Application of a Heat Integrated Post-combustion CO_2 Capture System with Hitachi Advanced Solvent into Existing Coal-Fired Power Plant

Award Number DE-FE0007395

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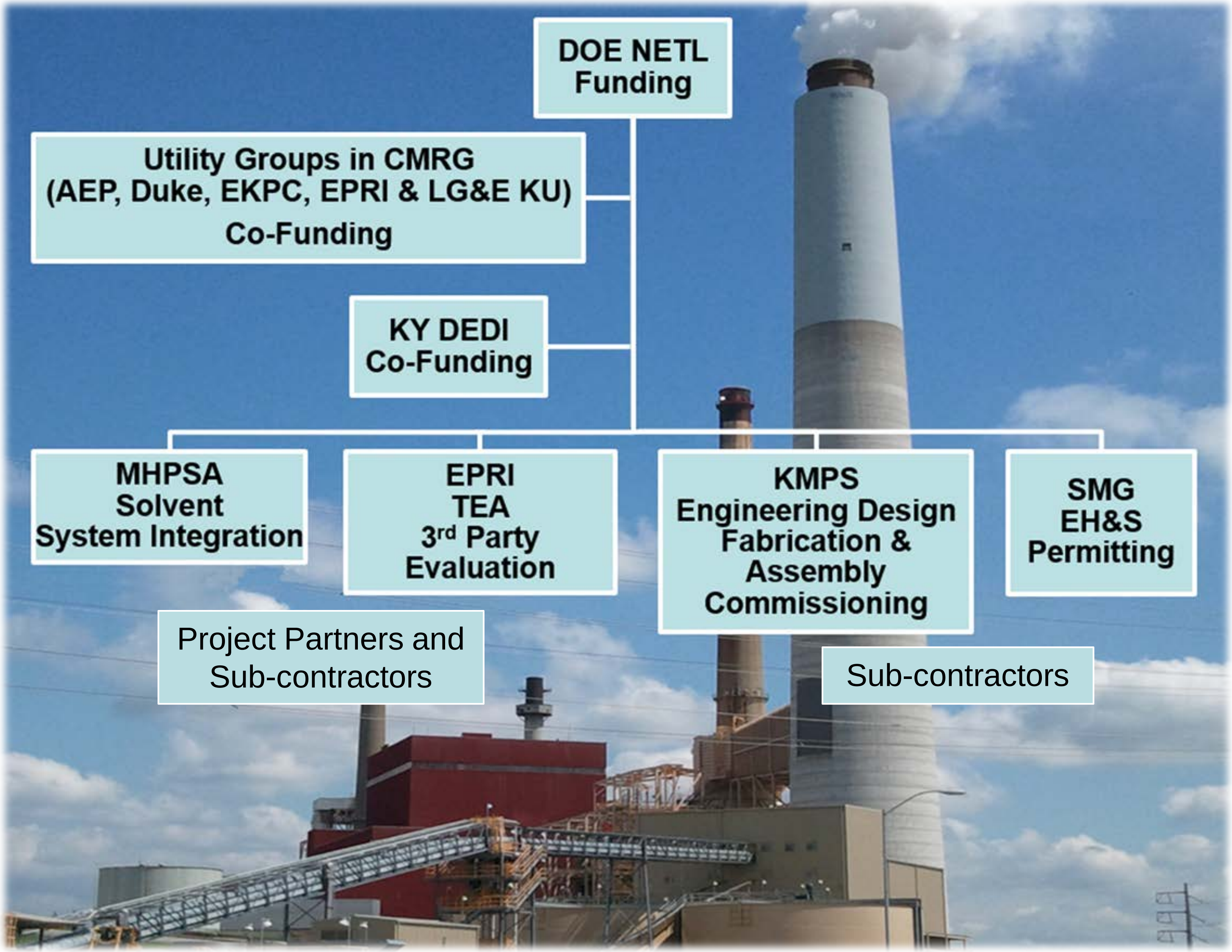
http://www.caer.uky.edu/powergen/home.shtml

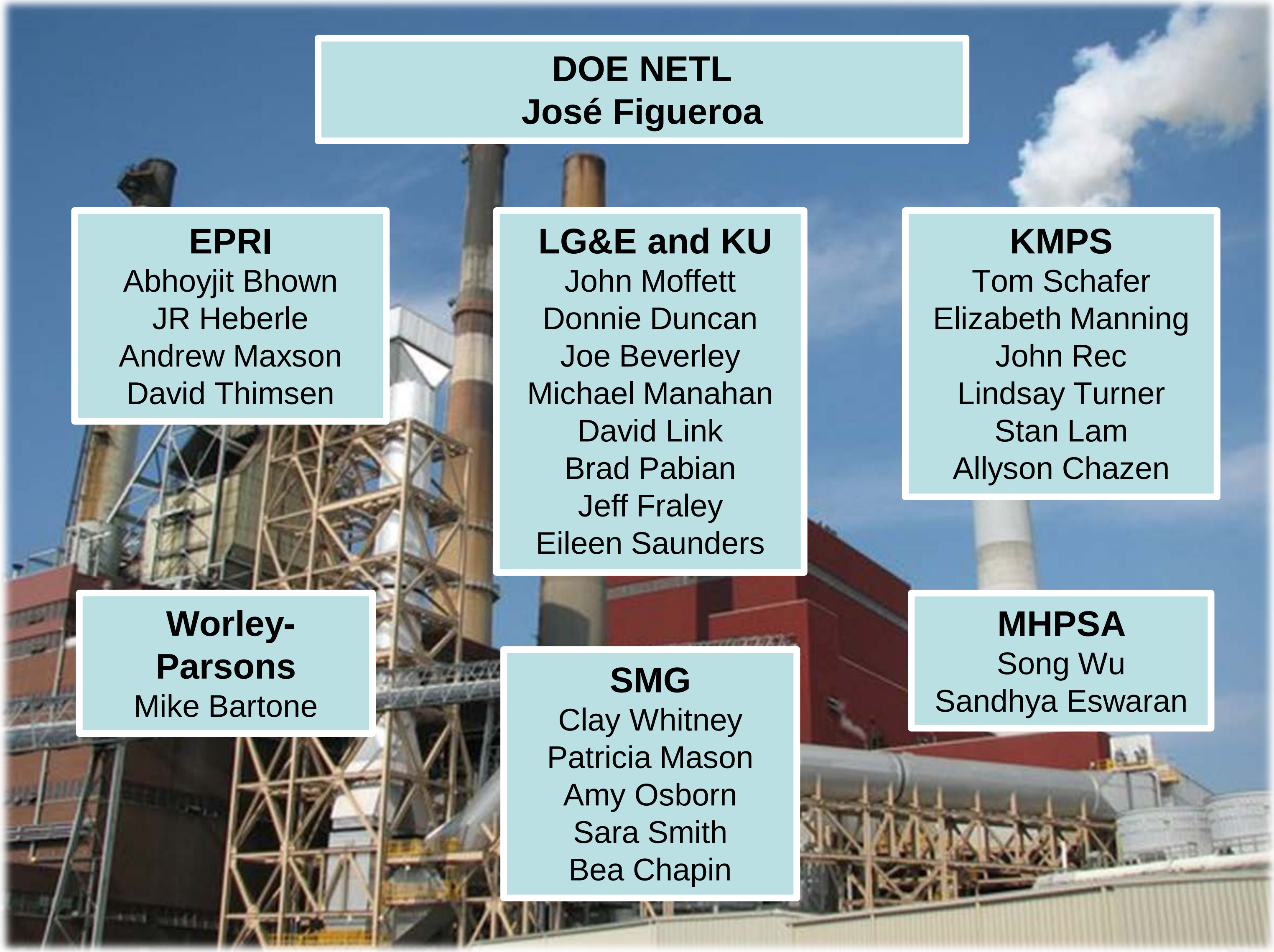
Project Overview

- 2 MWth (0.7 MWe) advanced post-combustion CO_2 capture pilot plant
- Capture and release program
- Designed as a modular process
- Testing at LG&E and KU EW Brown Generating Station, Harrodsburg, KY
- Includes several UKy-CAER developed technologies
- Testing of two solvents (MEA and H3-1)

Project Organization



Project Participants



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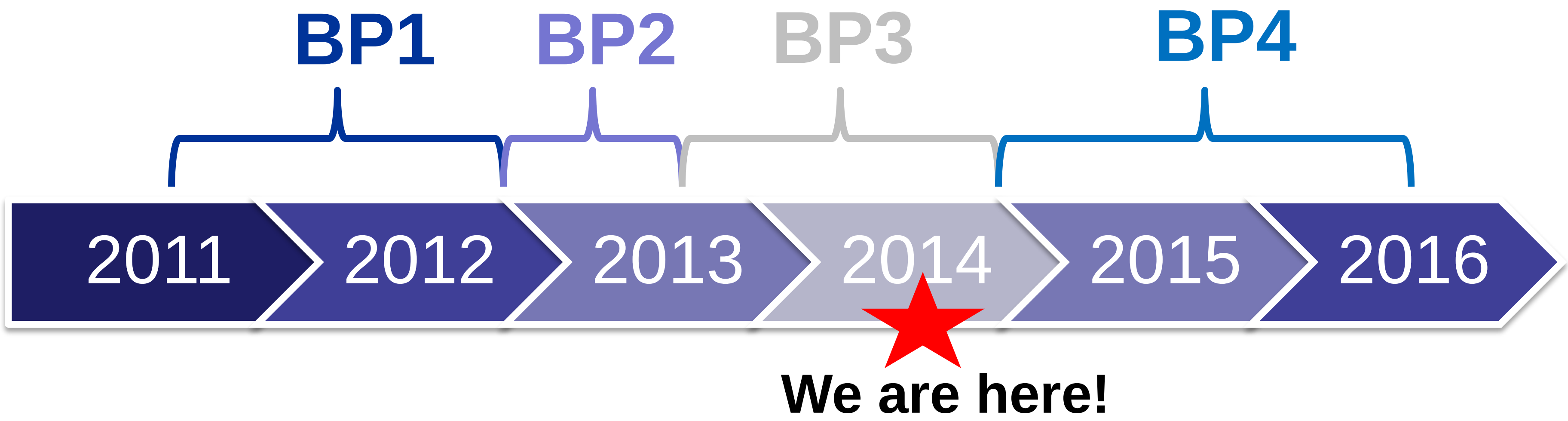
Project Performance Dates

BP1: October 1, 2011 to January 31, 2013 [16 months]

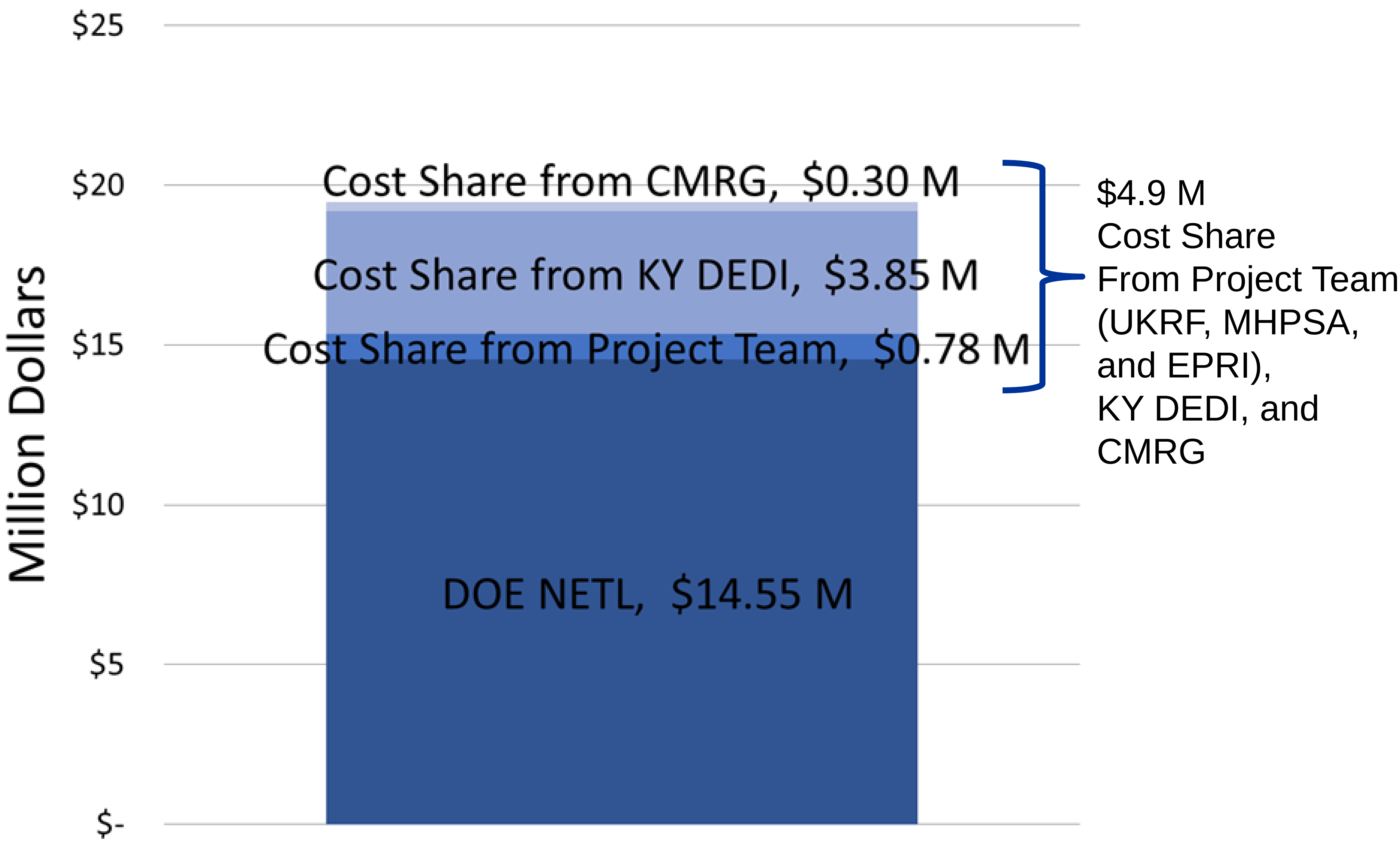
BP2: February 1, 2013 to August 31, 2013 [7 months]

BP3: September 1, 2013 to December 31, 2014 [16 months]

BP4: January 1, 2015 to July 31, 2016 [18 months]



Project Funding



Project Goal and Objectives

Goal

- Develop a pathway to achieve the US DOE NETL post-combustion CCS target of 90% CO_2 capture with a cost increase (LCOE) of less than 35% ($40/tonne CO_2 captured)

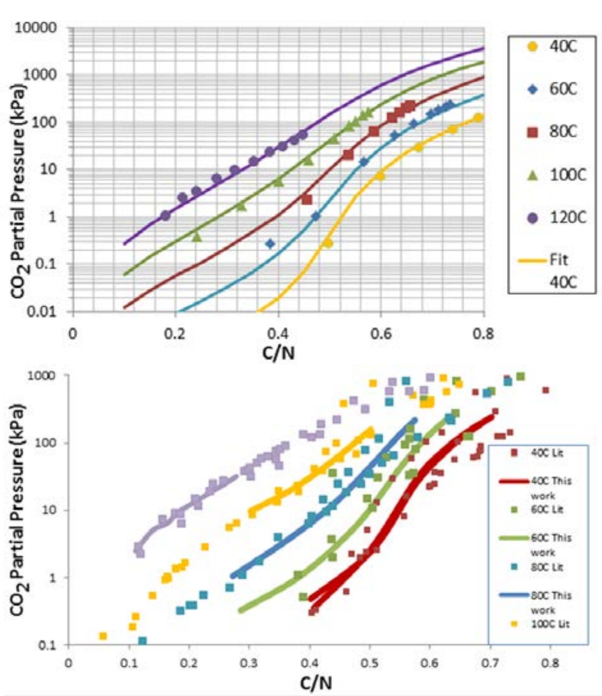
Objectives

- To demonstrate a heat-integrated post-combustion CO_2 capture system with an advanced solvent
- To collect corrosion data leading to selection of appropriate materials of construction for a 550 MWe commercial-scale carbon capture plant
- To gather data on solvent degradation, water management, system dynamic control and other information during the long-term verification campaigns
- To provide data and design information for larger-scale pilot plant followed by a commercial-scale project

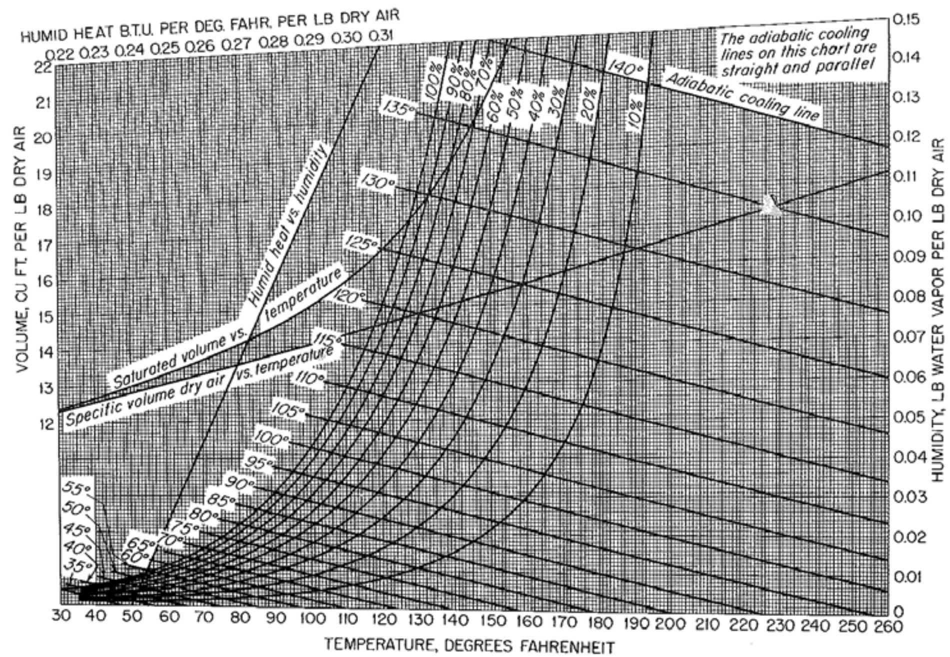
Fundamental Science

Two Principles

1. Non-linear chemical absorption/desorption relationship between carbon loading and CO_2 partial pressure
2. Non-linear relationship between relative humidity for wet air and the wet-bulb temperature



VLE Data Collected at UKy-CAER.

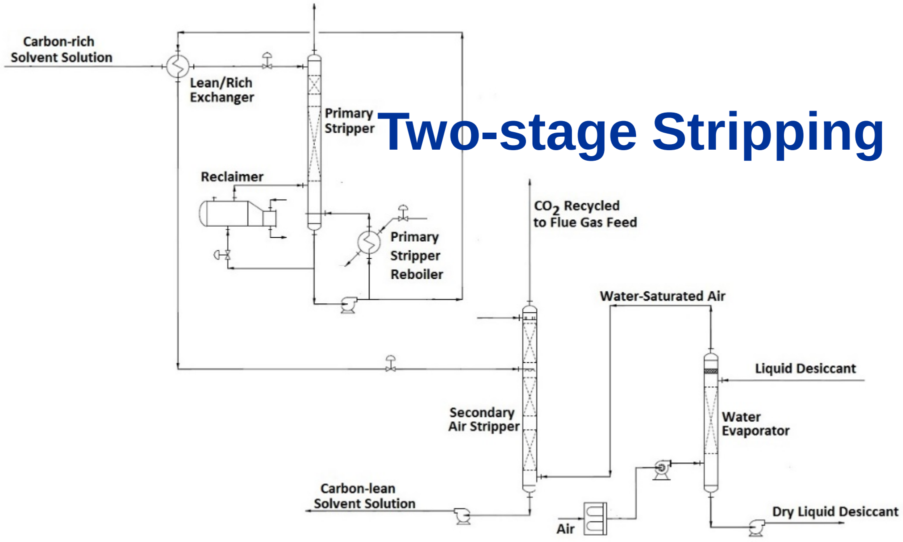


Humidity Chart. Air-water at 1 atm.

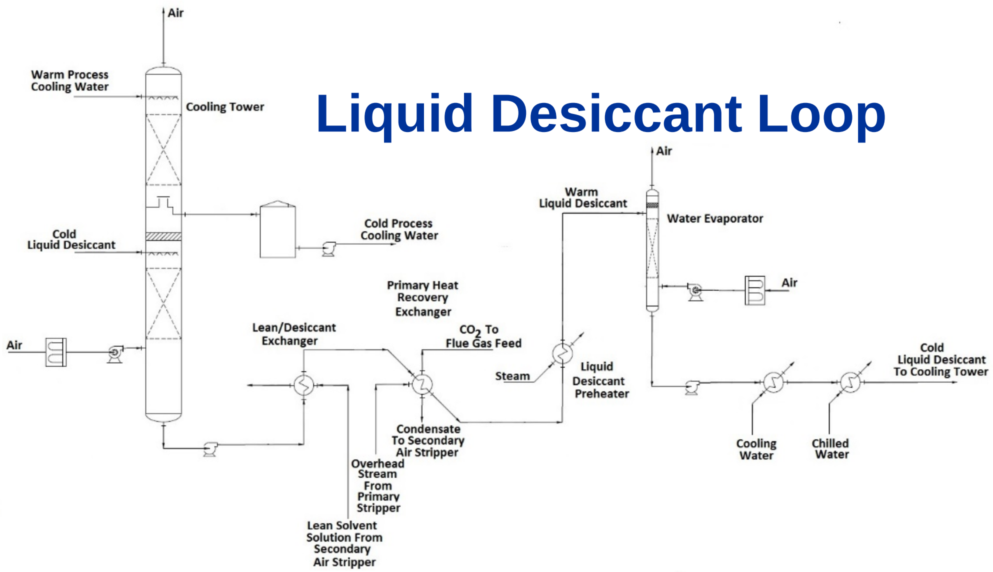
McCabe, Warren L., Smith, Julian C., and Harriot, Peter. Unit Operations of Chemical Engineering. Fifth Edition. Mc-Graw-Hill, Inc. 1993.

Technology Background

Two-stage Stripping



Liquid Desiccant Loop

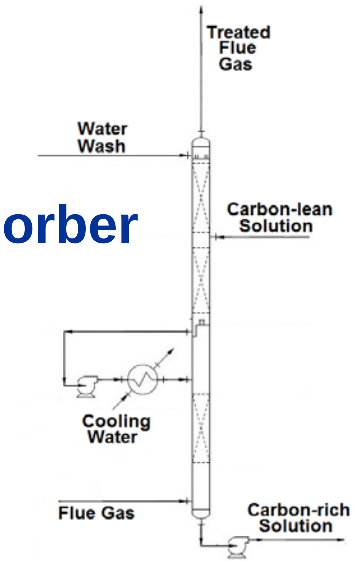


Conditions at top of primary stripper
T ~ 200 °F
P ~ 20 psia

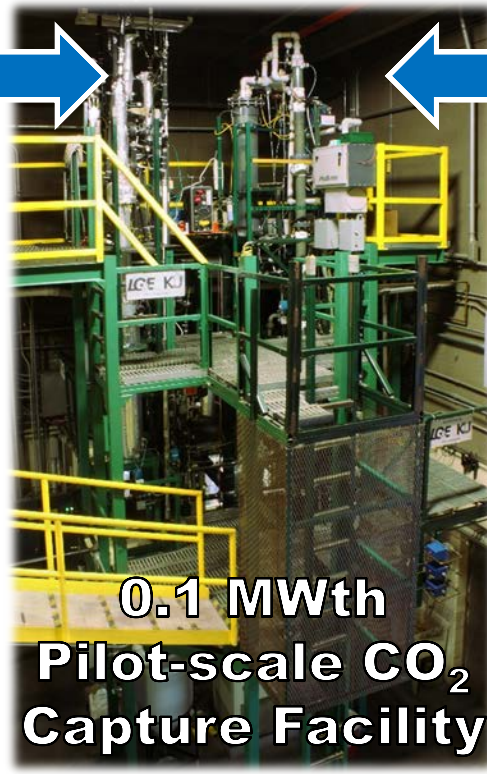
Conditions at top of secondary air stripper
T ~ 180 °F
P ~ 15 psia

Conditions at top of absorber
T ~ 100 °F
P ~ 15 psia

Absorber



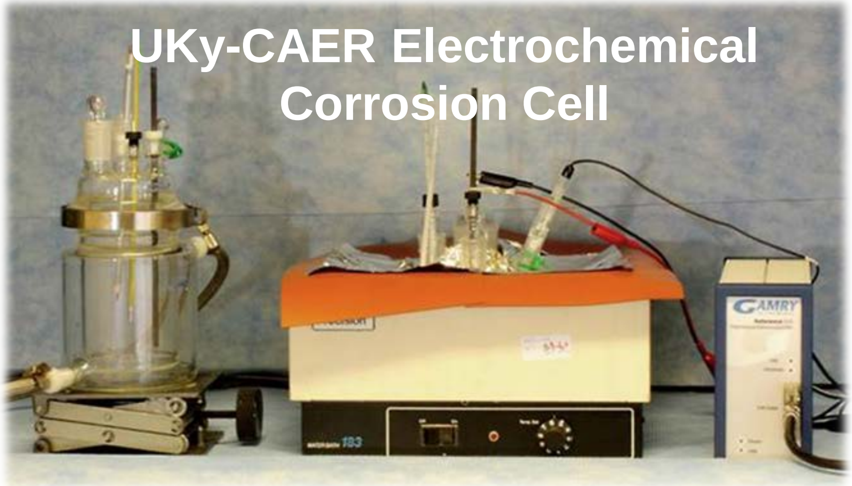
Previous Technology Development



H3-1 has a lower regeneration energy, a higher CO_2 absorption capacity, and a lower degradation rate than 30wt% MEA. Experimental data for H3-1 was collected at UKy-CAER labs to fill in data gaps and complete an Aspen kinetic model.

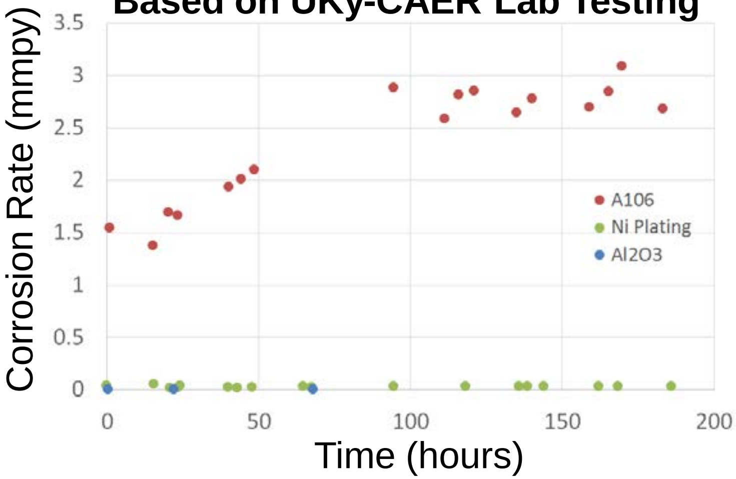
Solvent emissions and degradation studies have been conducted at UKy-CAER. Solvent degradation product detection methods have been developed and are in practice.

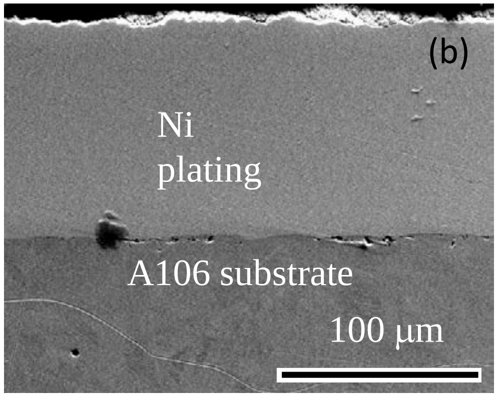
Previous Technology Development



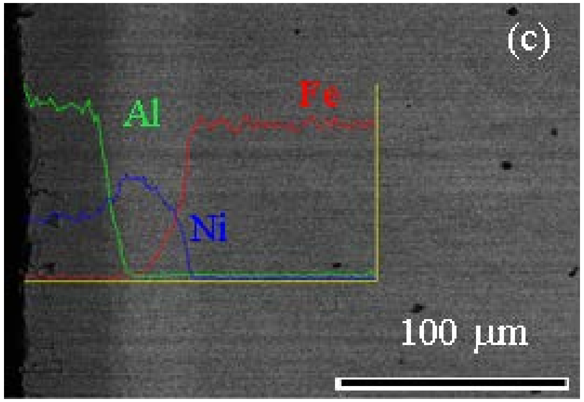
Lab-scale corrosion studies have been performed to establish the corrosion resistant potential of the UKy-CAER developed coatings.

Expected Corrosion Rates Based on UKy-CAER Lab Testing



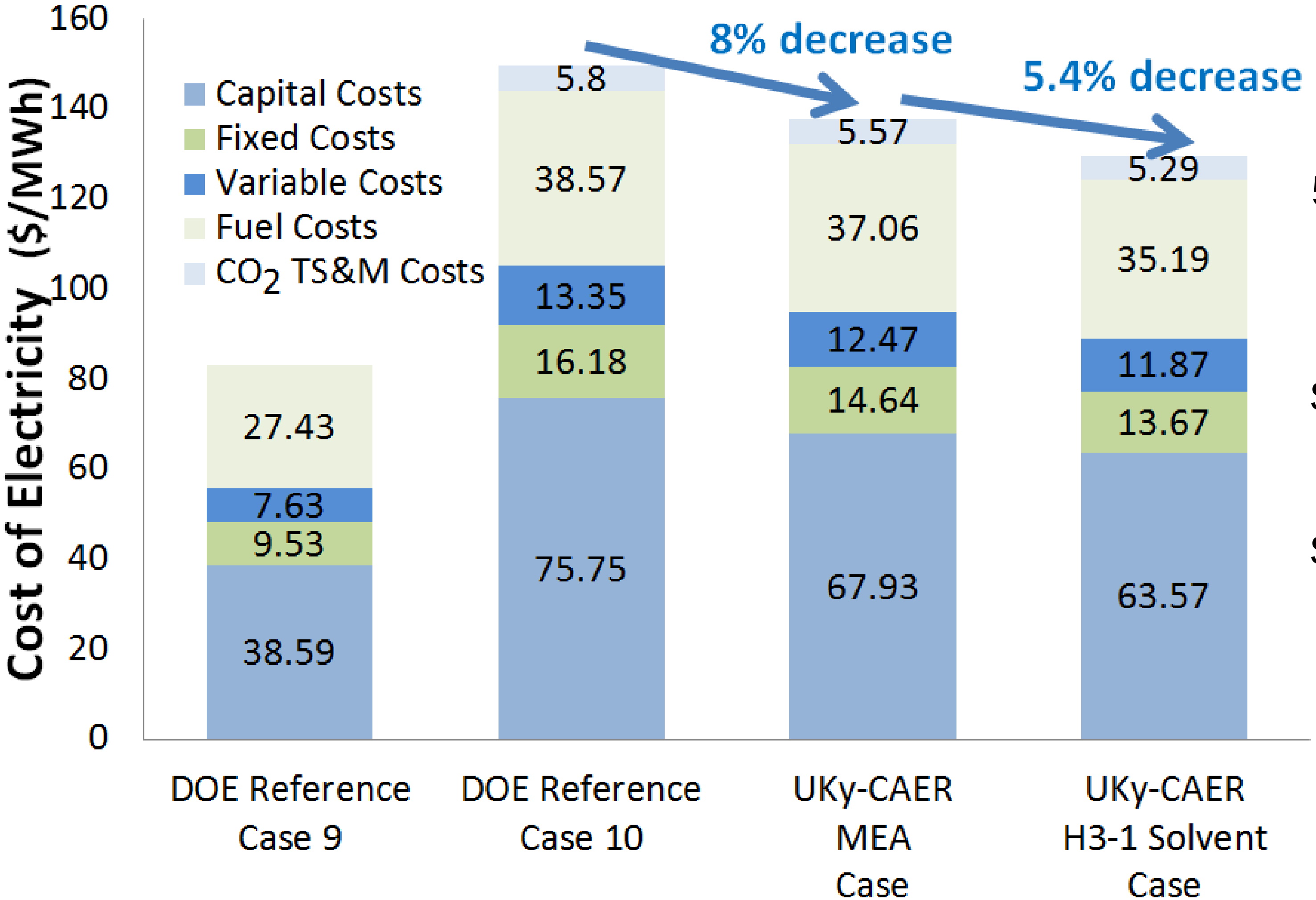


Ni Coating



Ni_2Al_3 Coating

Technical and Economic Advantages



55.8% increase in Cost of Electricity from RC9

$46.93/tonne CO_2 Captured, lower than RC10 by $14.38/tonne CO_2

All at 90% capture rate and CO_2 compression to 2200 psia.

Technical and Economic Challenges

- Liquid desiccant loop applicability to large-scale power plant
- Low bench-scale solvent degradation combined with air stripper exposure to be verified at pilot-scale during long-term testing
- Possible new byproduct is identified with an environmental, health, or safety risk
  - Periodic gas sampling and analysis will be conducted by UKy-CAER and EPRI, separately. If necessary, process modifications will be implemented or an alternate solvent will be considered
- Possibility of larger solvent losses due to a process upsets during test campaign
  - A root-cause analysis will be conducted to determine if process modifications are necessary

Experimental Design and Work Plan

30 wt% MEA Campaign

Parametric Campaign

Transient, Load-following Campaign

2000-hour Long Term Continuous Campaign

H3-1 Campaign

Parametric Campaign

Transient, Load-following Campaign

2500-hour Long Term Continuous Campaign

Evaluation Parameters

Energy Requirements

Solvent and Water Loss

CO_2 Absorption Capacity

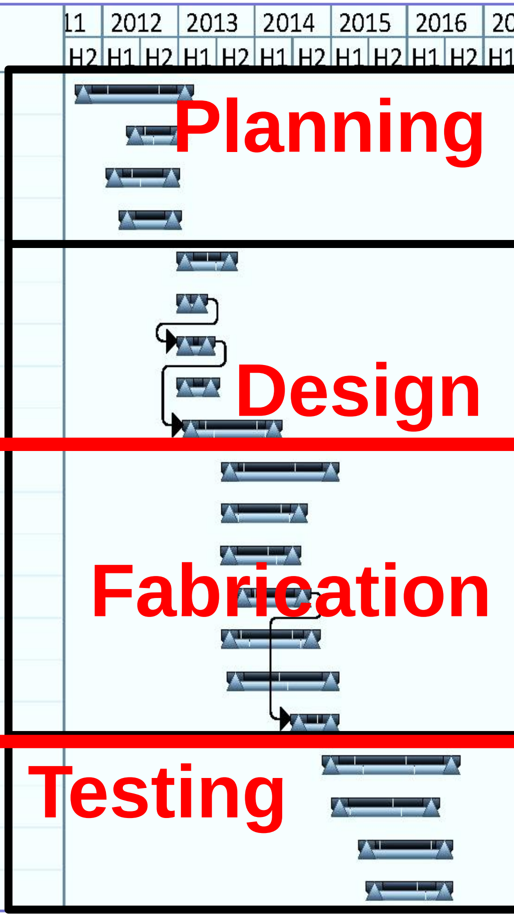
Solvent Degradation

Gaseous Emissions

Material Corrosion

Project Schedule

Task Name	Start	Finish
1 Project Planning and Management	10/3/11	1/31/13
2 Detailed Update of Techno-Economic Analysis	6/8/12	12/31/12
3 Initial EH&S Assessment	3/1/12	11/27/12
4 Basic Process Specification and Design	5/1/12	12/3/12
5 Project Planning and Management	2/1/13	8/31/13
6 Slipstream Site Survey	2/1/13	4/8/13
7 Finalized Engineering Specification and Design	2/1/13	5/16/13
8 Test Condition Selection and Test Plan	2/1/13	6/4/13
9 System Engineering Update and Model Refinements	3/1/13	4/1/14
10 Project Planning and Management	9/3/13	12/31/14
11 Update of EH&S Assessment	9/3/13	7/31/14
12 Site Preparation	9/1/13	7/1/14
13 Fabrication of Slip-stream Modules	11/4/13	8/18/14
14 Procurement and Installation of Control Room/Field Lab Section	9/3/13	9/30/14
15 Fabrication of Corrosion Coupons	10/1/13	12/31/14
16 Slipstream Facility Erection, Start-up, Commissioning and Shakedown	7/31/14	12/31/14
17 Project Planning and Management	1/1/15	7/31/16
18 Slip-stream Test Campaign	2/12/15	4/26/16
19 Final Update of Techno-Economic Analysis	6/22/15	6/28/16
20 Final EH&S Assessment	7/30/15	6/28/16



Project Key Milestones

BP	Title	Completion Date
1	Preliminary Technical and Economic Analysis that details the viable technical merit of UKy-CAER CCS process for slipstream scale study	12/18/12
1	Initial EH&S report that details environmental implication of slipstream operation and proposed mitigation for anticipated environmental safety obstacles to operation, if any	11/27/12
2	Finalize P&ID for slipstream modular unit fabrication	5/16/13
2	UKy-CAER Finalize Test Plan for slipstream campaigns with completed P&ID specifications	5/15/2013
3	Pouring of foundations for platform for slipstream modular units setup which meets engineering design load/specifications	8/1/14
3	KMPS fabricates slipstream modular units and delivers to EW Brown Generating Station for installation	9/15/14
3	Control Room/ Field Lab Trailer Assembled and Setup	8/30/14
3	Tie Ins in place for slipstream modular units and control room/ field lab trailer	4/30/14
3	Slipstream pilot unit commissioning	12/31/14
4	MEA long term test campaign, 2000 hours of load-following run with 30 wt% MEA	8/21/15
4	H3-1 long term test campaign, 2500 hours of load-following run	4/26/16
4	Final Technical Economic Analysis and Final EH&S Assessment	6/28/16
4	Project Final Scientific Report	9/30/16

CAER CENTER FOR APPLIED ENERGY RESEARCH

Project Key Success Criteria

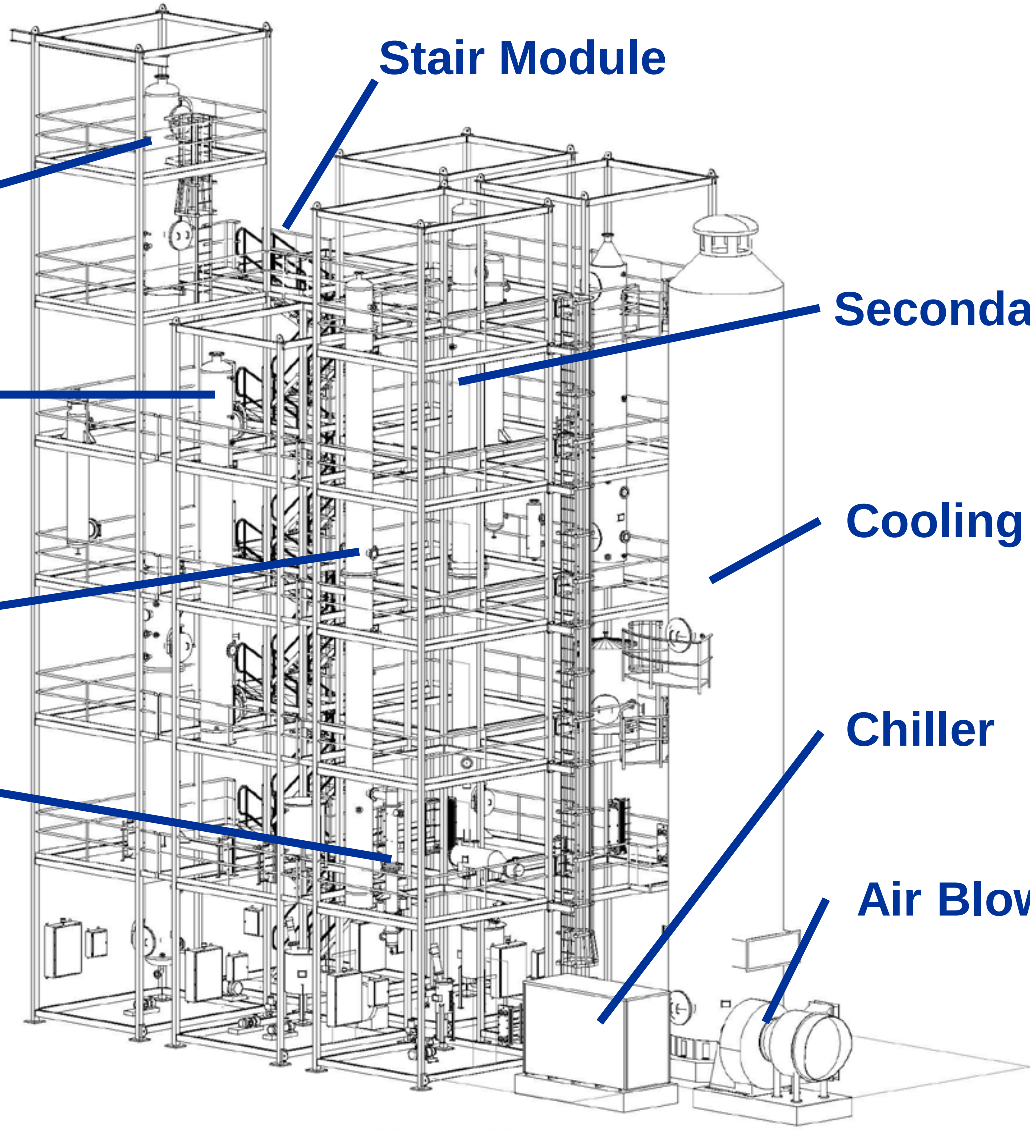
UK

BP	Success Criteria	Percent Complete
1	A complete specification list for the proposed 2 MWth pilot slip-stream facility detailing major equipment sizing with mass and energy balances that will serve as a blueprint for the engineering design. The specification list will show that the proposed design is within the approved budget.	100%
2	A finalized detailed engineering process design package meeting the specifications from Task 4. The final package will include a ± 10% accuracy price estimate of the system that is within the project budget stipulated in the agreement.	100%
2	A completed preliminary test matrix plan for the slip-stream test campaign to achieve the program objectives and success criteria of the 2MWth (0.7 MWe) pilot slip-stream modular facility.	100%
3	Inspection of the pilot plant site that has been appropriately graded for temporary parking, driveways, and the platform foundation sufficient for pilot plant erection by subcontractors.	100%
3	Documented delivery of the slip-stream modules and control room/field lab onto the plant site according to the design and construction specifications.	0%
4	A heat-integrated post-combustion CO_2 capture system with (a) 15-25% less energy consumption compared to the DOE reference case using 30 wt% MEA; (b) partial CO_2 recycling to enhance gaseous CO_2 pressure at the absorber inlet; (c) much cooler recirculating cooling water compared to a conventional cooling tower at the same ambient conditions; and (d) an advanced solvent that has less degradation and corrosivity than a 30 wt% MEA.	0%
4	The completed final technical and economic analysis of the proposed process concept for a 550 MW power plant that shows a pathway to achieving carbon capture up to 90% with a LCOE increase less than 35% according to the DOE guidelines.	0%
4	Final technical report issued including analysis of CO_2 capture, energy consumption, solvent make-up, coupon corrosion, water balance, solvent degradation, and gaseous emissions.	0%

Project Key Risks and Mitigation Strategies

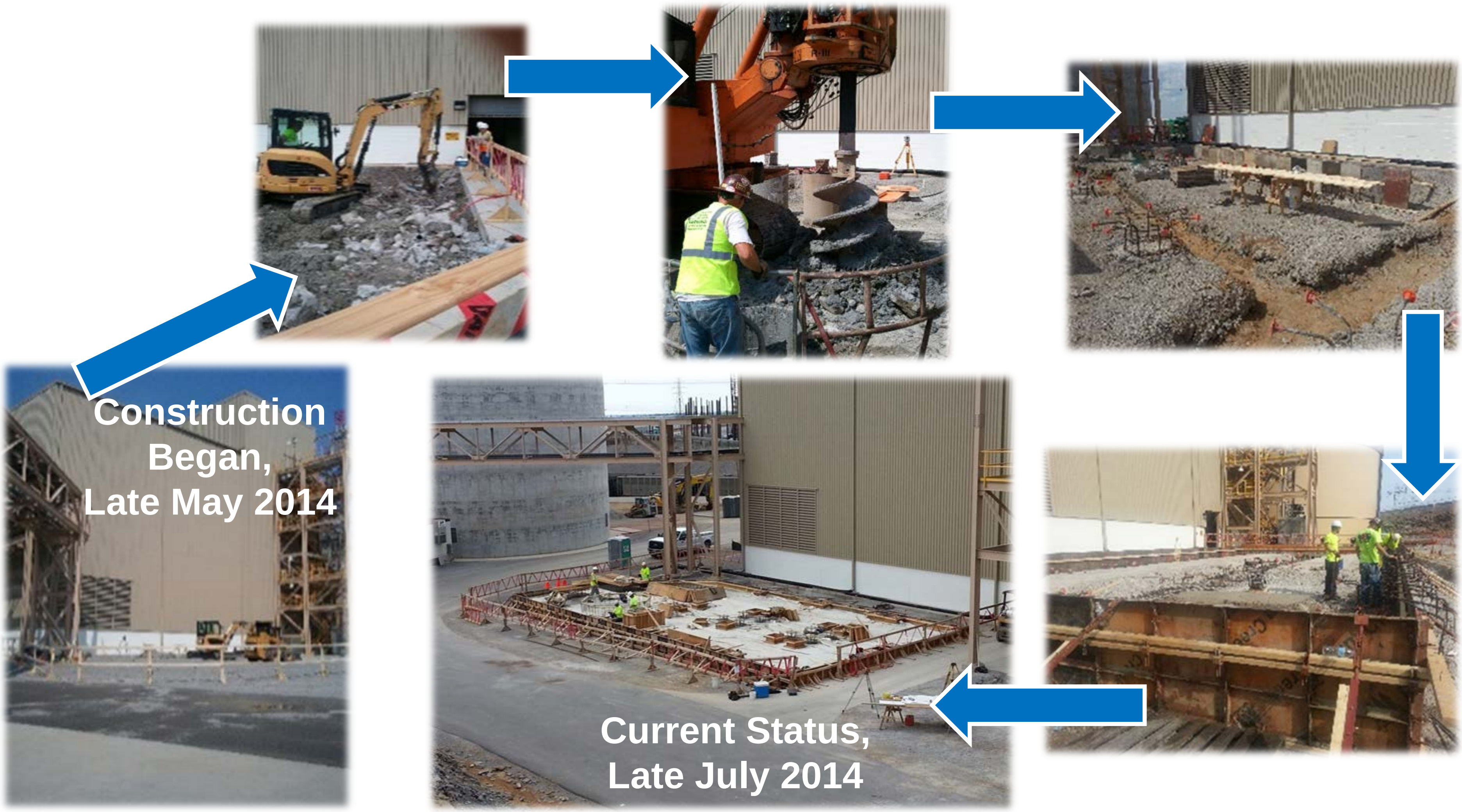
BP	Description	Probability	Impact	Mitigation and Response Strategies
3	The performance of the heat-integrated air stripper during commissioning does not meet the success criteria due to heat source constraints in the pilot-plant.	Low	Moderate	An additional heat source for the slipstream facility has been identified and included in the module design.
3	The performance of the heat integrated cooling system during commissioning does not meet the success criteria due to heat source constraints in the pilot-plant	Low	Moderate	An additional heat source has been identified and incorporated into the design, in the event that it is needed.

Project Test Equipment



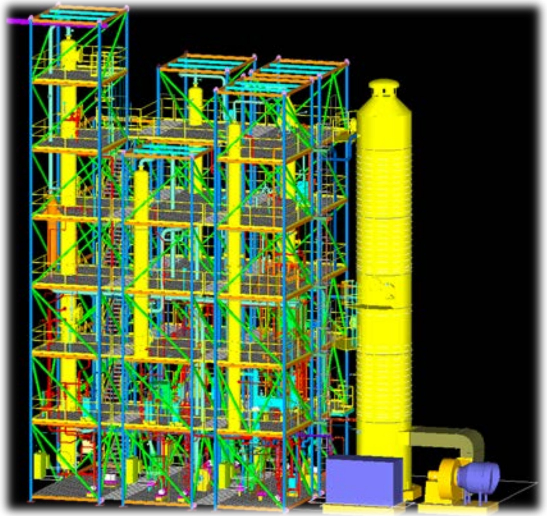
Key BP3 Accomplishments

BP3 Project Task 12 – Site Preparation



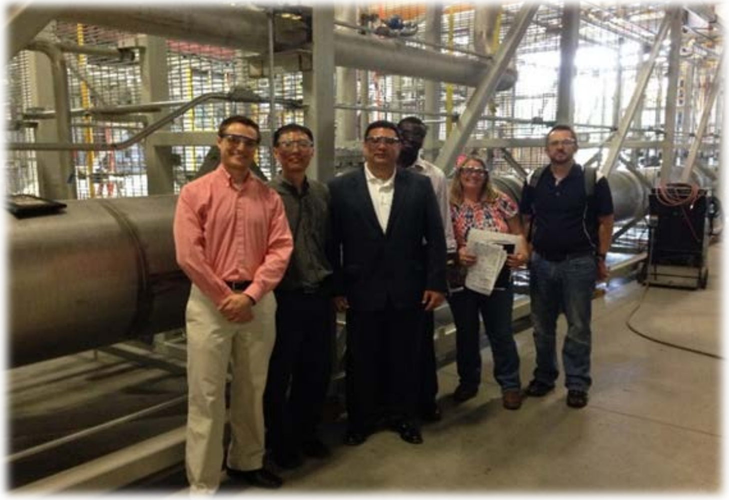
BP3 Project Task 13 – Fabrication of Modules

3D Model Review



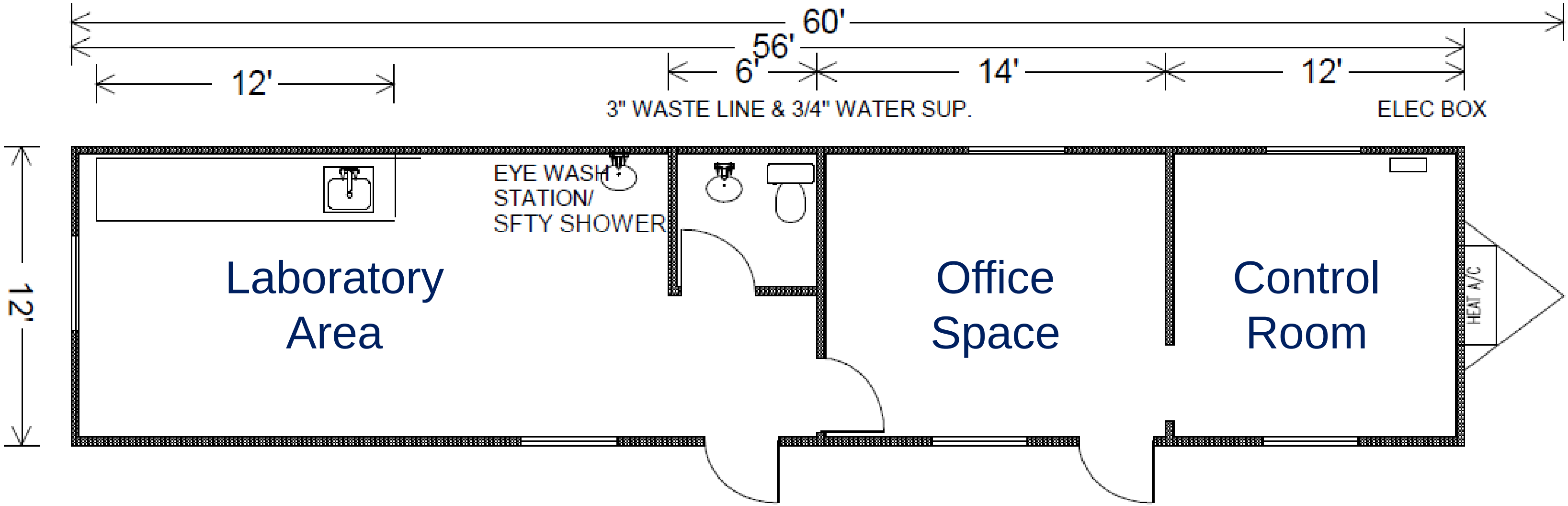
Module
Fabrication and Assembly

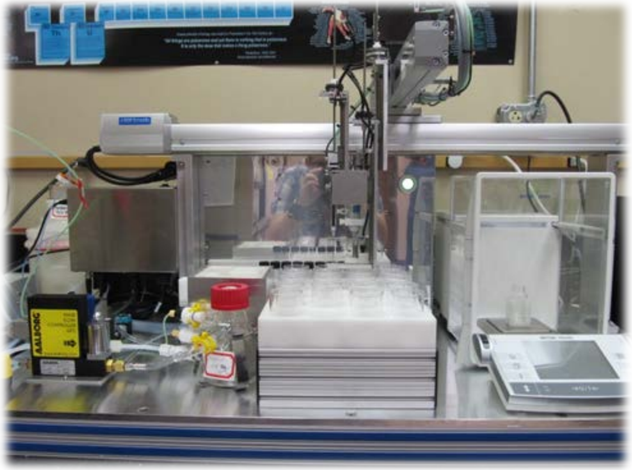
Module Assembly Shop
Progress Check
and Dimension Verification Visit



Key BP3 Accomplishments

BP3 Project Task 14 – Control Room/Field Lab



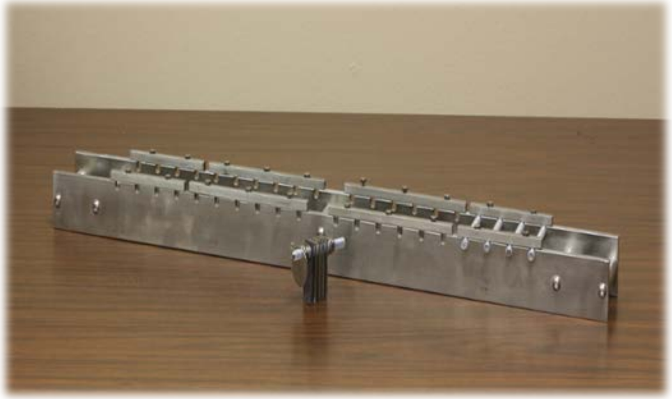


- Trailer Delivery expected in September 2014
- Alkalinity/CO_2 Loading/Density robot is currently being evaluated at UKy-CAER.

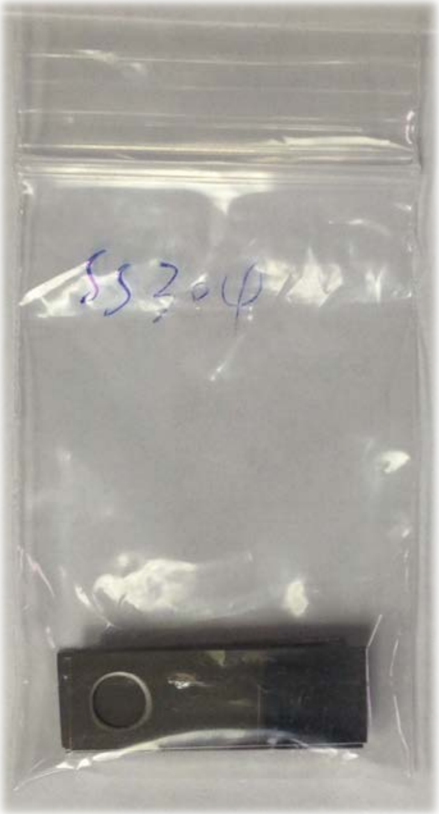
BP3 Project Task 15 – Corrosion Coupons

In-pipe Corrosion Coupon Racks

Column Corrosion Coupon Racks



Corrosion Coupons



Potential Future Research

Advanced technologies can be more closely studied

- Intercooler protocol development (cooling temperature and location variation)
- Application of sorbent to improve solvent stability or control heavy metals accumulation
- Solvent and water management for other second and third-generation system
- Solvent/mist mitigation options at the scrubber outlet
- Control logic to accommodate solvent specific dynamic behavior

Open, modular design

- Allows for ease of advanced process modification (such as addition of membranes or flash stripping, column design changes, etc.)

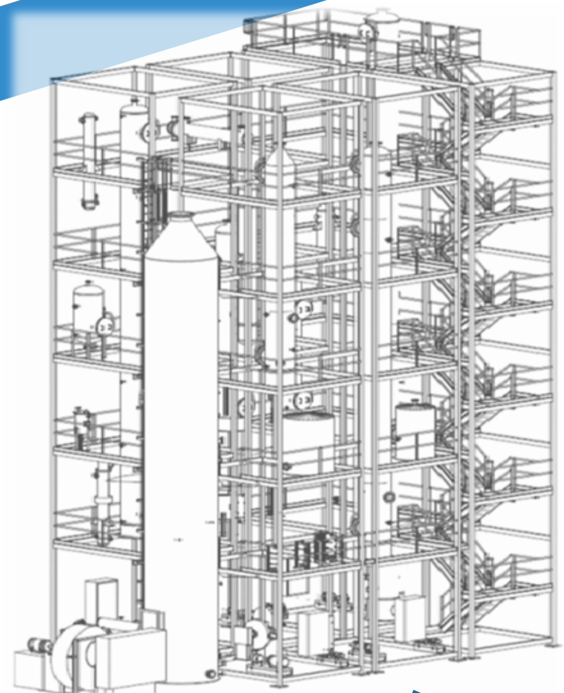
Future Plans

Technology Development Pathway

100-500 MWe
Full-scale Unit

10-25 MWe
Demonstration Unit
(LG&E KU and DEDI)

0.02 MWe
(0.1 MWth)
Pilot-scale Unit



0.7 MWe
(2 MWth)
Pilot-scale Unit

Shengli OFC 0.7 M ton/yr Unit
MoU Signed July 8, 2014

Acknowledgements

José Figueroa, DOE NETL

CMRG Members

John Moffett, LG&E and KU

Donnie Duncan, LG&E and KU

Joe Beverly, LG&E and KU

David Link, LG&E and KU

Michael Manahan, LG&E and KU

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Eileen Saunders, LG&E and KU