Large Pilot CAER Heat Integrated Post-combustion CO_2 Capture Technology for Reducing the Cost of Electricity

Award Number DE-FE0026497

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University of Kentucky - Center for Applied Energy Research

http://www.caer.uky.edu/powergen/home.shtml

Presentation Outline

- Project and Process Overview
- Project Organization and Team Members
- Project Schedule and Deliverables
  - Tasks
  - Work Delegation
  - Additional Reports
    - Absorber Internals Sensitivity Analysis
    - Solvent Sensitivity Analysis
    - Technology Gap Report
  - Design – Status Update

Project Overview

- 10MWe advanced post-combustion CO_2 capture large pilot including two heat-pump loops, enhanced absorber and water wash design

- Designed as semi-modular system: free-standing and modular components

- Host site will be Louisville Gas and Electric Company's, Trimble County Generating Station, approximately 80 miles from UKy-CAER

https://lge-ku.com/our-company/community/neighbor-neighbor/trimble-county-generating-station

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Project Goal and Objectives

Goal

- Develop a pathway to meet the DOE post-combustion CCS targets and bridge the gap to commercialization by showcasing the unique UKy-CAER process, advancing it from TRL 5/6 to 7/8, and to provide a platform to boost public awareness and confidence in CCS technology

Objectives

1) Detailed the design associated with capture facility including site preparation and utilities to validate the UKy-CAER mass transfer intensification and heat integration techniques for improved CCS performance, which can be applied to any advanced solvent

2) Sensitivity study on packing and solvent to select appropriate column internals and operating parameters

3) Identified twelve Technology Gaps that currently hinder commercial application of CCS technology

Project Funding and Team

Phase 1 Project Funding: $1,249,786 in total

- $999,070 from DOE NETL
- $250,716 cost share from the team

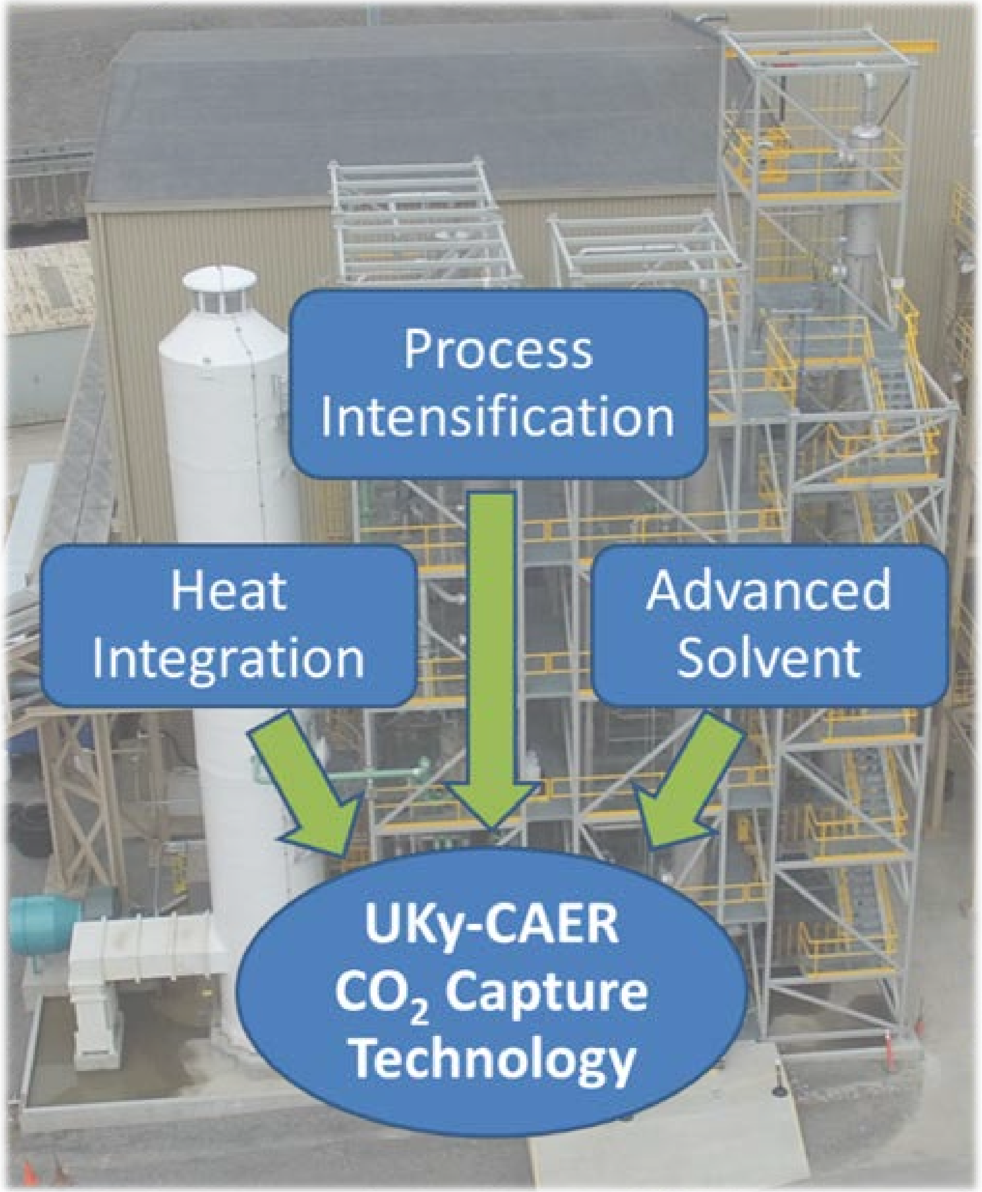
Phase 1 Period of Performance:

October 1, 2015 – September 30, 2016

UKy-CAER

0.7 MWe Project Team Members (DE-FE0007395)	10 MWe Project Team Members (DE-FE00024697)
Koch Modular Process Systems – Original Process Equipment Manufacturer (OPEM)	Koch Modular Process Systems – PI&D Process Design and Cost Estimation
Worley Parsons – Economic Analysis, Cost Verification	Worley Parsons – PI&D BOP Design and Cost Estimation, Economic Analysis
EPRI – TEA, Process & Equipment Modeling, and 3rd Party Verification	EPRI – Process & Equipment Modeling, TEA, and BOP Consultation
Smith Management Group – EH&S	Smith Management Group – EH&S
CMTA – Owner's Engineering Firm	CMTA – In-house Engineering Support
LG&E and KU – Host Site	LG&E and KU – Host Site

Process Description



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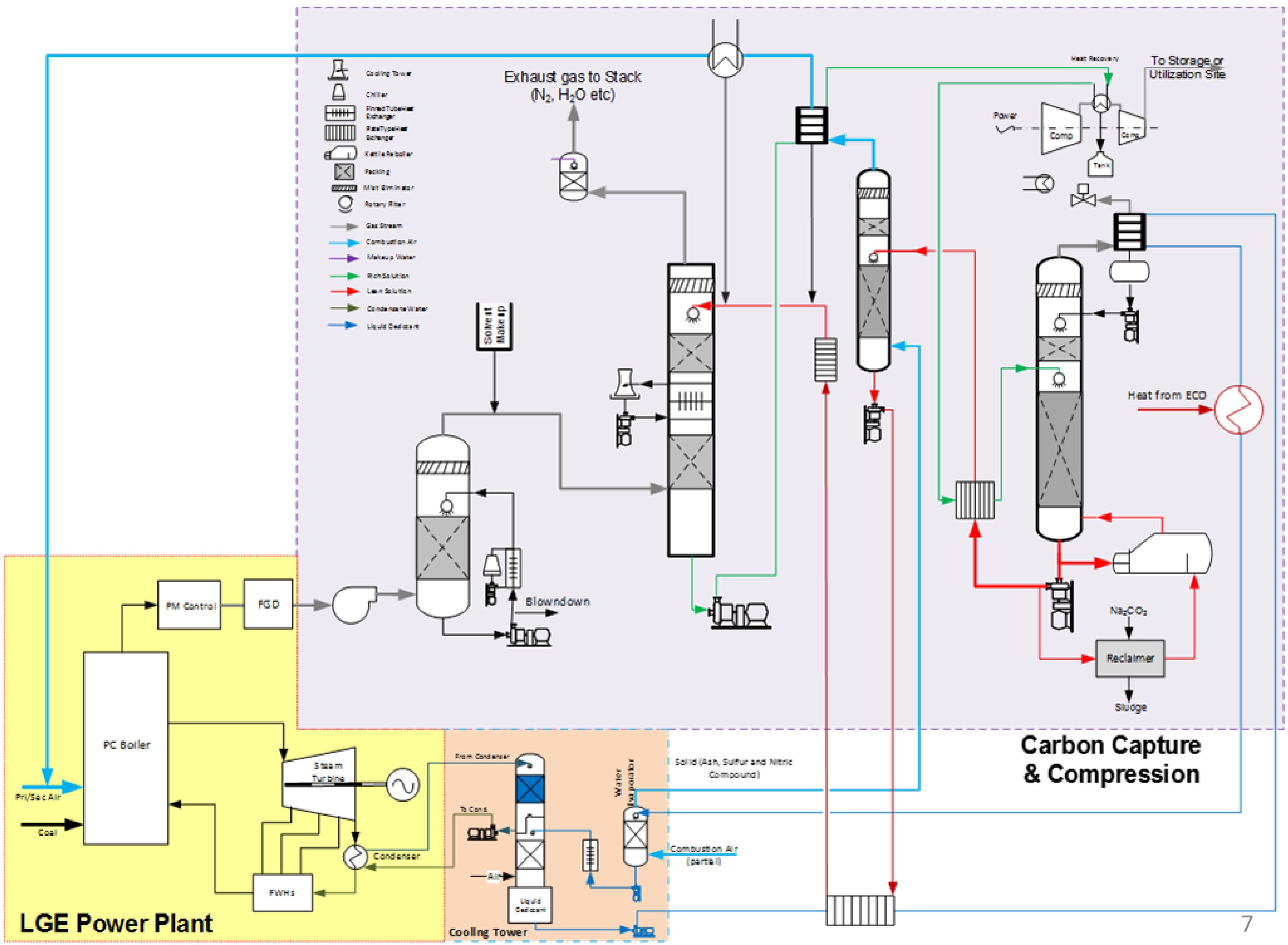

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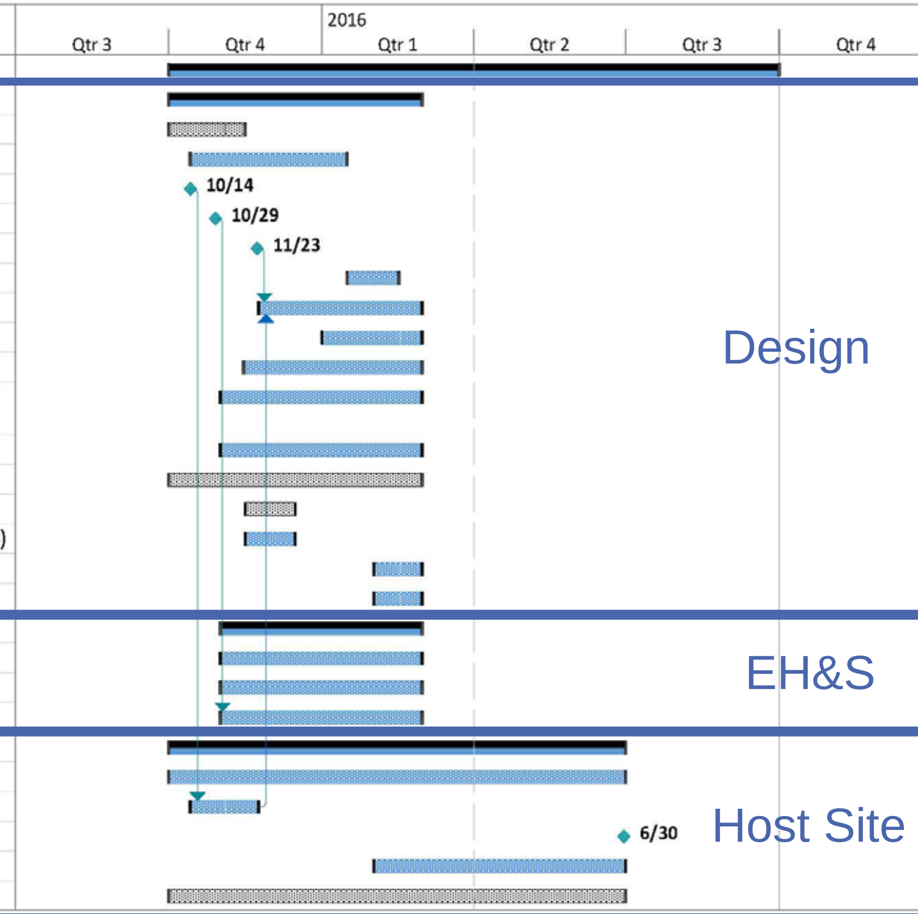
Phase 1: Project Schedule

ID	Task Name
1	1 Budget Period 1 Project Management and Planning
5	2 Basic Process Specification and Design
6	2.1 Aspen modeling of base case at 10MWe scale (UKy Lead)
8	2.2 Preliminary carbon capture system design (KMPS Lead)
9	*2.2.1 KMPS to provide approximate land requirement to UKy/WP*
10	*2.2.2 KMPS to provide general system volumes to UKy/SMG*
11	*2.2.3 KMPS to provide approximate system weights to UKy/WP*
12	2.3 Major equipment identification and selection (KMPS Lead)
14	2.4 Host site survey and general arrangement design (WP, UK and LG&E-KU)
15	2.5 Phase 2 cost estimate (KMPS and WP Lead)
16	2.6 Techno economic analysis (TEA) (EPRI and WP Lead)
18	2.7 Continuously update and revise the TEA with data collected from 0.7MW UKy-CAER small-pilot (UKy, EPRI and WP):
19	2.8 Identification of EPC candidates (WP, UKy and LG&E-KU)
20	2.9 Technology gap analysis (UKy Lead)
22	2.10 Sensitivity study - solvent selection (UKy Lead)
23	2.11 Sensitivity study - absorber column internal configuration determination (UKy and KMPS)
24	2.12 CO2 compression equipment selection (UKy and WP)
25	2.13 Steam supply selection (UKy and WP)
26	3 Complete EH&S Evaluation
27	3.1 Evaluation of Host Site Emission Permitting and Acquire Permit (if Necessary)
28	3.2 Complete Environtmental Questionnaire for Phase 2 (SMG Lead)
30	3.3 EH&S Assessment (SMG Lead)
32	4 Host Site Selection and Financial Agreements
33	4.1 Host Site Agreement Complete (UKy Lead)
34	*4.1.1 Host Site Selection (LG&E-KU)*
35	*4.1.2 Host Site Agreement*
36	4.2 Prepare Host Site Preparation/Integration Plan (UKy, KMPS and LG&E-KU)
37	4.3 Finalize Project Cost-Share Agreements (UKy Lead)



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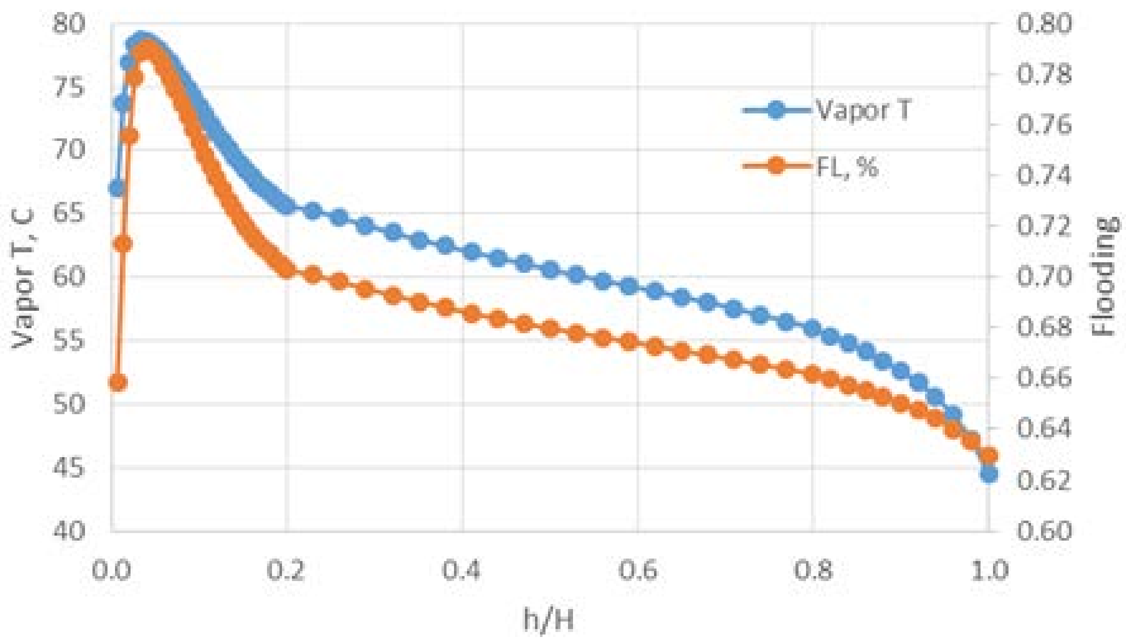
Absorber Internals – Sensitivity Study



- Diameter based on flooding management
  - Determined by temperature
  - Packing also affects flooding
  - Leads to under-utilization of some sections of the column

Increasing Capacity ← → Increasing Efficiency

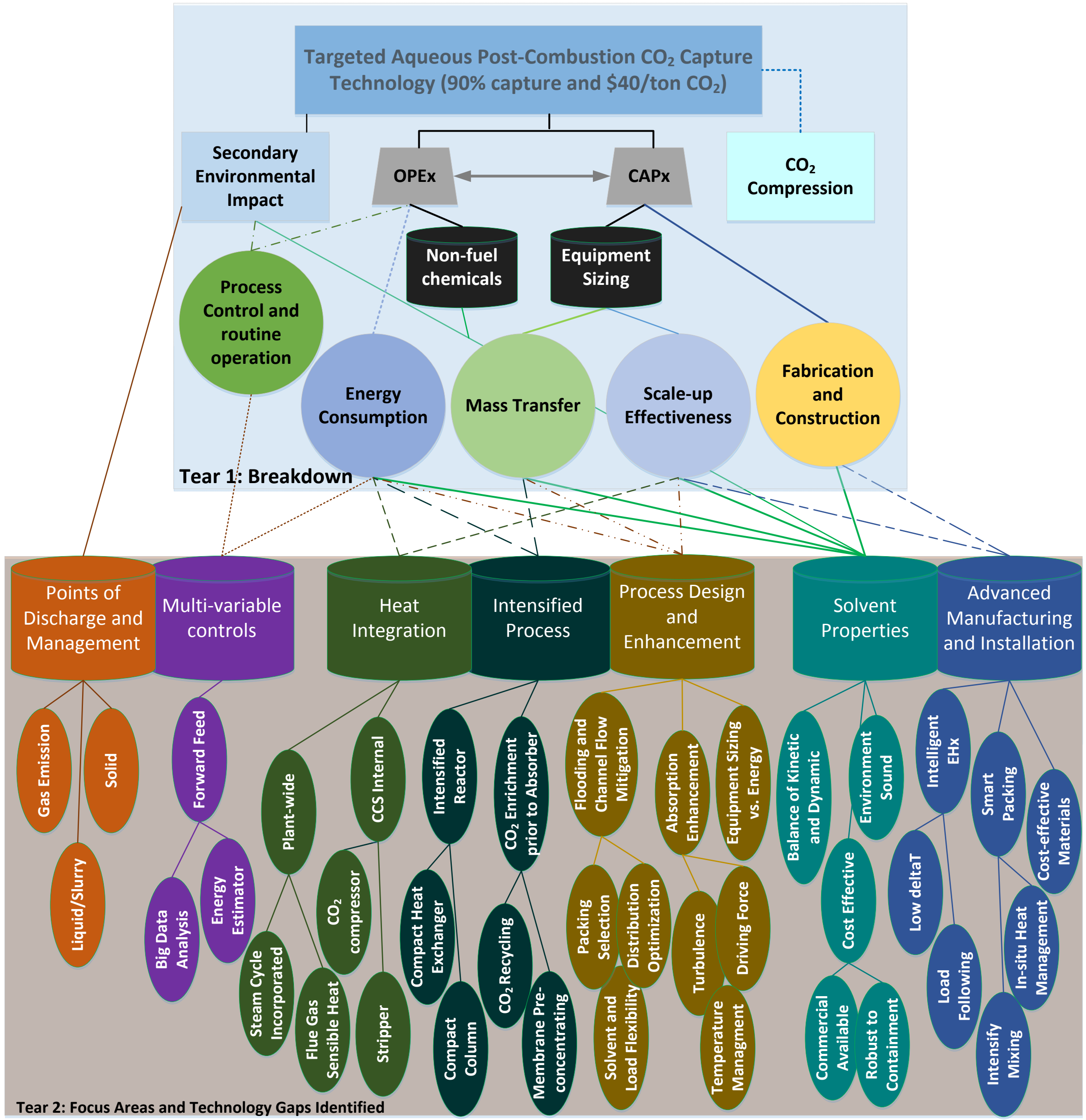
FLEXIPAC® Structured Packing Surface Area											
ft²/ft³	17	25	34	47	68	77	90	106	129	152	220
m²/m³	55	80	110	155	225	250	295	350	420	500	725
Inclination Angle 45°	4Y	3.5Y	3Y	2.5Y	2Y	250Y	1.6Y	1.4Y/350Y	1Y	500Y	700Y
Inclination Angle 60°	4X	3.5X	3X	2.5X	2X	250X	1.6X	1.4X/350X	1X	500X	700X

Structured Packing. Bulletin KGMTIG-1. Rev. 3-2010. 2003-2010. Koch-Glitch, LP.

Solvent – Sensitivity Study

Factor	Solvent A	Solvent B	Solvent C
Development Status	Tests at various sites from bench and pilot-scale	Pilot tests at various sites	Tests at CAER on lab- bench- and pilot scale
Energy Penalty	Up to ≥30% savings	~30% savings	~20 - 25% savings
Solvent Circulation Rate	~35-45% reduction	~40% reduction	~30% reduction
Cyclic Capacity	~1.5X	~2X	~1.5X
Physical Properties: (a) Viscosity (b) Surface Tension	2.5 – 3X ~0.6X	3 – 3.5X ~1.2X	~1.5X similar
Degradation Products/ Environmental Impact	Low thermal and oxidative degradation/Medium	Low thermal degradation/ Medium	Medium/Low

Technology Gap Analysis



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Technology Gap Analysis

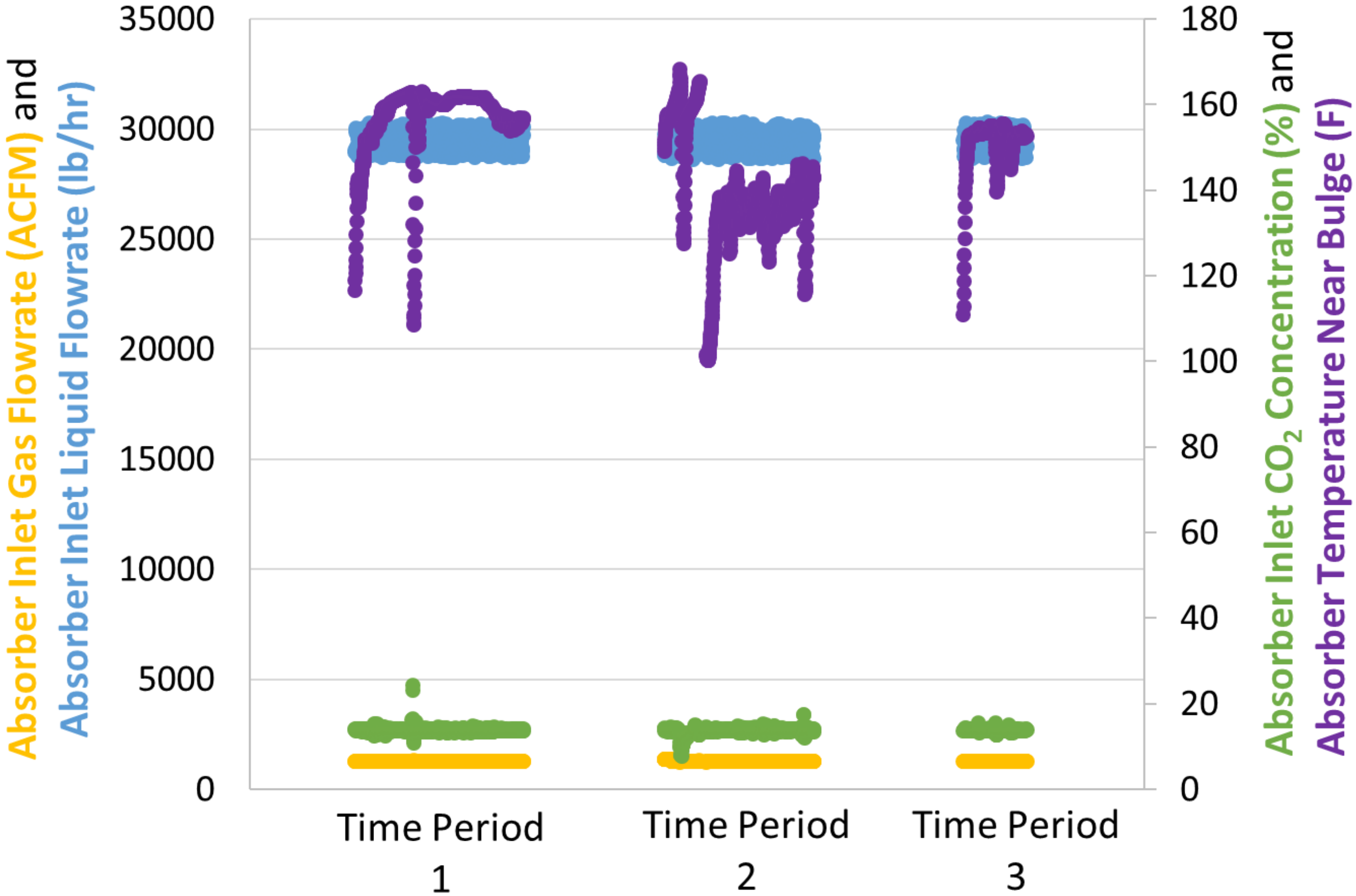
Near-term technical gaps:

1. Cost effective solvent with high stability, high cyclic capacity and fast kinetics
2. Gas/liquid distribution to prevent channel flow
3. Waste management and point of discharge (gas and liquid)
4. Equipment sizing vs. operating costs
5. Material and methods of construction
6. Process intensification
7. Unit operation to maintain the performance
8. Heat integration

Long-term technical gaps:

9. Smart packing
10. Appropriate absorber temperature profile
11. Heat exchange
12. Smart operations

Indication of Channel Flow



- Gas/Liquid Distribution disturbance yields channel flow
- The variation of local L/G and channel flow will lead to variation in temperature readings
- 160°F corresponds to normal operation
- The changing temperature values were caused by uneven flow or channel flow

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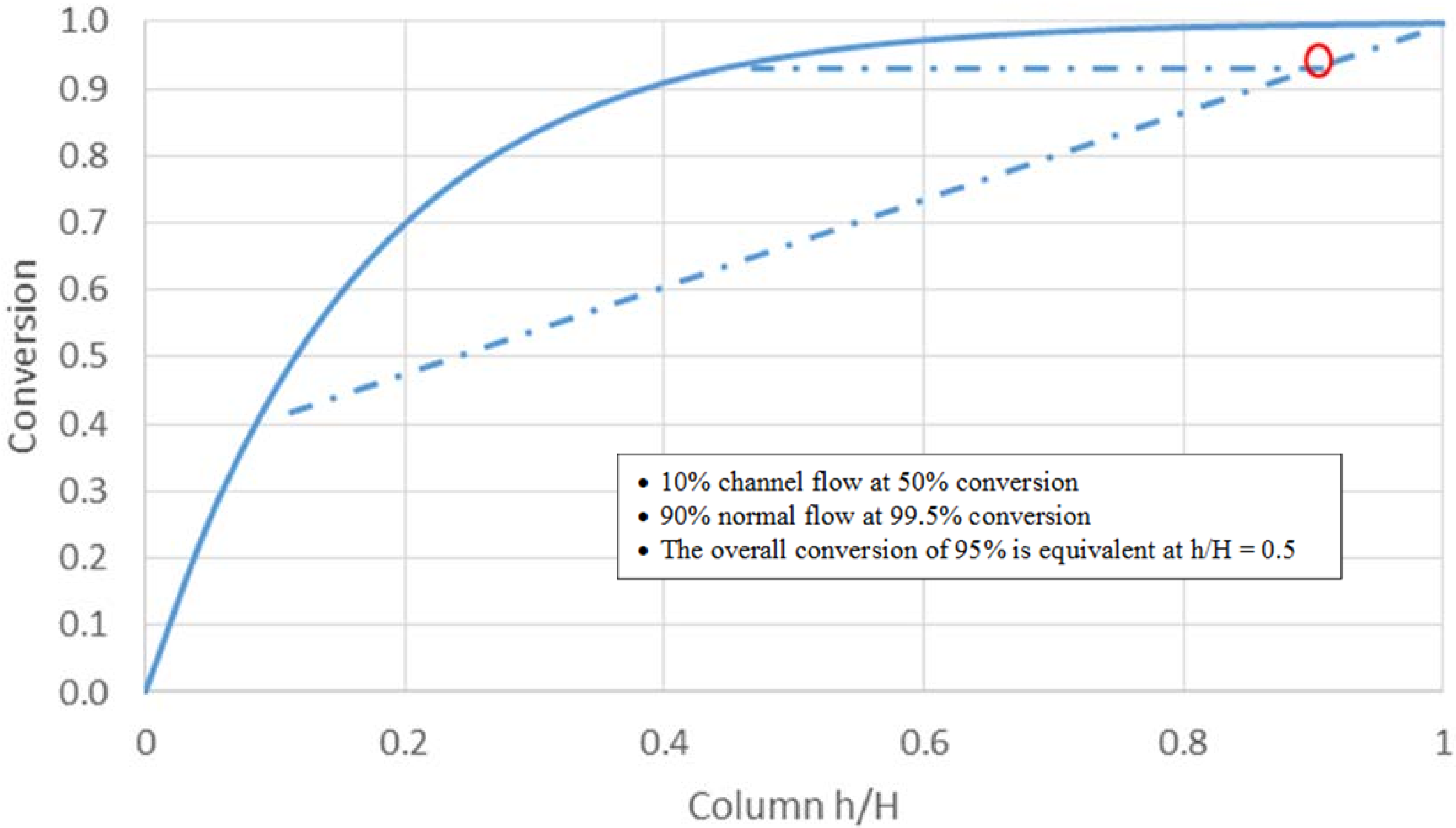
Impact on Absorber Performance

Capture Efficiency vs. Height



Effect of 10% Channel Flow:

- **Equivalent to 50% reduction in height/stages**

Host Site Consideration

Type	Proposed 10 MWe Pilot	Current 0.7 MWe Pilot	Units
	Out of Plant		
Land	1-2	0.1	acres
Electric Design Load	2,500	150	kW
Flue Gas Feed	100,000	6,871	lbs/hr
Plant Water	25	1.5	gpm
Superheated Steam	42,000	3,000	lbs/hr
Instrument Air	500	100	scfm
Plant Air	Not significant during normal operation		
	Return to Plant		
Flue Gas Condensate/Soda Ash Waste	40	2.8	gpm
Flue Gas to Stack	160,000	11,000	lbs/hr
Steam Condensate Return	42,000	3,000	lbs/hr
	Miscellaneous		
Solvent Supply	6	0.3	lbs/hr
Solid Waste	150	1	kg/day
Air Emissions (absorption reagent)	5	0.5	lbs/hr

Daily Estimates

- Flue Gas Feed:
  1,500 tons/day
- Steam Used:
  500 tons/day
- CO_2 Removed:
  240 tons/day

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LG&E Trimble County Generating Station

- 2,200 acres near Bedford, Ky
- Lowest cost coal fired unit in LG&E/KU territory and provides base load power
- Pollution Controls
  - Low NOx burners
  - SCR
  - Wet FGD
  - Dry ESP
  - Lime Injection
  - Baghouse
- ***Host Site Agreement signed and submitted in June***

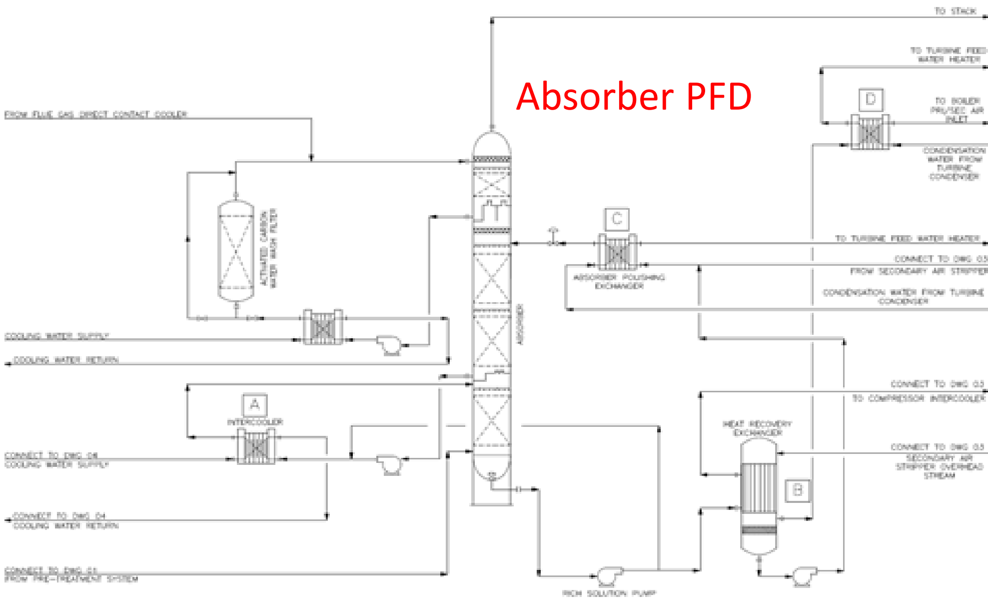
Large Pilot 10MWe CCS Location

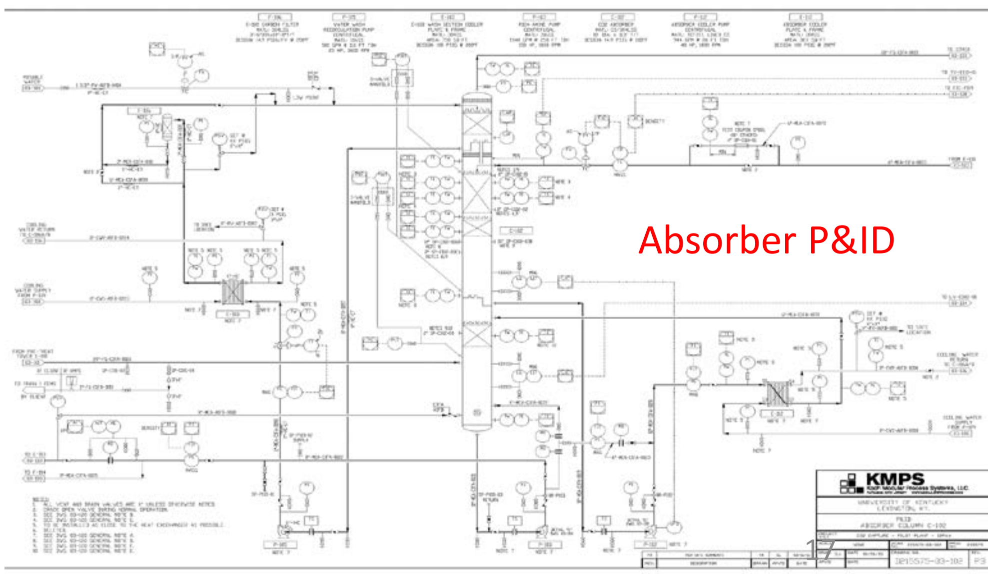
https://lge-ku.com/our-company/community/neighbor-neighbor/trimble-county-generating-station

CCS Specification and Design

Highlighted Tasks and Accomplishments

- Scale-Up and System Design (KMPS and UKy)
- Host Site Survey and BOP Design (WP, LG&E-KU, UKy)
- Phase 2 Cost Estimate (KMPS, WP)





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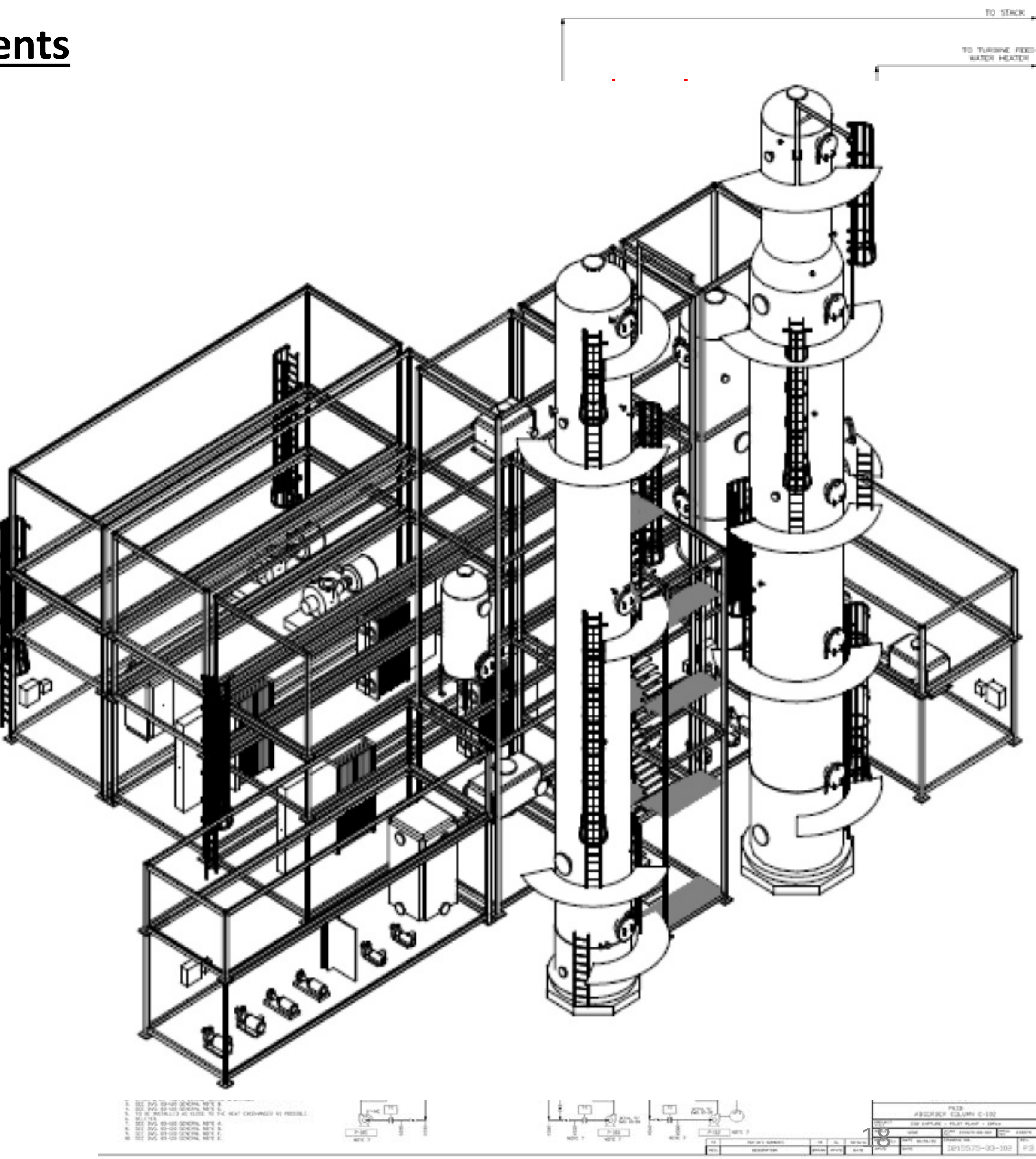
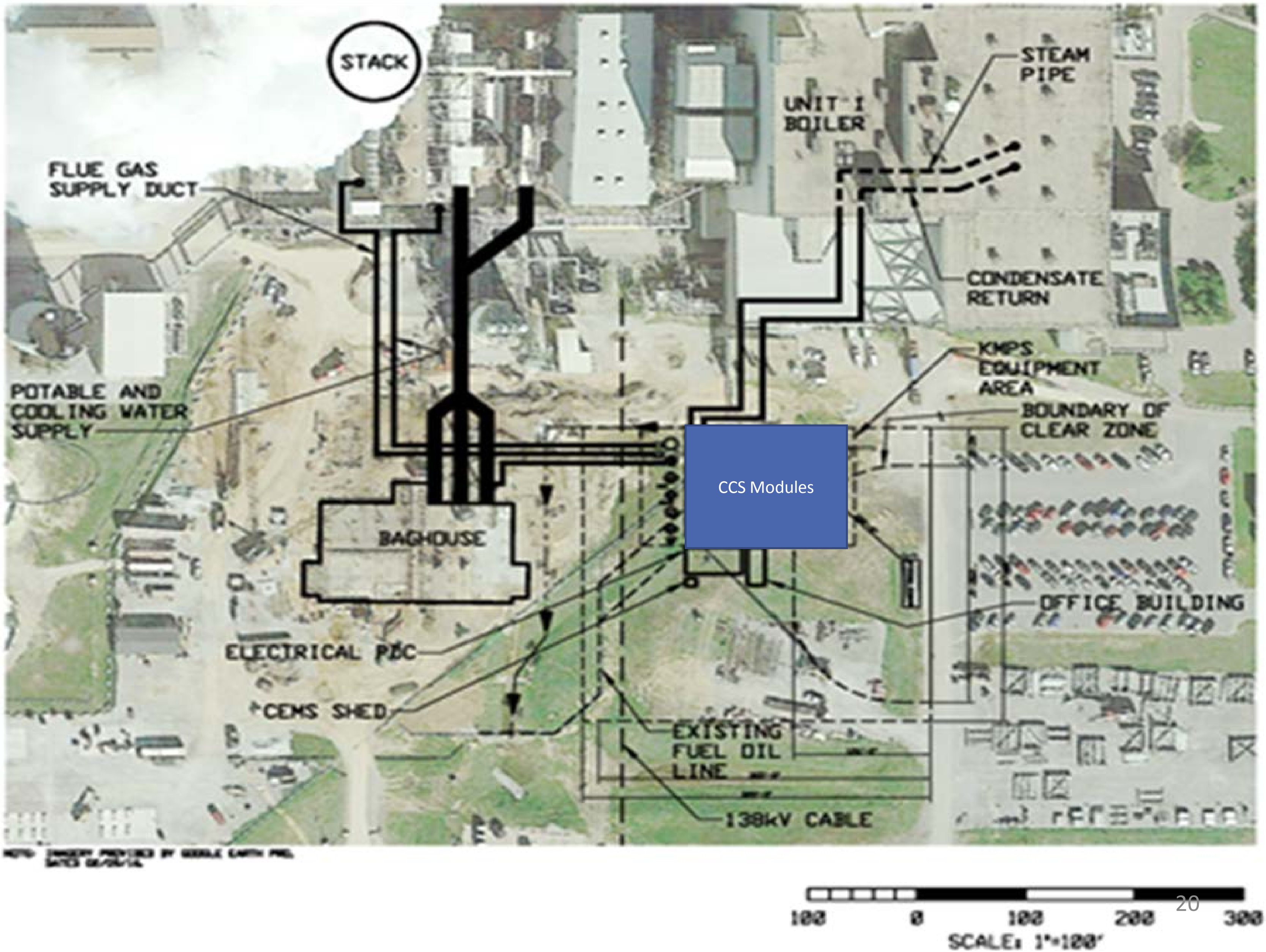
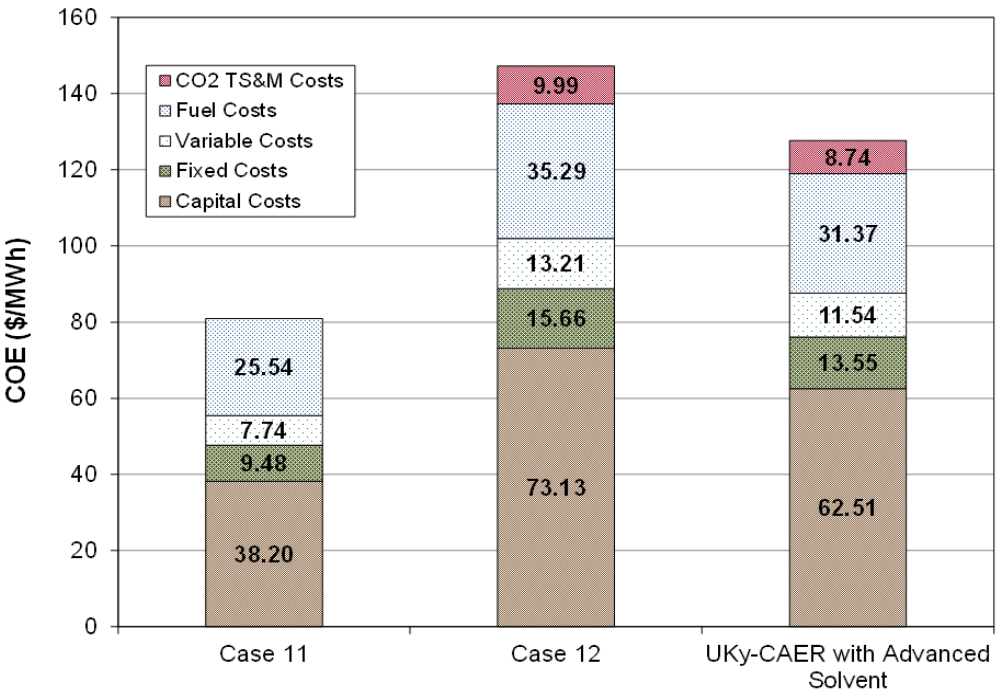


BOP Design

BOP Design


STACK
FLUE GAS SUPPLY DUCT
UNIT 1 BOILER
STEAM PIPE
CONDENSATE RETURN
KMPS EQUIPMENT AREA
BOUNDARY OF CLEAR ZONE
POTABLE AND COOLING WATER SUPPLY
BAGHOUSE
CCS Modules
OFFICE BUILDING
ELECTRICAL PDC
CEMS SHED
EXISTING FUEL OIL LINE
138kV CABLE
100 0 100 200 300
SCALE: 1"=100'

TEA



Advantage of the UKy-CAER Process using the Hitachi Advanced Solvent*:

- A lower COE by $19.6/MWh, a 13.3% reduction, equivalent to a 29.5% incremental reduction
- A lower LCOE by $24.81/MWh, also a 13.3% reduction
- A lower cost of CO_2 captured by $12.96/tonne CO_2, a 19.5% reduction
- A lower cost of CO_2 avoided by $28.10/tonne CO_2, a 29.3% reduction

*Advanced solvent analysis is based on the H3-1 solvent

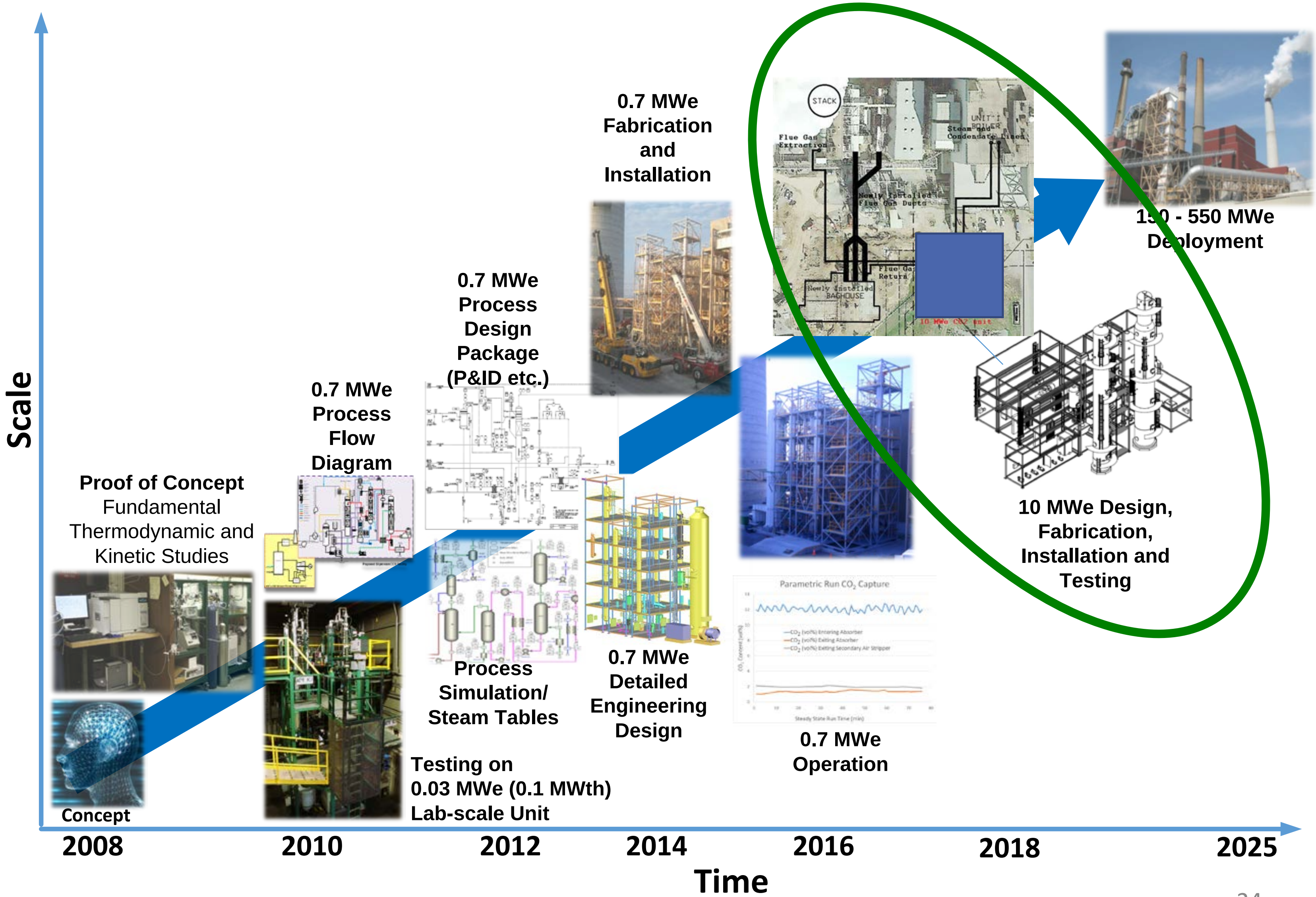
EH&S Evaluation

- Evaluation based on UKy-CAER small pilot research, literature review and solvent suppliers
- Recommended appropriate storage measures for chemicals
- Recommended proper PPE and handling methods
- Toxicity is minor for solvents:
  - Irritation only after direct contact (no ecotoxicity)
- Continue monitoring for nitrosamines as those compounds pose significant human risk even at low concentrations
- **No significant EH&S risks identified to affect implementation of the proposed project**

Summary

- Phase 1 Completed
  - Briefs and Reports (submitted before 3/31/16)
    - TEA
    - Technology Gap Assessment
    - EH&S Report and Environmental Questionnaires
    - Topical Report on Pilot Plant and Proposal for Phase 2
    - Design Package Topical Report
    - Solvent and Absorber Column Internals Sensitivity Analysis
    - Quarterly Reports
  - Project Cost Share agreements and Host Site agreement (submitted on 6/30/2016)
- Phase 2 begins 10/1/2016, if awarded

Technology Development Pathway



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Acknowledgements

- DOE NETL: Bruce Lani and David Lang
- Carbon Management Research Group (CMRG): David Link, Doug Durst, Curtis Sharp, Michael Kennedy, and Abhoyjit Bhown
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- WorleyParsons: Jim Simpson, Yonie Tamayo and Lawrence Grybosky
- Smith Management Group: Clayton Whitney, Daniel Hardin, Stewart McCollam and Sarah Carty
- Koch Modular Process Systems: John Rec, Lindsay Turner, Stan Lam and Elizabeth Manning
- Electric Power Research Institute: Abhoyjit Bhown and J.R. Heberle
- CMTA Engineers: Kevin Mussler
- University of Kentucky: Don Challman, Katherine Adams, Rodney Andrews