InnoSepra

Bench-Scale Development & Testing of a Novel Adsorption Process for Post-Combustion CO_2 Capture

DOE Funding Award DE-FE-007948

NETL CO_2 Capture Meeting

July 10, 2012

InnoSepra, LLC

Middlesex, NJ

About InnoSepra

- Started in 2007 by people with more than 70+ years of industrial gas experience
- > 50 commercialized technologies in > 150 plants at BOC (>$10 B in sales in 2006)
  - **PSA and TSA Air purification, UHP N_2 production for electronics, Nitrogen PSA, Oxygen PSA and VSA, CO_2 production and purification, and NO_X control**
- >>$100 million in value creation at BOC
- 110 U.S. and more than 500 international patents at BOC, and two major awards
  - **2001 Kirkpatrick Award for an ozone-based NO_X control process**
  - **1993 Kirkpatrick Award for olefin / paraffin separation**
- The current InnoSepra focus is on CO_2 capture, biogas purification, and bioethanol purification

Executive Summary

- Physical sorption to produce dry CO_2 at high purity (>98%) and high recovery (>90%) from the flue gas after the FGD.
- Potential for more than 50% reduction in the capital and more than 40% reduction in parasitic power for CO_2 capture compared to MEA
- The DOE project would address the need for testing with contaminants, and at a bigger scale (>1 tons per day) to address the process risks, the effect of contaminants, and to confirm process economics.

The Project Overview

Project Budget

Source	BP1 Oct 1, 2011 to Aug 31,2012	BP2 Sep 1, 2012 to Feb 28, 2012	BP3 Mar 1, 2013 to Dec 31,2013	Total
Dept of Energy	$850,187	$696,204	$1,048,494	$2,529,885
Cost Share	$212,547	$174,052	$268,756	$655,355
Total Project	$1,062,734	$870,256	$1,317,250	$3,185,240

Project Scope

First Budget Period

- Lab scale process data, isotherms, and heat and mass transfer rate measurement
- The effect of contaminants
- Process modeling
- Preliminary technical and economic feasibility study

Second Budget Period

- Bench unit design and construction (~5 tpd CO_2)
- Lab testing with synthetic flue gas

Third Budget Period

- Testing at the NRG WA Parish coal fired power station
- Updated technical and economic feasibility
- Preliminary technology EH&S risk assessment

Project Participants

DOE/NETL

- Elaine Everitt (Project Manager), David Lang, Lynn Brickett, Shailesh Vora, and James Black

InnoSepra

EPRI

- Process modeling, plant testing, and economic assessment
- Cost share

NRG

- Field testing, commercial feedback
- Cost share

New Mexico State University

- Fundamental adsorption data

PNNL

- Environmental assessment

Adsorptech

- Process design, equipment costing, and commissioning

Project Objectives

The overall project objective

- Demonstrate the effectiveness of the InnoSepra process to achieve at least 90% CO_2 removal with a potential pathway for no more than a 35% increase in LCOE for retrofits

Specific project objectives

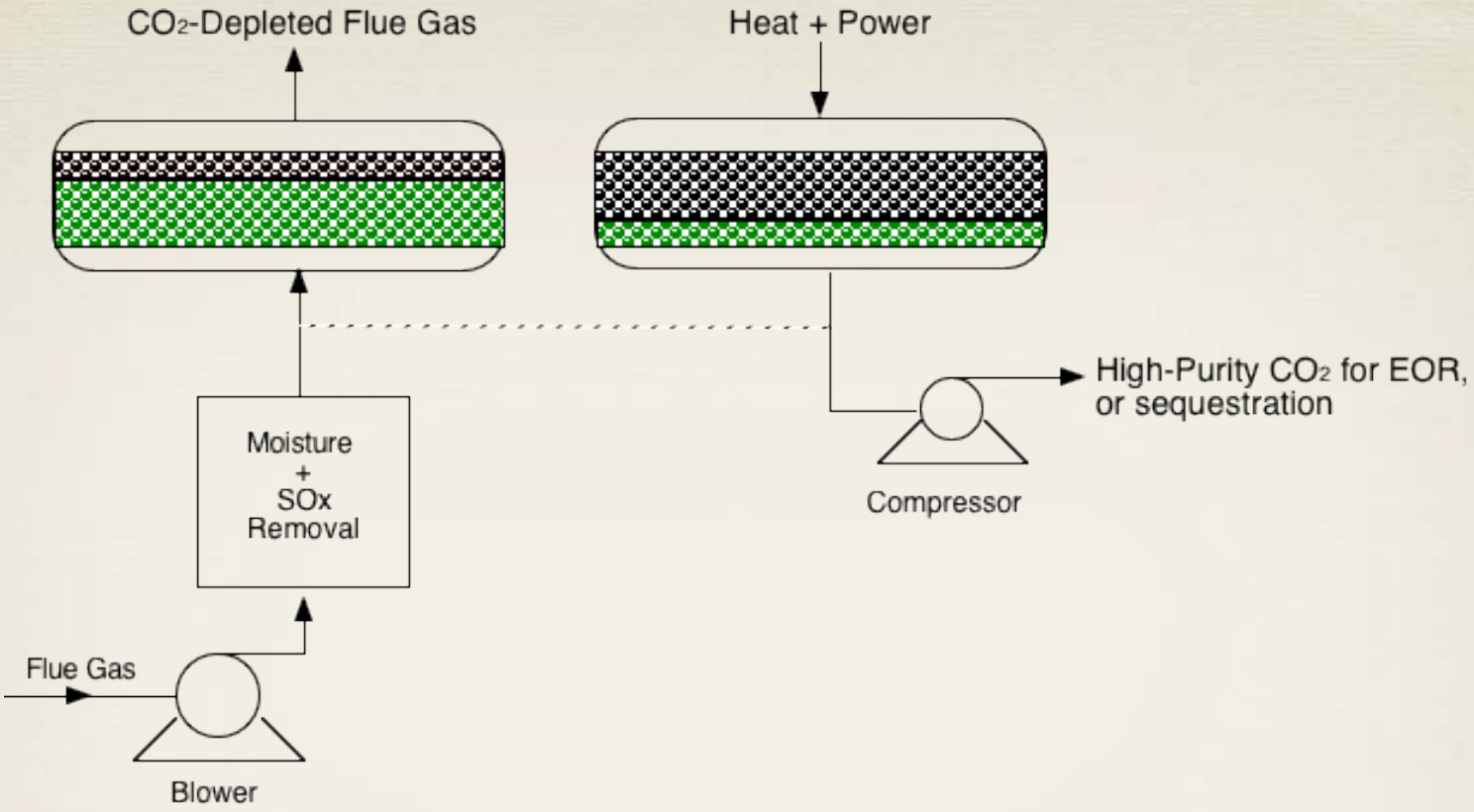
- Confirm the design basis for bench-scale testing based on lab scale results and process modeling
- Design, build and test the bench scale unit in the lab
- Test the bench scale unit on actual coal-based flue gas
- Capital, operating cost, and LCOE for a commercial 550 MW power plant

Background Information

Potential Sorbent-Based Processes for CO_2 Capture

- **Capture CO_2 by physical sorption**
  - 140-240 kcal/kg heats of adsorption
- **Capture CO_2 by chemical reaction**
  - CO_2 removed by reaction at 60-80^oC and the material regenerated at >120^oC
  - 740-940 kcal/kg heats of reaction
    - Similar to the amine-based absorption systems
  - Ex. $Na_2CO_3 + CO_2 + H_2O$ -------> $2\ NaHCO_3$
    ΔH_{rxn} = -740 Kcal/kg of CO_2

InnoSepra Process Overview



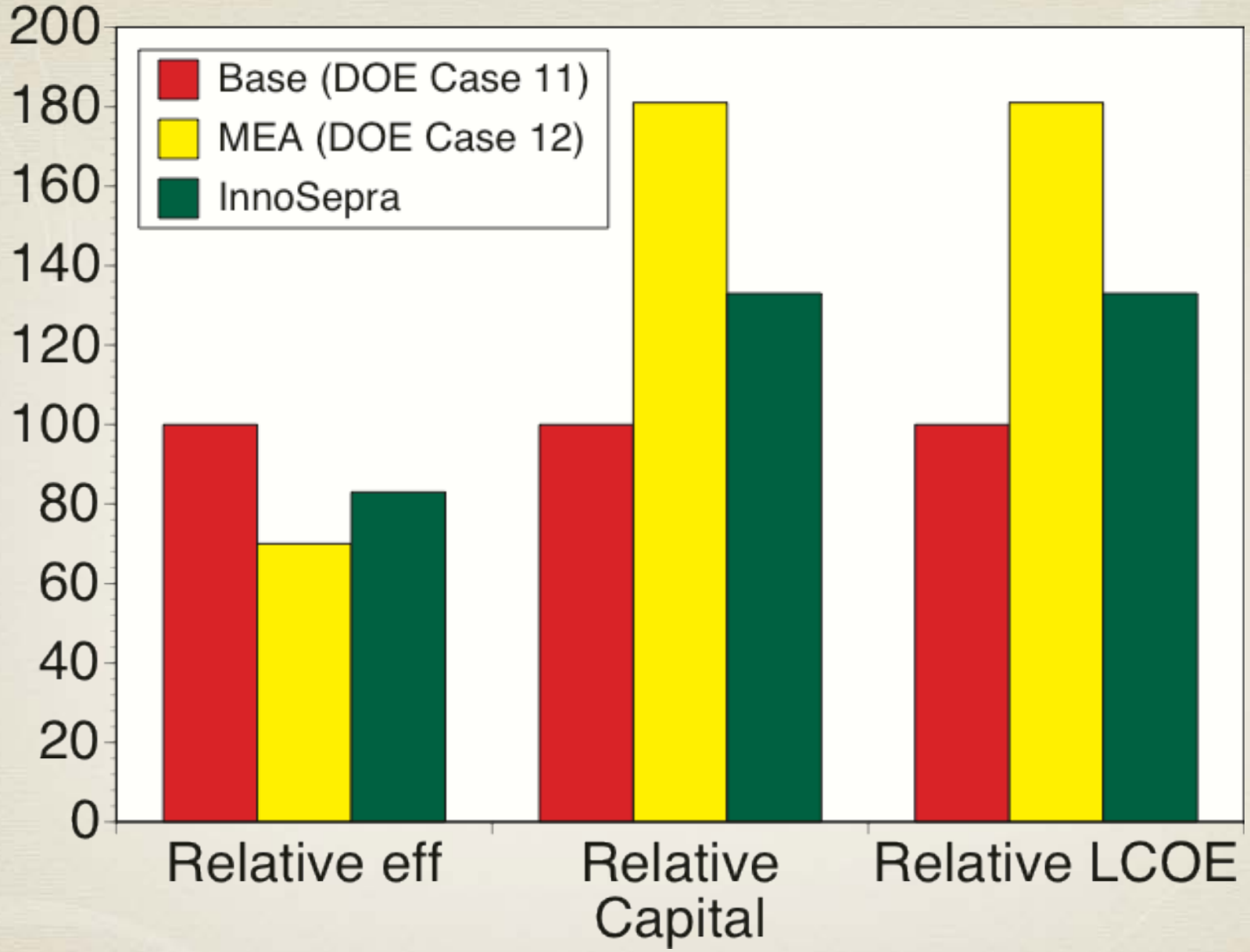
- Flue gas pretreatment to remove moisture, SO_X, and Hg
- High purity CO_2 (>98%) at high recovery (>90%) produced during regeneration
- Total regeneration energy requirement of less than 460 Kcal/Kg with potential for up to 25% reduction
- Regeneration temperatures of less than 100°C

Indicative CO_2 Recovery Cost for a 500 MW Supercritical PC Power Plant

Estimated Capital Cost	$240 MM
Power consumption including compression	80 MW
CO_2 production rate	10,000 tpd
Total annual cost	$95.4 MM
CO_2 Recovery Cost*	$29.0/ton

*Assuming 85% plant utilization factor.

Comparison with MEA for DOE Baseline Study

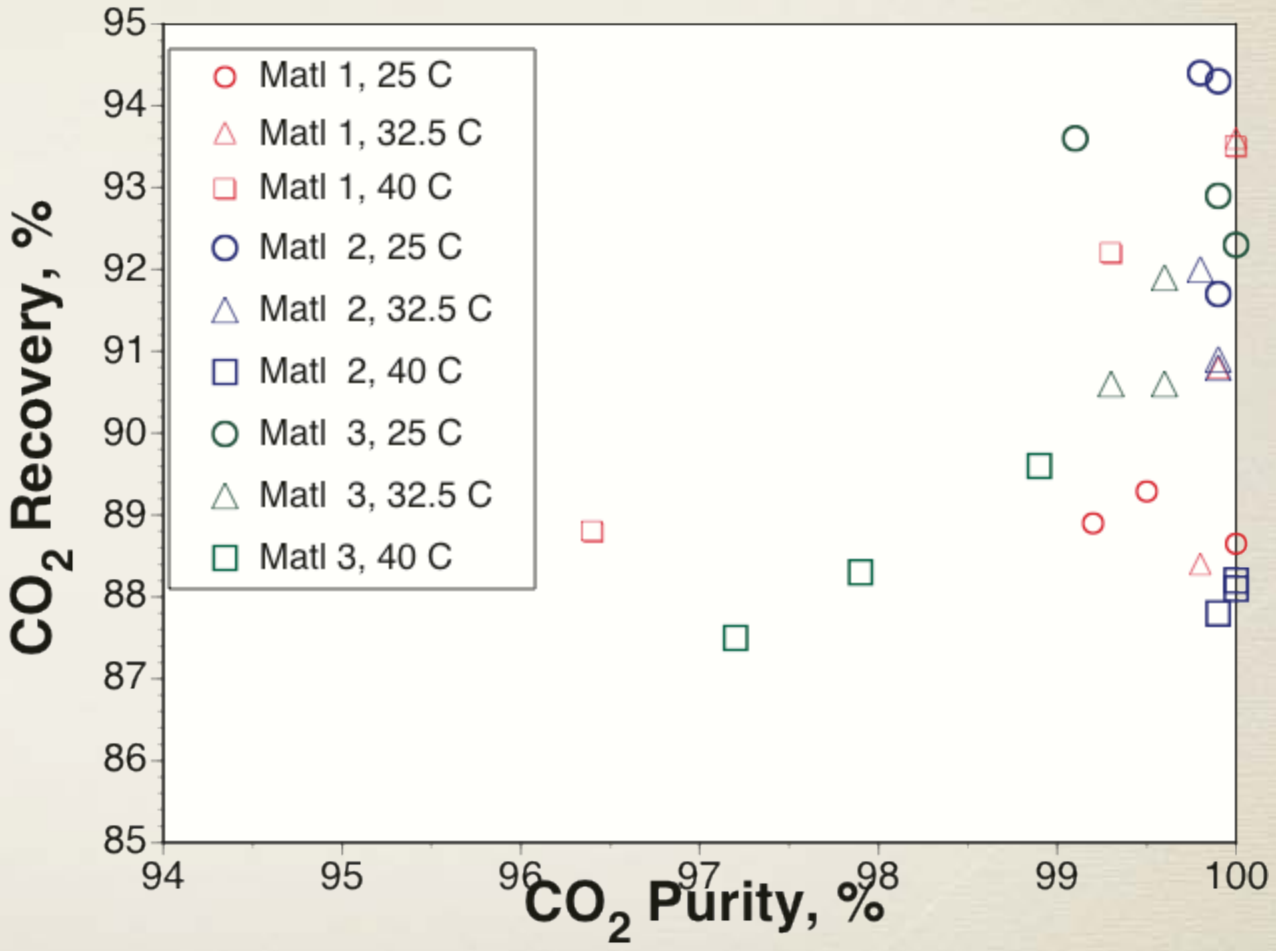


"Cost and Performance Baseline for Fossil Energy Plants", DOE/ NETL-2007/1281, Aug 2007. (http://www.netl.doe.gov/energyanalyses/pubs/Bituminous%20Baseline_Final%20Report.pdf)

Current Project Status

Technical Merit and Approach

- Task 2: Laboratory testing to identify preferred adsorbents



Technical Merit and Approach

Task 3: Obtain Heat & Mass Transfer Data

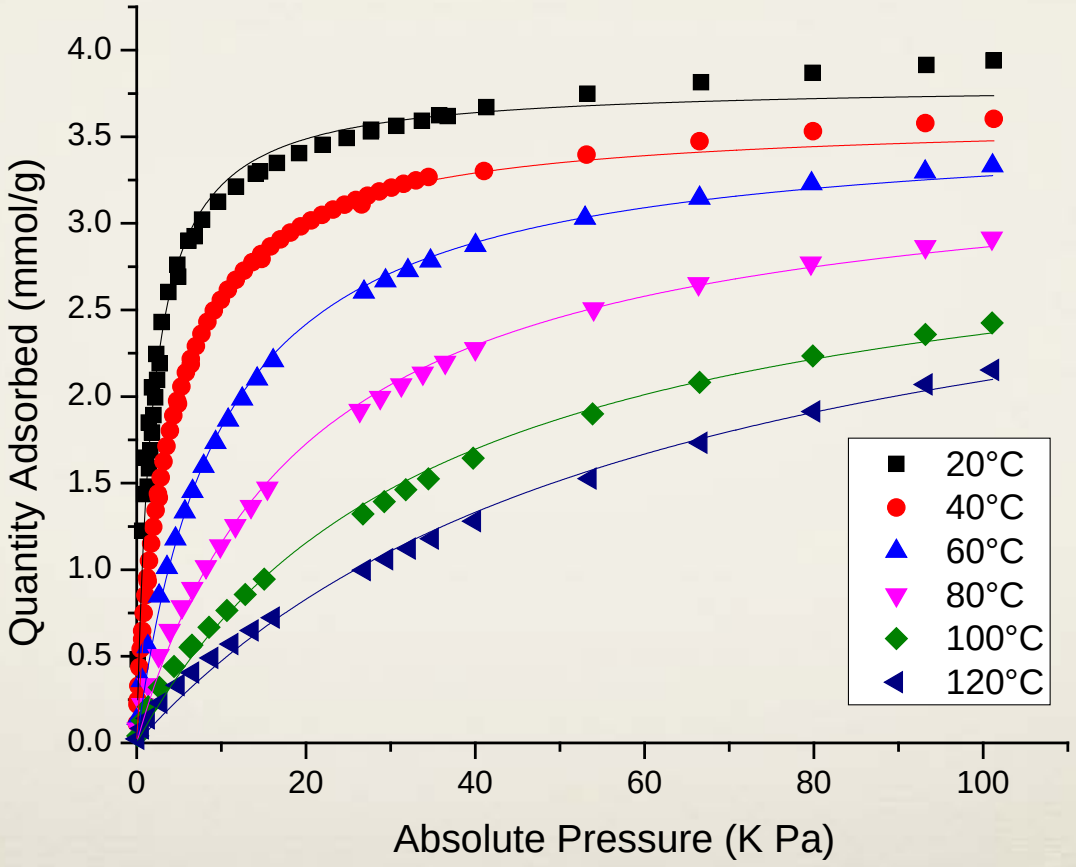
- Heat and mass transfer data were obtained for various process configurations and during various process steps
- The heat transfer rates have been increased significantly by optimization and by utilization of synergies between coupled heat and mass transfer

Task 4: Laboratory testing to determine the adsorbent requirements for SO_X and H_2O removal, and effect of NO_X on CO_2 adsorption

- Moisture and SO_X can be removed to a level of <1 ppm each based on several weeks of testing
- The equipment size for moisture and SO_X is smaller than the equipment for CO_2 adsorption
- No impact of NO on the CO_2 removal

Technical Merit and Approach

- Task 5: Obtain Thermodynamics, Kinetics, and Adsorbent Properties
  - Adsorption isotherms and kinetic data for CO_2, N_2, and O_2



CO_2

Future Plans

Current DOE Project

- Develop and Validate Process Model
- Complete Preliminary Technical and Economic Feasibility Study
- Design and Fabrication of Bench Scale Unit
- Lab Testing of Bench Scale Unit
- Install and commission at NRG's W.A. Parish plant
- Testing with actual flue gas for up to 8 weeks
- Set commercial unit process configuration
- Independent techno-economic analysis
- Prepare EH&S risk assessment

Next Scale Up Phase

- Testing at 5-10 MW scale
- Can be used to design up to 2,500 tpd CO_2 capture systems

Summary

- The InnoSepra CO_2 capture process combines several innovative features to reduce the capital and the power cost for CO_2 capture
  - A novel bed design, and process cycle allow production of >98% purity CO_2 at >90% recovery with materials with a heat of adsorption of 200 Kcal/kg to reduce the parasitic power to <450 Kcal/kg.
- The capital and the parasitic power based on an externally funded technology study show significant savings compared to MEA.
- A significant progress has been made since the start of the DOE project validating some of the process data.
- Potential approaches to further decrease the CO_2 capture cost have been identified.

Acknowledge and Disclaimer

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