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

Heather Nikolic, Jesse Thompson and Kunlei Liu

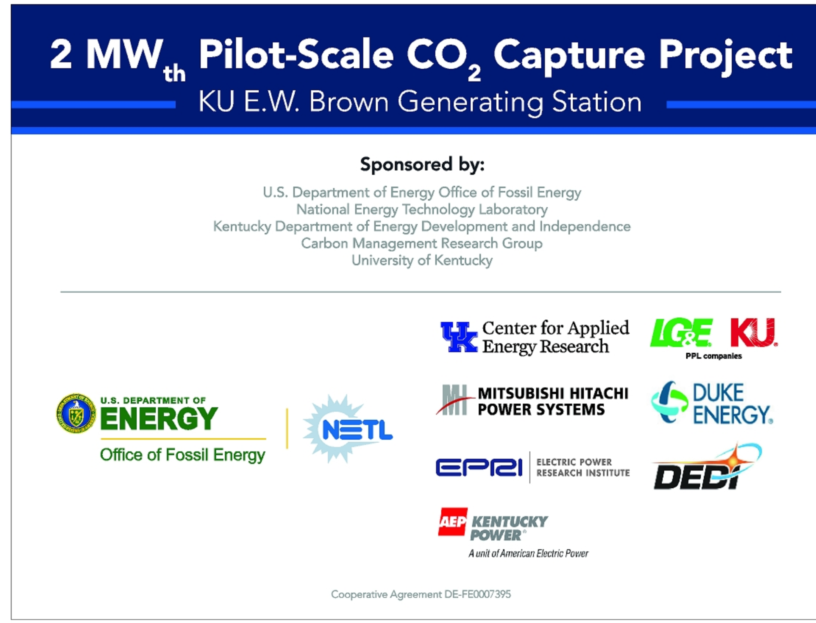
University of Kentucky - Center for Applied Energy Research

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

NETL CO_2 Capture Technology Meeting, Pittsburgh, PA, August 8 – 12, 2016

Presentation Outline

- Project Overview
- Milestones
- Success Criteria
- Key Findings

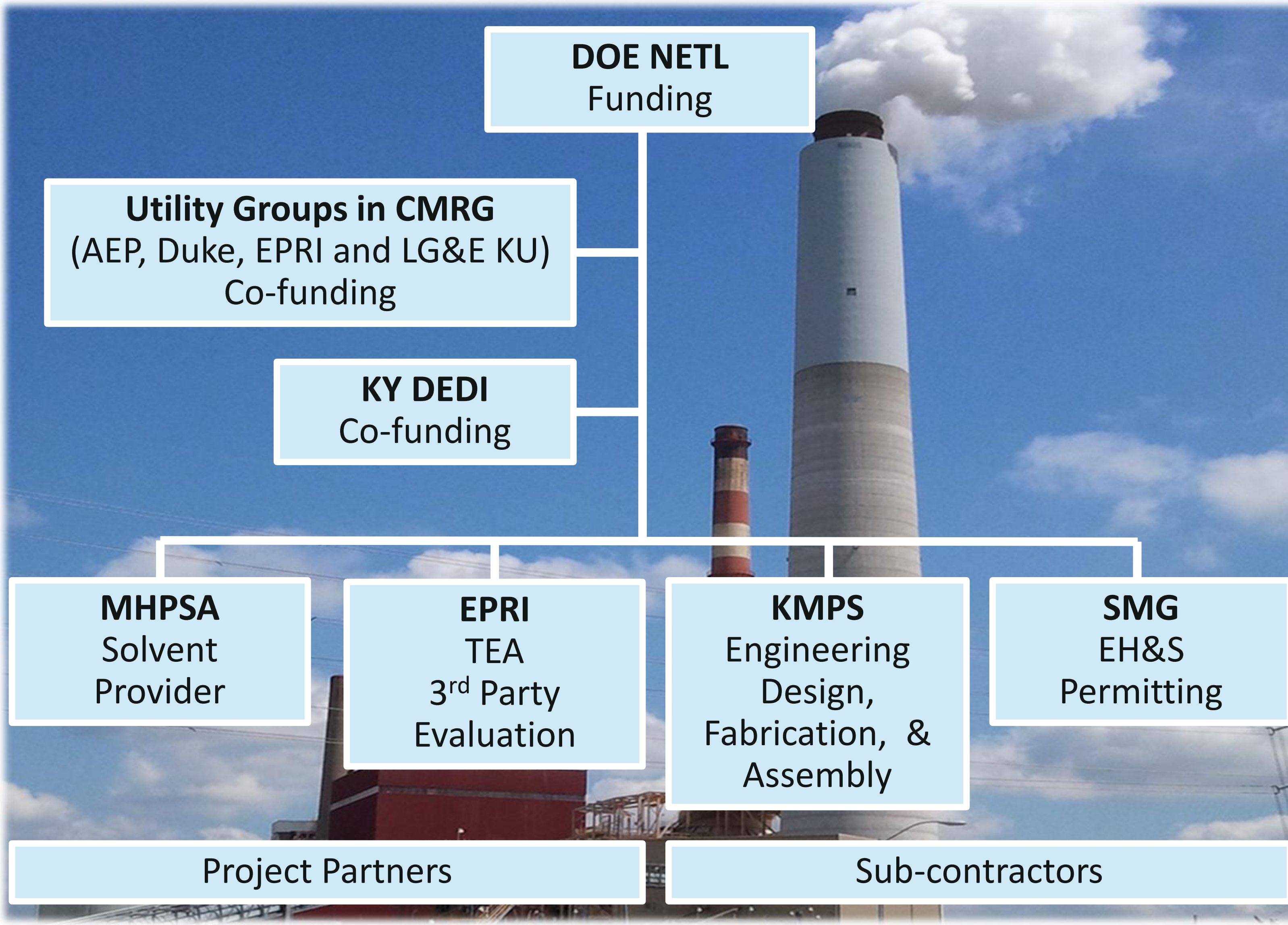


Project Overview

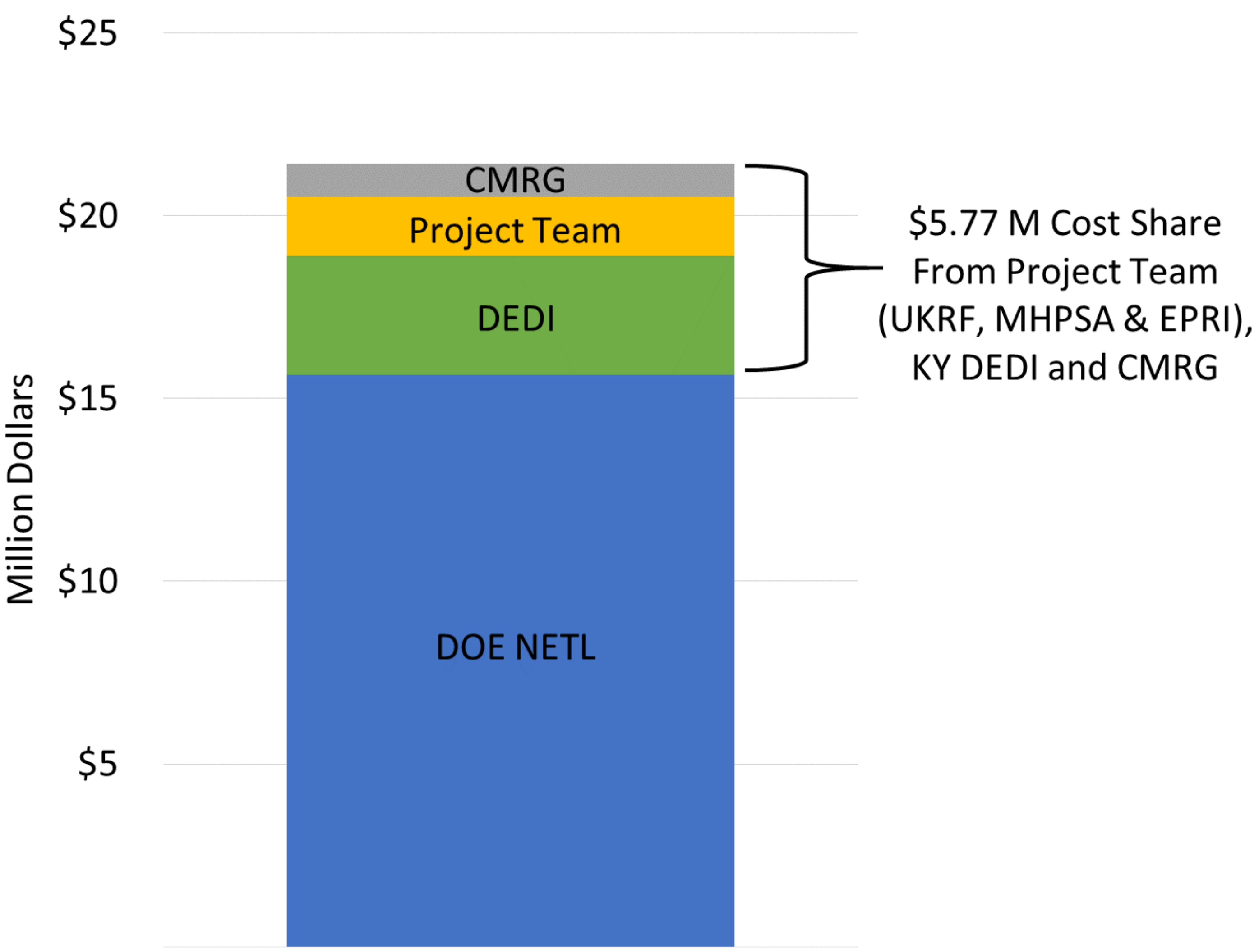
- 2 MWth (0.7 MWe) advanced post-combustion CO_2 capture pilot
- Catch and release program
- Designed as a modular configuration
- Testing at Kentucky Utilities E.W. Brown Generating Station, Harrodsburg, KY, approximately 30 miles from UKy-CAER

- Includes several UKy-CAER developed technologies
- Two solvent testing campaigns (MEA baseline and advanced H3-1)

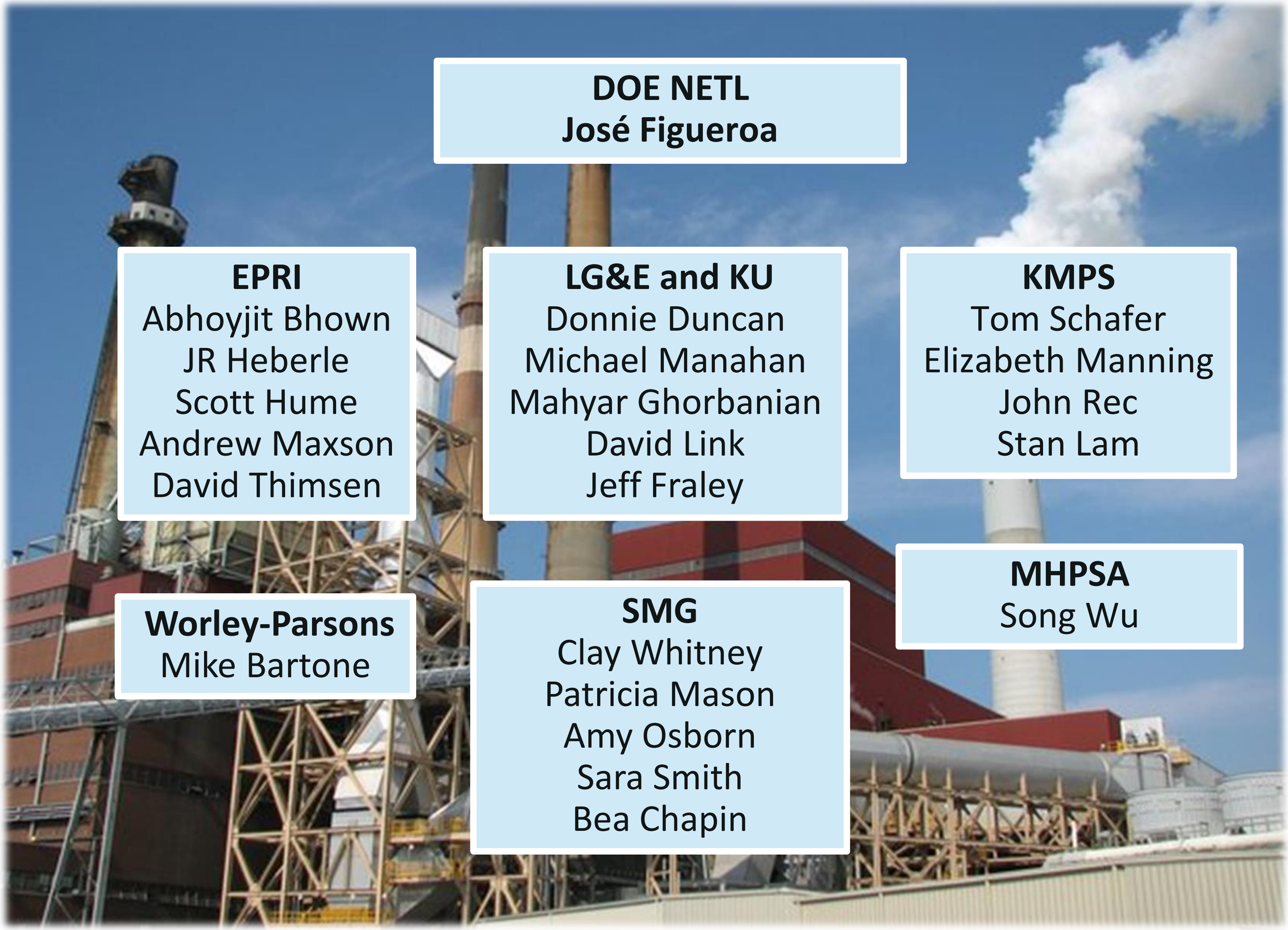
Project Organization



Project Funding



Project Participants



DOE NETL
José Figueroa

EPRI
Abhoyjit Bhown
JR Heberle
Scott Hume
Andrew Maxson
David Thimsen

LG&E and KU
Donnie Duncan
Michael Manahan
Mahyar Ghorbanian
David Link
Jeff Fraley

KMPS
Tom Schafer
Elizabeth Manning
John Rec
Stan Lam

Worley-Parsons
Mike Bartone

SMG
Clay Whitney
Patricia Mason
Amy Osborn
Sara Smith
Bea Chapin

MHPSA
Song Wu

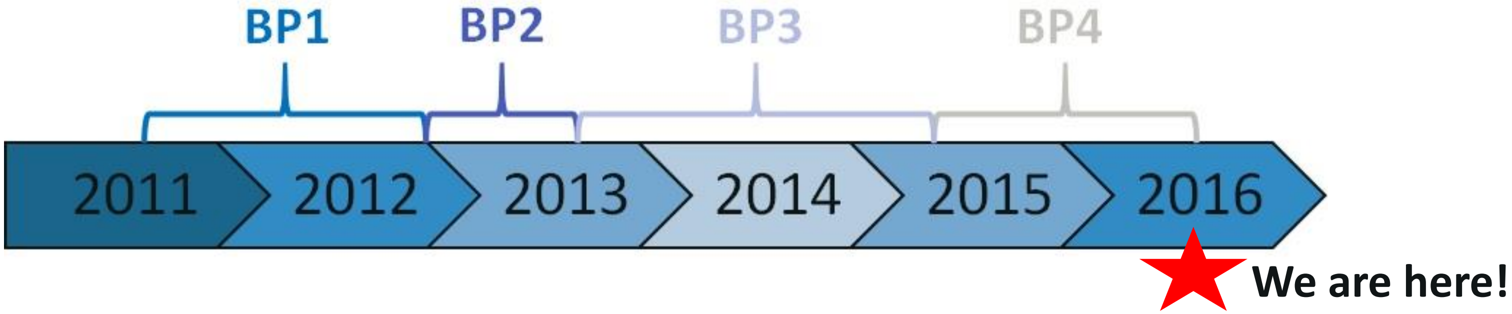
Project Performance Dates

BP1: October 1, 2011 to January 31, 2013 (16 months)

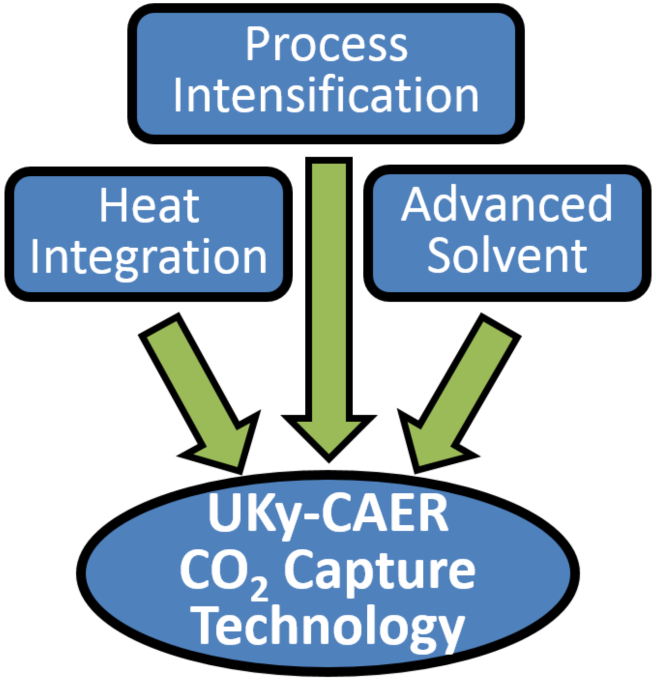
BP2: February 1, 2013 to August 31, 2013 (7 months)

BP3: September 1, 2013 to March 31, 2015 (19 months)

BP4: April 1, 2015 to September 30, 2016 (18 months)



Project Goal and Objectives



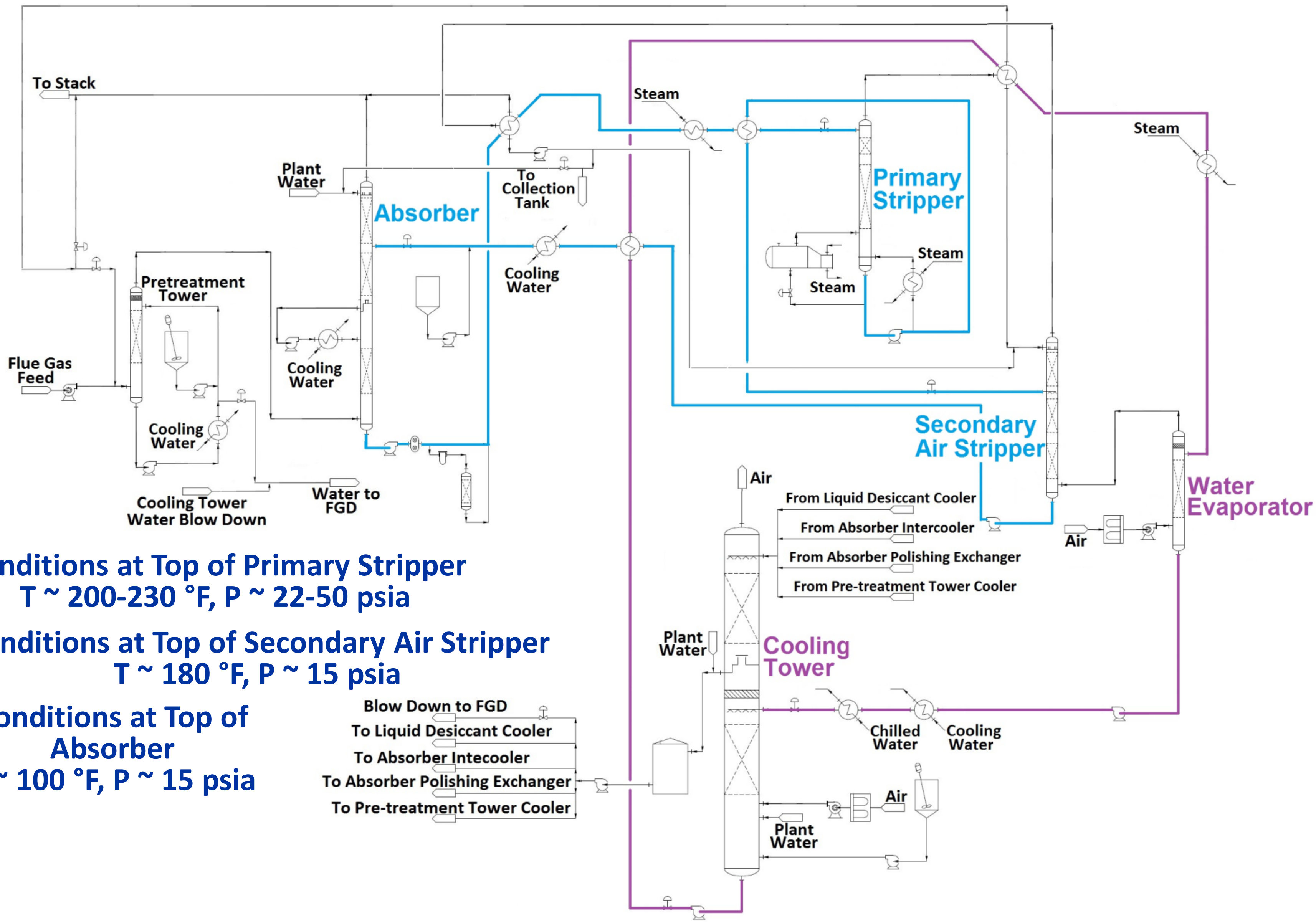
Goal

- Develop a pathway to achieve the US DOE NETL post-combustion CCS target of 90% CO_2 capture with a cost less than \$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

Technology Description



Conditions at Top of Primary Stripper
T ~ 200-230 °F, P ~ 22-50 psia

Conditions at Top of Secondary Air Stripper
T ~ 180 °F, P ~ 15 psia

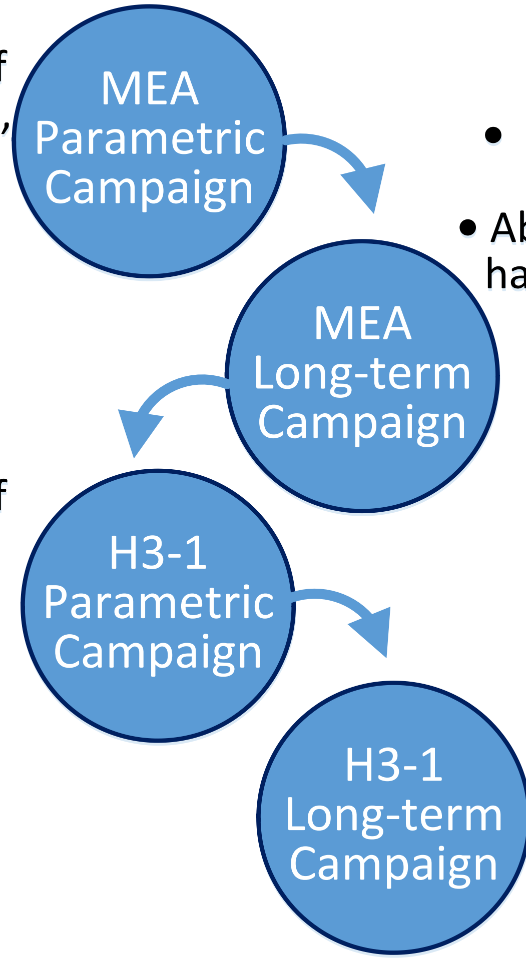
Conditions at Top of Absorber
T ~ 100 °F, P ~ 15 psia

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	5/15/13
3	Pouring of foundations for platform for slipstream modular units setup which meets engineering design load/specifications	9/11/14
3	KMPS fabricates slipstream modular units and delivers to host site, EW Brown Generating Station, for installation	8/28/14
3	Control Room/ Field Lab Trailer Assembled, Setup and Permitted	2/20/15
3	Tie-in piping with power plant complete	3/6/15
3	Slipstream pilot unit commissioning	3/31/15
4	MEA long term test campaign ✓	1/15/16
4	H3-1 long term test campaign ✓	7/1/16
4	Final Technical Economic Analysis and Final EH&S Assessment	9/30/2016
4	Project Final Scientific Report	9/30/2016

Project Key Findings

- Process can easily capture 90% of CO_2
- Solvent regeneration energy of 1200–1750 BTU/lb CO_2-captured, ~13% lower than Reference Case 10 (RC 10)



- Ambient conditions have an impact on CO_2 capture
- Absorber liquid/gas distribution has an impact on performance
- Lean/rich exchanger performance is critical
- Elemental accumulation in the solvent needs to be monitored

- Solvent regeneration energy of 900–1600 BTU/lb CO_2-captured, ~36% lower than RC10
- Secondary air stripper performs as expected

- 90% CO_2 capture and low solvent regeneration energies are possible with a range of solvent concentrations

Project BP4 Success Criteria - Achieved

A heat-integrated post-combustion CO_2 capture system with:

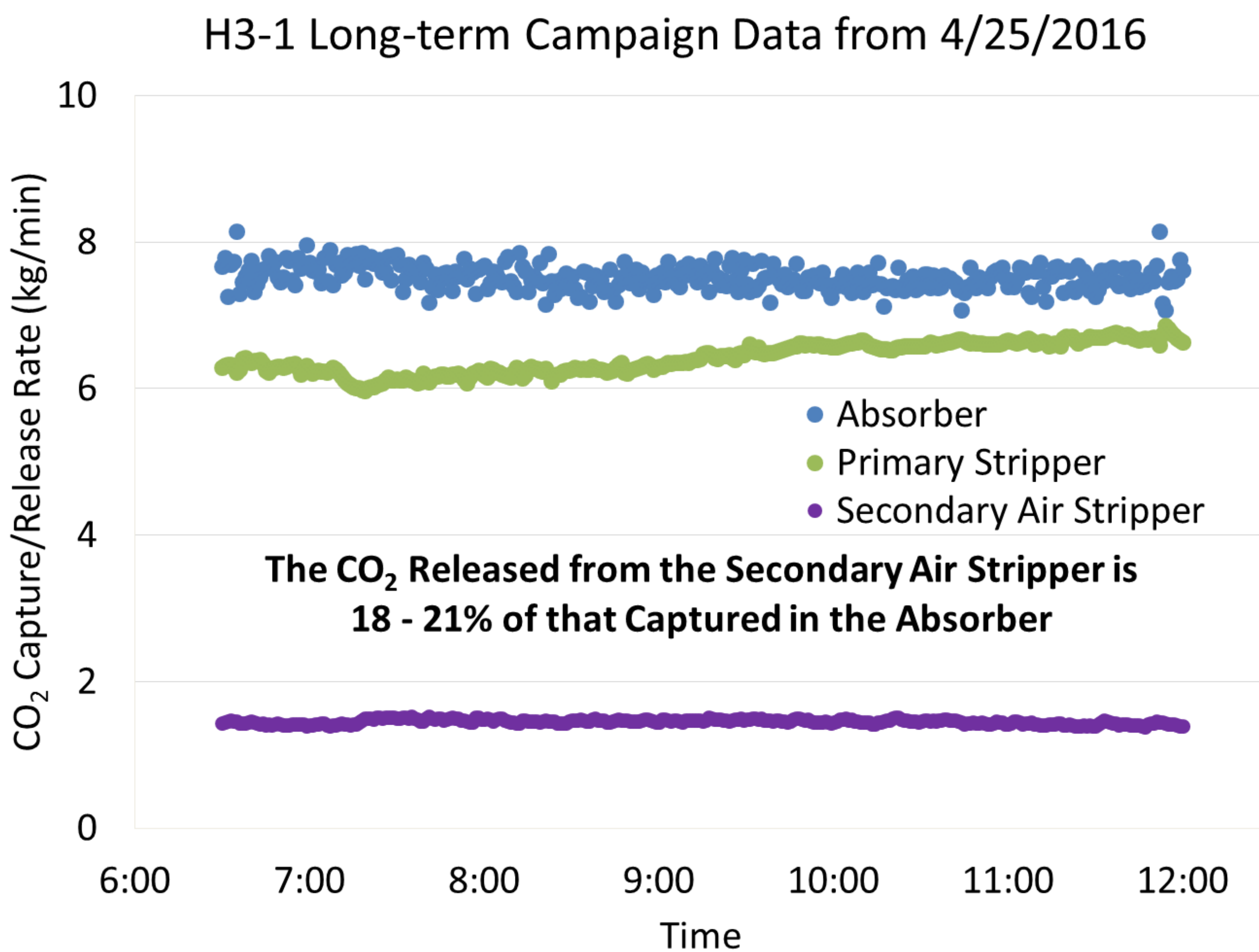
5-25% less energy consumption compared to the DOE Reference Case 10.

Preliminary Experimental Results **Compared to the Technical and Economic Analysis**	**Solvent Regeneration Energy**
DOE Reference Case 9 (no CO_2 Capture)	
DOE Reference Case 10 (RC 10)	1540 BTU/lb-CO_2
UKy-CAER CCS process MEA case, according to TEA	1340 BTU/lb-CO_2 13% lower than RC 10
UKy-CAER CCS process MEA case, experimental parametric campaign	**1200 to 1750 BTU/lb-CO_2** Range due to changing operating conditions during parametric campaign.
UKy-CAER CCS process H3-1 case, according to TEA	973 BTU/lb-CO_2 36% lower than RC 10
UKy-CAER CCS process H3-1 case, experimental parametric campaign	**900 to 1600 BTU/lb-CO_2** Range due to changing operating conditions during parametric campaign.

The assumptions made in the TEA seem reasonable, based on the parametric campaigns.

Project BP4 Success Criteria - Achieved

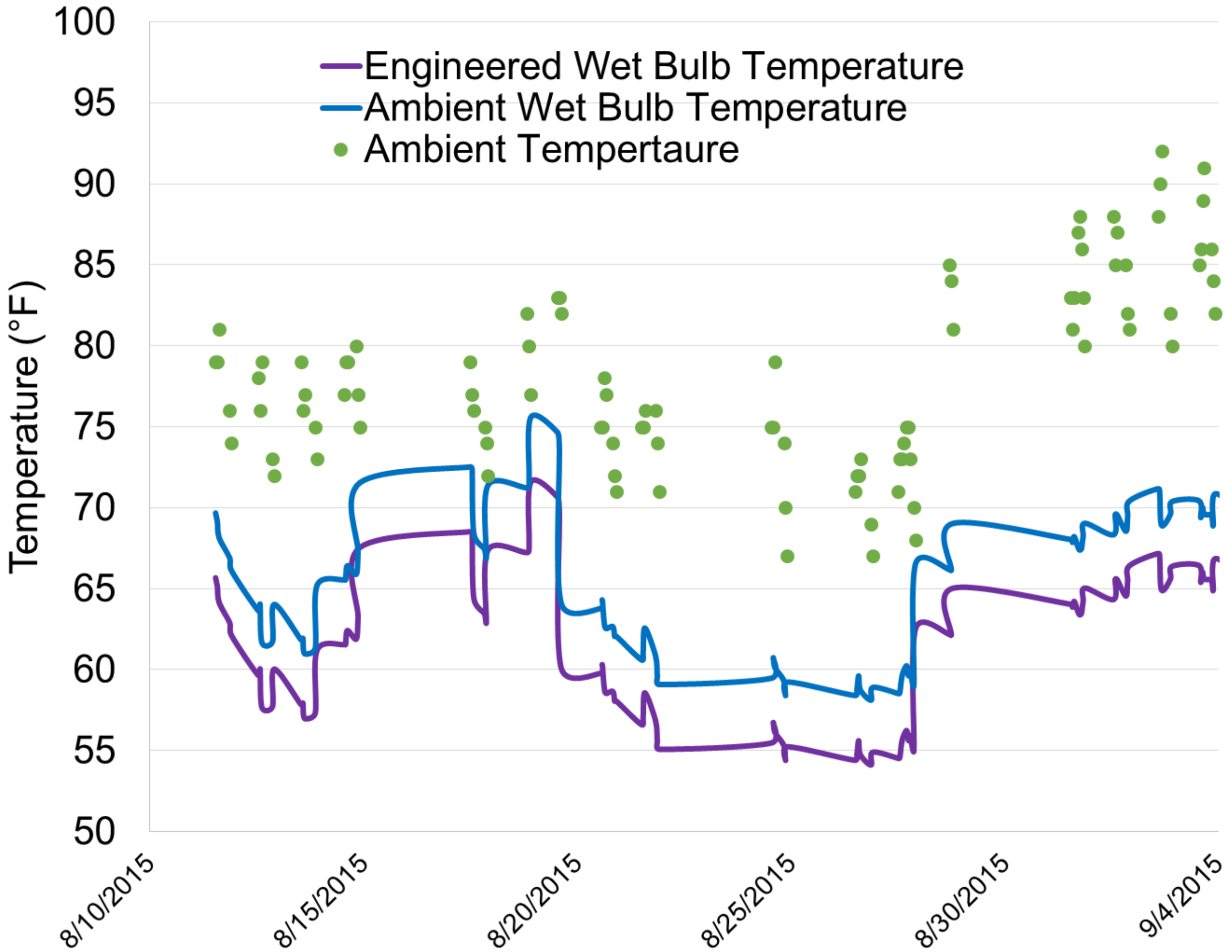
A heat-integrated post-combustion CO_2 capture system with:



Partial CO_2 recycling (10-20% of CO_2 captured) to enhance gaseous CO_2 pressure at the absorber inlet.

Project BP4 Success Criteria - Achieved

A heat-integrated post-combustion CO_2 capture system with:

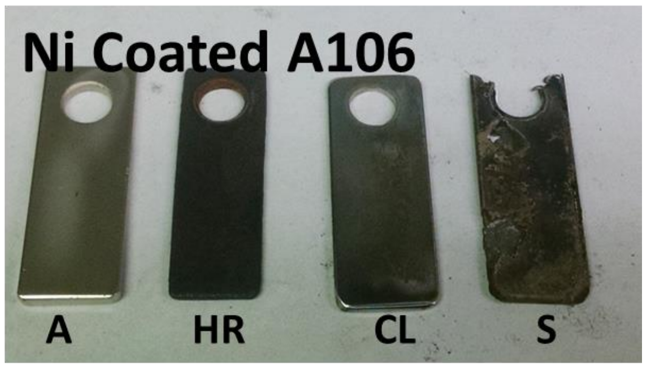
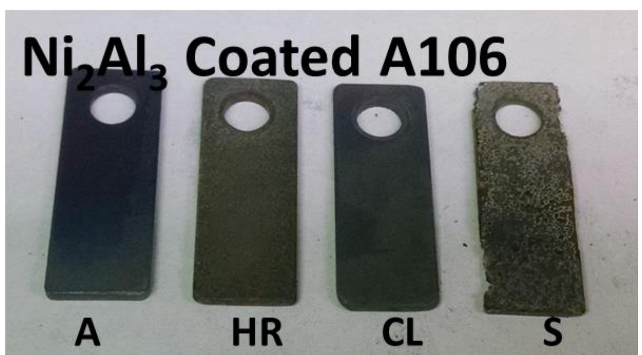
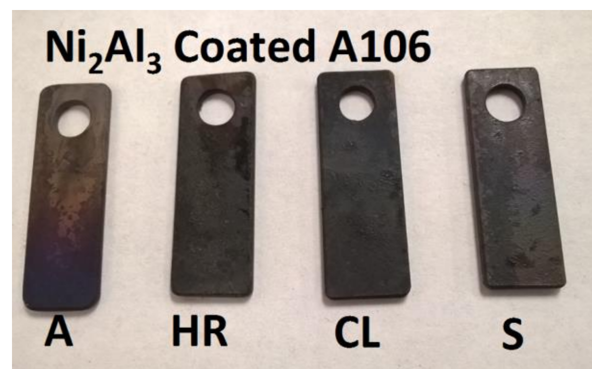


Much cooler recirculating cooling water, 3-9 °F compared to a conventional cooling tower at the same ambient conditions.

Project BP4 Success Criteria - Achieved

A heat-integrated post-combustion CO_2 capture system with:

An advanced solvent that has 15-20% less corrosivity than a 30 wt% MEA.

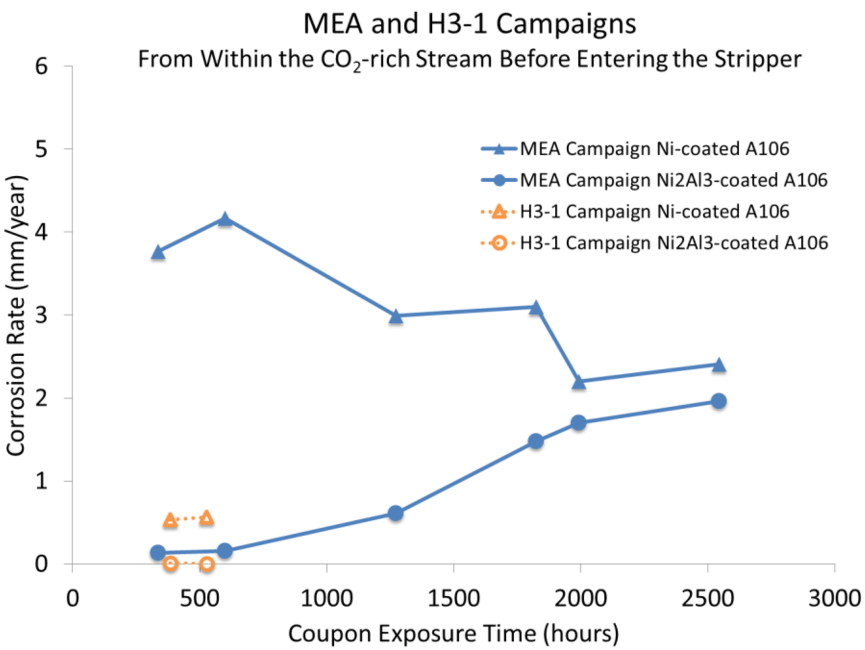
	MEA	**H3-1**
After ~100 Long-term Campaign Hours		
After ~250 Long-term Campaign Hours		

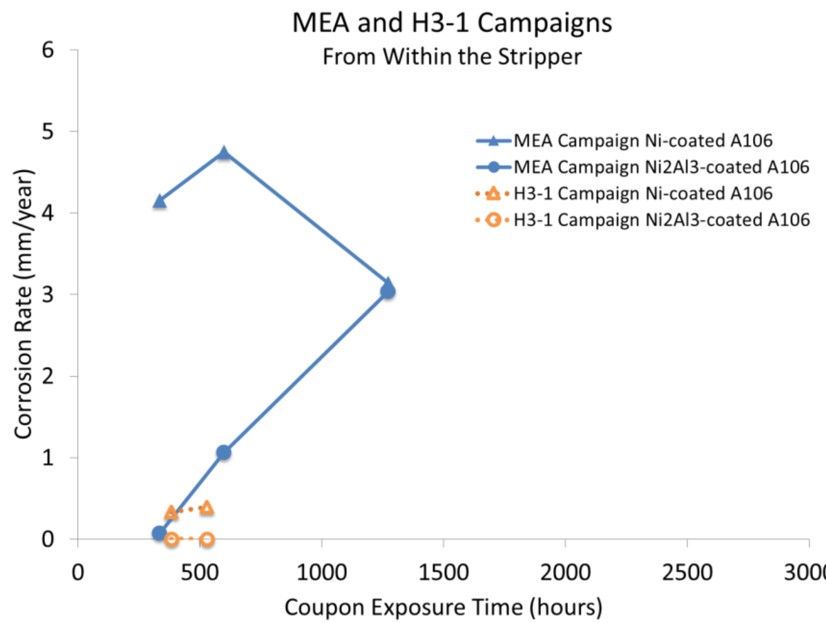
A = absorber location
HR = designates the hot, CO_2-rich amine stream
CL = designates the cold, CO_2-lean amine stream location
S = stripper location

Project BP4 Success Criteria - Achieved

A heat-integrated post-combustion CO_2 capture system with:

An advanced solvent that has 15-20% less corrosivity than a 30 wt% MEA.

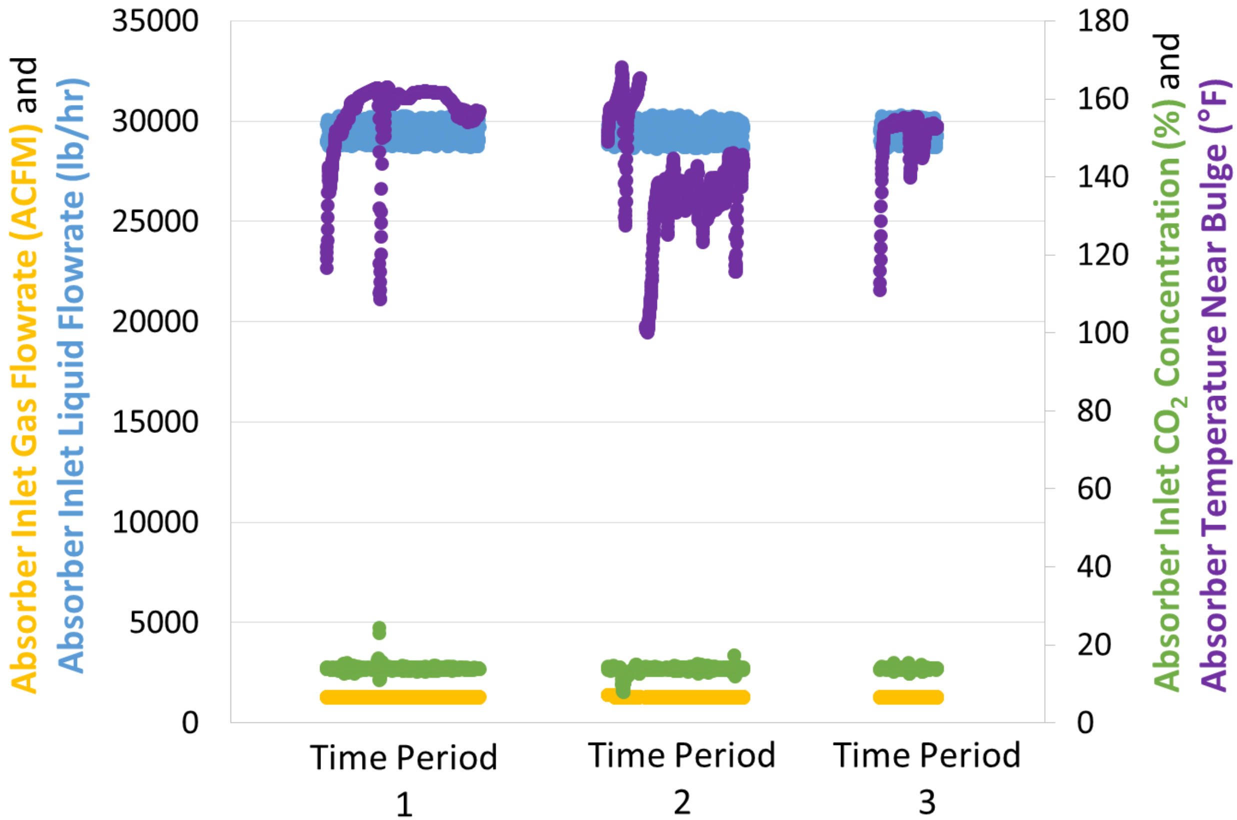




H3-1 is ~90% less corrosive than MEA.

Project BP4 Key Finding

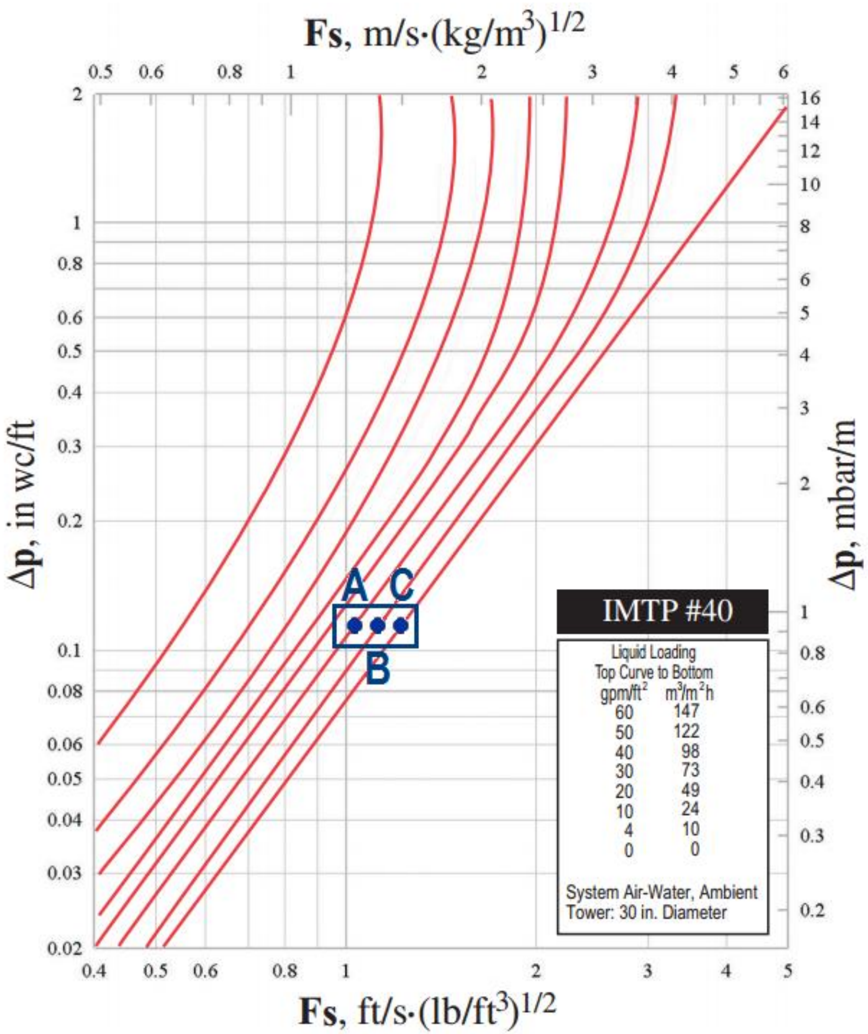
Liquid/gas distribution can significantly reduce the absorber efficiency.



Process data with constant absorber L/G, inlet CO_2 concentration, inlet amine CO_2-loading and temperature.

Project BP4 Key Finding

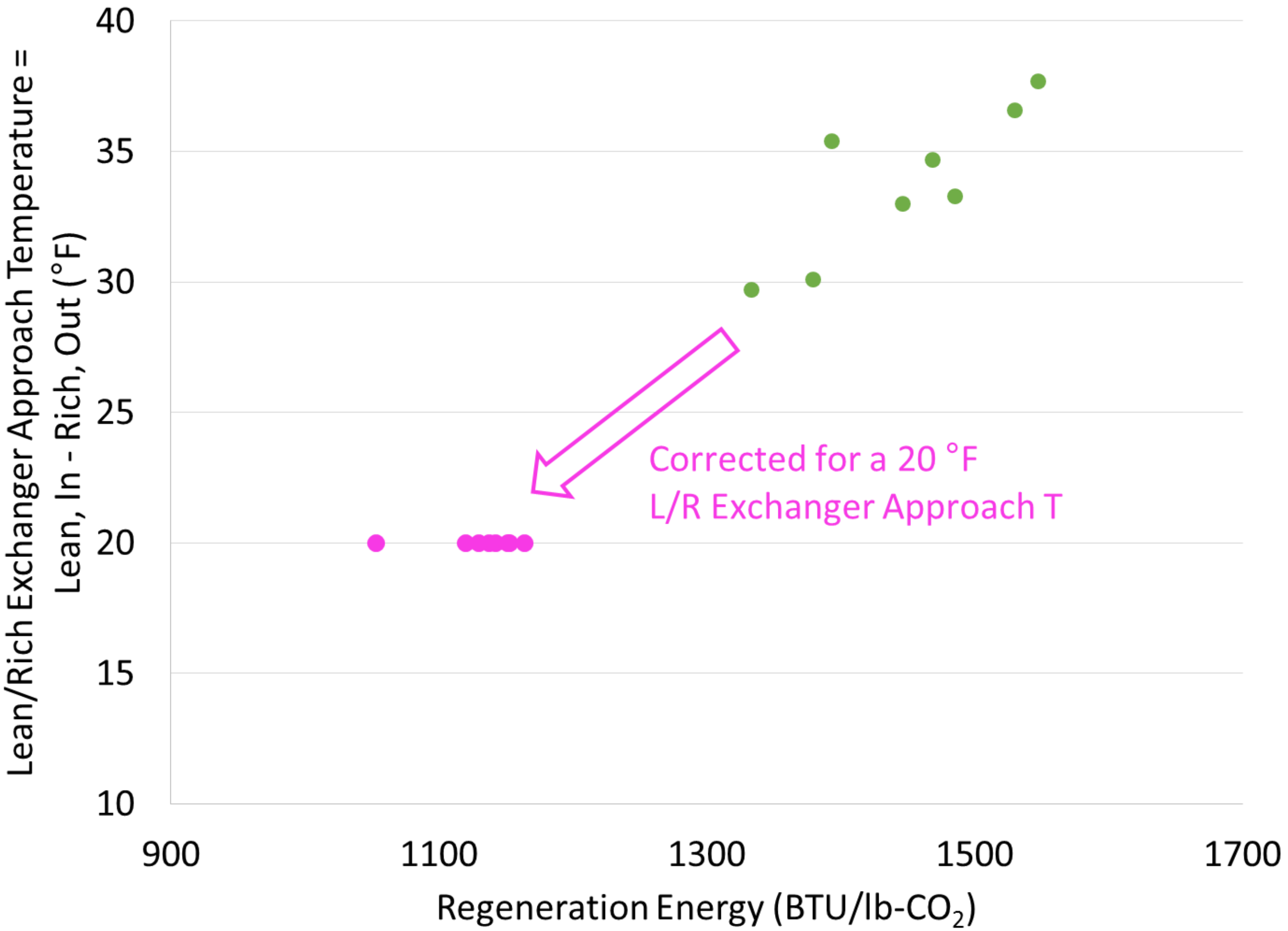
Liquid/gas distribution can significantly reduce the absorber efficiency.



Koch-Glitsch Bulletin KGIMTP-2. Rev. 3-2010.

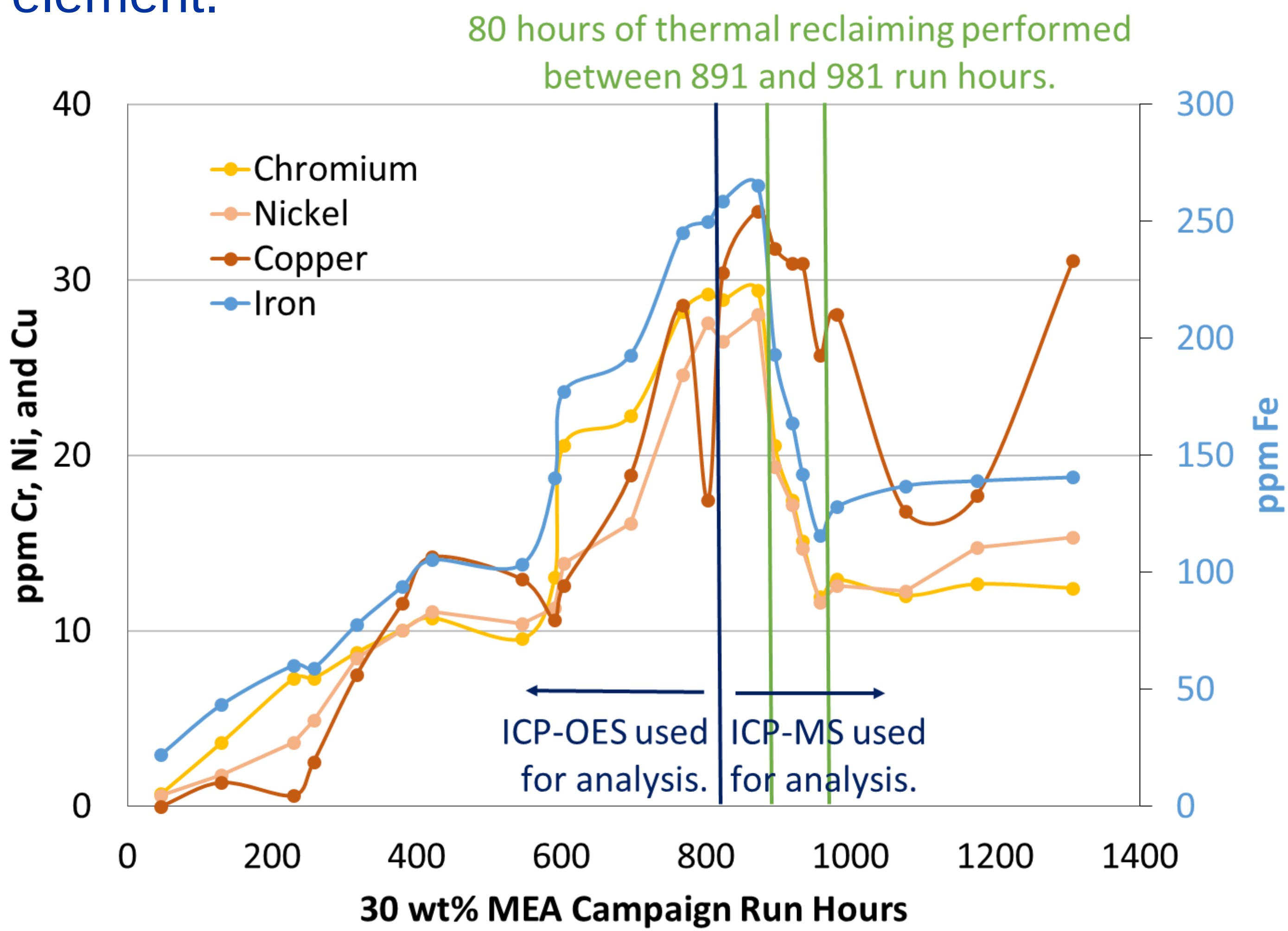
Project BP4 Key Finding

Understanding the L/R exchanger performance is critical when comparing regeneration energies.



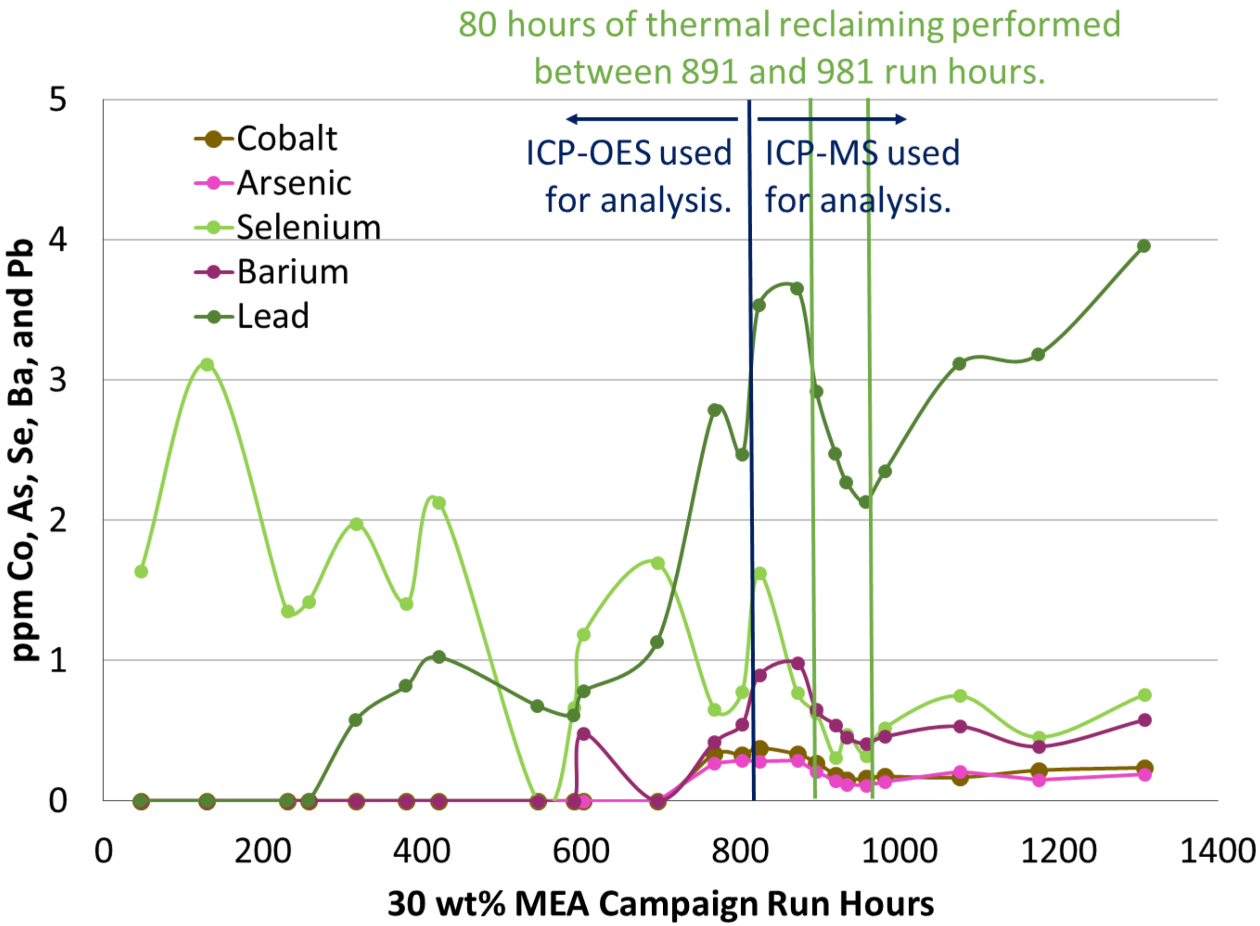
Project BP4 Key Results

80 hours of thermal reclaiming removed ~ 50% of each element.



Project BP4 Key Results

80 hours of thermal reclaiming removed ~ 50% of each element.



Cadmium and silver concentrations remained below limits of detection.

Project BP4 Key Results

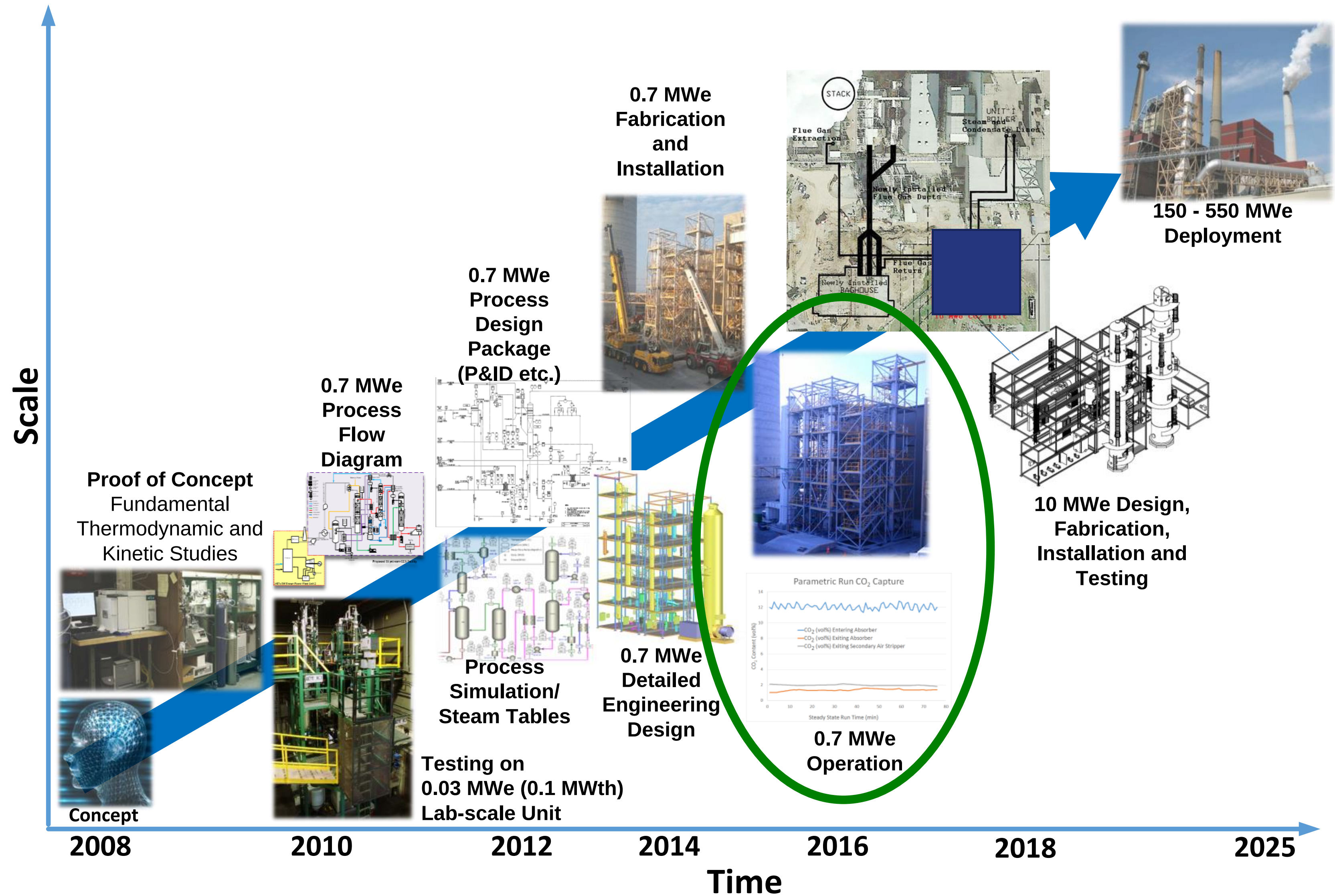
Thermal reclaiming may be necessary to keep elements below the RCRA limits.

Elemental Analysis of H3-1 Solvent from Near the End of the Campaign		
Element	Average of Replicate Samples (ppm)	RCRA limit (ppm)
Cr	0.82	5
As	< 0.63	5
Se	3.21	1
Ag	< 0.13	5
Cd	< 0.63	1
Ba	< 2.5	100
Pb	< 0.63	5

Key Knowledge Gained

- Liquid/gas distribution can significantly reduce the absorber efficiency.
- It is important to consider the L/R exchanger performance when reporting and comparing solvent regeneration values.
- Thermal reclaiming may be needed for RCRA element management.

Technology Development Pathway



NETL CO_2 Capture Technology Meeting, Pittsburgh, PA, August 8 – 12, 2016

Acknowledgements

José Figueroa, DOE NETL

CMRG Members

Donnie Duncan, **David Link**, **Michael Manahan**, **Mahyar Ghorbanian**, and **Jeff Fraley**, LG&E and KU

UKy-CAER Slipstream Team

The Slipstream Team: Kunlei Liu, Lisa Richburg, Fan Zhen, Andy Placido, Jon Pelgen, Reynolds Frimpong, Amanda Warriner, Len Goodpaster, Marshall Marcum, Otto Hoffmann, Ti Wang, Leland Widger, Jonny Bryant, Brad Irvin, James Landon, Wei li, Jesse Thompson, Megan Combs, Saloni Bhatnagar, and Keemia Abad