Front End Engineering Design of Linde-BASF Advanced Post-Combustion CO_2 Capture Technology at a Southern Company Natural Gas-Fired Power Plant

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Carbon Management and Natural Gas & Oil Research Project Review Meeting
Virtual Meetings August 2, 2021

Southern Company

Research & Development

Disclaimer

Project Overview and Objectives

Project Overview:

- Funding: **$7,101,737**
  - DOE: $5,674,533
  - Recipients: $1,427,204
- Work Period: 10/1/2019 - 9/30/2021*
  - *Project team has requested a no-cost extension that is being processed by NETL.

Project Objectives:

- Complete a Front-End Engineering and Design (FEED) study for installing the Linde-BASF advanced aqueous amine solvent-based post-combustion CO2 capture technology (PCC) at an existing domestic natural gas-fired combined cycle (NGCC) power plant within Southern Company's portfolio of assets.
- Provide a reference case for a more detailed understanding of CO2 capture costs in a commercial application to support the development of cost-effective, environmentally sound, and high-performing technologies for the reduction of CO2 emissions from NGCC plants.

Linde-BASF Post-Combustion Carbon Capture (PCC) Technology

- OASE® blue solvent
  - Advanced aqueous amine solvent
  - Favorable kinetics and reduced steam energy requirements
  - Demonstrated solvent stability
  - Lower solvent circulation rate

- Technology tested from 2009-2017 in two pilot plants
  - Different flue gas sources
  - Wide range of flue gas compositions and impurities
  - Achieved Technology Readiness Level of 6
  - Multiple process design improvements achieved

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Linde-BASF Post-Combustion Carbon Capture (PCC) Technology

Notable Linde-BASF process improvements

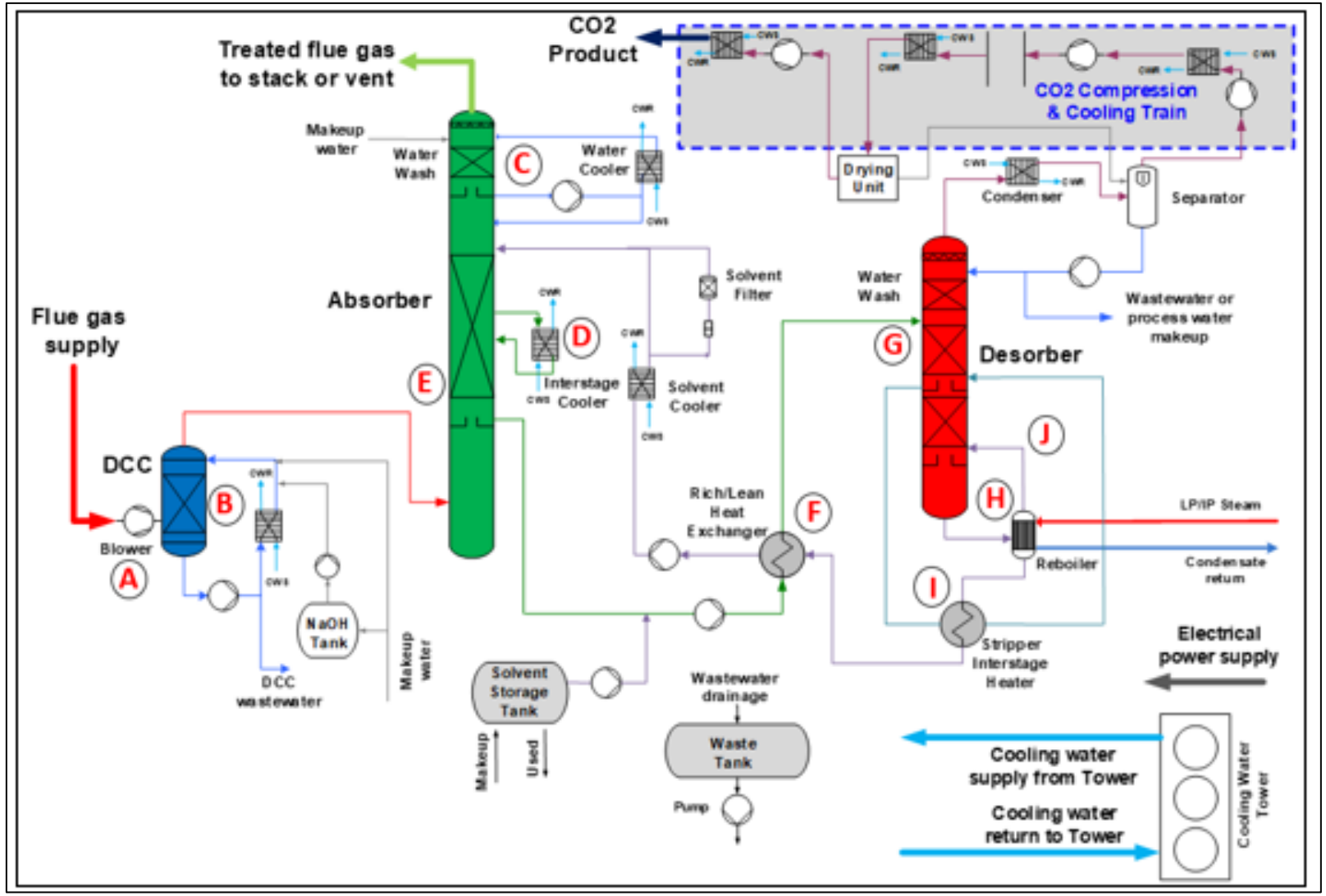
(C, E) Dry bed water wash design to minimize solvent losses

(G) Stripper regeneration at 3.4 bars reducing CO_2 compressor cost and power consumption

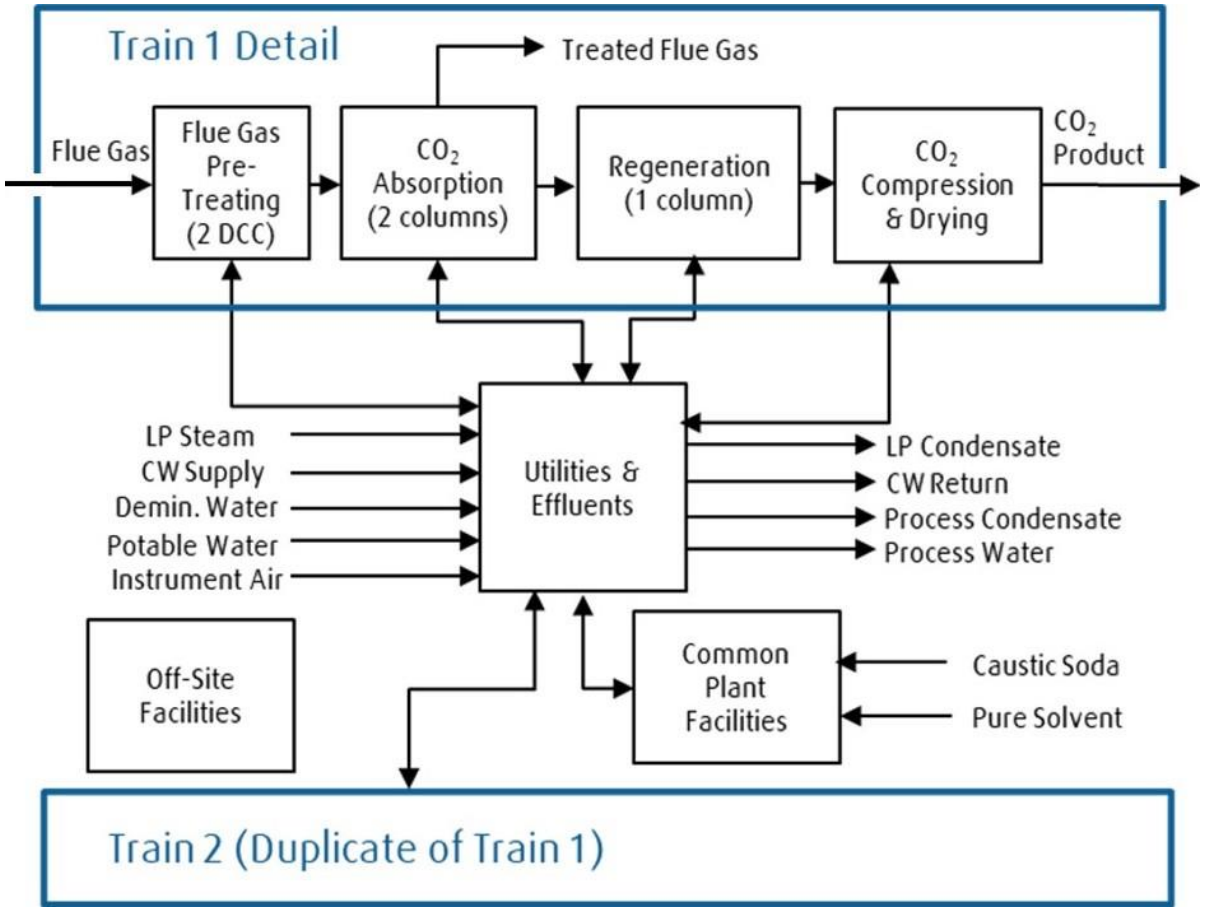
(I) Advanced Stripper Interstage Heater to reduce regenerator steam consumption.

Reduced capital costs/energy costs

- Optimized BASF OASE® blue solvent
- Efficient CO_2 capture from low-pressure sources
- Longer solvent life (can handle higher O_2 conc)
- Lower solvent circulation rate



Project Scope



CO_2 Capture Boundary Limits

- General Responsibilities:
  - Southern Company is responsible for the design of interconnections to the existing plant facility, all modifications outside CO2 capture boundary limits (OSBL), and all deep foundations.
  - Linde is responsible for the design of all above-ground equipment and foundations inside boundary limits (ISBL).

- Design Basis:
  - 90% capture at full NGCC load.
  - Steam extracted from combined-cycle LP steam system.
  - Product CO_2 at Kinder Morgan pipeline transportation specs.

Project Milestones

Task/Subtask Number	Milestone Title & Description	Completion Date	Verification Method
1.1	*Project kickoff meeting*	*11/22/2019*	*Presentation file*
1.1	*Updated Project Management Plan (PMP)*	*2/28/2020*	*PMP file*
2.2	*Host site evaluation and selection, including design basis*	*4/29/2020*	*Quarterly Progress Report*
3.2	*Basic engineering complete*	*12/2/2020*	*Quarterly Progress Report*
4.1	*HAZOP complete*	*12/17/2020*	*Quarterly Progress Report, HAZOP report*
4.0	Front-end engineering packages complete	6/30/2021*	FEED Study Report
5.3	Finalized cost and schedule analysis	9/30/2021*	Topical Report

*Project has requested a no-cost extension that is being processed by NETL.

Success Criteria and Decision Points

Decision Point	Date	Success Criteria
Host site selected	*4/29/2020*	*Letter of confirmation from selected host site; design basis created for that site.*
Basic engineering completed successfully	*12/2/2020*	*Solvent system basic design complete. All information required to conduct HAZOP complete.*
Front-End Engineering Design complete	6/30/2021*	All design packages ready for equipment/material estimation from vendors. HAZOP revisions addressed.
Cost and schedule estimate complete	9/30/2021*	Cost and schedule estimate completed and reviewed.

*Project has requested a no-cost extension that is being processed by NETL.

Host Site - Plant Daniel Unit 4

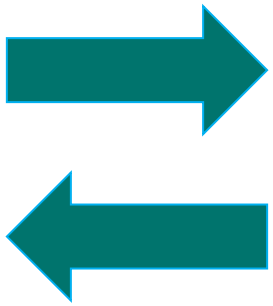
- Located in Moss Point, MS
- (2) GE 7FA gas turbines -> (1) Vogt triple pressure HRSG -> (1) GE TC2F D11 steam turbine, 525 MW net
- Began commercial operation in May 2001
- Estimated storage costs at $3-5/ton from pre-feasibility geological studies

Approximate Area of CO_2 Capture Equipment

Task 3: Conceptual Design

SCS Scope (OSBL):

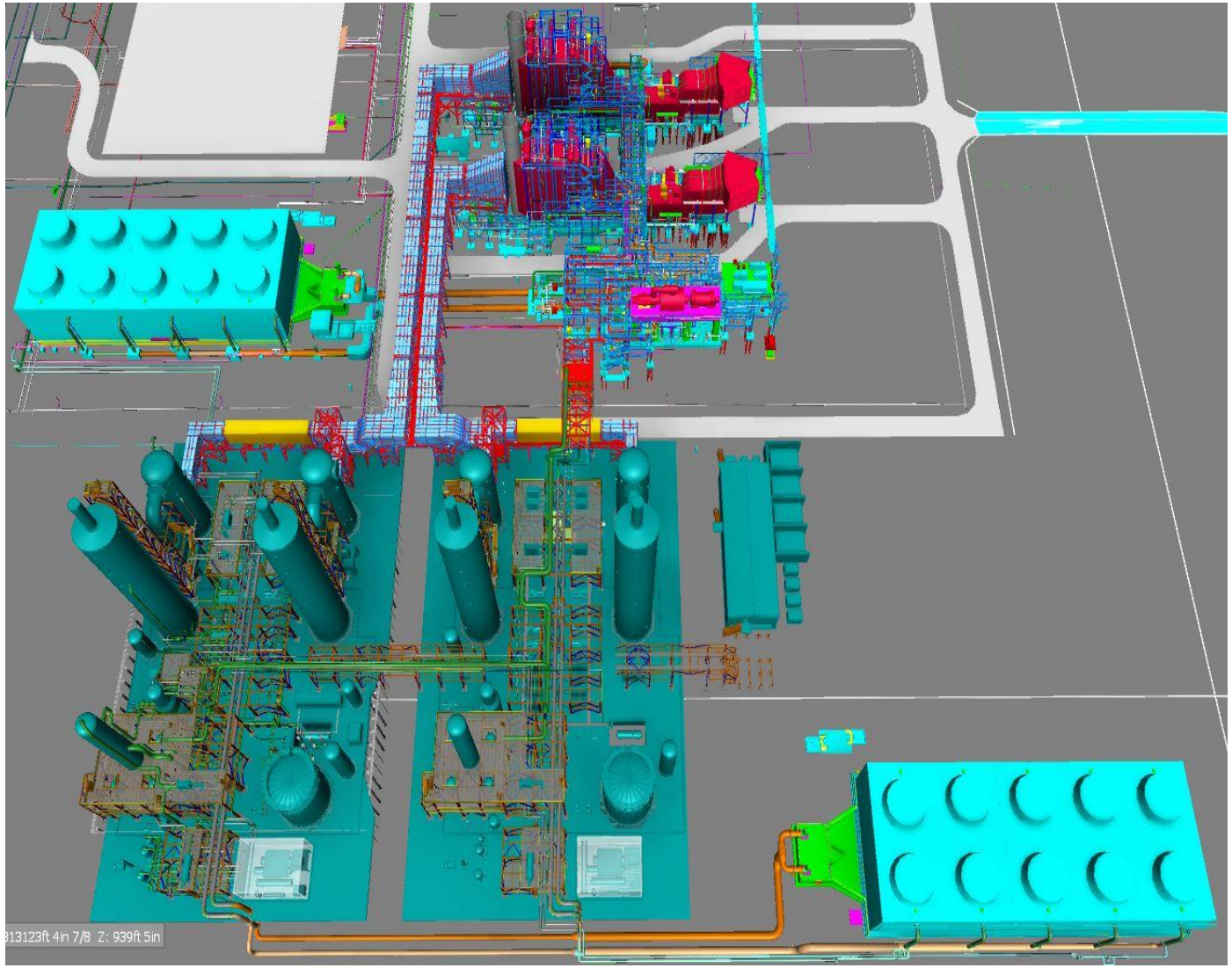
- Evaluation and identification of the steam source and quality for the carbon capture system.
- Evaluation of utility availability and identification of any necessary additions.
- Reconciliation between Linde and SCS design standards.



Linde Scope (ISBL):

- Basic design completed by BASF based on OASE® blue solvent technology. This includes preliminary heat and material balances and key equipment sizing.
- Linde completed basic engineering including, the development of the first version of PFD, detailed heat & material balances, P&ID, and plot plan.

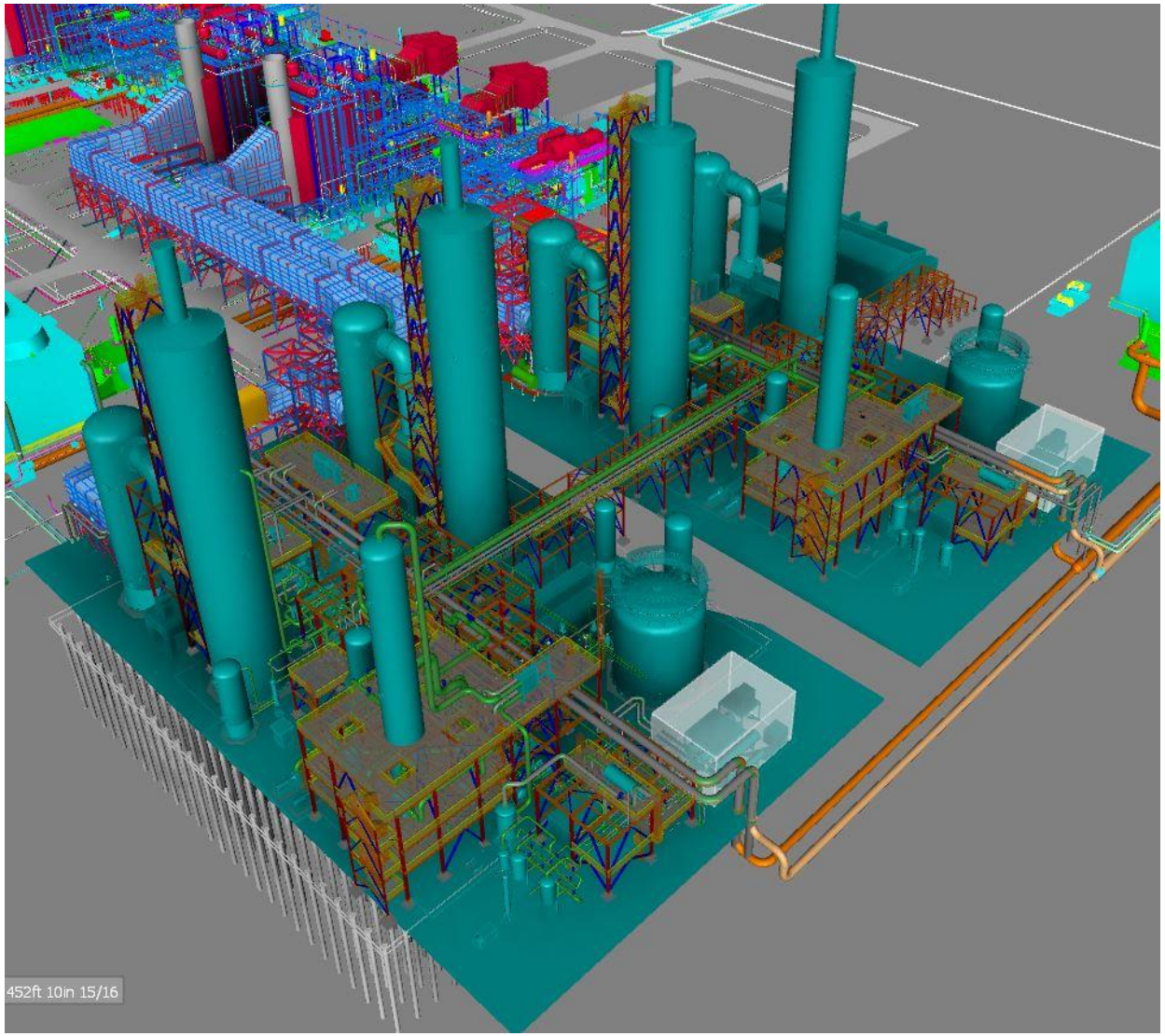
Task 4: FEED – Integration between organizations



- SCS created and implemented an integrated 3D model file transfer system so that all project engineers and designers are working from a common model.
- Biweekly project team updates are held.
- Discipline meetings are held as needed to address specific issues.
- Linde is providing their inputs for estimation, and SCS is rolling that into the overall estimate and schedule.

Task 4 - ISBL

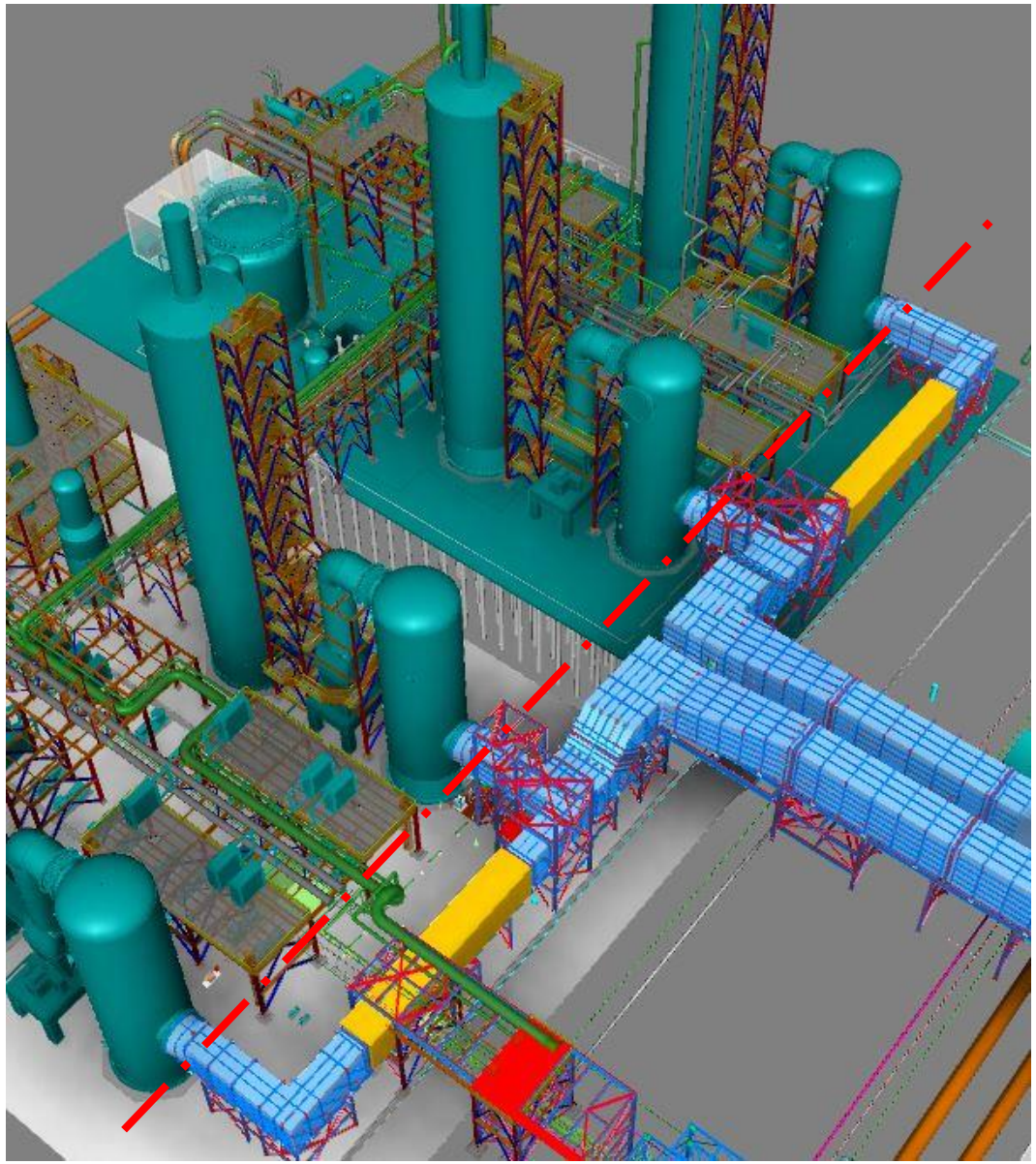
- Linde performed optimization of PCC plot plan, following the approach of 2PCC + Compressor trains with common utility supply and facilities support infrastructure.
- Linde and SCS reviewed and adjusted the plot to consider boundary limitations (e.g. underground systems), accessibility for power plant, and PCC plant.
- Optimization of tie-in points (regarding process conditions and locations).



Task 4: ISBL

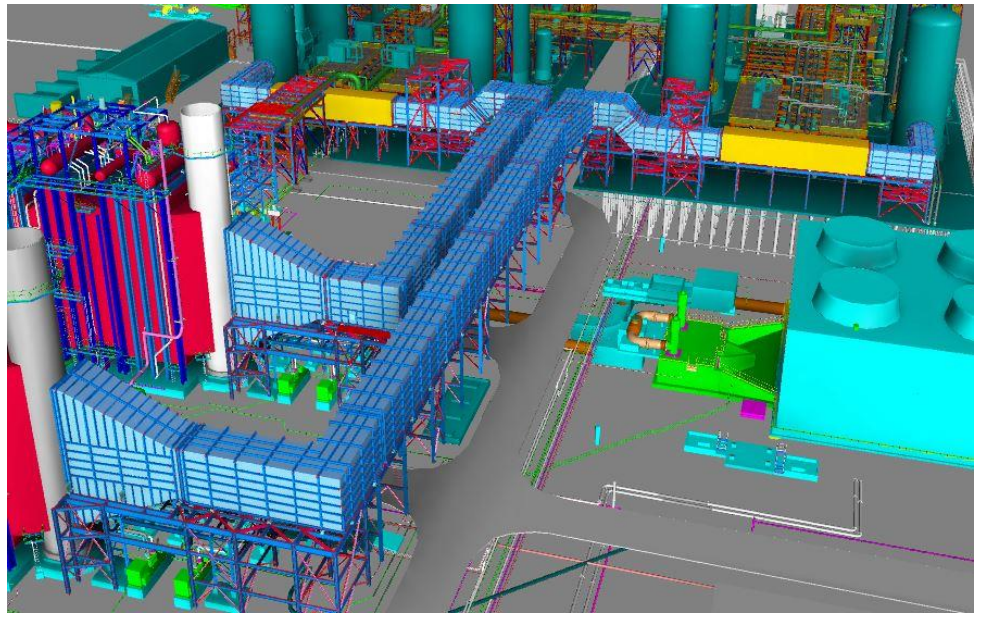
- Linde progressed ISBL cost development, incl. material take-offs and inquiries.

- Linde and SCS evaluated optimum of scope split (e.g. CEMS, control system)
  - Example: Appropriate structural steel scope split.

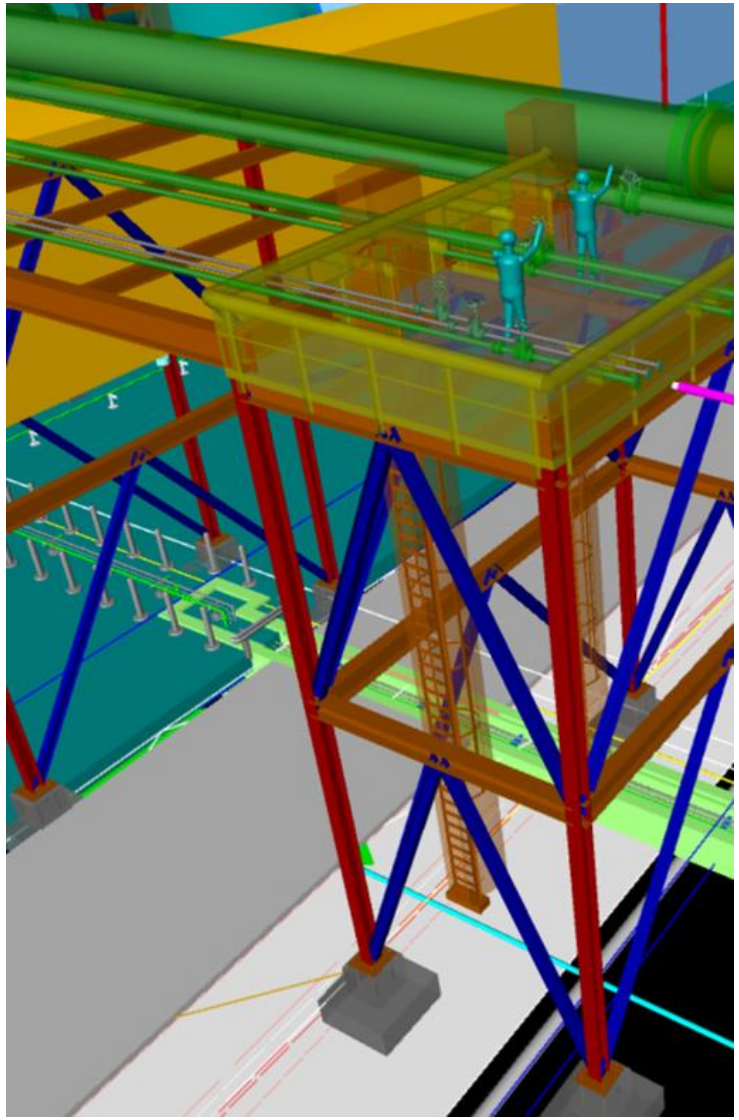


Task 4: FEED – Civil/Structural Engineering

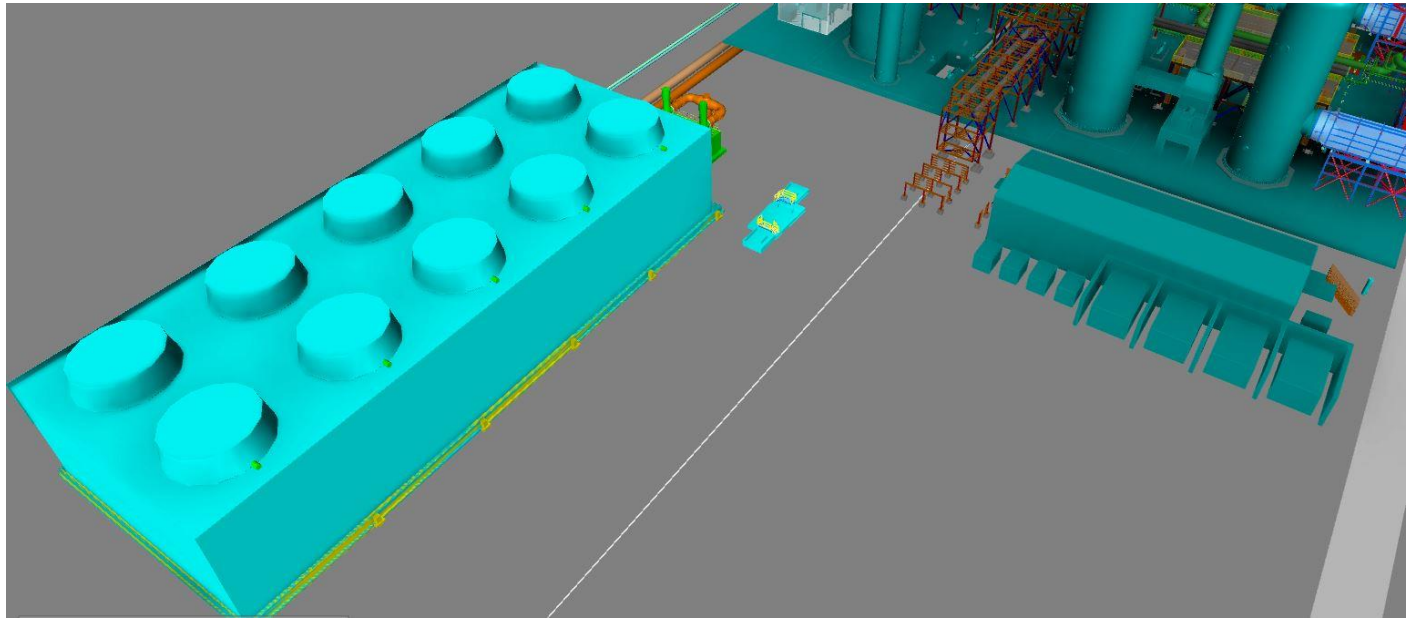
- Geotechnical investigation of the proposed project area used cone penetration testing in a grid pattern.
  - Testing indicated that augured cast-in-place piles (ACIPs) for deep foundations.
- Foundation design is balancing the ease of construction with required materials and necessary liquid containment.
- Structural steel design will conform to existing specifications to allow for modular construction.
- Original HRSG stack designer engaged for duct integration design.



Task 4 – FEED: Process/Mechanical/ICE Engineering OSBL



- Design underway for supplies of steam, process water, firewater from existing plant sources.
- Design of new infrastructure for cooling tower, instrument air, electrical supply, and expansion of DCS controls.



Challenges due to COVID-19:

- Travel restrictions eliminated the possibility of having in-person kickoff meetings, host site visits, and annual project team meetings.
  - The team has continued to use virtual meetings for these efforts.
- No in-person HAZOP meeting was possible for the two engineering organizations.
  - Travel restrictions were still in place.
  - There is a 7-hour time difference between the Linde engineering team and the SCS engineering team.
  - Linde team conducted HAZOP internally, and then SCS reviewed that HAZOP at a later date.

Summary

- Southern Company and Linde have assembled a diverse team to develop a FEED study with accompanying cost and schedule estimates.
- Despite major changes in work practices and plans due to the COVID-19 pandemic, the project team has adapted and continued the work.
  - No in-person team kickoff, no Linde site visits, no in-person HAZOP.
  - All project team members have spent significant time teleworking, and many continue to do so.
- The project team is working hard per the revised project schedule to complete the FEED packages and turn that information over to estimating.

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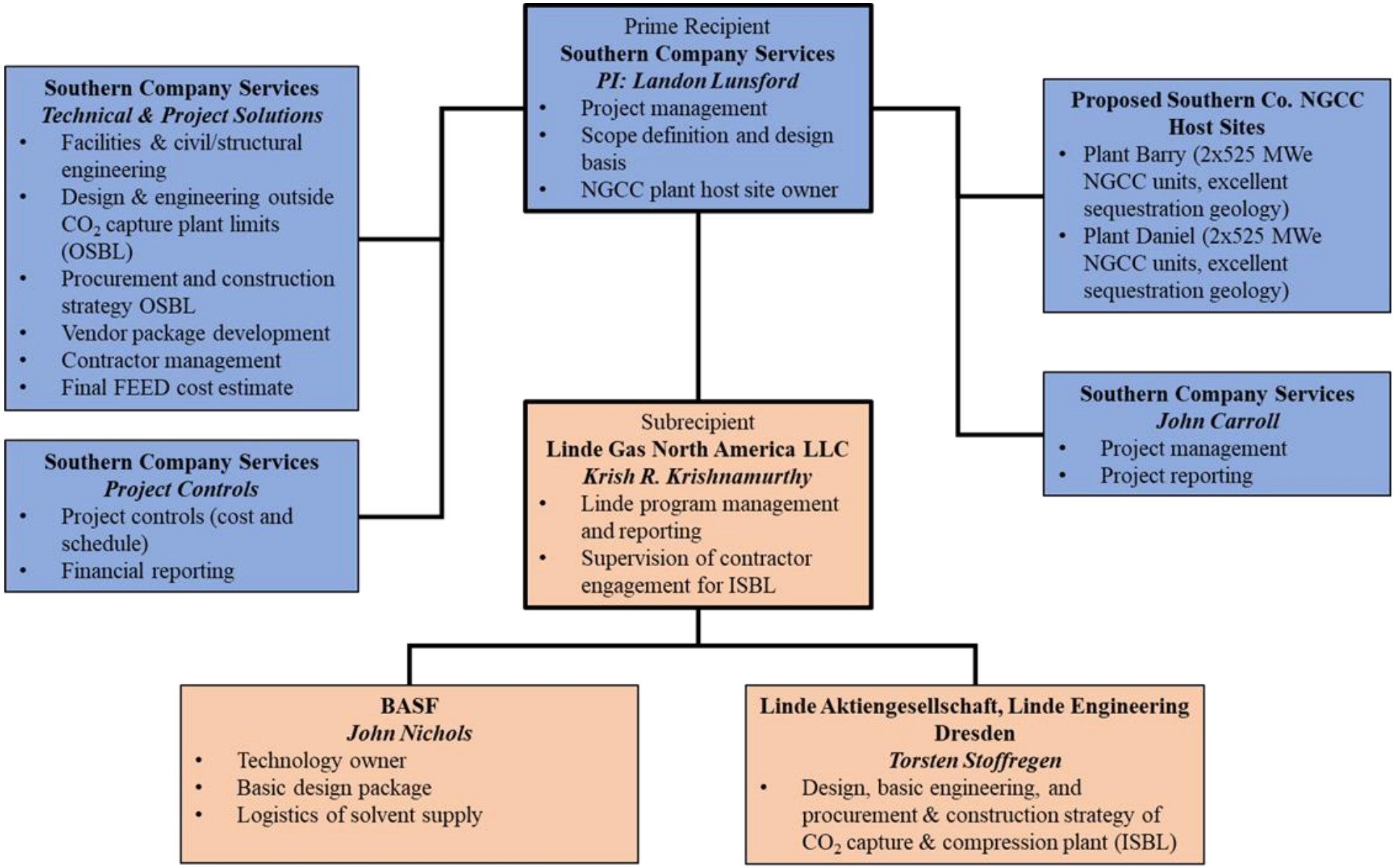
Questions?

Appendix

Research & Development

Project Organization Chart



Project Gantt Chart

				Budget Period 1								No-Cost Extension	
				10/1/19-9/30/2021								10/1/2021-3/31/2022	
	Start Date	Planned End	New End	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Task 1.0 - Project Management & Planning	1/29/2020	9/30/2021	3/31/2021										
Subtask 1.1 - Project Management	1/29/2020	9/30/2021	3/31/2021										
Subtask 1.2 - Project Administration	1/29/2020	9/30/2021	3/31/2021										
Subtask 1.3 - Project Controls	1/29/2020	9/30/2021	3/31/2021										
Milestones:													
-Project kickoff meeting				◊									
-Updated Project Management Plan					◊								
Task 2.0 - Scope Definition and Design Basis	1/29/2020	4/29/2020	4/29/2020										
Subtask 2.1 - Requirements Definition	1/29/2020	2/29/2020	4/29/2020										
Subtask 2.2 - Host Site Evaluation and Selection	3/1/2020	4/29/2020	4/29/2020										
Milestones:													
-Host site evaluation and selection including design basis						◊							
Task 3.0 - Conceptual Design	4/15/2020	9/30/2020	12/2/2020										
Subtask 3.1 - Basic Design	4/15/2020	5/15/2020	5/30/2020										
Subtask 3.2 - Basic Engineering	5/15/2020	9/30/2020	12/2/2020										
Milestones:													
-Basic engineering complete							◊	◊					
Task 4. 0 - Front End Engineering Design Study	9/30/2020	6/30/2021	10/31/2021										
Subtask 4.1 - Process Engineering	9/30/2020	6/30/2021	8/31/2021										
Subtask 4.2 - Mechanical Engineering	9/30/2020	6/30/2021	8/31/2021										
Subtask 4.3 - Instrumentation, Controls and Electrical Engingeering	9/30/2020	6/30/2021	9/30/2021										
Subtask 4.4 - Civil/Structural Engineering	9/30/2020	6/30/2021	10/31/2021										
Subtask 4.5 - Facilities Engineering	9/30/2020	6/30/2021	10/31/2021										
Milestones:													
-HAZOP complete								◊	◊				
-Fronte-End Engineering packages complete											◊	◊	
Task 5.0 - Cost and Schedule Estimation	1/1/2021	9/30/2021	3/31/2022										
Subtask 5.1 - Procurement and Fabrication Planning	1/1/2021	9/30/2021	3/31/2022										
Subtask 5.2 - Construction Management and Planning	1/1/2021	9/30/2021	3/31/2022										
Subtask 5.3 - Cost and Schedule Estimation	1/1/2021	9/30/2021	3/31/2022										
Milestones:													
-Finalized cost and schedule analysis											◊		◊

Originally planned but not realized	
Realized as planned	
Extended Time	
Original Milestone Time	◊

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