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**
DOE Project Manager: José D. Figueroa

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University of Kentucky
Center for Applied Energy Research

Main CAER Facility Located Off-campus in Lexington, KY
(est. 1977)
162 employees, $12M Budget

UK's first LEED Research Laboratory
$19.8 M Renewable Energy Lab
(finished in June)

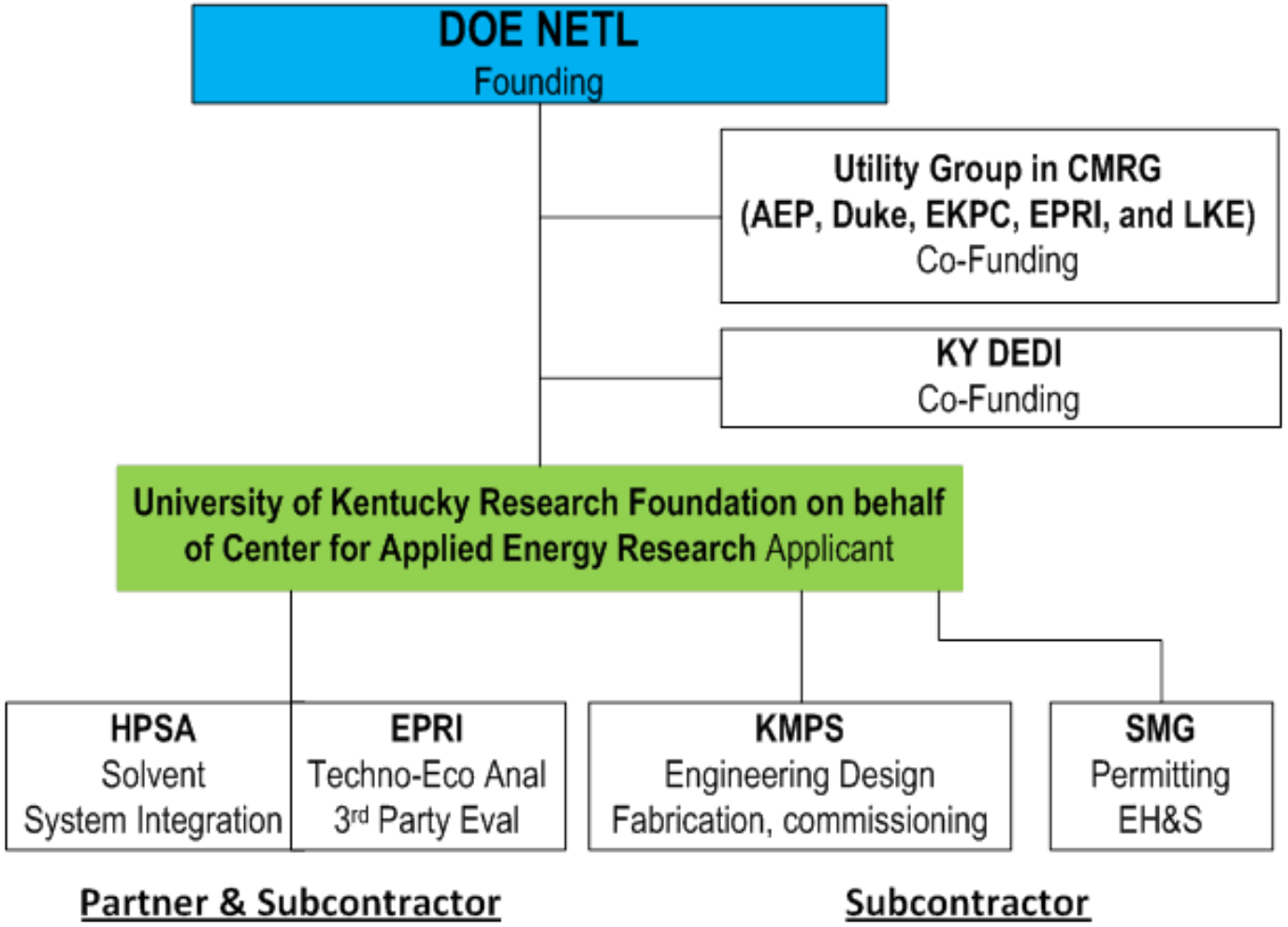
Project Overview

- Project Funding:
  - $14.55M from DOE NETL
  - $ 4.73M cost share from team, KY DEDI and CMRG
    - $0.78M from team
    - $3.65M from KY DEDI
    - $0.3M from Carbon Management Research Group (CMRG)
- 4-year project consisting of 4 budget periods

Project Overview

- Overall Performance Dates (no-cost extension is in progress):
  - BP-1 October 1, 2011 to August 31, 2012
  - BP-2 September 1, 2012 to January 31, 2013
  - BP-3 February 1, 2013 to January 31, 2014
  - BP-4 February 1, 2014 to January 31, 2016

Project Participants



Team Members

- EPRI
  - Abhoyjit Bhown
  - Dick Rhudy
  - George Booras
  - Andrew Maxson
  - David Thimsen
  - Ron Schoff
- HPSA
  - Song Wu
  - Sandhya Eswaran
- KMPS
  - Tom Schafer
  - Stan Lam
  - Allyson Chazen

LKE
- John Moffett
- David Link
- Jeff Fraley
- Donald Duncan

SMG
- Sara Smith
- Clay Whitney

UKRF
- Kunlei Liu
- Jim Neathery
- Joe Remias
- Lisa Richburg
- Heather Nikolic
- Jesse Thompson
- Others

Worley-Parsons
- Jacqueline Bird
- Mike Bartone

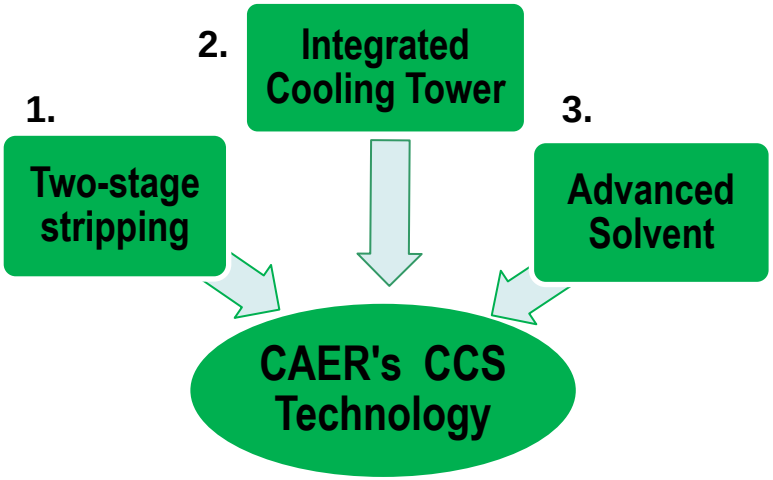
Overall Project Objectives

1) To gather data on solvent degradation kinetics, water management as well as other information during the long-term verification runs;
2) To provide scale-up data and design information for commercial-scale projects;
3) To demonstrate a heat-integrated post-combustion CO_2 capture system with advanced solvent; and
4) To collect information/data on material corrosion and identify appropriate materials for a 550 MWe commercial-scale carbon capture plant.

Technology Fundamentals

Engineering design, build and install an advanced CO_2 capture system into an existing PC power plant at a 0.7 MWe slipstream scale (~15 TPD CO_2)

Three novel processes will be designed and integrated: 2-stage solvent striping, cooling tower desiccant, and Hitachi solvent

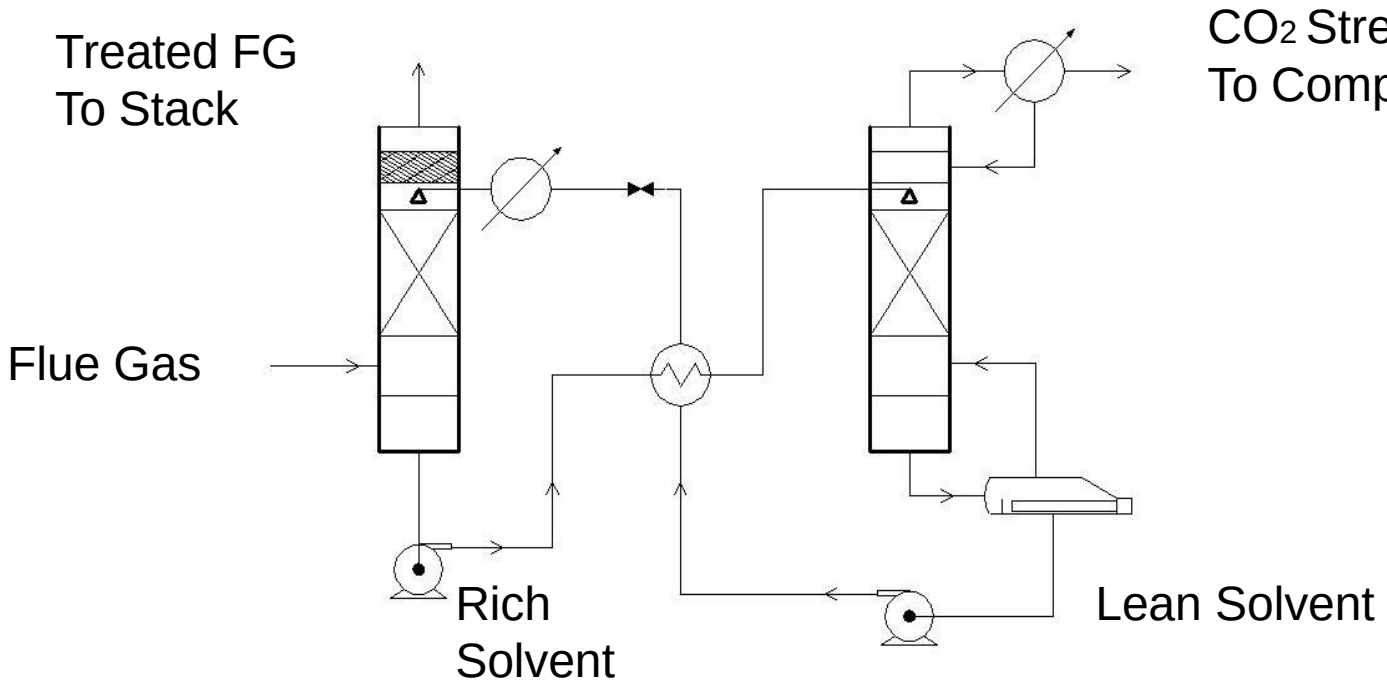


1. **Two-stage Stripping:**
   - Increase solvent working capacity by providing a secondary air-stripping column following the conventional steam stripping column.
   - Air stripping stream sent to boiler as combustion air to increase flue gas P_{CO_2} exiting boiler

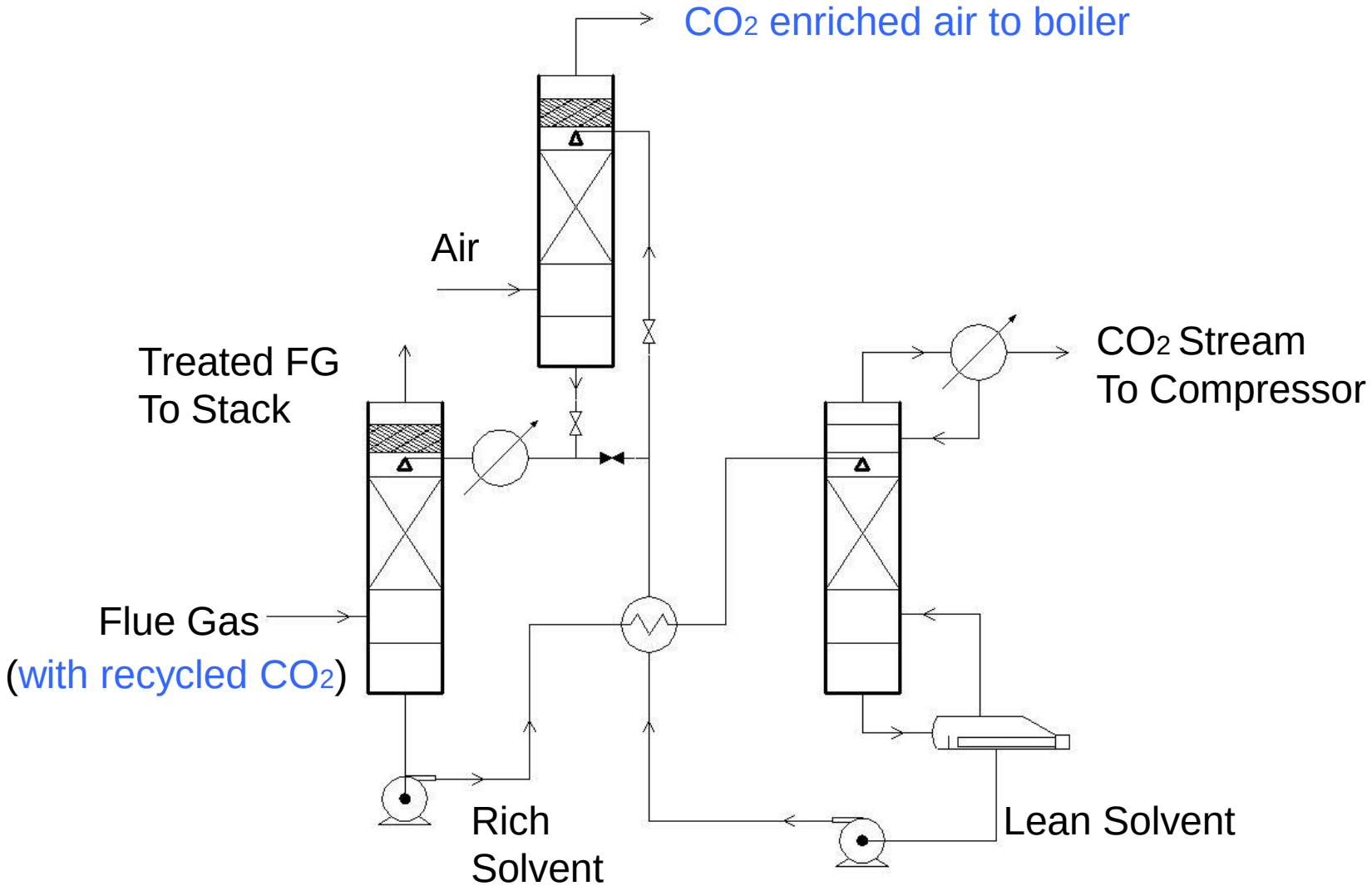
2. **Integrated Cooling Tower:**
   - Use regenerated CO_2 stream waste heat to dry liquid desiccant
   - Liquid desiccant is used to dry cooling tower air → Improved power plant cooling tower and steam turbine efficiency

3. **Advanced Hitachi Solvent:**
   - Primary amine analogous to MEA

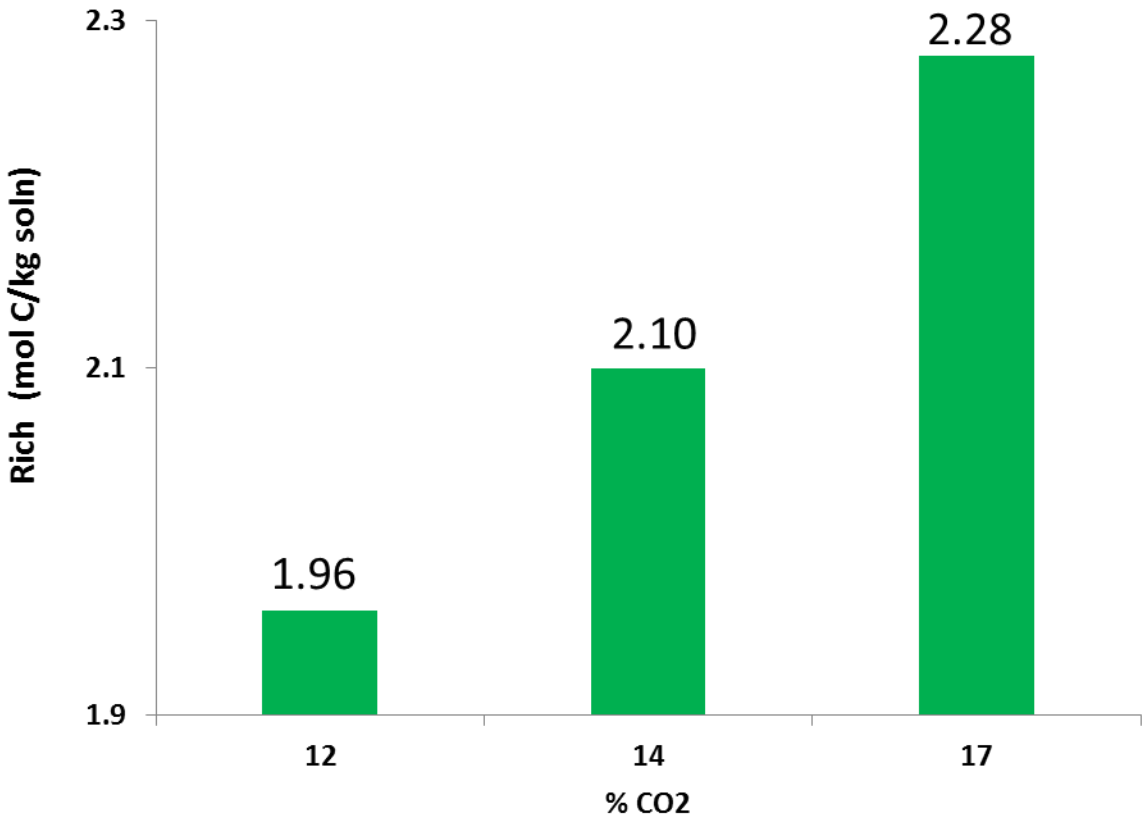
Conventional Absorber/Stripper CCS



CCS with Air Stripper and CO_2 Recycle



Background: The Effect of CO_2 Concentration at Absorber Inlet



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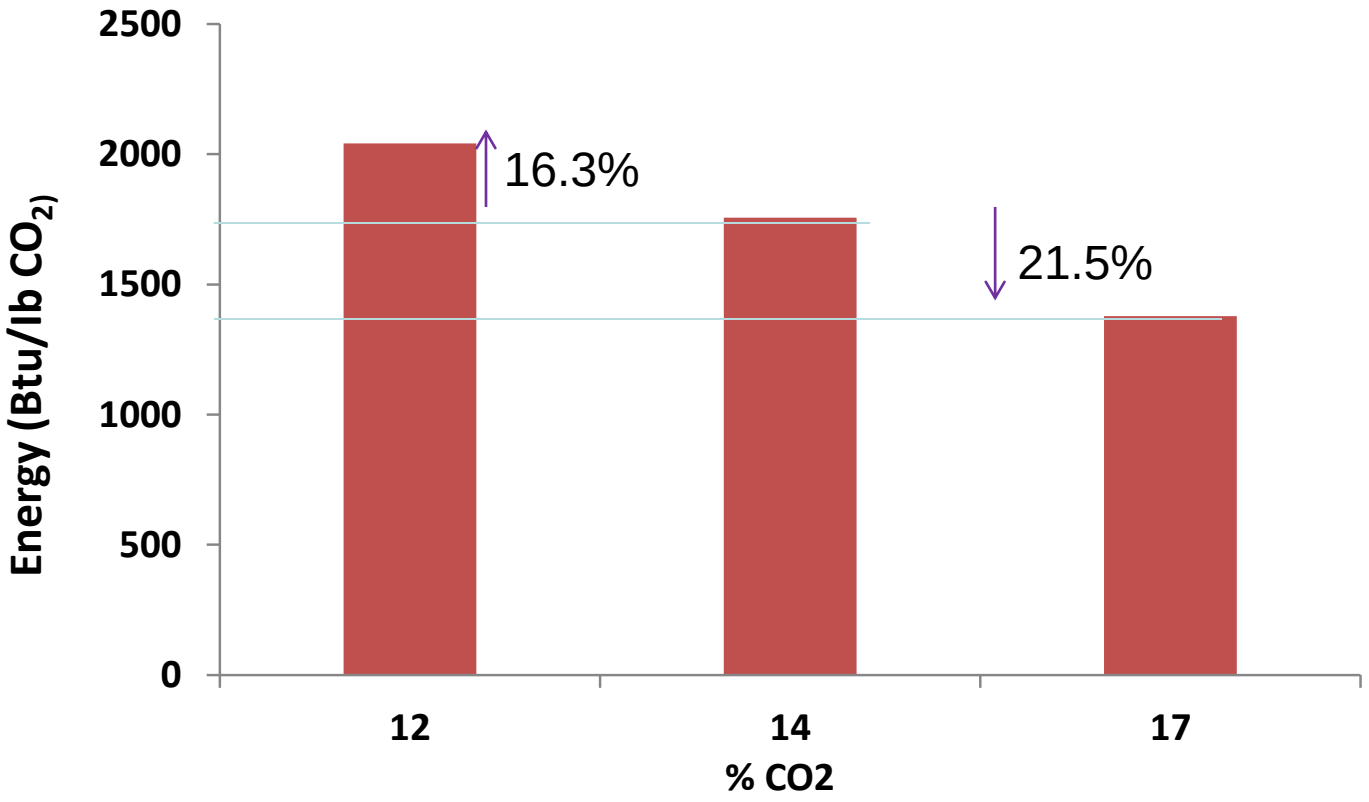
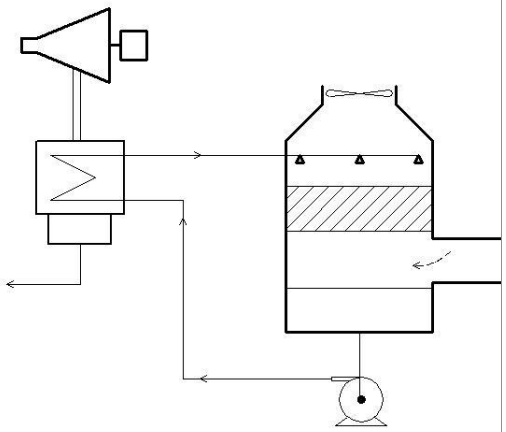
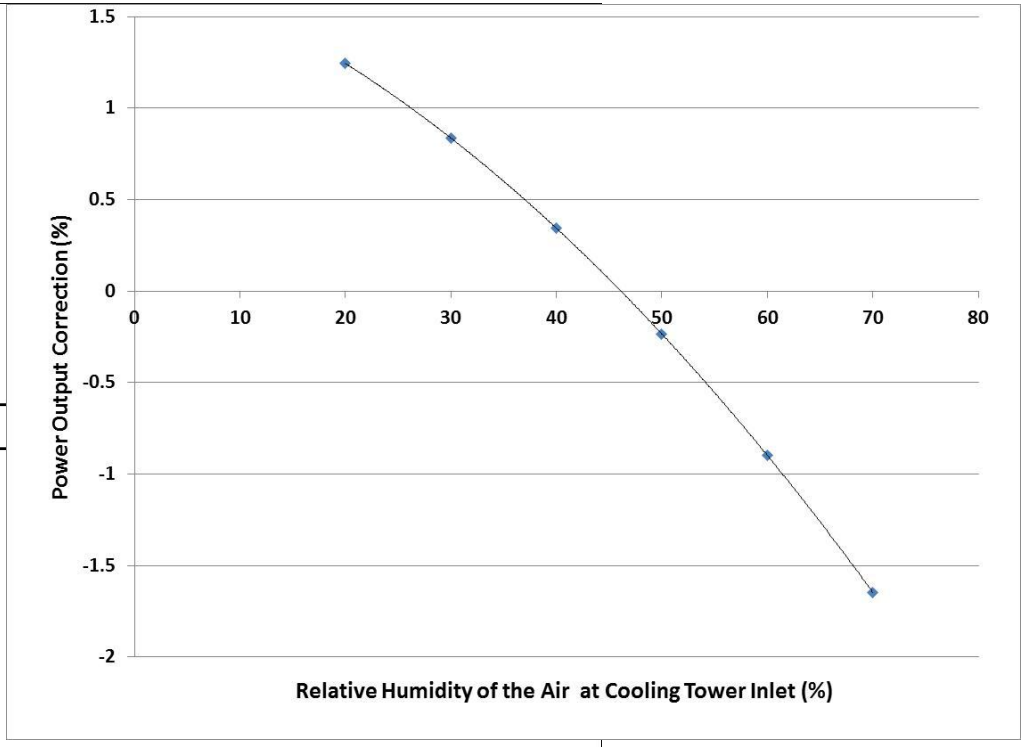
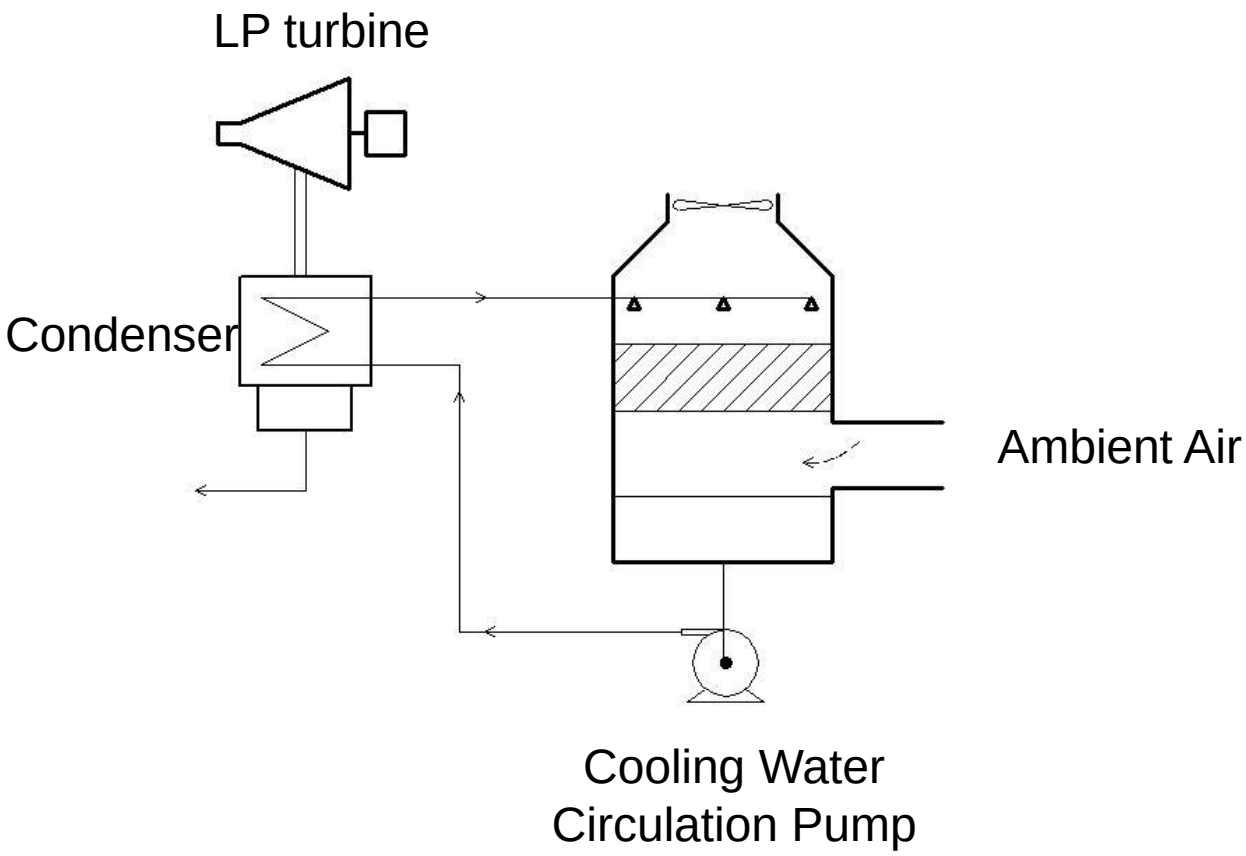


Background: Ambient Relative Humidity at Turbine Output

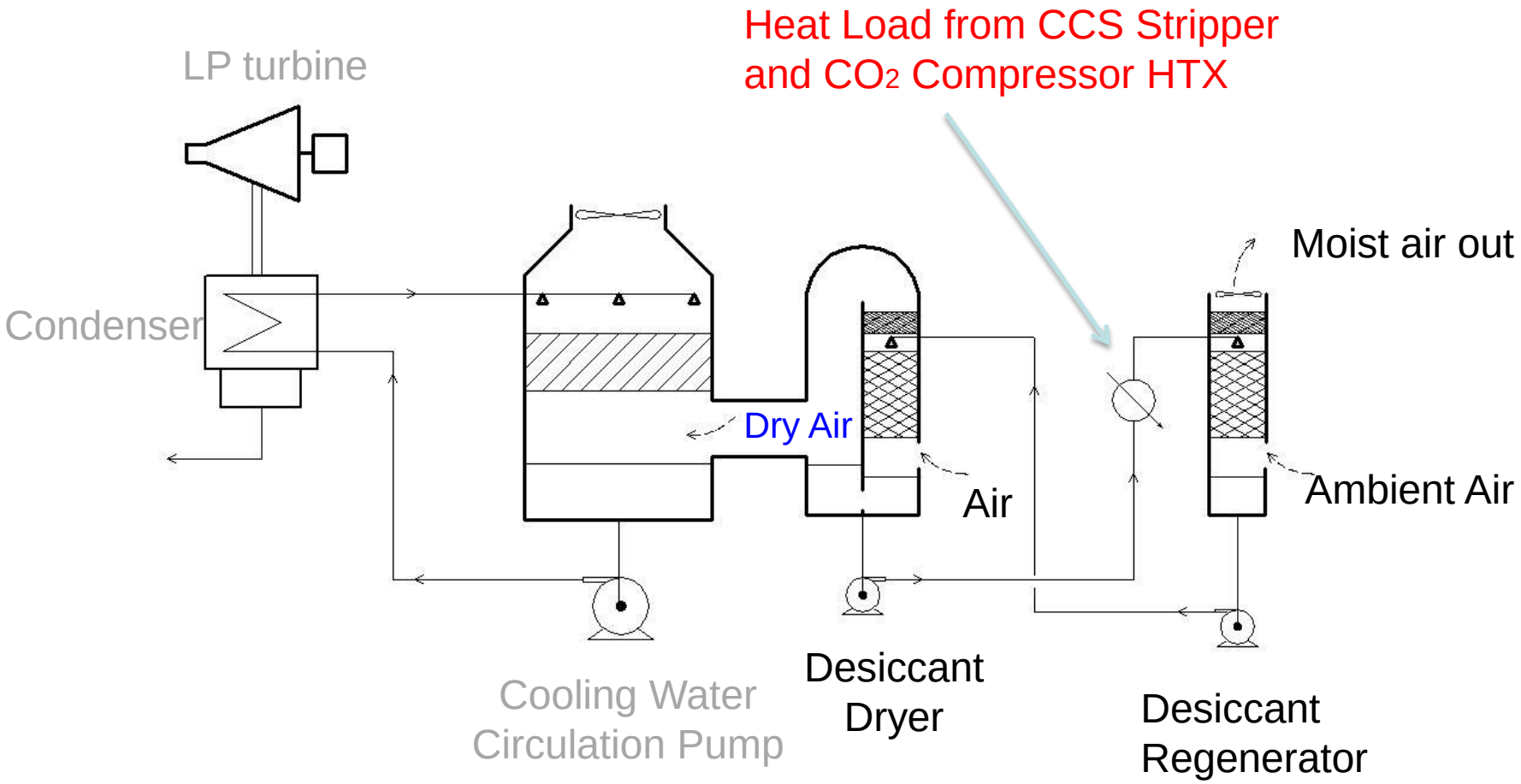




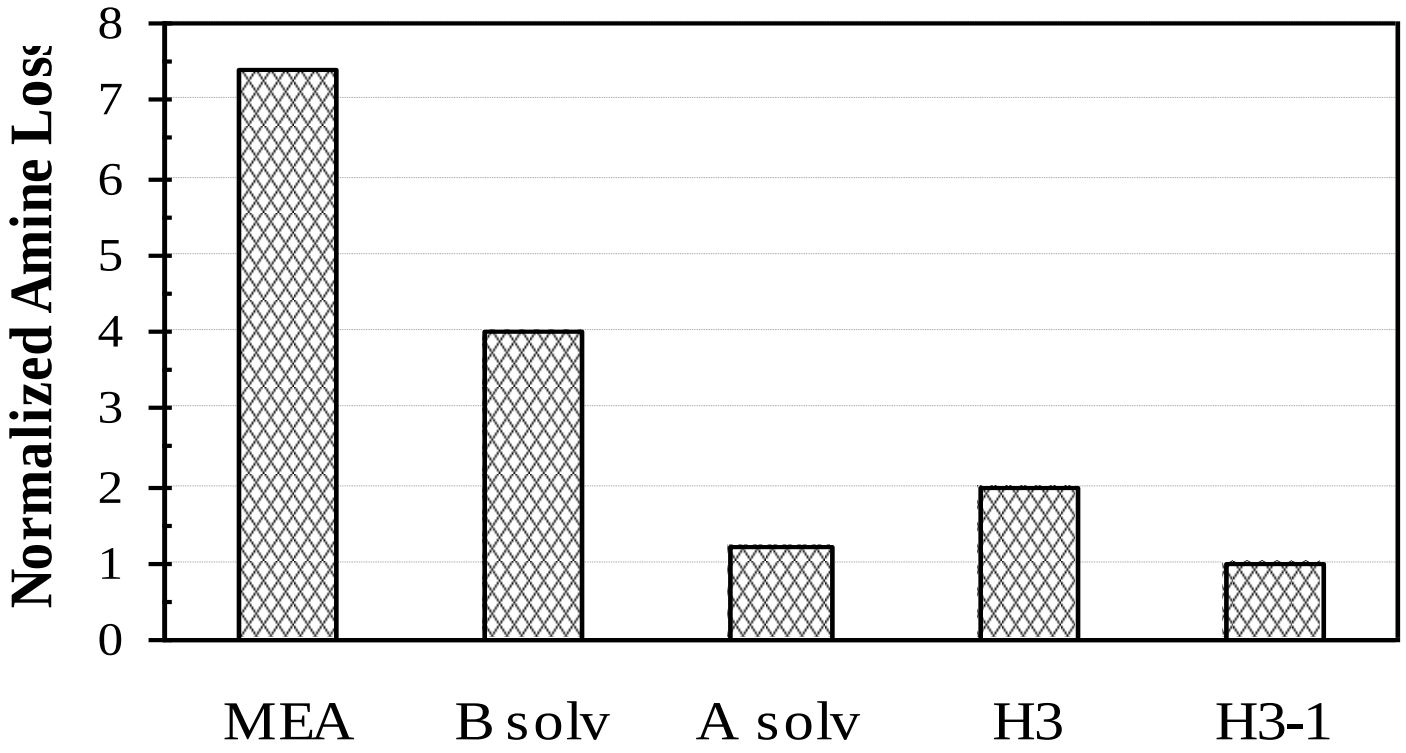
Conventional Cooling Tower



Cooling Tower With Heat Integration



Background: Hitachi Advanced Solvent (H3-1)



Experimental Work Plan

- The design, start-up/commissioning of a 2MWth test facility (1400cfm);
- Parametric investigation and long-term verification;
- New corrosion resistance coatings for material used in CCS system (access ports needed in scrubber and stripper areas);
- Solvent degradation (liquid product and gaseous emissions from CCS);
- A series of transient tests to quantify the ability of the carbon capture system to follow load demand.

Test Site: E.W. Brown

- Located at 815 Dix Dam Rd, Harrodsburg, KY 40330
- 40 miles from UKy-CAER

LKE's E.W. Brown

- Unit 1: B&W wall fired sub-critical boiler with Westinghouse 110 (gross) MW reheat turbine (1450 psig/1000°F/1000°F), ESP, and Low NOx burners;
- Unit 2: CE t-fired sub-critical boiler with Westinghouse 180 MW (gross) reheat turbine (1800 psig /1000°F /1000°F), ESP, Low NOx burners, and OFA;
- Unit 3: CE t-fired sub-critical boiler with Westinghouse 457 MW (gross) reheat turbine (2400 psig/1000°F /1000°F), ESP, Low NOx burners, and OFA.
- FGD common to all 3 units, in near future, SCR and SAM Mitigation Equipment.

Possible Test Coals During the Investigation

- Illinois/Western Ky bituminous (high sulfur)

Proximate Analysis	As-Received
% Moisture	14.3-16.3
% Ash	8.5-9.8
% Volatile	34.2-36.4
% Fixed Carbon	39.7-40.9
BTU	10580-11111
MAF BTU	14320-14431
% Total Sulfur	2.77-3.52
Sulfur Forms	
% Pyritic	1.4-1.9
% Sulfate	0.03-0.04
% Organic	1.4-1.6

Ultimate Analysis	As-Received
% Moisture	14.51
% Carbon	60.79
% Hydrogen	4.29
% Nitrogen	1.31
% Chlorine	*****
% Sulfur	3.28
% Ash	8.5
% Oxygen (Diff.)	7.32
Chlorine D6721 Dry Basis µg/g	117

Mineral Analysis	% Ignited Basis
Phos. Pentoxide, P_2O_5	0.17
Silica, SiO_2	41.4
Ferric Oxide, Fe_2O_3	29.79
Alumina, Al_2O_3	20.16
Titania, TiO_2	0.93
Lime, CaO	1.31
Magnesia, MgO	0.79
Sulfur Trioxide, SO_3	1.05
Potassium Oxide, K_2O	1.89
Sodium Oxide, Na_2O	0.43
Barium Oxide, BaO	0.05
Strontium Oxide, SrO	0.03
Manganese Dioxide, Mn_3O_4	0.04
Undetermined	1.96

BPs and Tasks

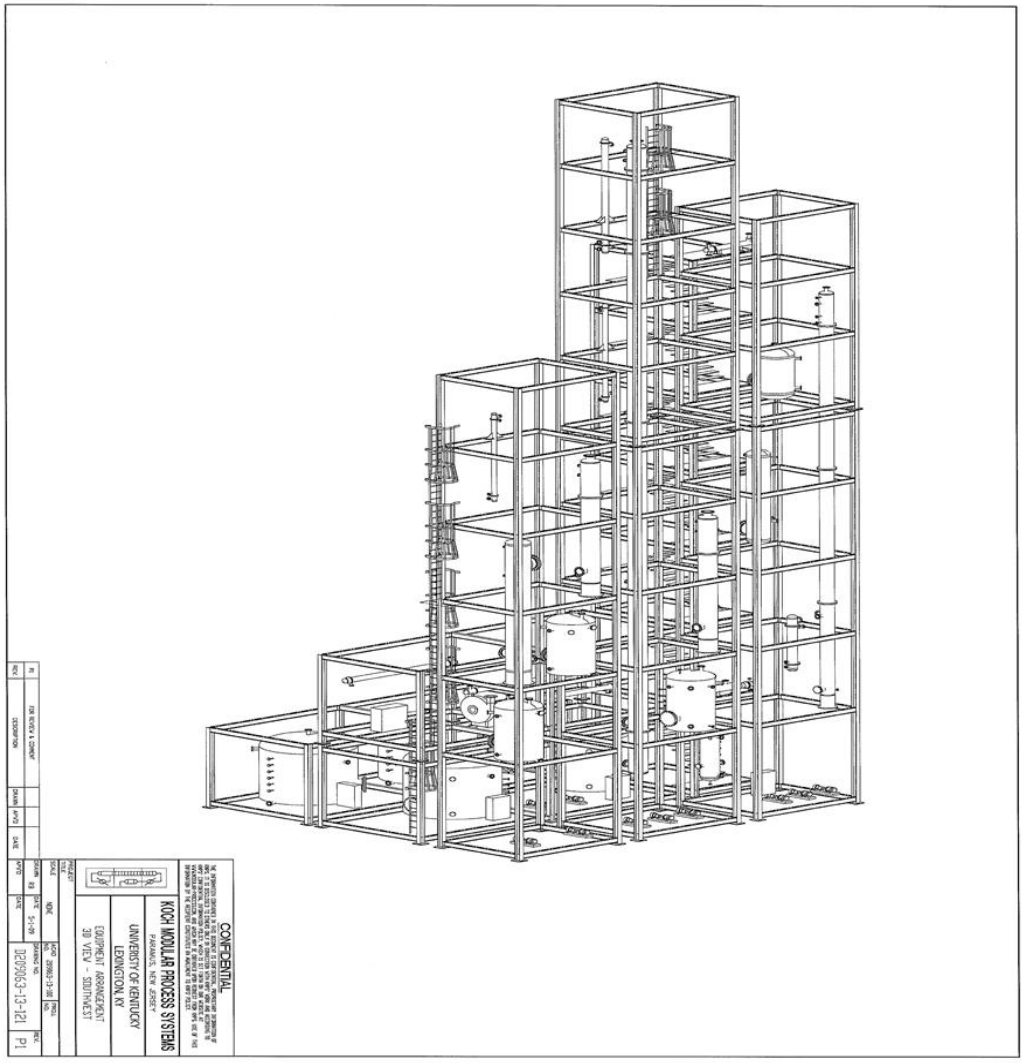
BP	Task	Name
	1.0, 5.0, 9.0, 17.0	Project Management & Planning
1	2.0	System and Economic Analysis.
	3.0	Initial EH&S Assessment
	4.0	Basic Process Specification and Design
2	6.0	Slipstream Site Suvery
	7.0	Finalized Engineering Specification and Design
	8.0	Test Condition Selection and Test Plan
3	10.0	System Engineering Update and Model Refinements
	11.0	Update of EH&S Assessment
	12.0	Site Preparation
	13.0	Fabrication of Slip-stream Modules
	14.0	Procurement and Installation of Control Room/Field
	15.0	Fabrication of Corrosion Coupons
	16.0	Slipstream Facility Erection, Start-up, Commissioning
4	18.0	Slip-stream Test Campaign
	19.0	Final Updater of Techno-Economic Analysis
	20.0	Final EH&S Assessment

Combined Flue Gas Extraction Point

Raw Flue Gas Data at MCR-GR Unit 3		
CO_2	% vol.	12.2
H_2O	% vol.	8.9
N_2	% vol.	
O_2	% vol.	5.1
NOx @ 6% O_2 dry	Lb/mmBtu	0.452
CO @ 6% O_2 dry	ppmv	
SO_2 @ 6% O_2 dry	ppmv	1,110.00
NH_3 @ 6% O_2 dry	ppmv	
PM @ 6% O_2 dry	mg/Nm^3	
Flue Gas Temperature	°F	300
Flue Gas Pressure	psia	
Flue Gas Flow to CCU	WSCFH	23,180,667

Note: Slip-stream extraction will be at the combined scrubber exit.

Preliminary 3-D View of Slipstream Unit



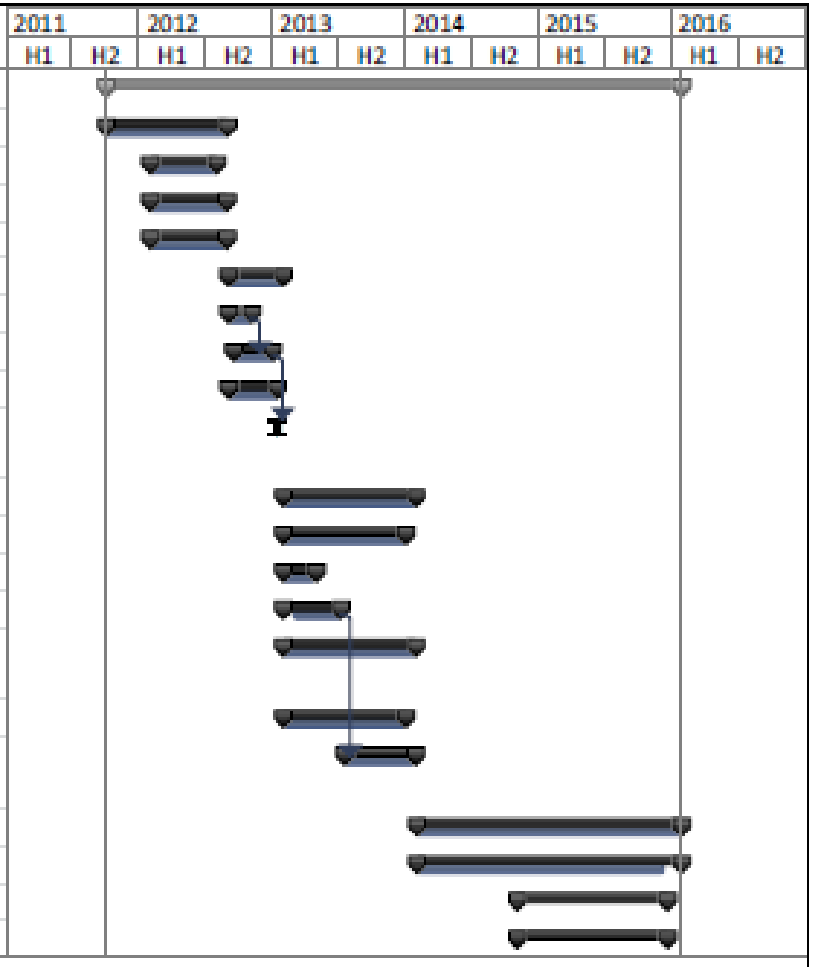
- 80 ft tall
- 1000 ft^2 footprint
  (15'x65', but could be rearranged)
- 5 to 6 modules with 100,000lbs/module
- Plus control/lab trailer and others

Progress and Current Status of Project

- Finalized budget for duration of project
- Finalized contract with UKy and DOE
- PSC with Smith Management Group (SMG)
- Several visits to Brown Station
- Finalized host site agreement with LKE
- Preliminary design with Aspen Plus complete and sent to Hitachi, EPRI, and KMPS for review
- RFP sent to KMPS for review
- Q4 2011 & Q1 2012 reports submitted to DOE
- BP1 continuation submitted to DOE
- Introduced multi-party NDA between all contributing parties
- Last stage of finalizing contracts with subs

Project Schedule

Task Name	Start	Finish
UKRF Master Gantt Chart DE-FE0007395	10/3/11	1/29/16
1 Project Planning and Management	10/3/11	8/31/12
2 Detailed Update of Techno-Economic Analysis	2/1/12	8/1/12
3 Initial EH&S Assessment	2/1/12	8/29/12
4 Basic Process Specification and Design	2/1/12	8/29/12
5 Project Planning and Management	9/4/12	1/31/13
6 Slipstream Site Survey	9/4/12	11/5/12
7 Finalized Engineering Specification and Design	9/18/12	1/2/13
8 Test Condition Selection and Test Plan	9/4/12	1/15/13
9 System Engineering Update and Model Refinements	1/7/13	1/22/13
10 Project Planning and Management	2/1/13	1/31/14
11 Update of EH&S Assessment	2/1/13	1/3/14
12 Site Preparation	2/1/13	5/2/13
13 Fabrication of Slip-stream Modules	2/1/13	7/8/13
14 Procurement and Installation of Control Room/Field Lab Section	2/1/13	1/31/14
15 Fabrication of Corrosion Coupons	2/1/13	1/3/14
16 Slipstream Facility Erection, Start-up, Commissioning and Shakedown	7/19/13	1/29/14
17 Project Planning and Management	2/3/14	1/29/16
18 Slip-stream Test Campaign	2/3/14	1/29/16
19 Final Update of Techno-Economic Analysis	11/6/14	12/23/15
20 Final EH&S Assessment	11/6/14	12/23/15



Moving Forward

- Finish the techno-economic analysis and submit report to DOE
- Finish the EH&S assessment and report
- Work with KMPS to obtain finalized design
- Prepare BP1 end report for DOE

Thank You