fuelcellenergy

Pilot Test of Novel Electrochemical Membrane System for Carbon Dioxide Capture and Power Generation

DE-FE0026580

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Omni William Penn Hotel, Pittsburgh, PA

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Electrochemical Membrane (ECM) Carbon Capture Pilot Pant Project

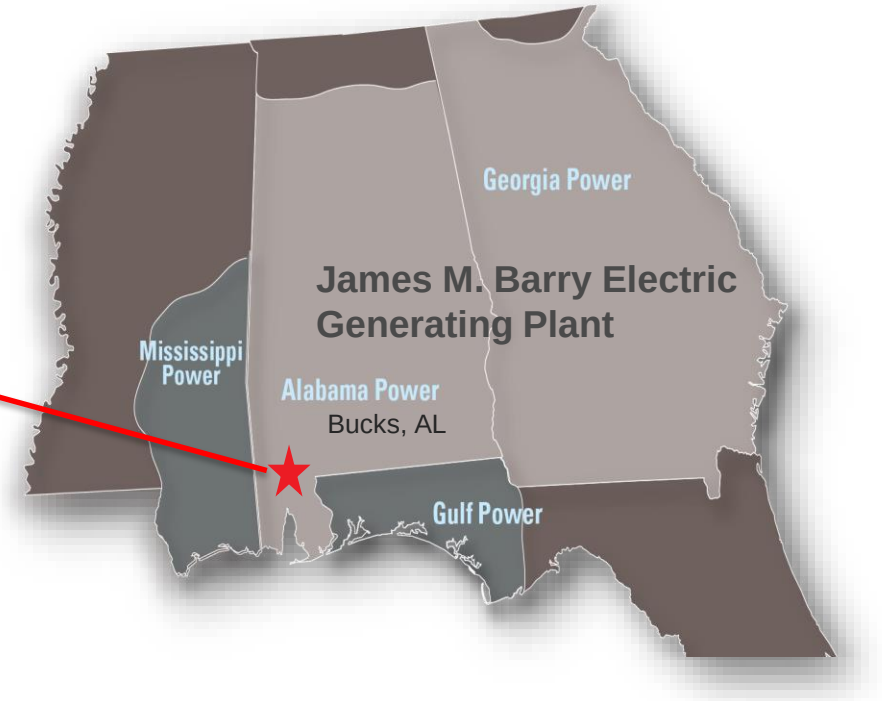
- Design a small pilot scale (60 T/D) carbon capture plant prototypical of a commercial unit
- Fabricate and install the pilot-scale plant at a coal facility
- Conduct >2 months of tests, demonstrating >90% capture (>95% CO_2 purity)
- Complete Techno-Economic Analysis (TEA) of ECM carbon capture applied to a 550 MW baseline supercritical PC plant, achieving 30% less COE compared to amine scrubbers
- Determine Environmental, Health and Safety (EH&S) requirements of ECM Carbon Capture plants

Project Team Structure

- TEA Support (review ECM system design, equipment and plant costing)
- Pilot system key equipment specification and selection
- Flue gas clean-up system design

- Demonstration site host
- Construction management
- Environmental support
- Pilot plant installation and test support

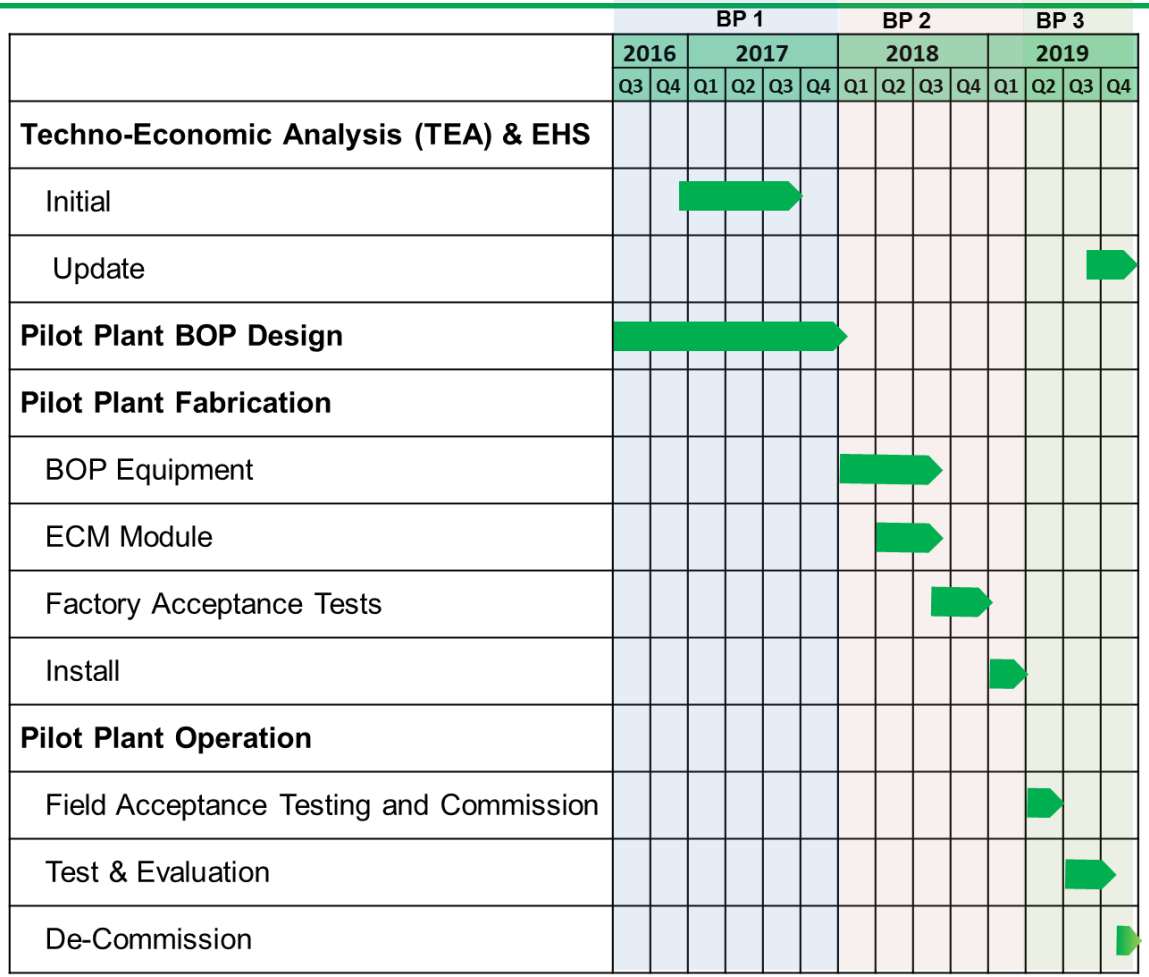
Pilot Demonstration Site



- James M. Barry Electric Generating Station, Alabama Power/Southern Co.
- Location: Bucks, Al
- Nameplate Capacity: 1,771 MWe, Mix of Coal and Natural gas

Southern Company

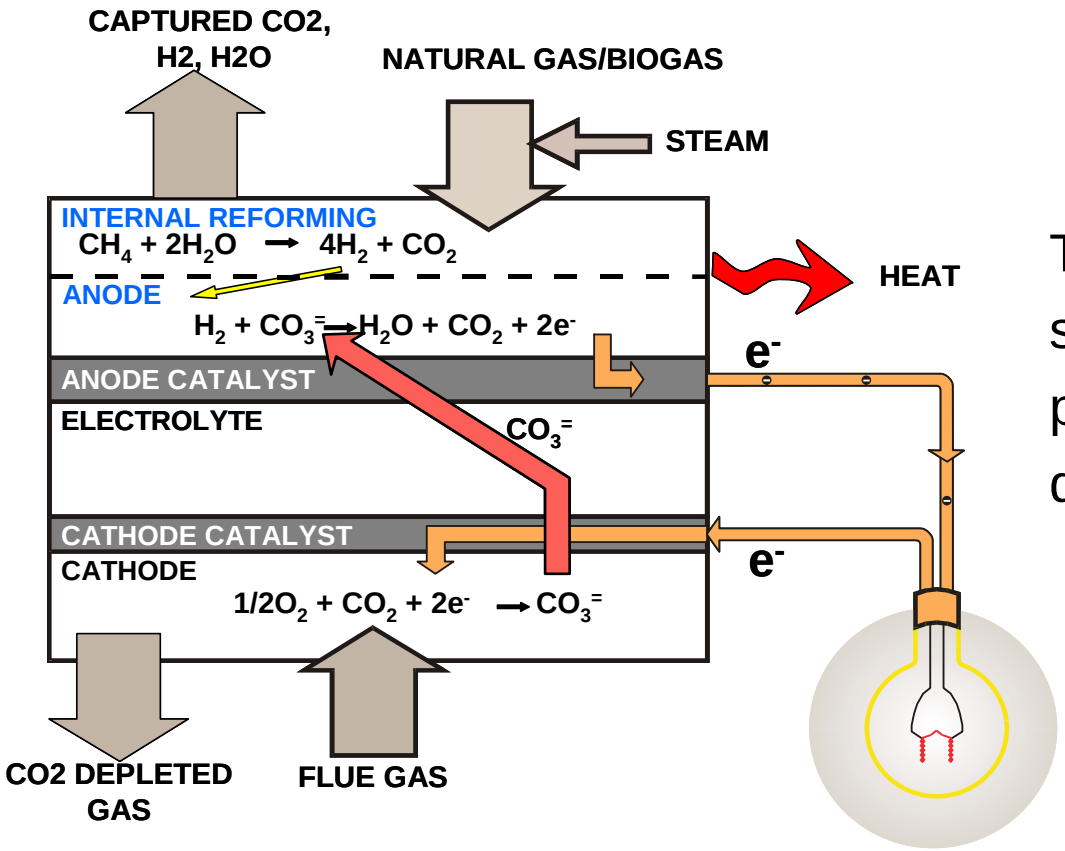
Project Schedule and Budget



	Budget Period 1 (10/1/2015 - 12/31/2017)		Budget Period 2 (1/1/2018 - 3/31/2019)		Budget Period 3 (4/1/2019 - 12/31/2019)		Total Project (10/1/2015 - 12/31/2019)	
	Government Share	Cost Share	Government Share	Cost Share	Government Share	Cost Share	Government Share	Cost Share
Total	$ 3,879,796	$ 969,949	$ 9,539,174	$12,136,072	$ 1,581,030	$ 2,011,442	$ 15,000,000	$15,117,464
Cost Share	80.00%	20.00%	44.01%	55.99%	44.01%	55.99%	49.80%	50.20%

Electrochemical Membrane (ECM) Technology Overview

ECM Operating Principle

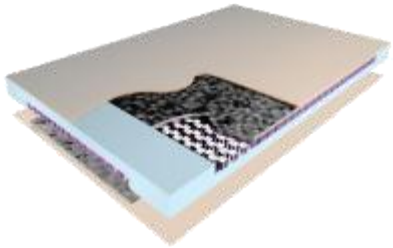


The driving force for CO_2 separation is electrochemical potential, not pressure differential across the membrane

Net Results

- Simultaneous Power Production and CO_2 Separation from Flue Gas of an Existing Facility
- Excess Process Water Byproduct
- Complete Selectivity towards CO_2 as Compared to N_2

Modular Technology



ECM Assembly

ECM Stack
(Using 400 ECM Assemblies)

ECM Module
(4 Stacks)

Enclosed Module

Modules Utilized in Large-Scale Applications

ECM Pilot Plant Development

Pilot Plant Performance

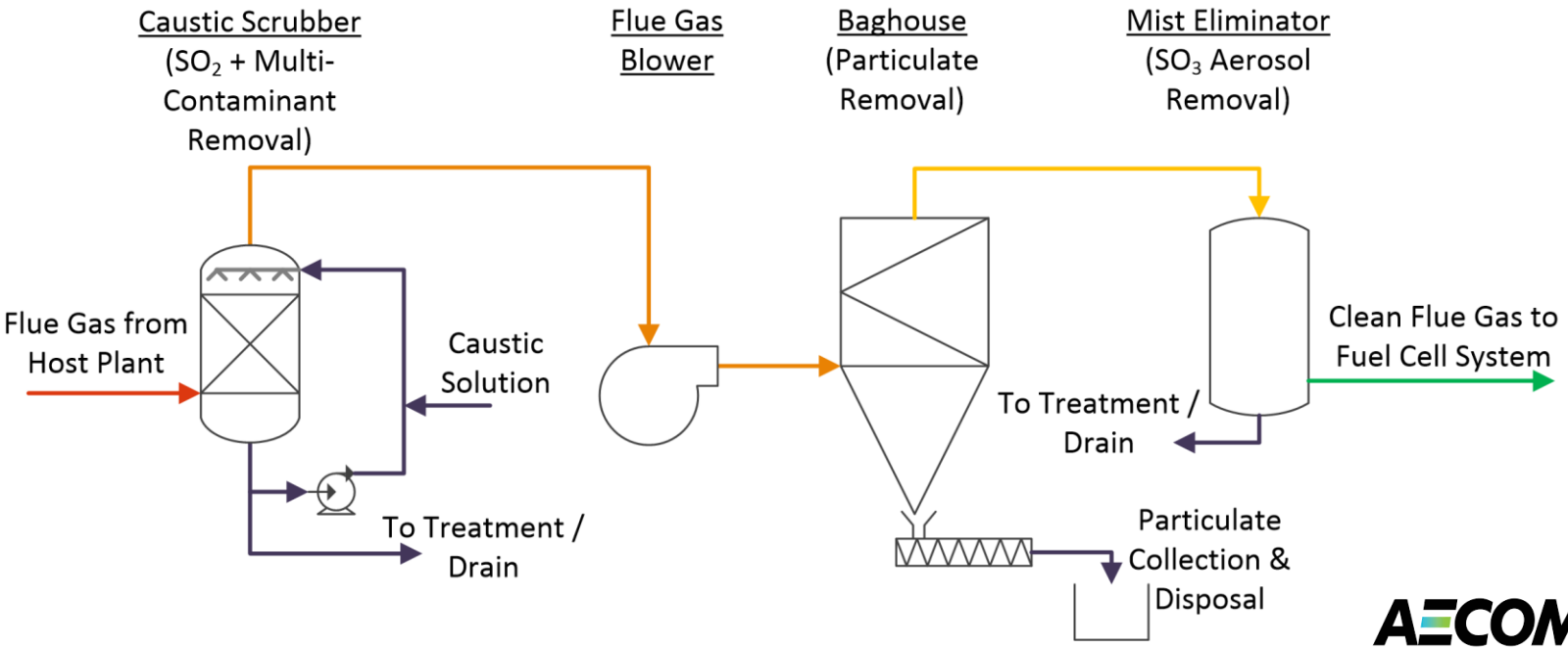
- Pilot Plant is designed to capture up to 60 tonnes per day of CO_2 from coal-fired power plant flue gas
- Operate in stand-alone power generation mode when either flue gas feed or CO_2 sink are unavailable (the system is water-neutral in this mode)

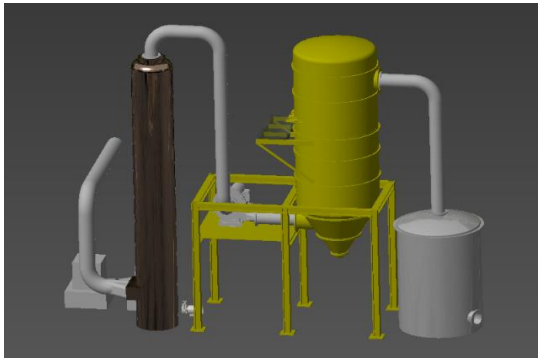
Operating Mode	90% Capture Coal-Derived FG	
MCFC Gross Power, DC	**1863.4**	**kW**
Energy & Water Input		
Natural Gas Fuel Flow	169.4	scfm
Fuel Energy (LHV)	2877.8	kW
Water Consumed/(Produced)	(1.8)	gpm
Consumed Power		
AC Power Consumption	(611.0)	kW
Inverter Loss	(74.5)	kW
Total Parasitic Power Consumption	**(685.6)**	**kW**
Net Generation & Efficiency		
CEPACS Plant Net AC Output	**1177.8**	**kW**
Electrical Efficiency (LHV)	**40.9**	**%**
Carbon Capture		
Total Carbon Capture, %	**92**	**%**
Carbon Capture from FG, %	**90**	**%**
Total CO_2 Captured, Tons per Day	**67**	**T/D**
CO_2 Purity	**99.6**	**%**

Pilot Plant DOE Project Status

- Site Access Agreement and Services Agreement executed between FCE and Southern Company Services
- Detailed analysis of tie-in locations and permitting requirements:
  - No air permit expected (exhaust routed back to main stack)
  - Water discharge permit applicability being investigated
  - Detailed design for tie-ins to be developed by AECOM
- Detailed design of pilot system:
  - Process configuration analysis and optimization were completed
  - Equipment specifications and RFPs are underway
  - Detailed process and electrical engineering (P&IDs, piping design, power distribution drawings, etc.) are ongoing
  - Plant packaging and skid design are underway

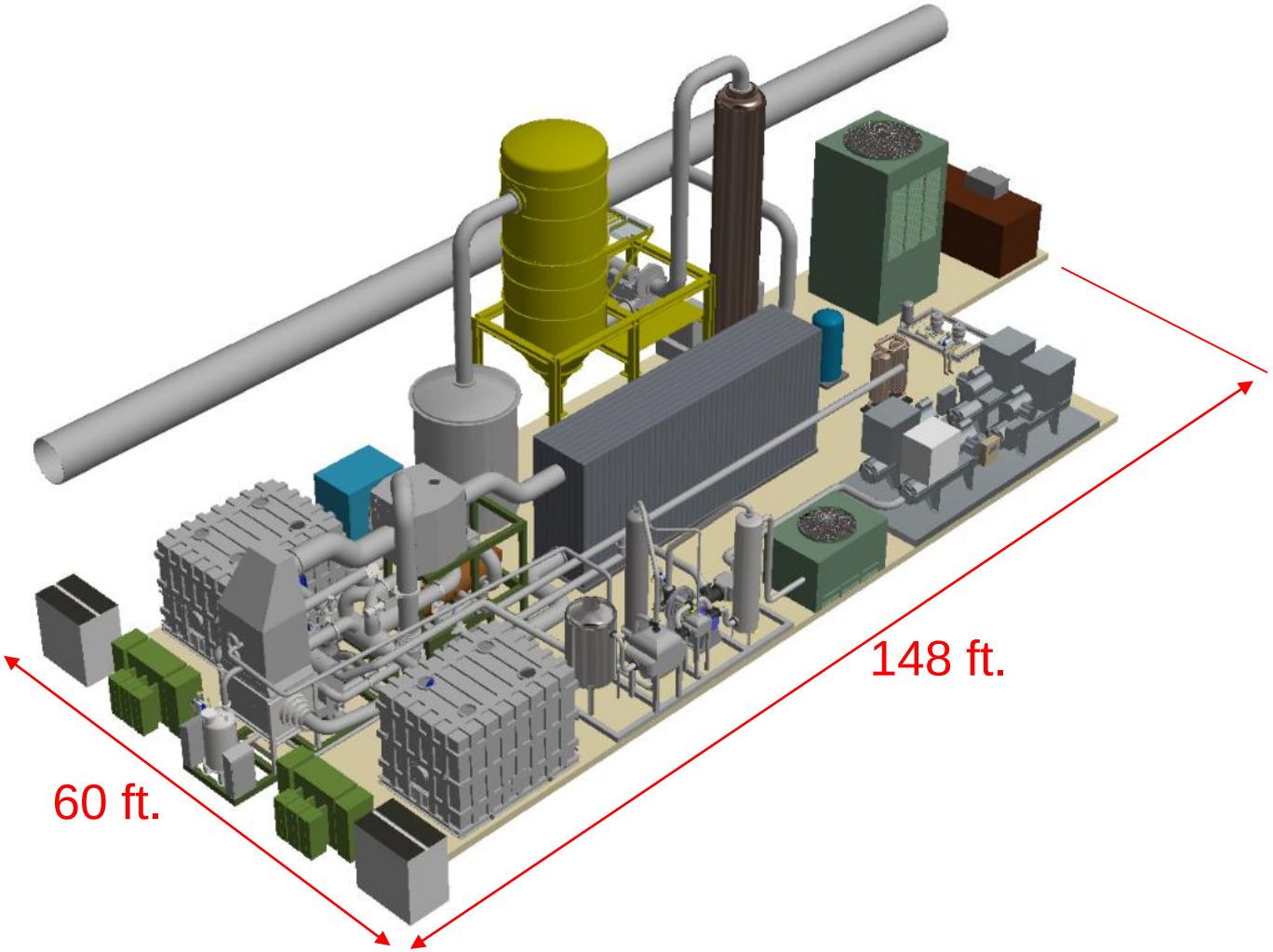
Flue Gas Polishing System





- Cleanup equipment train design, specifications, and RFQ process completed in partnership with AECOM
- Vendor bids selected for each piece of equipment, ready for purchasing

Pilot Plant Layout



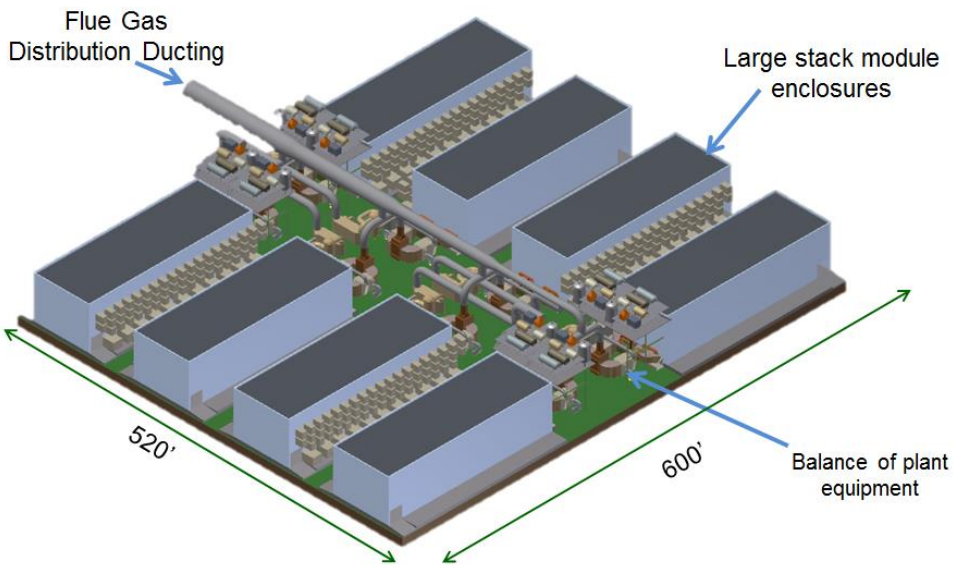
Overlay on Proposed Location

Techno-Economic Analysis

Large Scale Coal Capture System

Combined Electric Power and Carbon-dioxide Separation (CEPACS) System Concept Implementation for 550 MW Reference Supercritical PC Plant*

- **4.3 Million tons of CO_2 capture per year**
- 319 MW ECM-based system would capture 90% of CO_2 from 550MW plant
- 2.5 GWh ultra-clean power generated per year @ 40.7% Efficiency (based on HHV NG)
- Cost of CO_2 capture in low power value coal regions targeted to meet DOE goal of less than $40/tonne, or less than incremental $0.02/kWh COE. Cost of capture is significantly less in high power cost areas, where higher power value drives additional revenue to project

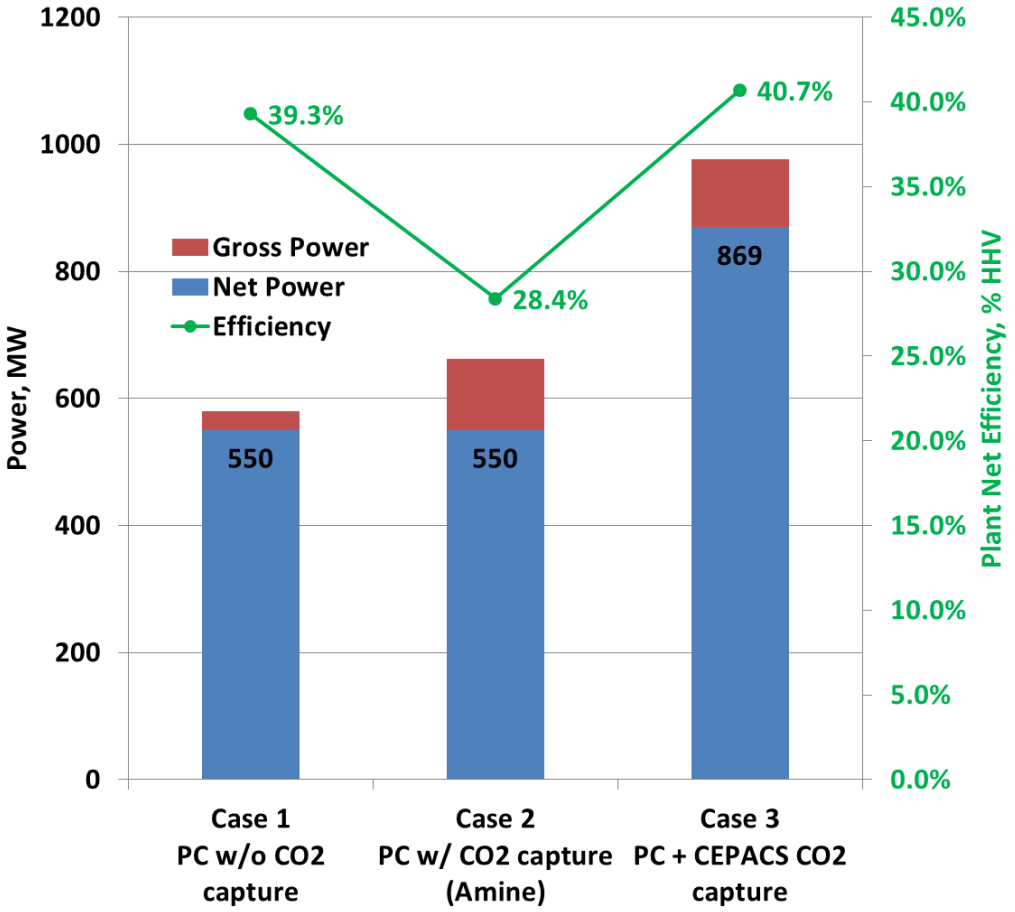


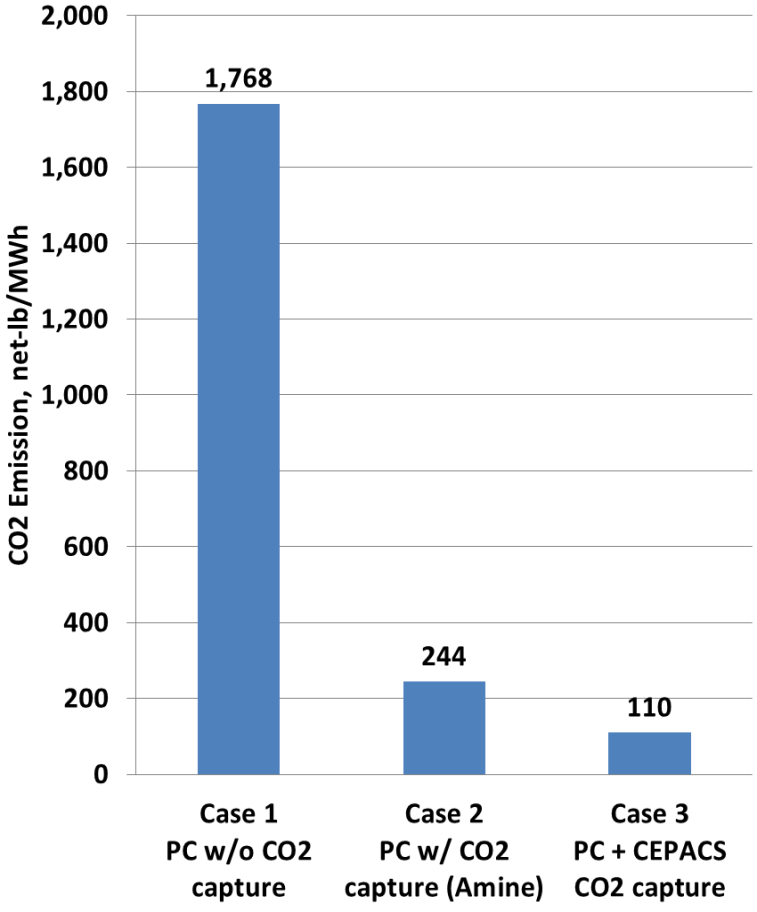
319 MW Plant for capture from coal systems, developed in DOE program

Future long term development for 90% capture of CO_2 from large coal power plants

* Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, Revision 2a, DOE/NETL-2010/1397, September 2013.

CEPACS System Performance

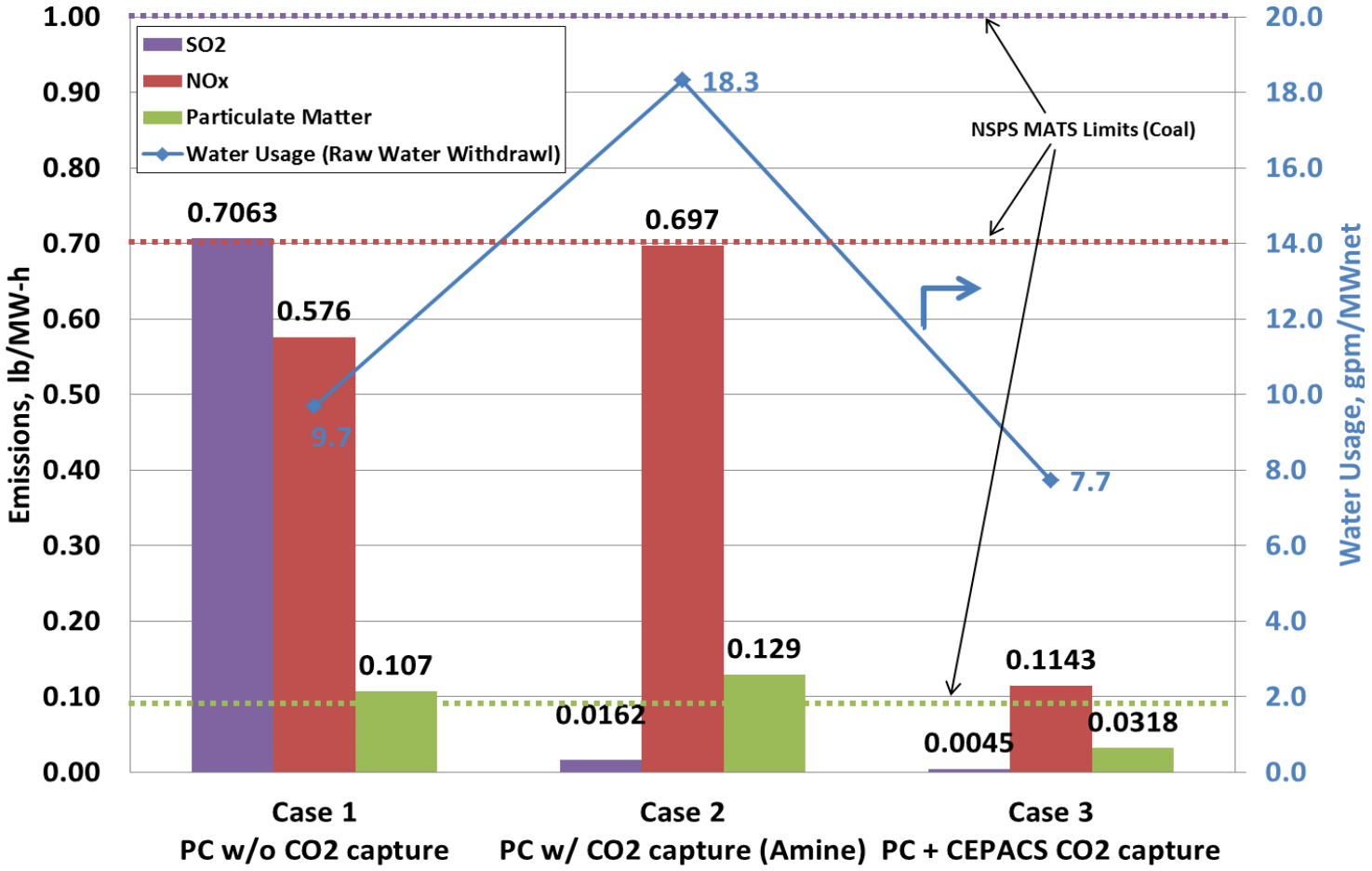




- CEPACS System increases power output of Baseline PC plant by 58%
- PC plant retrofitted with CEPACS system is 43% (12.3 percentage points) more efficient than the plant with amine scrubbing for carbon capture

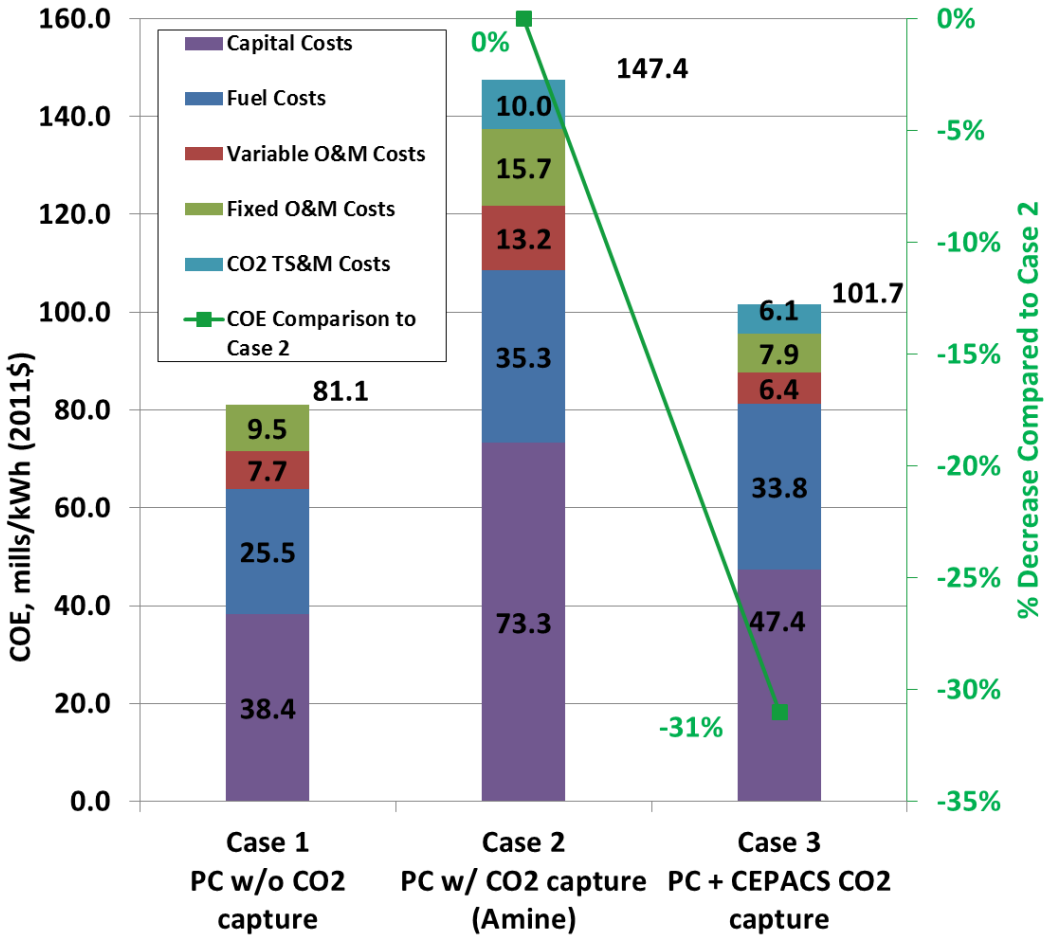
- PC + CEPACS System CO_2 Emissions are 55% lower than PC w/ Amine due to power generation (vs. consumption) @ 90% capture level

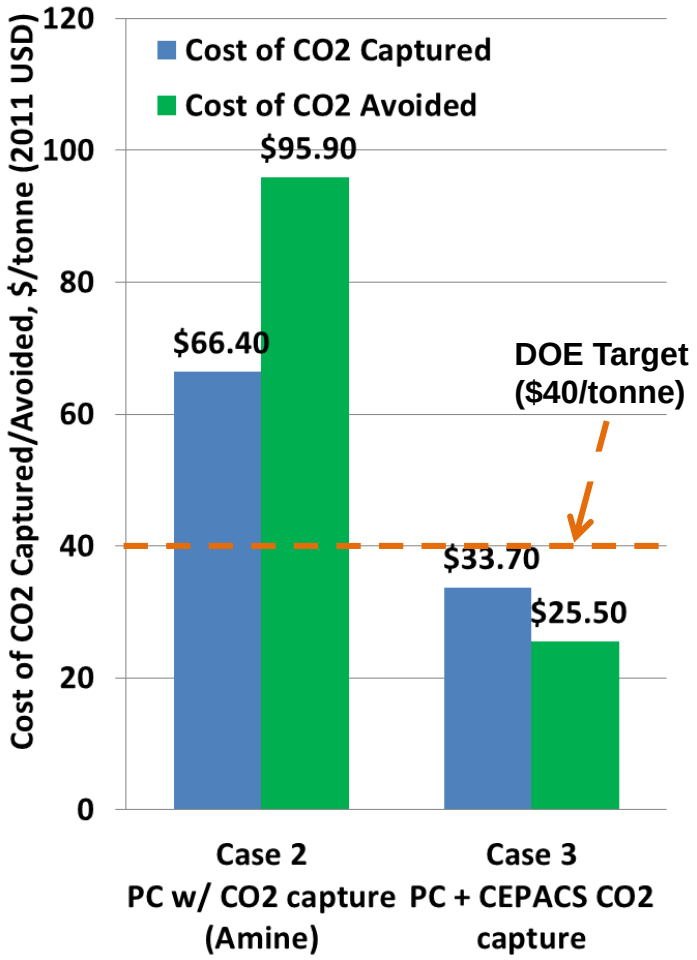
CEPACS System Performance: Emissions and Water Usage



- PC plant retrofitted with CEPACS system has lower emissions of NO_x, SO_x, and Particulate Matter (PM) than a PC plant retrofitted with Amine scrubber for CO_2 capture, below MATS limits
- CEPACS system produces excess process water, resulting in:
  - 58% less raw water withdrawal than with amine scrubbing
  - 20% less raw water withdrawal compared to baseline plant *without* CO_2 capture

CEPACS System Economics



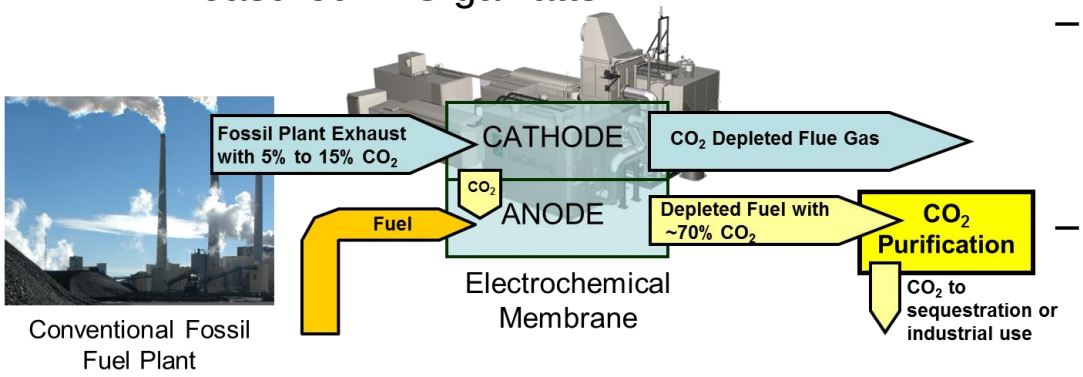


- PC plant retrofitted with CEPACS system has 31% lower COE than the plant with amine scrubbing for CO_2 Capture
- ECM-Based CEPACS System can meet DOE Target of <$40/tonne CO_2 captured (2011 USD)

ECM Carbon Capture Recent Projects

JDA with ExxonMobil

- **Collaboration partner with extensive resources**
  - World's largest energy company & public gas producer
  - Working interest in approximately 25% of the world's CCS capacity
  - ~7 million metric tons CO_2 captured for sequestration annually
- **Opportunity**
  - Integration with combined cycle gas plants
  - Global market opportunity measured in Gigawatts



ALBERTA INNOVATES

- Project evaluating ECM carbon capture in oil sands applications
- Project members:
  - Alberta Innovates
  - Husky Energy
  - MEG Energy
  - Canadian Oil Sands Innovation Alliance (COSIA) members: BP, Canadian Natural Resources Limited, Cenovus Energy, Devon Canada Corporation, Shell, and Suncor
- Sites Studied:
  - Husky Energy-owned Steam Assisted Gravity Drainage (SAGD) heavy oil thermal facility near Lloydminster, Saskatchewan, Canada
  - Scotford bitumen upgrading facility near Edmonton, Alberta, Canada

ECM Carbon Capture Summary

- Utilizes commercially proven fuel cell technology
- Modular and lower costs, enhanced economics from power co-production
- Produces excess process water
- Additional benefits of NO_X destruction and water production
- Provides opportunity for phase addition and incremental CO_2 capture

Acknowledgements

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