CO_2 Capture at LG&E Cane Run NGCC Power Plant

DE-FE0032223

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2023 Carbon Management Research Project Review Meeting
Pittsburgh
August 28th, 2023

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- Acknowledgment: "This material is based upon work supported by the Department of Energy Electric Power Research institute Inc. under Award Number DE-FE0032223.

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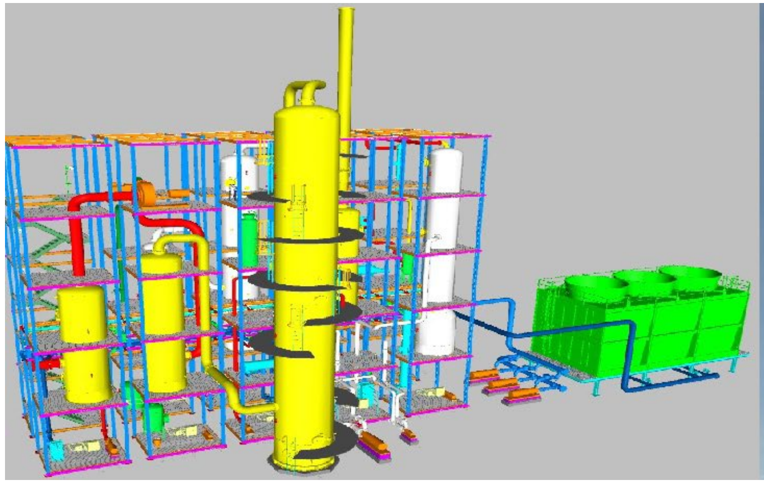
Project Overview

- FEED study for retrofitting the LG&E (a PPL Corporation Facility) Cane Run Unit 7, a 640 MW NGCC located in Louisville KY, with the University of Kentucky’s solvent-based carbon capture system
- Funding = $7,3303,164. DOE $5,842,517 + Cost-share $1,460,647
- Project performance dates 12/22/2022 – 6/30/2024



Source UK

Source PPL

Project Team

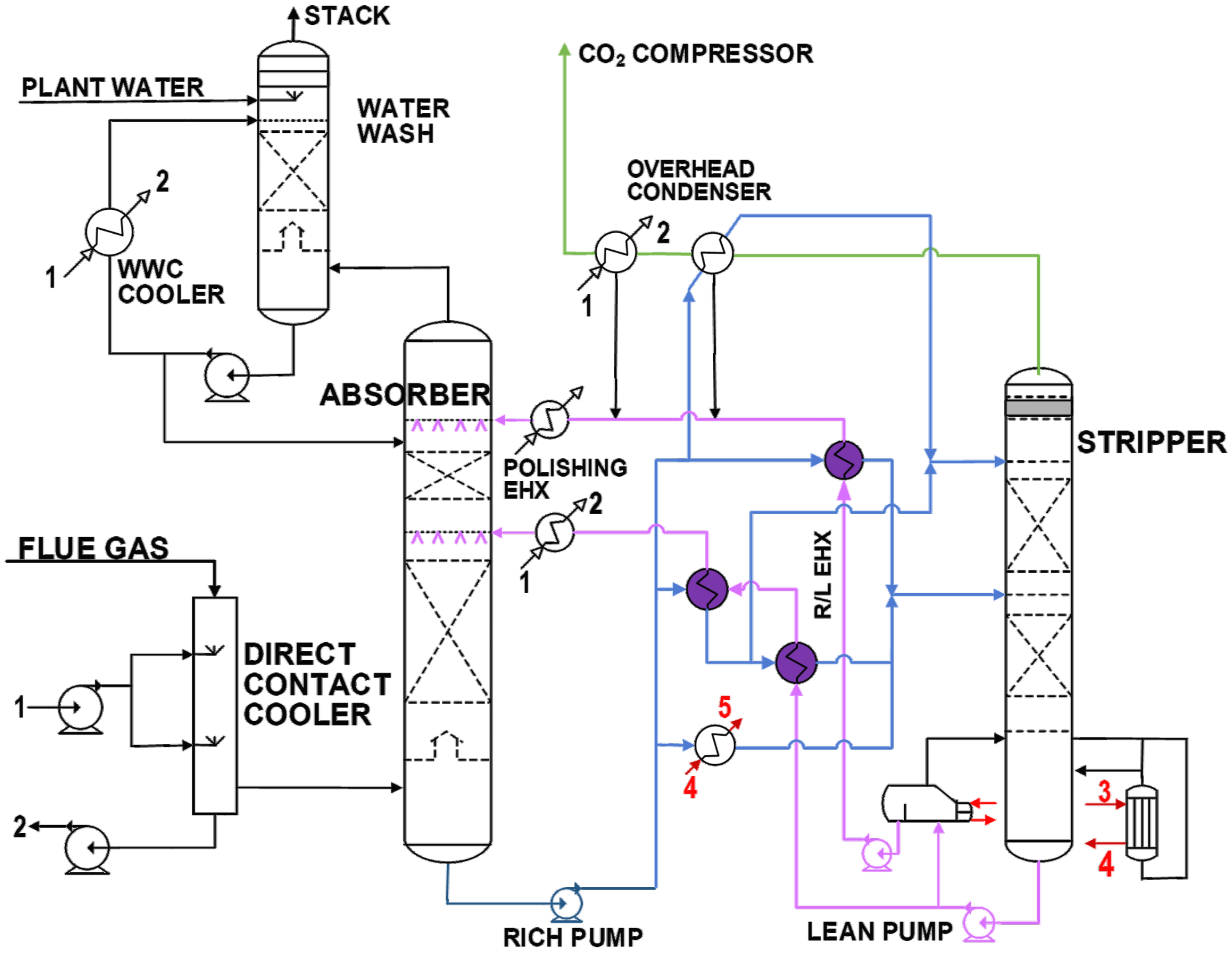
- **EPRI**: Non-profit, electric sector R&D; prime
- **Louisville Gas and Electric & Kentucky Utilities, a PPL Company** (PPL): owners of Cane Run Unit 7 NGCC plant located just SW of Louisville, KY along the Ohio River
- **University of Kentucky (UK)** Carbon capture technology developers
  - **Vogt Power International**: HRSG OEM, subcontractor to UK
  - **ALL4**: Performing EH&S, subcontractor to UK
- **Bechtel**: Performing Front-End Engineering and Design (FEED)
- **University of Michigan**: Global CO_2 Initiative for LCA

PPL companies

A Babcock Power Inc. Company

UK CCS Process

- Aqueous amine solvent
- Split lean solvent feed to absorber
  - 95% capture rate
- Split rich solvent feed to stripper
  - Reboiler duty <1060 BTU/lb (2.45 MJ/kg)
- In-duct water spray flue gas cooling
  - Reduced capital cost



Source UK

UK CCS Experience

- Active research since 2006
- Technology validated and scaled up from lab to pilot scales
- >10,000 operational hours on coal and simulated-NGCC flue gas
- Solvent with \$6.5kg/chemical cost, 0.6 kg/tonne CO_2 make-up rate, and Aspen Plus® model experimentally verified at pilot scale

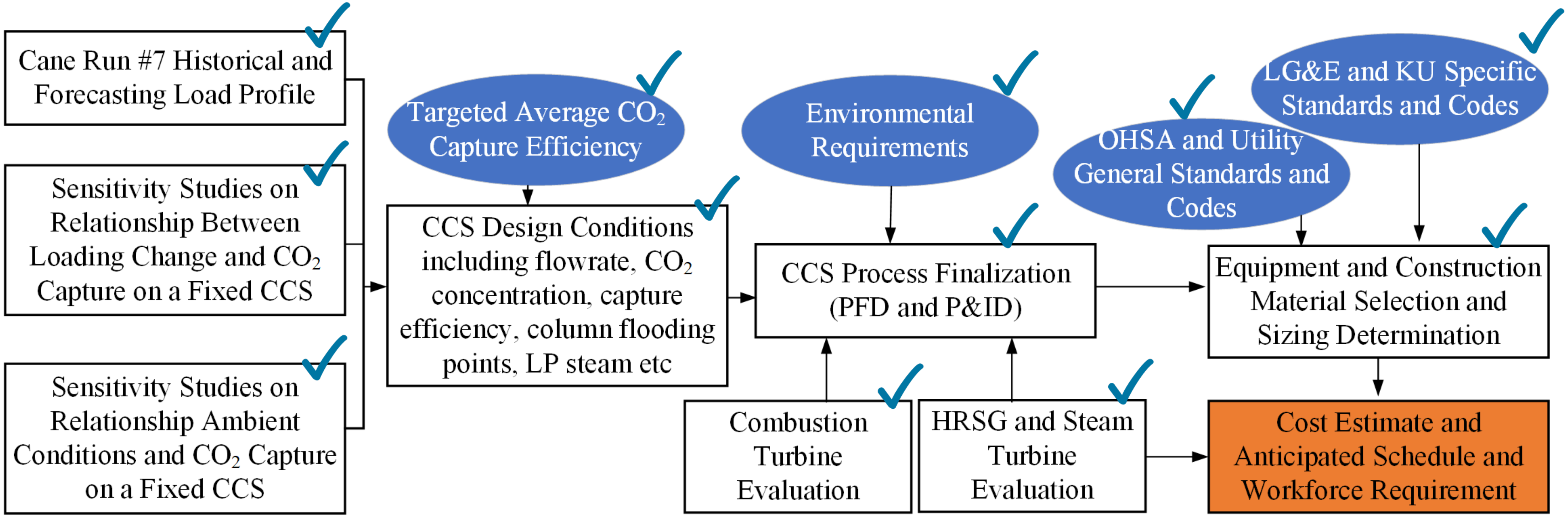
Cane Run 7 – Host Site

- **Location:** Louisville, KY
- **Capacity:** 640 MW
- **Fuel:** Natural Gas
- **Opened:** 2015
  - Cane Run 7 is Kentucky's first natural gas combined-cycle (NGCC) generating unit
- **Retirements:**
  - Coal units 1 through 6 were demolished in 2019
- **Capacity Factor:**
  - ~85% from 2016-2021

Source LGE-KU/PPL

Source LGE-KU/PPL

Pre-FEED Activities



- >95% equipment/process service factor
- Baseload condition based on historic & forecasted generation data
- Solvent-independent design
- Design for reliability and operability
- Full-plant integration and CT operation impact analysis

- Vogt Power on team to analyze:
  - Impact on HRSG operations
  - In-duct cooling, without DCC
  - Elimination of flue gas boost fan, with HRSG accommodating additional pressure
  - Best steam extraction location and impact on steam cycle

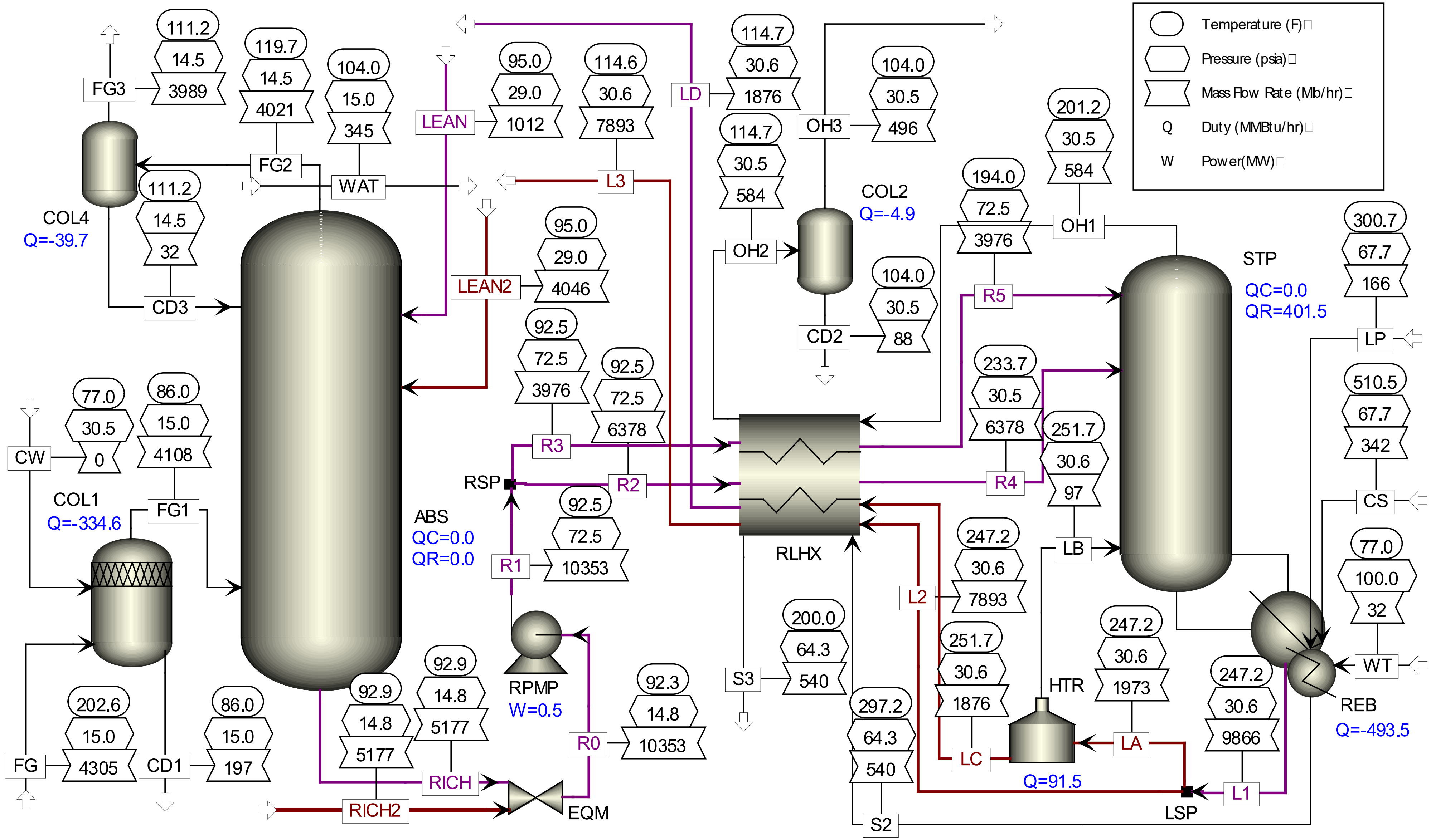
✓ - Completed

Design Condition Selected

- Evaluated historical plant operation by season
  - Cooling water temperature
  - CO_2, O_2, and NO_x concentration
  - Gas flow rate

Cases	Case 1: 89F Amb. 2x100% EC ON with CCS LP Drum Extraction	Case 2: 89F Amb. 2x100% EC OFF with CCS LP Drum Extraction	Case 12: 105F Amb. 2x100% EC ON with CCS LP Drum Extraction	Case 10: 58F Amb, 2x100% EC OFF with CCS LP Drum Extraction	Case 03: 14F Amb, 2x100% EC OFF with CCS LP Drum Extraction	Case 17: -20F Amb. 2x100% EC OFF with CCS LP Drum Extraction
Gas Flowrate (lb/hr)	4,375,115	4,269,000	4,305,133	4,479,781	4,283,214	4,238,141
CO_2 Concentration (wt%)	5.97	5.92	5.96	5.98	6.15	6.21
H_2O Concentration (wt%)	6.80	6.57	7.02	5.30	4.95	4.90
CO_2 Captured (ton/hr) at 95% Removal Efficiency	124.1	120.0	121.9	127.2	125.1	125.0

Design Heat and Mass Balance



Energy Advantage of UK CCS

- Reduction in reboiler duty due to:
  - Solvent: 27%
  - Process: 17%
  - Combined: 42%
- Expected reboiler duty of 1009 btu/lb (2.35 GJ/tonne)

	Simple CO_2 Capture Process		UK Process Intensified Process			
Solvent	UK	MEA	UK		MEA	
Case Name	I7	D.31	ME-d		MEA-M	
Stream	FG	FG	FG		FG	
T (°F)	202.6	202.6	202.6		202.6	
P (psia)	15	15	15		15	
Mass Flowrate (Mlb/hr)	4305	4305	4305		4305	
Y_H2O	0.11	0.11	0.11		0.11	
Y_CO2	0.04	0.04	0.04		0.04	
Y_N2	0.73	0.73	0.73		0.73	
Y_O2	0.12	0.12	0.12		0.12	
Block	COL1	COL1	COL1		COL1	
T (°F)	104	86	86		86	
Stream	LEAN	LEAN	LEAN	LEAN2	LEAN	LEAN2
T (°F)	104	95	95	95	95	95
P (psia)	29	29	29	29	29	29
Mass Flowrate (Mlb/hr)	3484	6224	1012	4046	1442	5769
X_H2O	0.86	0.85	0.85	0.84	0.85	0.85
X_CO2	0.02	0.03	0.02	0.03	0.03	0.04
X_Am	0.12	0.11	0.12	0.12	0.11	0.11
C/N	0.14	0.31	0.20	0.27	0.31	0.34
Stream	R5	R5	R5	R4	R5	R4
T (°F)	244	240	194	234	194	240
P (psia)	72.52	72.52	72.52	30.46	72.52	30.46
Liq C/N	0.48	0.50	0.49	0.38	0.50	0.42
Split %			38.4	61.6	47	53
SRD (Btu/lb)	1282	1755	1009		1459	

Next Steps: Feed Study

- FEED submission
- Reviews and revisions
- Class 3 cost estimate
- Transportation and logistics
- Quantity takeoffs
- Schedule
- Construction plan/Story boards
- Engineering, procurement and construction implementation plan
- Vendor quotes
- Material requisitions/RFQ'S
- Model Development (CAD)
- Layout
- Equipment lists
- Equipment designs/Selection
- Piping and Instrumentation Diagrams (P&ID's)
- HazOp
- Revised P&ID's
- Uncertainties Log
- Risk register
- Management control and reports

Community Benefits and Societal Impacts

- Planned evaluation of community impacts:
  - Environmental co-benefits of CO_2 capture
  - Workforce development and jobs creation
  - Economic impact
  - Development of community engagement strategy
- Societal Impacts
  - Accelerating decarbonization through de-risking CCS
  - All information to be made public except confidential vendor information
  - Potential for lowering energy and capital costs of CO_2 capture

Lessons Learned

- Design philosophy of reliability and operability has increasing importance for real-world deployment
- Increasing backpressure on gas turbine possible mechanism to eliminate FD fan
  - Requires collaboration between GT supplier, HRSG, and carbon capture
- Optimization of steam extraction point from NGCC requires full HRSG and steam turbine models
  - Modification possible, but important to bring in OEMs to understand repercussions from performance and service agreements

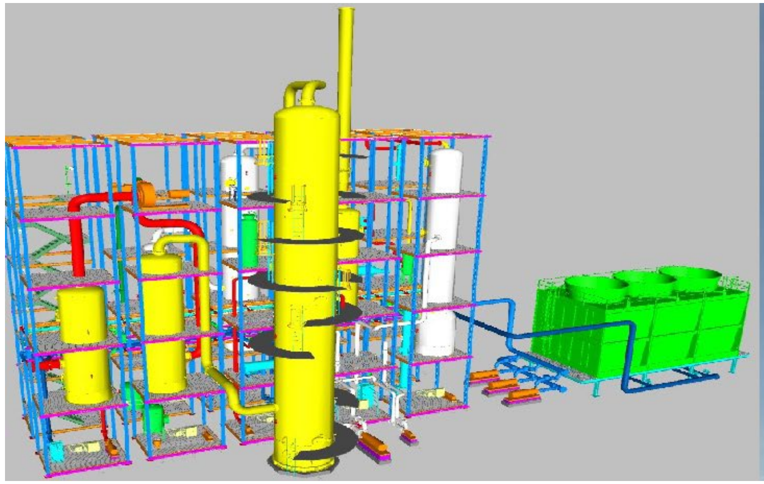
The FEED study will guide CCS scale up

- Evaluate the impact of the carbon capture process on:
  - Power delivery and cost for full scale deployment
  - The operation and possible modifications to the HRSG and steam turbine.
- Land and Permit Requirements
  - This includes the CCS system layout and long-term planning for possible future NGCC units at the site.
- Evaluation of Local Storge and Pipeline Options
- The FEED learnings combined with planned 20 MW demonstration capture unit will inform CCS at Cane Run Unit 7

Source PPL

Summary

- FEED study for retrofitting the LG&E (a PPL Corporation Facility) Cane Run Unit 7, a 640 MW NGCC located in Louisville KY, with the University of Kentucky's solvent-based carbon capture system for 95% CO_2 capture
- Pre-FEED nearly complete with promising performance estimates
- All results to be made public other than confidential vendor information



Source UK

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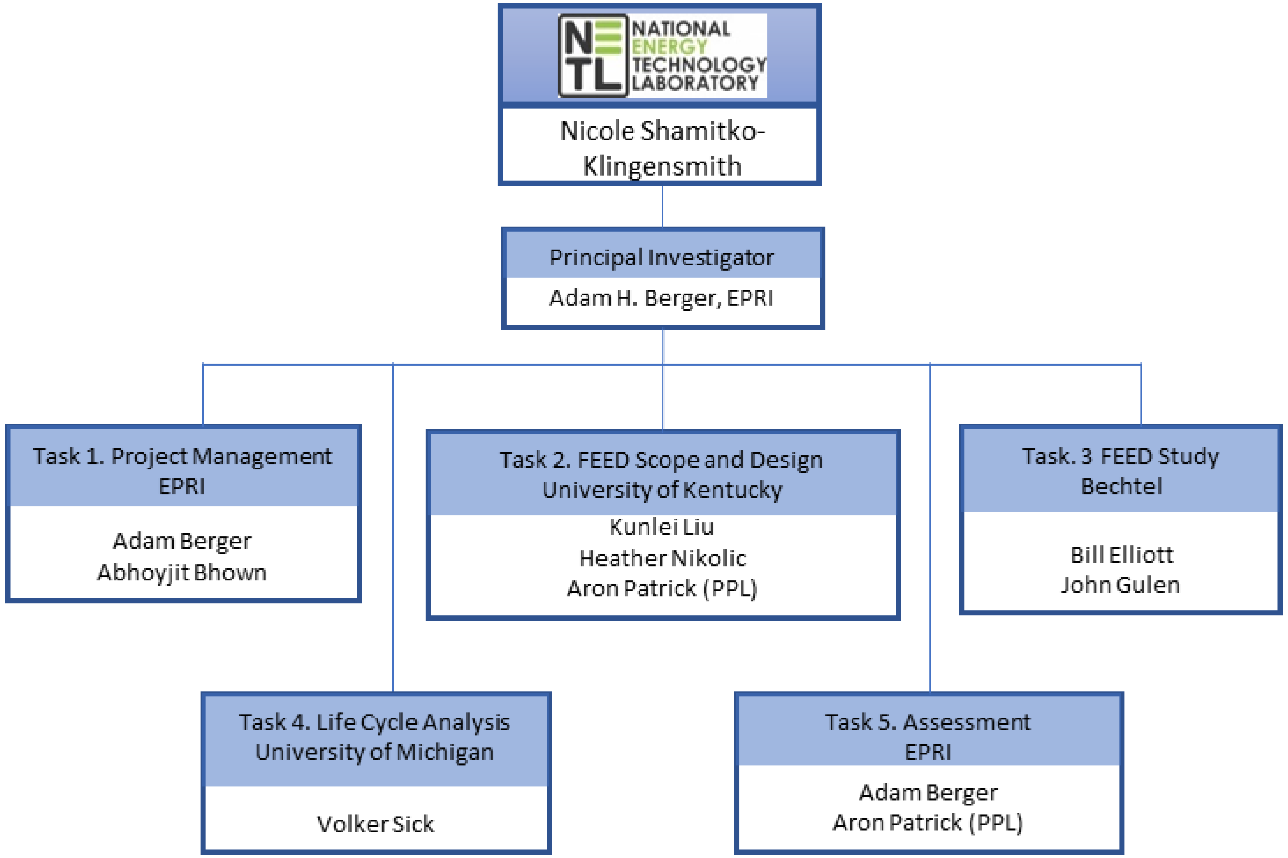
Overall Task List and Org Chart

- Task 1: Project Management and Planning
- Task 2: Preliminary-Front-End Engineering Design (Pre-FEED)
- Task 3: FEED Package
- Task 4: Life Cycle Assessment
- Task 5: Commercial, Environmental, and Economic Assessments



Gantt Chart (12/22/2022 – 6/30/2024)

Task list and schedule			2023				2024		Project month	
	Lead Organization		Q1	Q2	Q3	Q4	Q5	Q6	Start	Finish
1	**EPRI**	**Project Management and Planning**							1	18
1.1	EPRI	Project Management and Planning							1	18
1.2	UKy	Technology Maturation Plan							2	15
1.3	EPRI	Workforce Readiness Plan							12	12
2	**Uky**	**FEED Scope and Design**							1	6
2.1	UKy	FEED Scope							1	4
2.2	UKy	CCS Design Basis							1	5
2.3	UKy	Initial Design							1	6
2.4	UKy	CO2 Transportation and Long Duration Storage							4	6
2.5	UKy	Environmental Health and Safety							14	15
3	**Bechtel**	**FEED Study**							1	18
3.1	Bechtel	Initial Design Support							1	5
3.2	Bechtel	Process Engineering Design Package Review							3	6
3.3	Bechtel	Initial Electrical, Automation Systems, Utilities, and Other Engineering Design Package							7	8
3.4	Bechtel	Layout Design Package							9	10
3.5	Bechtel	Final Electrical, Automation Systems, Utilities, and Other Engineering Design Package and Material Take-Off of Main Components Design Package							11	11
3.6	Bechtel	Site Security & Logistics							12	12
3.7	Bechtel	Basic Contracting/Purchasing Strategy, HAZOP, and Constructability Review							13	13
3.8	Bechtel	Cost Estimating Design Package							14	15
3.9	Bechtel	Close-Out							16	18
4	**U Mich**	**Life-Cycle Assessment**								
4.1	U Mich	Preliminary LCA							4	5
4.2	U Mich	Final LCA							14	15
5	**EPRI**	**Assessment**							14	15
5.1	EPRI	Techno-Economic Analysis							14	15
5.2	EPRI	Environemntal Justice Analysis							15	15
5.3	EPRI	Economic Revitalization and Job Creation							14	15
5.4	EPRI	Business Case Analysis							15	15