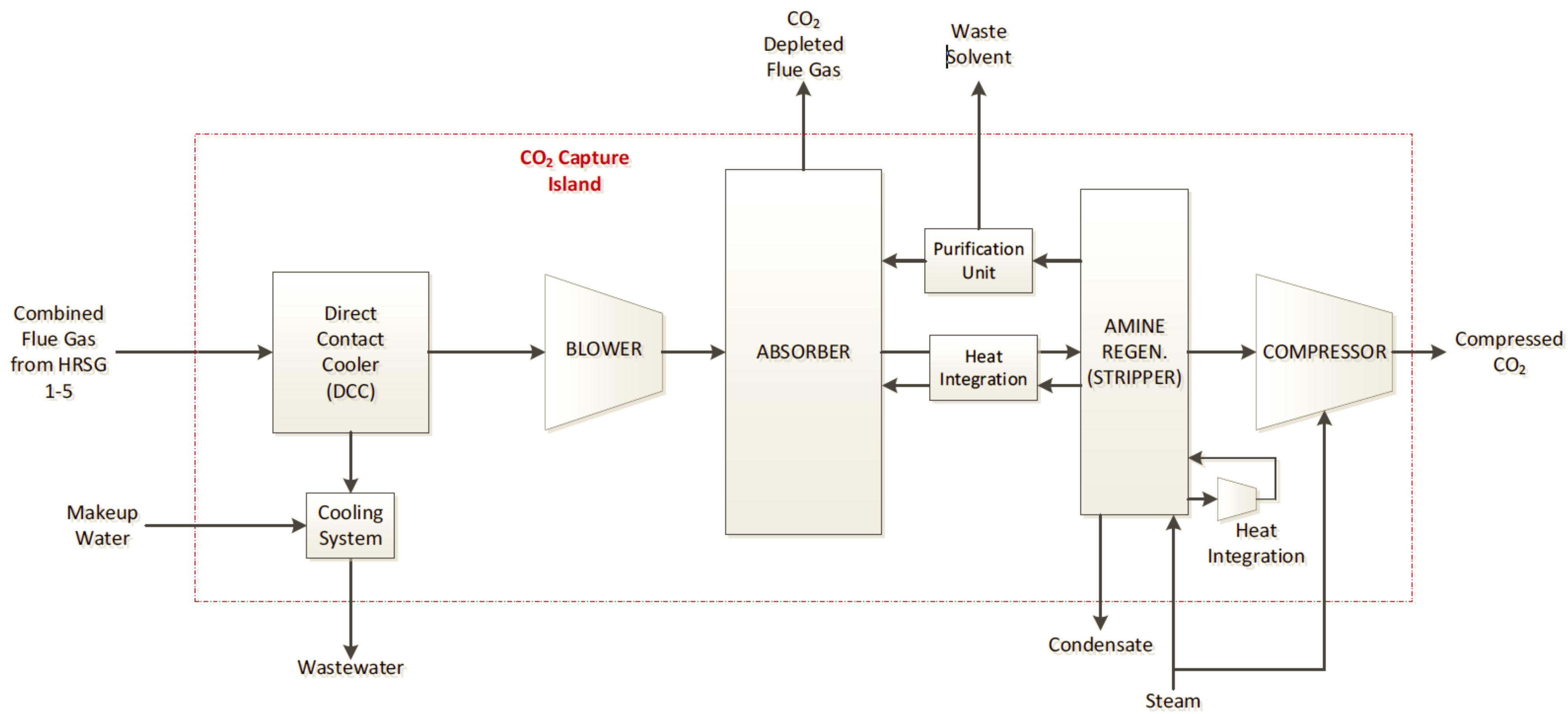


Project Overview

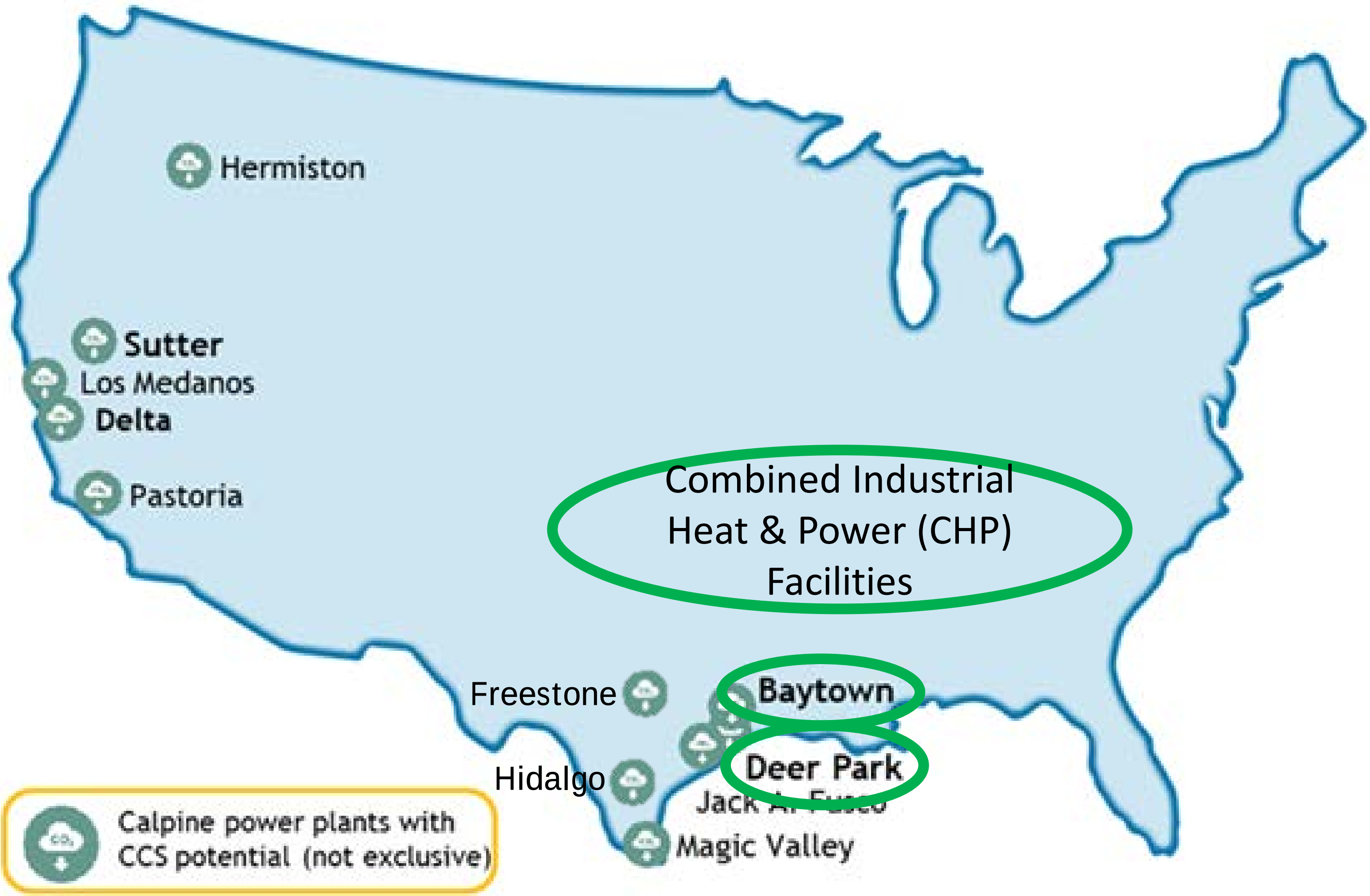
- Award Period: 2/1/2022 through 7/31/2023
  - No cost extension to 11/30/2023 routing for approval
- Funding
  - Total Funding: $6,093,785
    - Federal Funding: $4,791,966
    - Cost Share Funding: $1,301,819 (21.36%)
- Objectives
  - ✓ Conduct a Front-End Engineering Design (FEED) Study on a modular, commercial-scale, 6.5 million tonnes per annum (MTPA) sizing basis for carbon dioxide (CO_2), Generation 2 Post Combustion Carbon Capture (PCC) System.
  - ✓ This PCC system will capture 95% of total CO_2 emissions from flue gas generated at Calpine's Deer Park Energy Center (DKEC), a natural gas combined cycle (NGCC) power plant located in Deer Park, TX.
  - ✓ Addition of a PCC system at DKEC will allow the unit to serve as a regional anchor for a nascent carbon capture and management industry in the Houston area, speeding the commercialization of NGCC PCC and other carbon capture technologies for deployment in the U.S.

Technology Background

- Shell's CANSOLV PCC system uses a tailored, amine-based absorbent to capture pollutants from NGCC flue gas, producing pure CO_2 that can be permanently sequestered. The core of Shell's system is its high efficiency DC-103 aqueous amine solvent



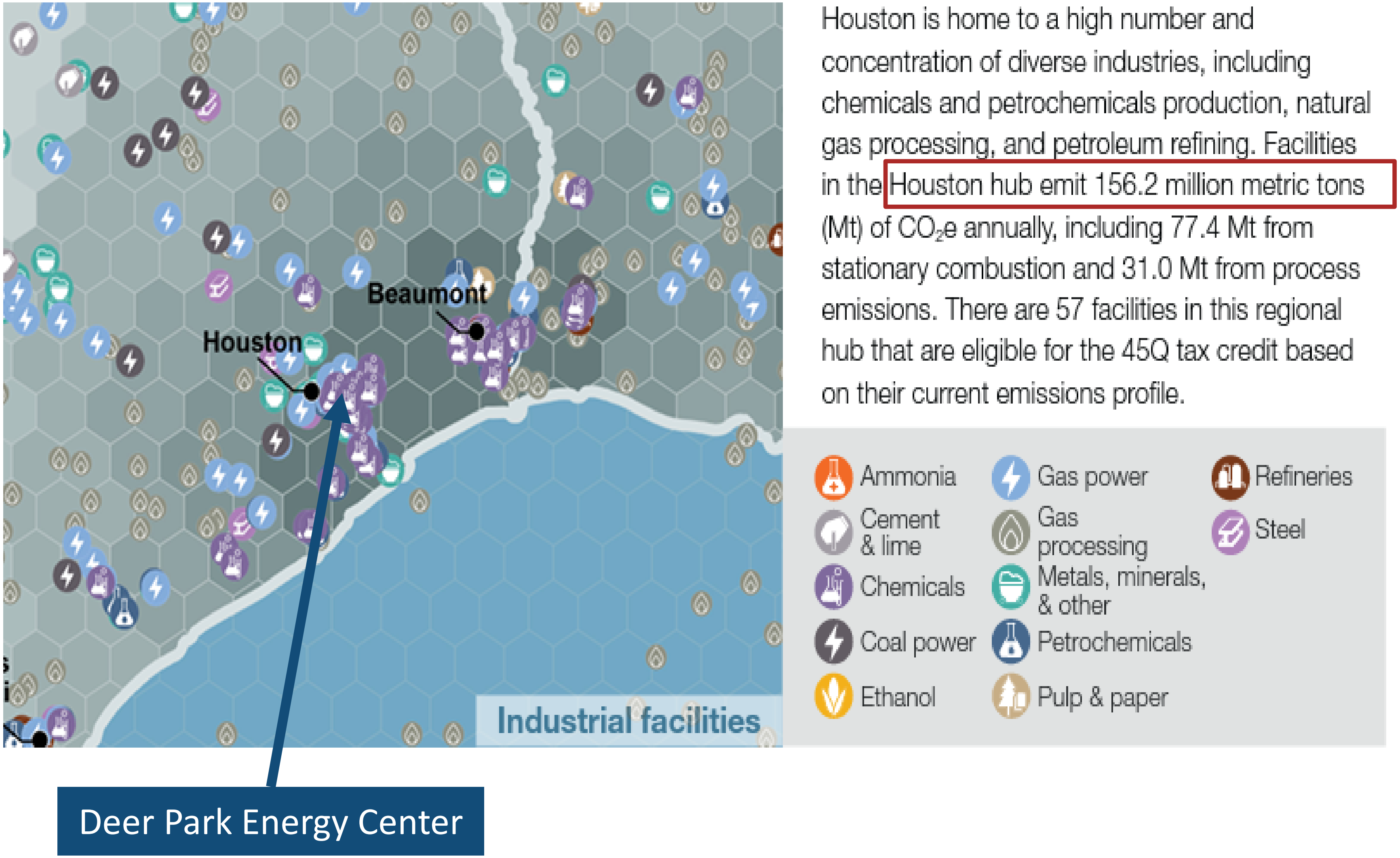
Calpine CCS Map



Calpine Site Selection : Deer Park Benefits

- Scale : approximately 6.5 million tonnes per annum (MTPA) CO_2 potential.
- Technology : 95% capture, Generation 2 solvent + process. Focus on managing effects of high oxygen environments associated with NGCC vs Coal.
- Site Characteristics : Steam and Power co-generation facility with high existing capacity factor and steam generation potential.
- Infrastructure/Hub : There are 193 separate point sources proximate to DKEC in the greater Houston area eligible for 45Q tax credits totaling over 156 MTPA CO_2 emissions (GPI Carbon Hubs).
- Sequestration Potential : University of Texas Bureau of Economic Geology (UT-BEG) and Southeast Regional Carbon Sequestration Partnership (SECARB) geotechnical studies indicate large volume reservoirs adequate for safe, secure carbon storage exist proximate to DKEC.

Deer Park Proximity to Large Point Sources



Houston is home to a high number and concentration of diverse industries, including chemicals and petrochemicals production, natural gas processing, and petroleum refining. Facilities in the Houston hub emit 156.2 million metric tons (Mt) of CO_2e annually, including 77.4 Mt from stationary combustion and 31.0 Mt from process emissions. There are 57 facilities in this regional hub that are eligible for the 45Q tax credit based on their current emissions profile.

Technical Approach

1. Establish design inputs and design basis
2. Determine train configuration and major process sparing / redundancy requirements
3. Develop process equipment layout.
4. Coordinate overall facility layout, considering process island layout and land use limitations from property owner (Shell Chemical Manufacturing)
5. Develop ISBL and OSBL designs to ultimately support development of inputs to cost estimate
6. Develop capital cost, O&M costs, and equivalent cost of capture.
7. Identify next steps required for bridging phase or execution of CCUS project

Project Schedule

Task/ Subtask	Milestone Title & Description	Completion Date
2.2	Project Design Basis Complete	07/15/2022
2.1	Project Scope and Design Complete	07/14/2022
2.3.1	Vendor Quotes for Inside Battery Limits received	12/19/2022
2.3.1	Inside Battery Limits CO_2 Capture Island Process Engineering Complete	02/21/2023
2.3.2	Vendor Quotes for Outside Battery Limits received	12/29/2022
2.3.2	Outside Battery Limits Process Engineering Complete	2/17/2023
2.3.3	Project Execution Plan and Constructability Review Complete	1/30/2023 & 3/3/2023
2.3.4	Hazard and Operability (HAZOP) Review Complete	12/08/2022
2.4	Project Cost Estimate Complete	3/3/2023
2.5	Steam and Power Sourcing Study Complete	08/19/22
2.5	Water and Wastewater Treatment Study Complete	08/19/22
2.5	Cooling Water Supply & Optimization Study Complete	06/27/2022
2.5	Flue Gas Cooling Options Study Complete	07/27/2022
3.1	Business Case Analysis	05/17/2023
3.4	Technology EH&S Risk Assessment	05/17/2023
3.2	Techno-Economic Analysis (TEA)	05/17/2023
3.3	Life Cycle Analysis (LCA)	05/17/2023
4.1	Environmental Justice Analysis	05/17/2023
4.2	Economic Revitalization and Job Creation Outcomes Analysis	05/17/2023
2.6	**FEED Summary Report**	05/17/2023

Success Criteria

Performance Metric	Success Criteria	Status
Cost and Schedule Targets	Development of all items identified in SOPO within budget and schedule parameters as defined in this application.	Yes
Technical Documentation	Development of technical engineering documents per applicable engineering codes. Development of AACE Level 3 Estimate for scope defined by Calpine.	Yes
Train Configuration	Design of CCUS equipment to maximize unit throughput while minimizing total installed cost, while treating 100% of the flue gas from five units at DKEC and capturing 95% of the CO_2 in the flue gas.	Yes
Unit Derates	Integration of steam driven compressor and steam turbine into existing cycle confirming site-specific advantages of the excess steam capacity and CHP configuration.	Yes
Constructability	Development of a constructability plan that confirms the train configuration and integration options, minimize DKEC unit downtime, and phases the project per Calpine targets.	Yes
Cost of Capture	Project design results in a capital and O&M cost estimate within the AACE Class 3 range of accuracy that results in a cost of capture less than previously reported applications on NGCC facilities in NETL Cost and Performance Baseline for Fossil Energy Plants Volume 1 Bituminous Coal (PC) and Natural Gas to Electricity Case B31B.	Yes
Project Execution & Corporate Approval	Development of schedule based on equipment lead times and engineering completion date to result in start of construction no later than January 2026 and corporate approval of project execution.	Yes

Project Award Management

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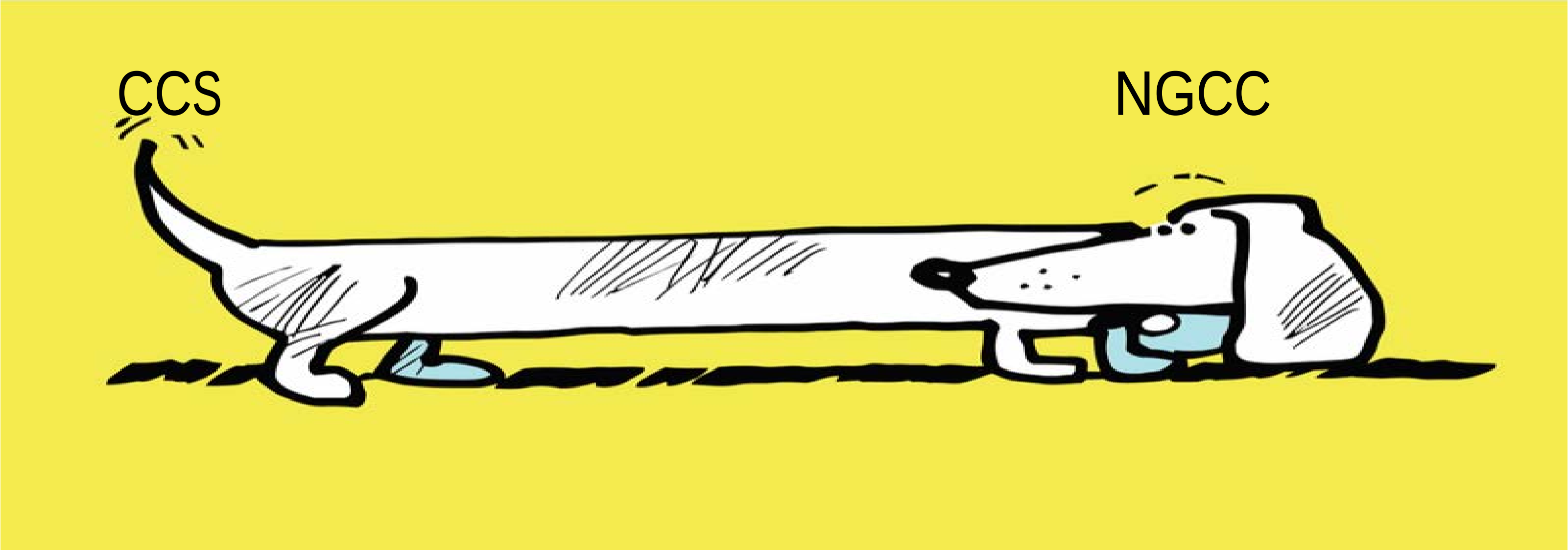
Project Execution & Corporate Approval	Development of schedule based on equipment lead times and engineering completion date to result in start of construction no later than January 2026 and corporate approval of project execution.

Project scope completed under budget and on schedule.
Thanks to DOE and Project Team Partners!

NGCC – CCS Design Considerations



Ensure that tail (minor CCS optimizations) do not wag the dog (NGCC)

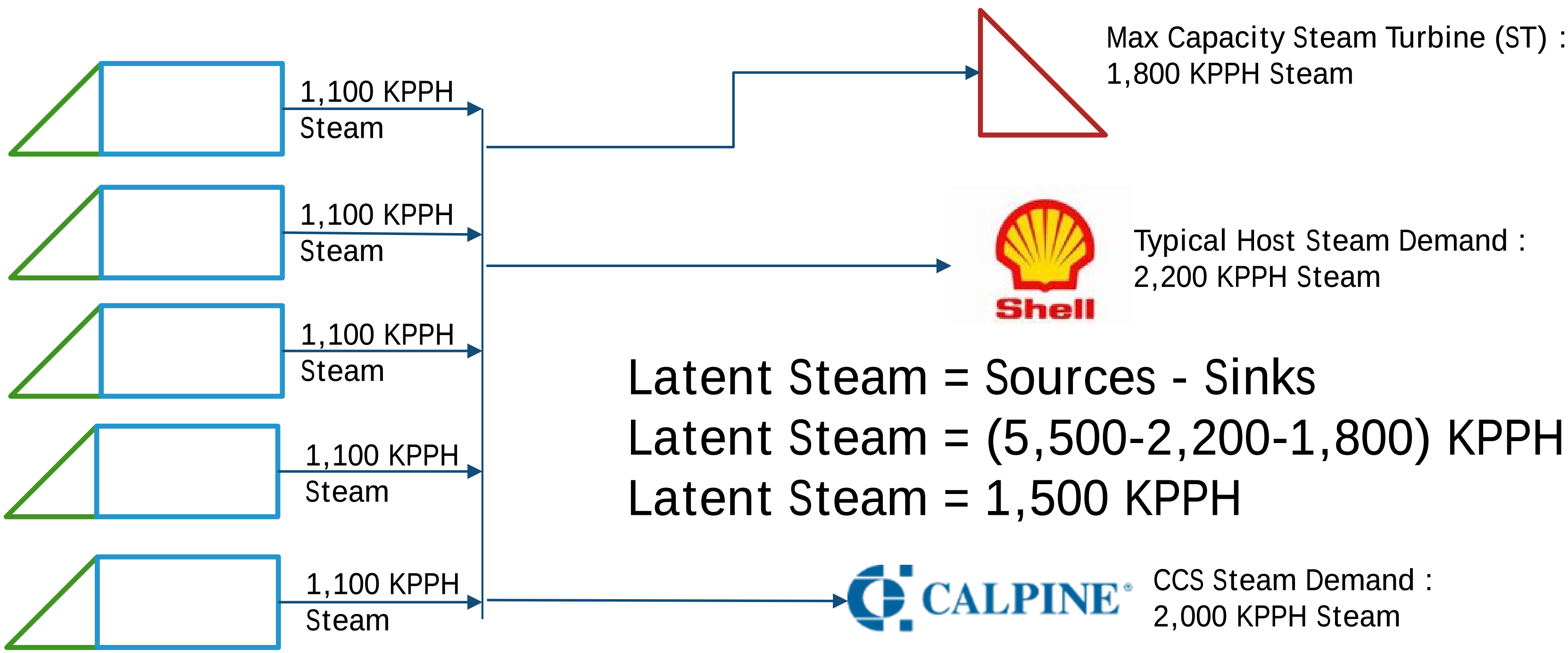
NGCC = Raw material supply source for CCS, high reliability is key.

Take **adequate** amount of technical risk for FOAK projects.

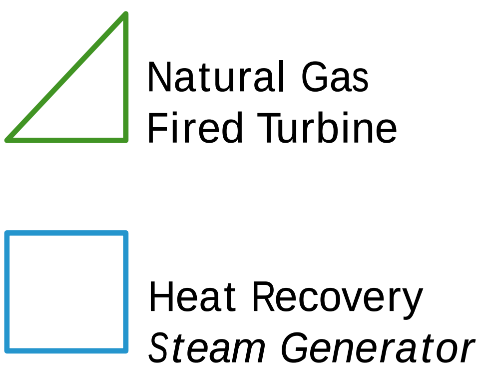
CHP vs NGCC

Standard NGCC	Combined Industrial Heat & Power (CHP)
• Provides electrical energy to grid • Typically paid for energy and/or power generation capacity • Heat Recovery Steam Generator (HRSG) sized to generate steam equal to Steam turbine (ST) demand • CCS steam demand results in ST derate	• Provides high temperature industrial heat (steam) to manufacturing site host (Host) • Provides electrical energy to grid and Host • HRSG sized to fit ST demand, Host demand and Host reliability needs • CCS steam demand *may not* result in derate

CHP Steam Profile Calpine Deer Park



Latent Steam = Sources - Sinks
Latent Steam = (5,500-2,200-1,800) KPPH
Latent Steam = 1,500 KPPH

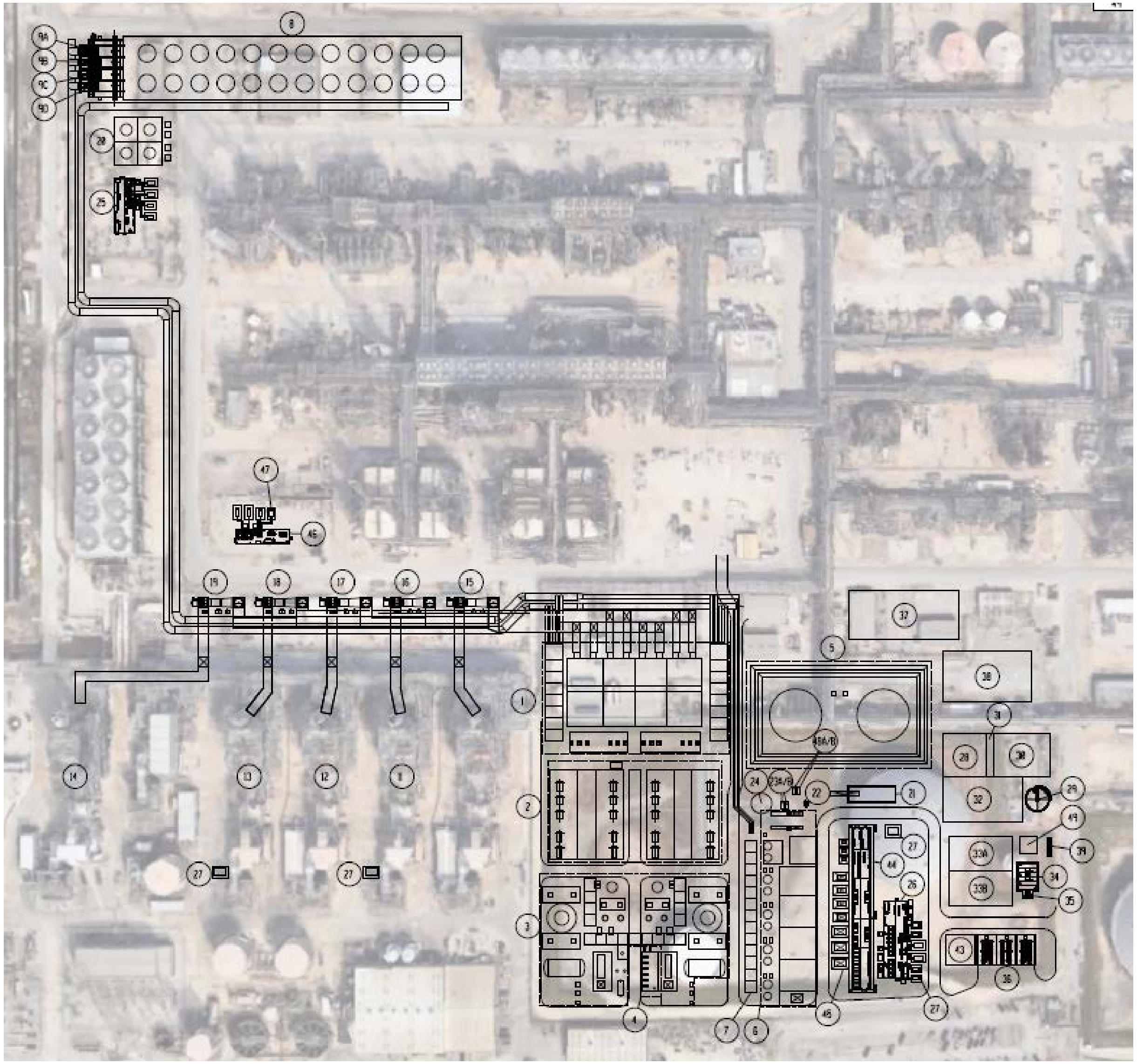


CCS ST Derate = CCS Steam – Latent Steam
CCS ST Derate = (2,000-1,500) KPPH
CCS ST Derate (CHP) = 500 KPPH ~ 70[1] MW
CCS ST Derate (NGCC) = 2,000 KPPH ~ 285[1] MW

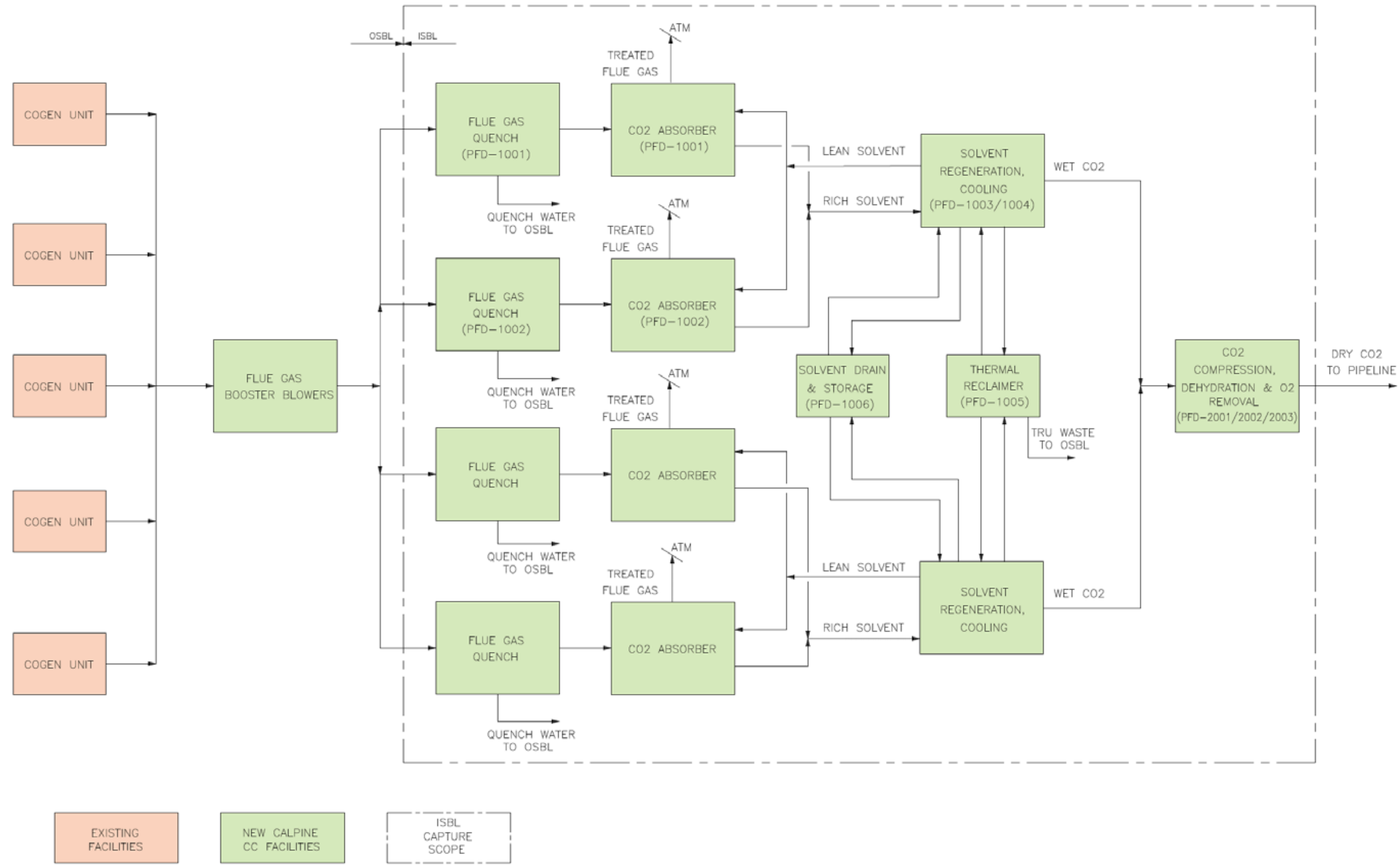
Net ST Derate Benefit CHP = 215 MW

1 – Assumes 7 KPPH/MW STG thermal to electrical efficiency

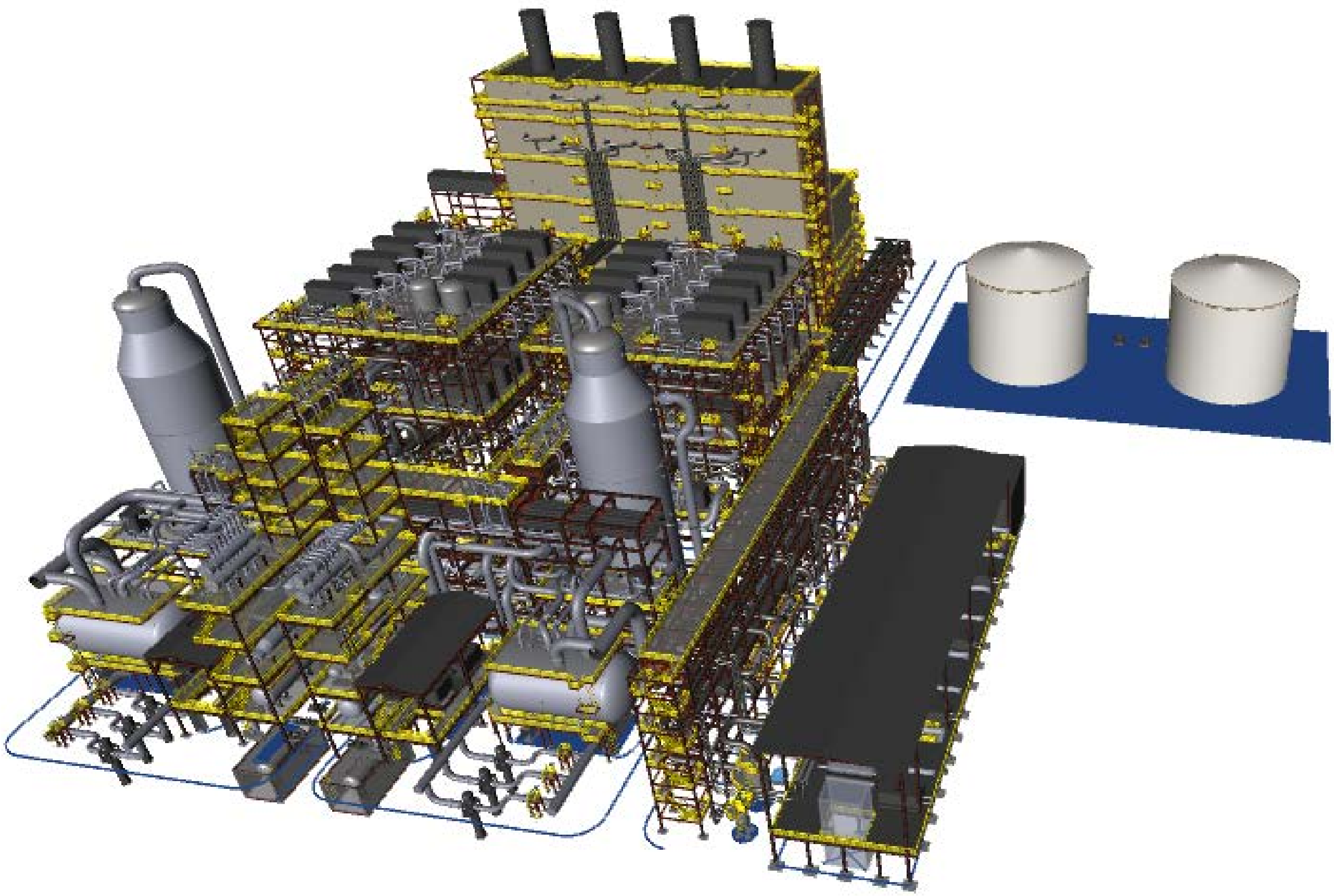
Project General Arrangement



ISBL Design - Overview



ISBL Design - Overview



Constructability Considerations

1. Site Host Reliability
   – Shell site requires 24x7 reliable energy products to ensure safe & economic operation

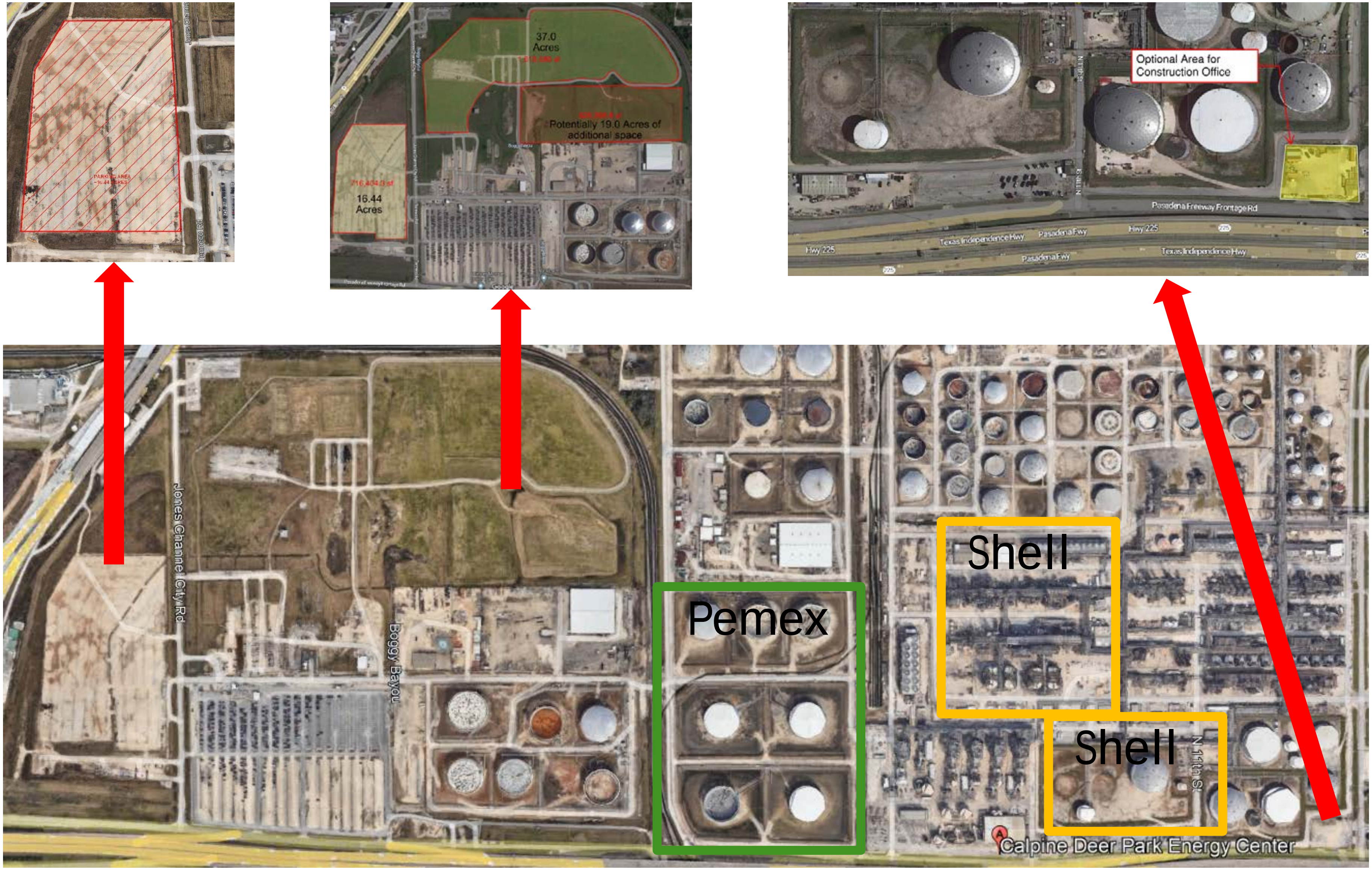
2. Calpine Site Footprint
   – Located adjacent to major highway, Shell Chemical Site, and Pemex tank farm

3. Heritage Brownfield Plot
   – CCS project plot has 75+ years of operating history

4. Limited Plot Space Requires Vertically Oriented Design

Project site constructable with expected labor productivity decreases and capital cost increases due to site specific considerations.

Constructability



Constructability

5 CT Cost Overview

- AACE Class 3 (-20% / +30%)
  - EPC Cost Buildup
- Quotes for major equipment and commodities (ISBL and OSBL)
- Labor "penalties" for congested facility and limited laydown areas
- Capital Costs reported in $2023-Q1

	CO_2 Capture System
Direct Cost (ISBL)	$875,465,973
Direct Cost (OSBL)	$389,919,595
Total Direct Cost	$1,265,385,568
Project Indirect	$754,338,147
Contingency	$302,959,000
Escalation	$0
Interest During Construction	$0
CO_2 Technology Costs	$59,200,000
Total	$2,381,882,715

		CO_2 Capture System
Annualized Capital Cost	$/yr	349,573,003
O&M Cost	$/yr	213,727,354
CO_2 Captured	tonne/yr	5,575,825
Cost of Capture[1]	$/tonne	101[2]

Note 1: Cost of Capture reported without 45Q credits.
Note 2: Annualization Factor: 0.147
Interest Rate: 10% WACC
Payback Period: 12 Years

5-3 CT Cost Overview

- Scaled / Adjusted estimate – 5 CT costs as basis
- Considered AACE Class 4
- CCUS scaled to allow one train to treat flue gas from 3 CT's
  - Approximately 60% capacity, not 50% capacity from original design
- Phased approach
  - Phase 1 includes certain considerations for future addition of 2nd CCUS train.
  - Common systems support final CCUS capacity
  - Full size underground utilities
  - Full size back pressure turbine
  - 3x 50% CO2 compressors
  - Full size utility racks
  - Full capacity auxiliary power system

- Capital Cost Comparison:
  - Original Full Scope (5 CT / 2 CCUS): $2,381,882,715
  - Phase 1 Scope (3 CT / 1 CCUS): $1,691,857,310

- Phased approach expected to exceed total original full scope cost, due to inefficiencies in phased construction

Conclusions

1. Site selection is critical.
   - Construction complexity and **CapEx** = f(site accessibility)
   - DCC & Absorber require stick building

2. Optimal scale major project trains = ~1.5-1.8 MTPA
   - Compressor is limiting major unit operation
   - Site specific logistics may affect optimal, maximum train size
   - DCC/Absorber cell count dictated by turndown requirements

3. CCS + Combined Heat & Power (CHP) limit power output reduction
   - "Latent steam" minimizes existing STG derate
   - Back-pressure turbine maximizes efficiency when using HP steam

4. Base train size repeatable to other Calpine CHPs
   - BOP/logistics dictate site specific design and cost

Development and Commercialization Plans

Deer Park Development & Commercialization

- Refine facility scope and estimate to support EPC contract negotiations
- Optimize facility size to maximize use of latent steam, decarbonize industrial heat and limit reduction of facility power production potential
- Optimize scope to standardize major equipment sizing with sister facility -> Baytown Energy Center

Baytown Energy Center Development & Commercialization

- Calpine CHP located ~ 15 miles from DKEC
- FEED ongoing, similar capacity to half Deer Park Capacity (1 Train)
- Identical SCT solvent utilized
- Land availability and heavy haul shipping access decrease construction complexity
- Air Permit received
- Active CO_2 sequestration, PPA, and EPC negotiations

Calpine pipeline of 11 NGCC retrofits with 20+ MTPA emissions

Thank You to DOE and the Project Team!