

BP3 Review Presentation



Application of a Heat Integrated Post-combustion CO₂ Capture System with Hitachi Advanced Solvent into Existing Coal-Fired Power Plant

University of Kentucky Research Foundation
In Partnership with
Electric Power Research Institute (with WorleyParsons)
Mitsubishi Hitachi Power Systems America
and

Smith Management Group

March 2015



Achievement in BP3



- Facility ready for Parametric Study
- The H3-1 Kinetic Model Complete
- All Other Preparations Complete
- Request for move to BP4









Visitors and Interest Received



- Introductory Presentation for LG&E Personnel, March 14, 2014
 Approximately 80 employees in attendance
- Ribbon Cutting Ceremony, July 21, 2014 attendance includes: UKy-CAER Associate Director for Research and Project Principal Investigator, Dr. Kunlei Liu, LG&E and KU, John Moffett, US DOE NETL Carbon Capture Program Manager, John Litynski, KY State Senator, Jared Carpenter, KY State Representative, Rocky Adkins, LG&E and KU Energy Chief Operating Officer, Paul Thompson, KY Governor, Steve Beshear, UK President, Eli Capilouto, KY State Representative, Kim King, KY Energy and Environment Cabinet Secretary, Dr. Len Peters, UKy-CAER Director, Dr. Rodney Andrews
- Several News Stories, July 21 and 22, 2014
 Lexington Herald-Leader, Lexington, KY News; The Advocate Messenger, Danville, KY News; United Press International, Business News; UKNOW, University of Kentucky News; WKYT, Kentucky Local News; The Futurist, Online Magazine; Energy.gov, US Department of Energy News
- CMRG Review Meeting Visit, November 20, 2014
 José Figueroa, Lynn Brickett, Doug Durst, David Link, Michael Manahan
- American Records Management Association (ARMA) Luncheon Presentation, January 15, 2015
- West Virginia University Visit, February 2, 2015
 James Wood, Jerry Fletcher and Sam Taylor
- First Energy Visit, February 4, 2014
 Eileen Buzzelli, Elizabeth Shaw and Michael Horvath
- Carbon Capture Scientific Visit, February 24, 2015
 Shiaoguo Chen, Zijiang Pan and Zhiwei Li
- Kentucky Department for Environmental Protection, March 18, 2015
 Barry Carman, LG&E and KU, Natasha Parker, Environmental Inspector, and Jarrod Bell, Environmental Scientist



Presentation Outline



- Introduction and **Project Summary**
- **BP3 Project Task Specific** Summary
 - Task 9B
 - Task 10
 - Task 12
 - Task 13
 - Task 14
 - Task 15
 - Task 16
- Lessons Learned So Far
- Conclusions
- Request to Proceed to BP4
- **Looking Ahead to BP4**



in Mercer County

Pilot System



Coal could have a future in Kentucky if pilot project succeeds, officials say





Project at Kentucky coal plant to trap carbon dioxide



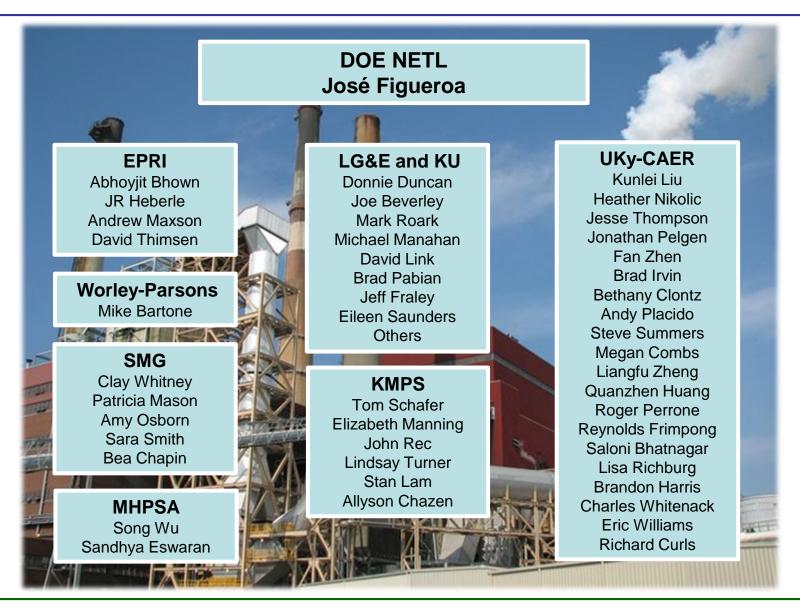
ENERGY.GOV

Construction Begins on DOE-Sponsored Carbon-Capture Project at Kentucky Power Plant



Team Members







Project Schedule



Task Name	Start	Finish	2011	2012	2013	2014	2015	2016	2017
1 Dunicat Managament and Dlamina Dudget Davied 1	10/2/11	1/21/12	HT H	Z H1 H	Z H1 H	Z HI F	IZ HI H	Z H1 H	Z H1
1 Project Management and Planning Budget Period 1	10/3/11	1/31/13	- 1						
2 Detailed Update of Techno-Economic Analysis	6/8/12	12/31/12					DIa	nnii	
3 Initial EH&S Assessment	3/1/12	11/27/12					ГІа		
4 Basic Process Specification and Design	5/1/12	12/3/12)
5 Project Management and Planning Budget Period 2	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						esi	an
8 Test Condition Selection and Test Plan	2/1/13	6/4/13						(C31)	9""
9 System Engineering Update and Model Refinements	3/1/13	3/4/15							
10 Project Management and Planning Budget Period 3	9/3/13	3/31/15			_				
11 Update of EH&S Assessment	9/3/13	3/31/15			_	20	rica	itio	n
12 Site Preparation	9/1/13	7/1/14			-				• •
13 Fabrication of Slip-stream Modules	11/4/13	8/18/14					Anc	1	
14 Procurement and Installation of Control Room/Field Lab	9/3/13	10/31/14			_			.	
Section						0 10 6	4	4:4	
15 Fabrication of Corrosion Coupons	10/1/13	2/28/15						ctic	m
16 Slipstream Facility Erection, Start-up, Commissioning	7/31/14	3/31/15							
and Shakedown	1 37	73.5 37.8							
17 Project Management and Planning Budget Period 4	4/1/15	9/30/16					-		,
18 Slip-stream Test Campaign	4/1/15	7/5/16							
19 Final Update of Techno-Economic Analysis	8/17/15	8/23/16						SIL	
20 Final EH&S Assessment	9/24/15	8/23/16							



BP3 Project Schedule



Task Name	Start	Finish		2012		2013		201	1	2015		2016	0.
			H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
9 System Engineering Update and Model Refinements	3/1/13	3/4/15											
9.2 9B Model Refinements on Hitachi case	10/2/13	3/4/15					_						
10 Project Management and Planning Budget Period 3	9/3/13	3/31/15											
11 Update of EH&S Assessment	9/3/13	3/31/15											
11.1 Operational Procedures and Safety Protocol for Slipstream	1/1/14	3/31/15								-			
11.2 Training for Operators	9/3/13	7/31/14					1						
11.2.1 Documentation of Training Completed	7/31/14	7/31/14							♦ 7.	/31			
12 Site Preparation	9/1/13	7/1/14					-		-				
12.1 Grading for Trailer	5/10/14	7/1/14											
12.2 Identify Contractor for Foundation work	9/3/13	5/9/14							1				
12.3 Pouring of Foundations for Platform	5/10/14	7/1/14						-	-				
13 Fabrication of Slip-stream Modules	11/4/13	8/18/14					-	V.					
14 Procurement and Installation of Control Room/Field Lab Section	9/3/13	10/31/14											
14.1 Procurement of Necessary Instrumentation	9/3/13	9/30/14						_	3				
14.2 Delivery & Install of Instrumentation and Equipment	12/5/13	9/30/14					4		-				
14.3 Base Trailer Fabrication	3/1/14	9/30/14											
14.4 Transport & Install Onsite	10/1/14	10/31/14								7			
14.5 Customization of Tie Ins	1/7/14	4/30/14					9		1	_			
14.6 Development of Analytical Method & Sampling Plan	9/3/13	9/30/14											
15 Fabrication of Corrosion Coupons	10/1/13	2/28/15					-						
15.1 Purchase and Setup Coating	10/2/13	2/14/14					12						
15.2 Prepare Coupons with Coating	2/17/14	12/31/14						Ž					
15.3 Build Corrosion Test Racks	2/17/14	2/28/15						9		-			
16 Slipstream Facility Erection, Start-up, Commissioning and Shakedown	7/31/14	3/31/15											
16.1 Module Assembly and Erection	7/31/14	2/28/15							—				
16.1.1 Delivery of Modules	7/31/14	8/21/14											
16.1.2 Install & Tie In Modules	8/25/14	2/26/15							-	—			
16.2 Start Up Individual Components	2/27/15	3/16/15								T,			
16.3 Commissioning & Shakedown	3/17/15	3/31/15								4			



Budget Details



Budget Period	Budget Period Start Date	Funding from DOE NETL	Recipient Cost Share	Total Estimated Cost	Status
BP1	10/01/2011	0/01/2011 \$573,301 \$353,400 \$926,7		\$926,701	COMPLETE
BP2	02/01/2013	\$650,806	\$242,051	\$892,857	COMPLETE
BP3	09/01/2013	\$9,472,774	\$2,384,089	\$11,856,863	\$600,000 Estimated uncosted carryover NOTE
BP4	04/01/2015	\$4,955,422	\$2,793,446	\$7,748,868	DOE funding received through forward funding
Proje	ct Totals	\$15,652,303	\$5,772,986	\$21,425,289	

\$300,000 deliberately withheld from KMPS until after the PATs



Activity Preview















kentucky.com Lexington Herald-Leader News, sports and entertainment

Coal could have a future in Kentucky if pilot project succeeds, officials say

BY BILL ESTEP

BY BILL ESTEP



Gov. Steve Besthear, center in suit, spoke with Kentucky Utilities employees at the E.W. Brown Generating Station in Mercer County after taking part in the announcement of a pilot project to set removal of carbon-disoide from emissions from coal-fired power plants on 7/21/2014. It is the first such project in Kentucky. The foundation for the until its under development in the forecrounce IIIB Eaten choto



Detailed P3 Project Tasks



Task 9B	Aspen kinetic modeling and preliminary TEA update - COMPLETE
Task 10	Project management and planning – ON GOING
Task 11	EH&S revision to include prelim operations procedure and safety protocol - COMPLETE
Task 12	Site preparation - <u>COMPLETE</u>
Task 13	Procurement and fabrication of slipstream modules - COMPLETE
Task 14	Procurement and Installation of control room/field lab - COMPLETE
Task 15	Fabrication of corrosion coupons – <u>COMPLETE</u>
Task 16	Slipstream facility erection, start-up, commissioning, and shakedown - ON SCHEDULE







Task 9B

Aspen kinetic modeling -- **COMPLETE**

- Equilibrium and kinetic models completed for H3-1 case and gave very close performance prediction compared to preliminary value
 - The revised energy consumption is ~1045 BTU/lb CO₂ captured
 - Resulting 28.9% HHV, compared to 28.7% from preliminary TEA







Task 10

Project management and planning

- Ribbon-cutting ceremony held at Brown Station, July 21, 2014
- Project Presentation at 2014 NETL CO₂ Capture Technology Meeting, July 30, 2014
- Topical Report to Quantify the Applicability of the Liquid Desiccant System issued, September 30, 2014
- Project Presentations at CMRG Review Meetings, May 13 and November 21, 2014



Task 10Ribbon Cutting Ceremony, July 21, 2014





Commonwealth of Kentucky Governor, Steve Beshear





University of Kentucky President, Eli Capilouto

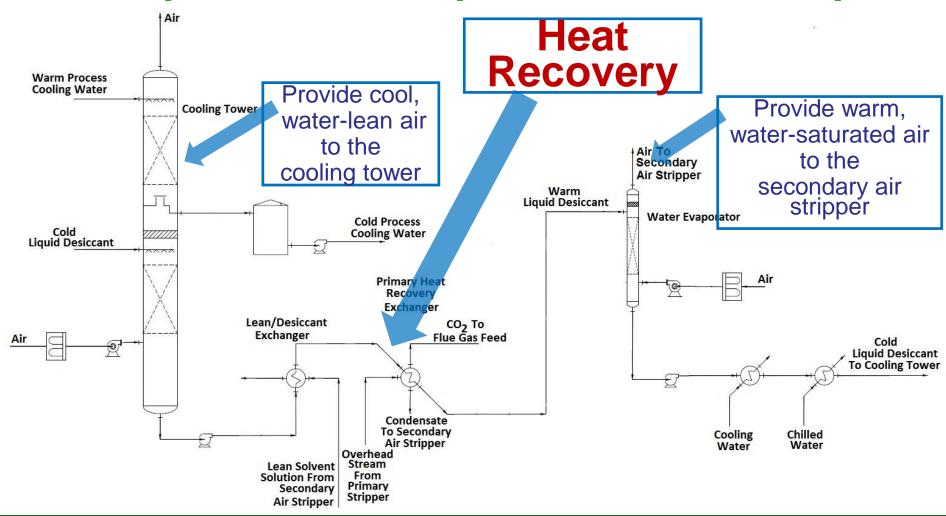




Task 10 Topical Report Issued



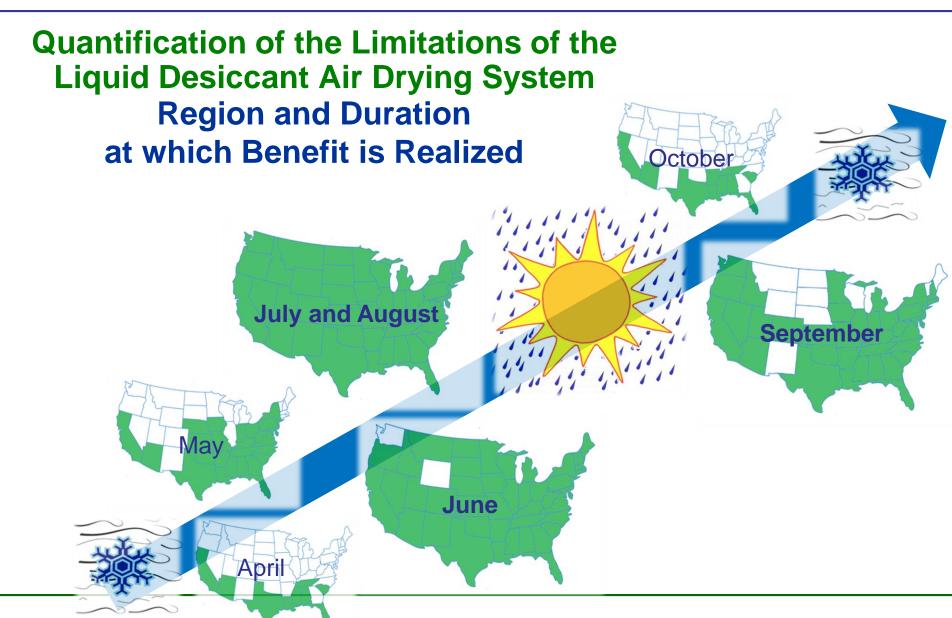
Purpose of the Liquid Desiccant Loop





Task 10 Topical Report Issued











Task 11

EH&S revision to include preliminary operations procedure and safety protocol - COMPLETE

- KMPS provided the operating procedures and manual,
 October 3, 2014 and updated February 2, 2015
- Revised EH&S on March 28, 2013 and January 15, 2015
- Amine handling standard operating procedure (SOP) written, January 22, 2015
- Soda ash and calcium chloride handling SOPs written, expected March 12, 2015
- Emergency Action Plan written September 5, 2014, updated February 25, 2015
- 34 operational SOPs written, February 2, 2015







Task 12

Site preparation - COMPLETE

- Power Plant tie-in isolation valves complete, April 30, 2014
- Foundation construction complete, September 11, 2014



Task 12 DetailsFoundation Completion











Task 13

Procurement and fabrication of slipstream modules - **COMPLETE**

- Verified module anchor bolt hole dimensions during visit to the assembly shop, June 25, 2014
- Verified foundation anchor bolt dimensions, July 17, 2014
- Modules 1, 2 & 3 received August 20 and erected on August 21, 2014
- Modules 4, 5 & 6 received on August 28 and erected on August 28 & 29, 2014
- Remaining scope to make complete as-installed, November 30, 2014
- KMPS reimbursements to the project in the amount of \$48,078 expected after performance acceptance tests, April 6, 2015



Task 13 Details Anchor Bolt and Bolt Hole Dimensional Checks











Assembly Shop Visit

- A gauge was constructed to quickly check the module feet anchor bolt hole dimensions
- Foot-to-foot dimensions also checked

In the Field

 All anchor bolt dimensions all checked before concrete pour



Task 13 Details













Task 14

Procurement and Installation of control room/field lab - COMPLETE

- Trailer received, set and secured, November 14, 2014
- Installation of gas analyzer, December 3, 2014, other lab equipment, January 30, 2015, and control system, March 2015
- Unofficial occupancy permit obtained, February 9, 2015
- Official occupancy permit expected, March 13, 2015

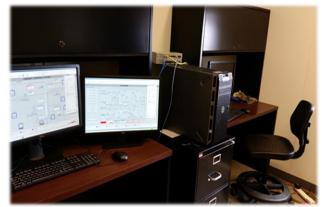


Task 14 Details

Procurement and Installation of Control Room/Field Lab







Control room

Robot analyzer: measures density, alkalinity, and C loading





CEMS Gas analyzer measures O₂, CO₂, CO, SO₂, NO, and NO₂

Field lab









Task 15

Fabrication of corrosion coupons – COMPLETE

MEA Campaign Corrosion Coupons									
A106	96 samples needed	96 samples complete							
SS204	96 samples complete	96 samples complete							
Nickel Plated	96 samples complete	96 samples complete							
Nickel Aluminide Plated	96 samples complete	96 samples complete							

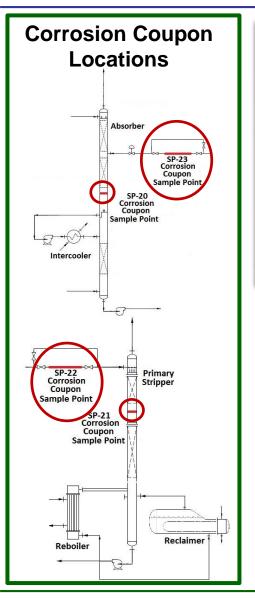
H3-1 Campaign Corrosion Coupons									
A106	120 samples needed	120 samples complete							
SS204	120 samples complete	120 samples complete							
Nickel Plated	120 samples complete	120 samples complete							
Nickel Aluminide Plated	120 samples complete	120 samples complete							



Task 15 Details



Fabrication of Coupons and Retainment Racks

















Task 16

Slipstream facility erection, start-up, commissioning, and shakedown – On schedule

- All major equipment, including process modules, received and erected, October 22, 2014
- Utility piping installed, December 3, 2014
- Tie-in piping with power plant complete, March 1, 2015
 - ✓ Expansion joint is the exception. Installed on March 19th, 2015
 - ✓ The PRV is the exception. Installed (replaced) on March 22nd, 2015
- Modules and control room/field lab powered up, February 11, 2015
- Pressure testing of process loops, hydraulic testing, March 15, 2015
- System commissioning, March 30, 2015
- Performance acceptance testing, end of May, 2015



Task 16 Details









Task 16 Details

UK

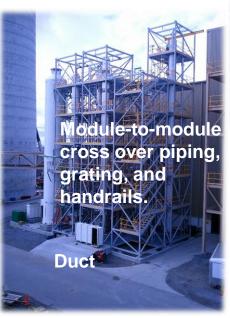
Erection and Installation of Other Equipment



There were ~260 pieces and boxes of loose shipped equipment from KMPS.













Task 16 Details Preparation for Start up



- Removal of all shipping covers
- U bolt pipe guide loosening
- Rupture disk installation
- Blind Flange Installation
- Foundation valve installation
- Tagged all sample ports
- Temporary bracing removal
- U-bolt pipe guide loosening
- C106 trim instrumentation control wiring
- Column belly band guide adjustment
- Control wiring between electrical panels, off-module equipment, and control room
- Control room set up
- Field lab set up and equipment assembly
- CEMS wiring
- CEMS calibration gas connections

- Plumb control room/field lab tank
- LOTO program creation and implementation
- Energize entire process and control room/field lab
- Lubricate rotational equipment
- Rotational equipment check
- Leak test piping systems
- Valve ID location spreadsheet creation
- Installation of safety signage
- Construct barrier over top lifting lug to avoid a trip hazard
- P gauge check
- T gauge check
- RTD installation
- Materials storage shed clean-up
- System step-by-step commissioning



Conclusions



- Milestones and deliverables have been met
- Equilibrium and kinetic modeling complete
- EH&S revised, start-up and operating procedures written, operational SOPs written, PM schedule created
- Foundation construction complete
- Process modules fabricated, shipped and erected
- Loose-shipped equipment shipped and installed
- Tie-in piping systems designed and installed
- Control room/field lab procured and set up
- Corrosion coupons and retainment rack fabrication complete
- Leak and hydro testing complete
- Process and control room/field lab powered
- Water circulated in liquid lines



Request



- Requesting approval to continue to BP4
- BP4 budget: DOE \$4,955,422/ cost share \$2,793,446
- DOE share for BP4 has been received through forward funding
- BP4 dates: April 1, 2015 September 31, 2016
- BP4 will include testing of the process with H3-1 and MEA (baseline)



Lessons Learned So Far



- 1) There is a difference in standards between a University and a commercial facility. Maintaining a **good working relationship**, that benefits both organizations, is crucial to working through a project of this nature.
- 2) OSHA standards are not black and White.
- 3) For any future project of this nature, a host site safety review of all areas of the project where safety standards may apply would be helpful for good communication and to address potential issues earlier rather than later.





Specific examples include: definition of construction work, cross-over grating requirements, human access to the modules, yellow reflective paint

4) Finding unknown buried things is common during excavation. Budget and schedule allowances should be made.



BP4 Schedule



Task Name	Start	Finish		2012		2013		2014		2015		2016	
			H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
17 Project Management and Planning Budget Period 4	4/1/15	9/30/16											
18 Slip-stream Test Campaign	4/1/15	7/5/16								-			•
18.1 Parametric study using 30% wt MEA (2 conditions per day)	5/13/15	8/6/15								-			
18.1.1 Completion of Parametric study using 30% wt MEA (27 conditions X3)	8/6/15	8/6/15									a /8/	6	
18.2 Parametric study using H3-1 (2 conditions per day)	11/21/15	2/25/16									•	T	
18.2.1 Completion of Parametric study using H3-1 (27 conditions X3)	2/25/16	2/25/16										♦ 2/	/25
18.3 System dynamics evaluation (2 conditions per day)	6/25/15	3/17/16									7		
18.3.1 Dynamics for MEA	8/7/15	8/27/15										40.00	
18.3.2 Dynamics for H3-1	2/26/16	3/17/16											
18.4 Long-term verification test/materials study (24/7)	8/28/15	7/5/16									V		
18.4.1 Long-term for MEA	8/28/15	11/20/15									-	K	
18.4.1.1 Complete MEA Study	11/20/15	11/20/15									•	11/20)
18.4.2 Long-term for H3-1	3/18/16	7/5/16										-	₩
18.4.2.1 Complete H3-1 Study	7/5/16	7/5/16											7/
18.5 Solvent degradation study	8/28/15	7/5/16									-		
18.5.1 MEA	8/28/15	11/20/15											
18.5.2 H3-1	3/18/16	7/5/16											3
19 Final Update of Techno-Economic Analysis	8/17/15	8/23/16									1		
20 Final EH&S Assessment	9/24/15	8/23/16									—		



Activities Planned in BP4



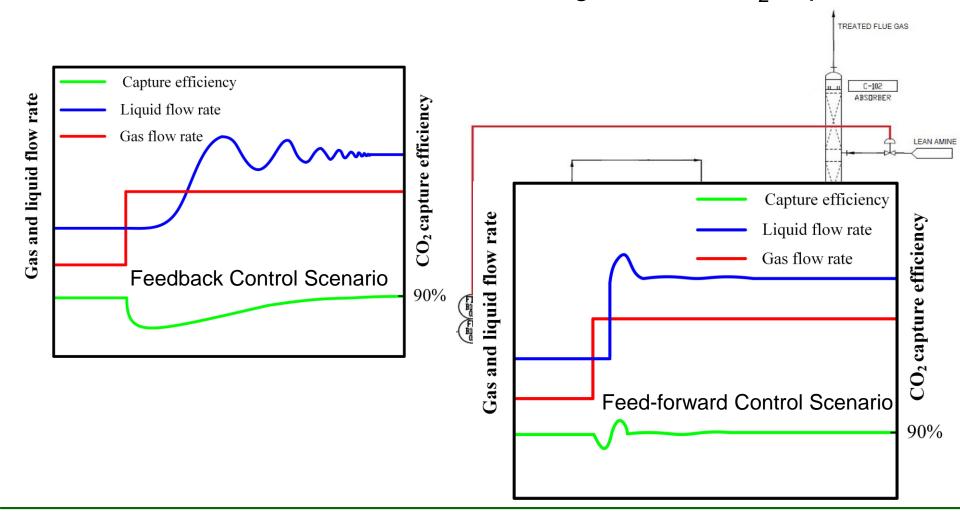
	BP4 Testing and Evaluations
MEA Testing Campaigns	Parametric and long term verification studies, including dynamic studies
H3-1 Testing Campaigns	Parametric and long term verification studies, including dynamic studies
Corrosion Studies	Corrosion coupons will be placed at four processes locations and removed periodically during both solvent long term verification runs to monitor the performance of two UKy-CAER developed corrosion resistant coatings.
Solvent Degradation Studies	Levels of solvent degradation products will monitored during the MEA campaign.
Solvent Emissions Monitoring	Gas sampling at the exit of each column will occur during the MEA campaign to evaluate the effectiveness of the UKy-CAER solvent recovery systems.
Effectiveness of the Liquid Desiccant Air Drying System	The amount of additional cooling provided by the liquid desiccant air drying system will be evaluated at various ambient conditions to determine usefulness at a commercial scale.
Reclaimer vs. Activated Carbon Filter	The UKy-CAER process includes both a reclaimer and an activated carbon filer for the removal of heat stable salts. We will monitor the HSS accumulation and operate both the reclaimer and the ACF to determine which is more effective for commercial scale use.
Accurate Modeling of All Column Profiles	Each column includes liquid/gas sampling ports to experimentally determine carbon contents along the profiles. The experimental data will be used to improve UKy-CAER developed models.
RCRA Metals Monitoring	Levels of the 8 RCRA metals in the solvents will be monitored



Dynamic Testing



Goal: To identify appropriate parameters to implement a feed-forward control scheme in order to maintain average of 90% CO₂ capture







ANOTHER LESSON LEARNED:



Many thanks to the following people!

José Figueroa, DOE NETL

CMRG Members

Donnie Duncan, LG&E and KU

Joe Beverley, LG&E and KU

Michael Manahan, LG&E and KU

David Link, LG&E and KU

Brad Pabian, LG&E and KU

Jeff Fraley, LG&E and KU

Eileen Saunders, LG&E and KU