InnoSepra

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

DOE Funding Award DE-FE-007948
Project-Kickoff Meeting
November 22, 2011

InnoSepra, LLC
Middlesex, NJ

Executive Summary

- The InnoSepra process utilizes physical sorption to produce dry CO_2 at high purity (>99%) and high recovery (>90%) from the flue gas taken 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 based on lab scale testing
- The process needs to be tested with flue gas containing SO_X, and Hg, and at a bigger scale (>1 tons per day) to address the process risks, and the effect of contaminants
  - This DOE project will address various process risks and scale up issues through lab testing and field testing, process simulation, and detailed economic evaluation

Project Objectives

The overall project objective

- Demonstrate the effectiveness of the InnoSepra sorbent-based post-combustion CO_2 capture technology, to achieve at least 90% CO_2 removal with a potential pathway for no more than a 35% increase in cost of electricity as a retrofit to coal-fired utility plants

Specific project objectives

- Confirm the design basis for bench-scale testing based on lab scale results and process modeling
- Design, build and test a bench scale unit in the lab
- Test the bench scale unit on actual coal-based flue gas from a power plant
- Perform scale up modeling, process and equipment design, engineering, and costing for installation of the technology at a commercial 550 MW power plant to estimate CO_2 capture cost

Background Information

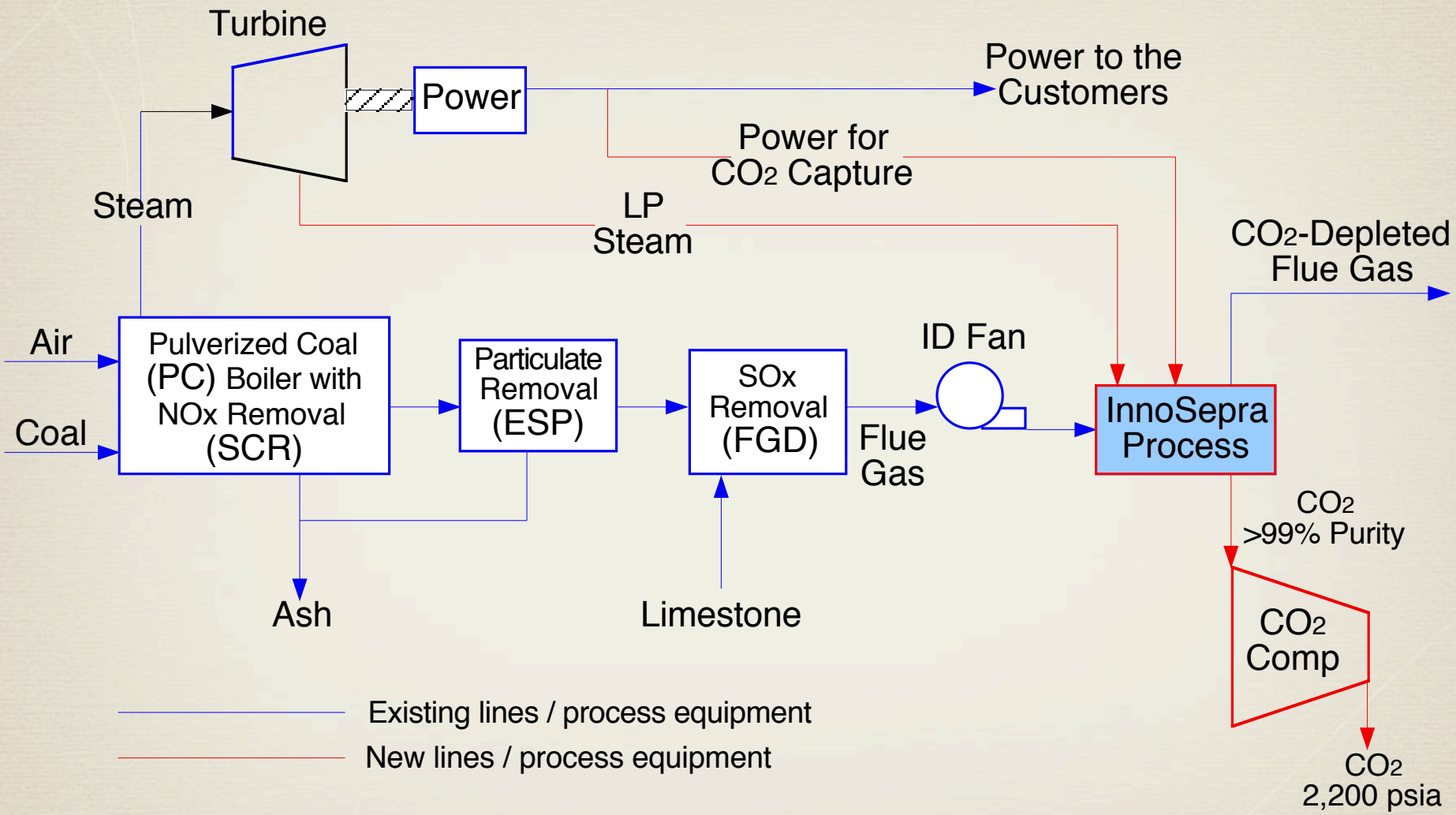
Post-Combustion CO_2 Capture Challenges

- Very large gas volumes at low pressure (~1.05 bara)
- Low CO_2 partial pressure, <150 mbar
- The impurities in the flue gas particularly NOX, SO_X, Hg, and particulates can have a significant impact on the solvents and sorbents used for CO_2 capture.
- Significant loss in power generation efficiency due to CO_2 capture, 7-10% absolute.

Sorbent-Based CO_2 Capture

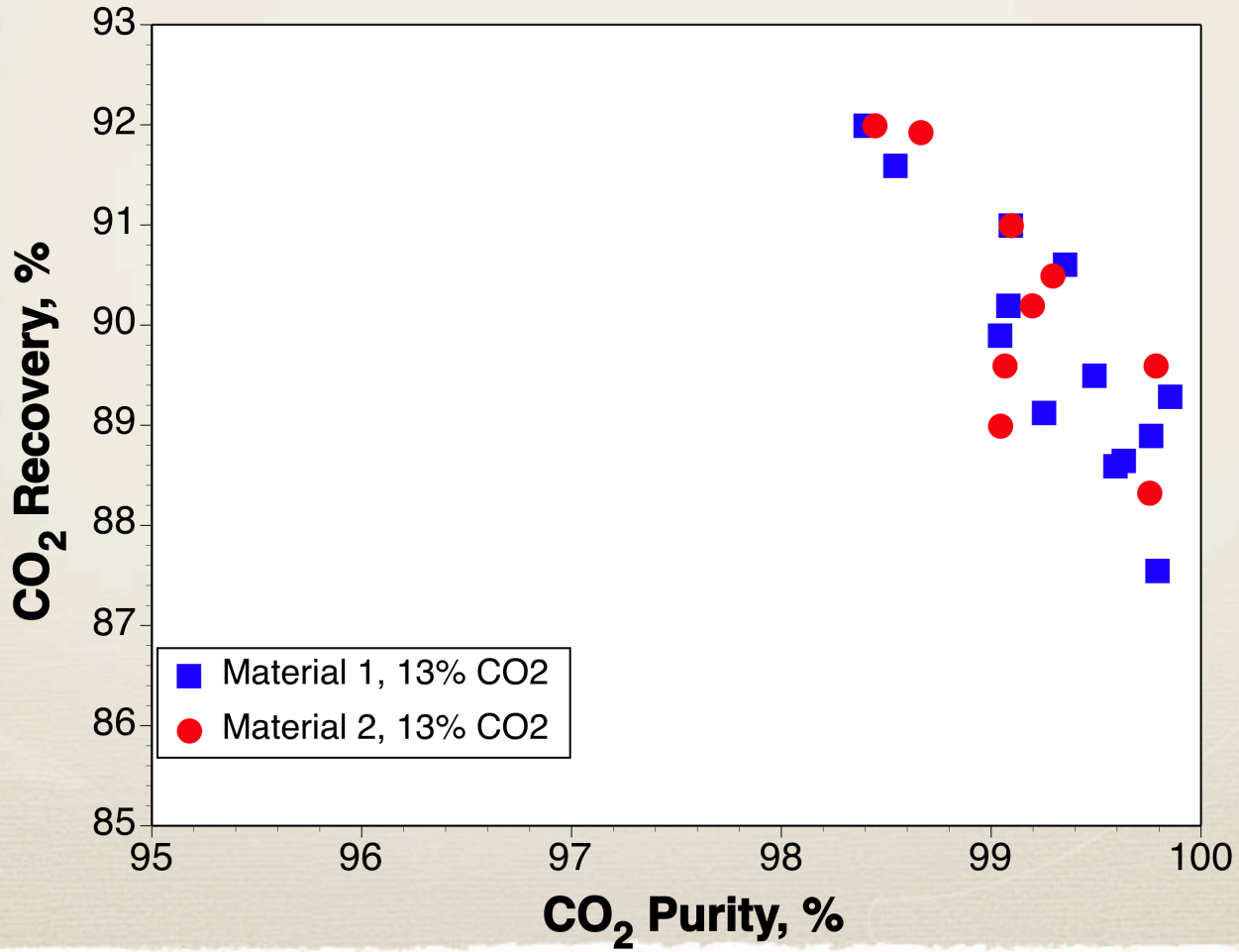
- **Capture CO_2 by physical sorption**
  - 140-240 kcal/kg heats of adsorption
    - Significantly lower than the total energy for amine systems
- **Capture CO_2 by chemical reaction** with amines / carbonates
  - 740-940 kcal/kg heats of reaction
    - Similar to the amine-based absorption systems
  - Ex. $Na_2CO_3 + CO_2 + H_2O$ -------> $2\ NaHCO_3$
    ΔH_{rxn} = -740 Kcal/kg of CO_2

CO_2 Capture from Power Plants

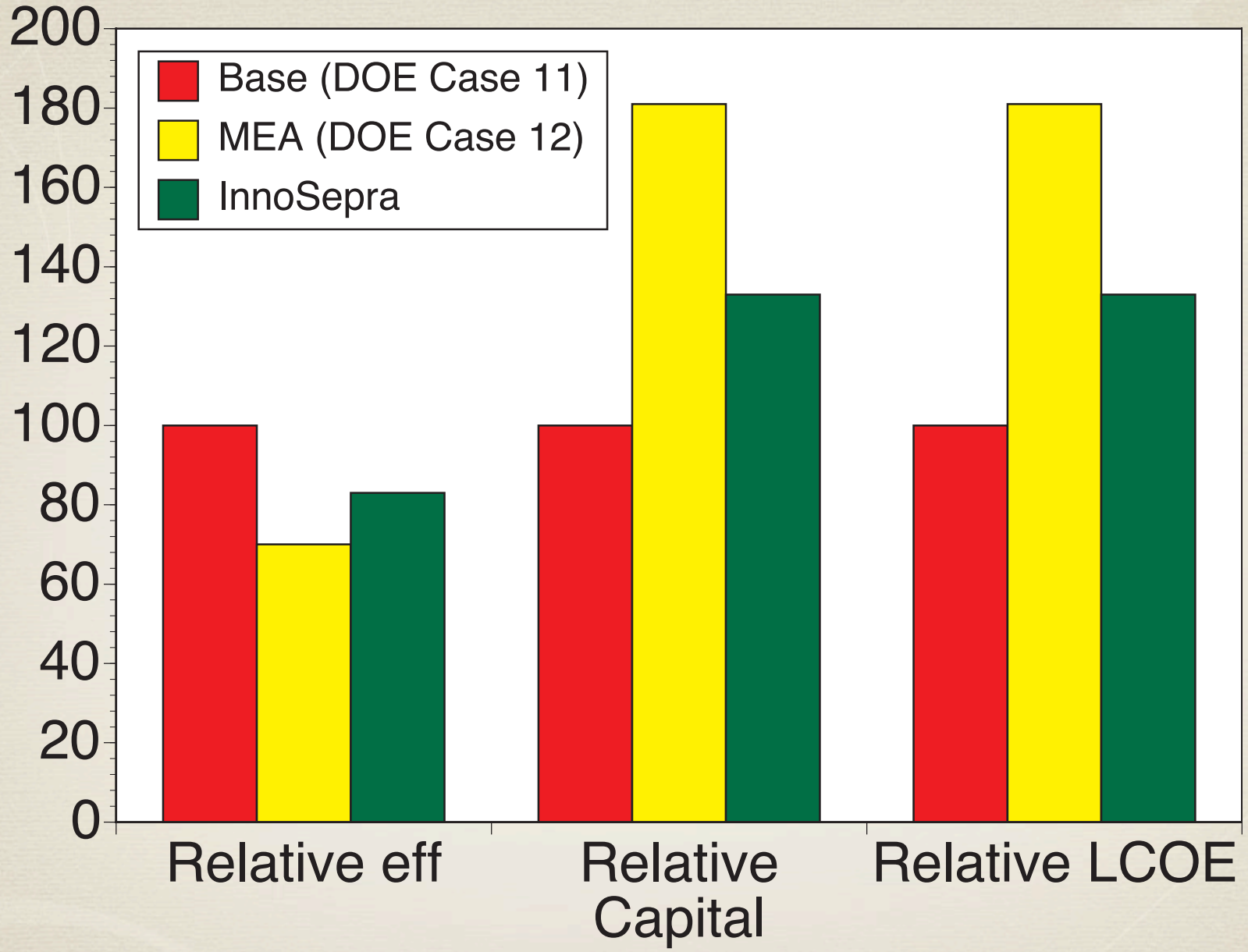


CO_2 Capture Testing Summary

- More than 10 commercial and laboratory materials tested for over 4 years, thousands of complete cycles
- 90% CO_2 recovery and over 99% purity under optimized conditions for a feed containing 13-15% CO_2
  - Possible to regenerate below 100°C with potential parasitic power consumption below 450 Kcal/Kg of CO_2.



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)

The DOE Project

Project Scope

In the first budget period InnoSepra will

- Experimentally determine the adsorption isotherms, and measure the heat and mass transfer rates
- Determine the effect of contaminants on the process performance
- Conduct a preliminary technical and economic feasibility study to demonstrate the commercial merits

In the second budget period InnoSepra will

- Design and construct the bench scale unit
- Commission the bench scale unit in the laboratory and conduct tests using a synthetic flue gas feed

In the third budget period InnoSepra will

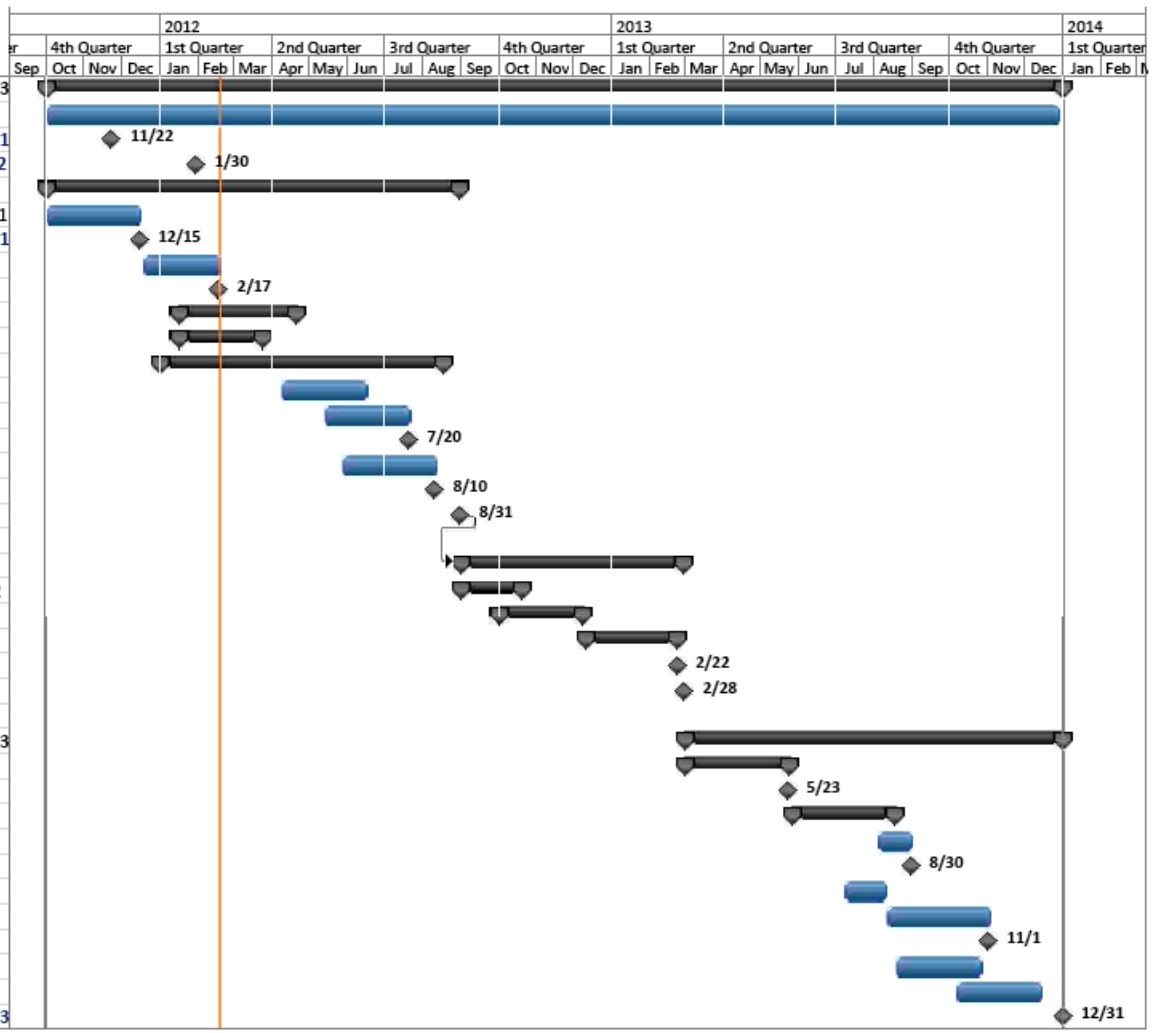
- Commission the unit at the NRG WA Parish coal fired power station and determine the performance of the InnoSepra process treating a flue gas from the FGD unit
- Update the technical and economic feasibility study based on lab and field tests
- Perform a preliminary technology environmental health and safety (EH&S) risk assessment

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 Timeline

ID	Task Name	Start	Finish
1	InnoSepra Bench Scale CO2 Capture process	Sat 10/1/11	Tue 12/31/13
2	1. Project Management Planning	Sat 10/1/11	Fri 12/27/13
3	Complete kick-off meeting	Tue 11/22/11	Tue 11/22/11
4	Complete Update of Project Management Plan	Mon 1/30/12	Mon 1/30/12
5	Budget Period 1	Sat 10/1/11	Fri 8/31/12
6	2. Bench Scale Unit Operating Conditions	Sat 10/1/11	Thu 12/15/11
7	Identify preferred CO2 adsorbents	Thu 12/15/11	Thu 12/15/11
8	3. Obtain Heat & Mass Transfer data	Mon 12/19/1	Fri 2/17/12
9	Heat and mass transfer data	Fri 2/17/12	Fri 2/17/12
10	4. Determine NOx, SOx Contaminants Effects	Mon 1/16/12	Fri 4/20/12
14	5. Adsorbent Properties	Mon 1/16/12	Fri 3/23/12
18	6. Develop & Validate Process Model	Mon 1/2/12	Fri 8/17/12
24	7. Preferred Heat Transfer Equip design	Mon 4/9/12	Fri 6/15/12
25	8. Preliminary Technoeconomic Feasibility Study	Mon 5/14/12	Fri 7/20/12
26	Technoeconomic study	Fri 7/20/12	Fri 7/20/12
27	9. Preliminary Design & Costing of Bench Scale Unit	Mon 5/28/12	Fri 8/10/12
28	Design and costing of bench scale unit	Fri 8/10/12	Fri 8/10/12
29	Go/No Go Decision	Fri 8/31/12	Fri 8/31/12
30			
31	Budget Period 2	Sat 9/1/12	Thu 2/28/13
32	10. Detailed design of Bench Scale unit for Field-testing	Sat 9/1/12	Fri 10/19/12
38	11. Fabricate Bench-Scale Unit for Field Testing	Mon 10/1/12	Fri 12/7/12
43	12. Lab Testing with Synthetic Flue Gas	Mon 12/10/1	Fri 2/22/13
48	Complete adsorbent testing in bench unit	Fri 2/22/13	Fri 2/22/13
49	Go/No Go Decision	Thu 2/28/13	Thu 2/28/13
50			
51	Budget period 3	Fri 3/1/13	Tue 12/31/13
52	13.Ship, Install & Commission Test Unit at NRG	Fri 3/1/13	Thu 5/23/13
56	Complete bench unit commissioning	Thu 5/23/13	Thu 5/23/13
57	14. Demonstrate the Process at NRG	Mon 5/27/13	Fri 8/16/13
63	15. Decommissioning/Dis-Assembly of Bench-Scale Unit	Mon 8/5/13	Fri 8/30/13
64	Bench unit decommissioning	Fri 8/30/13	Fri 8/30/13
65	16. Set Commercial Process Configuration	Mon 7/8/13	Fri 8/9/13
66	17. Updated Process Economics	Mon 8/12/13	Fri 11/1/13
67	Final technoeconomic study	Fri 11/1/13	Fri 11/1/13
68	18. Prepare Technology EH&S Risk Assessment	Mon 8/19/13	Fri 10/25/13
69	Prepare Final Report	Mon 10/7/13	Fri 12/13/13
70	Present Final Report	Tue 12/31/13	Tue 12/31/13



Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

Key Project Milestones

Budget Period 1

- Project kickoff meeting with DOE-NETL (11/22/2011)
- Identify two adsorbents with highest performance (12/20/11)
- Heat & mass transfer data, sorption isotherms (3/23/12)
- Preliminary technoeconomic evaluation (7/20/12)
- Rigorous process model (8/17/12)
- Design and costing of the bench scale unit (8/10/12)

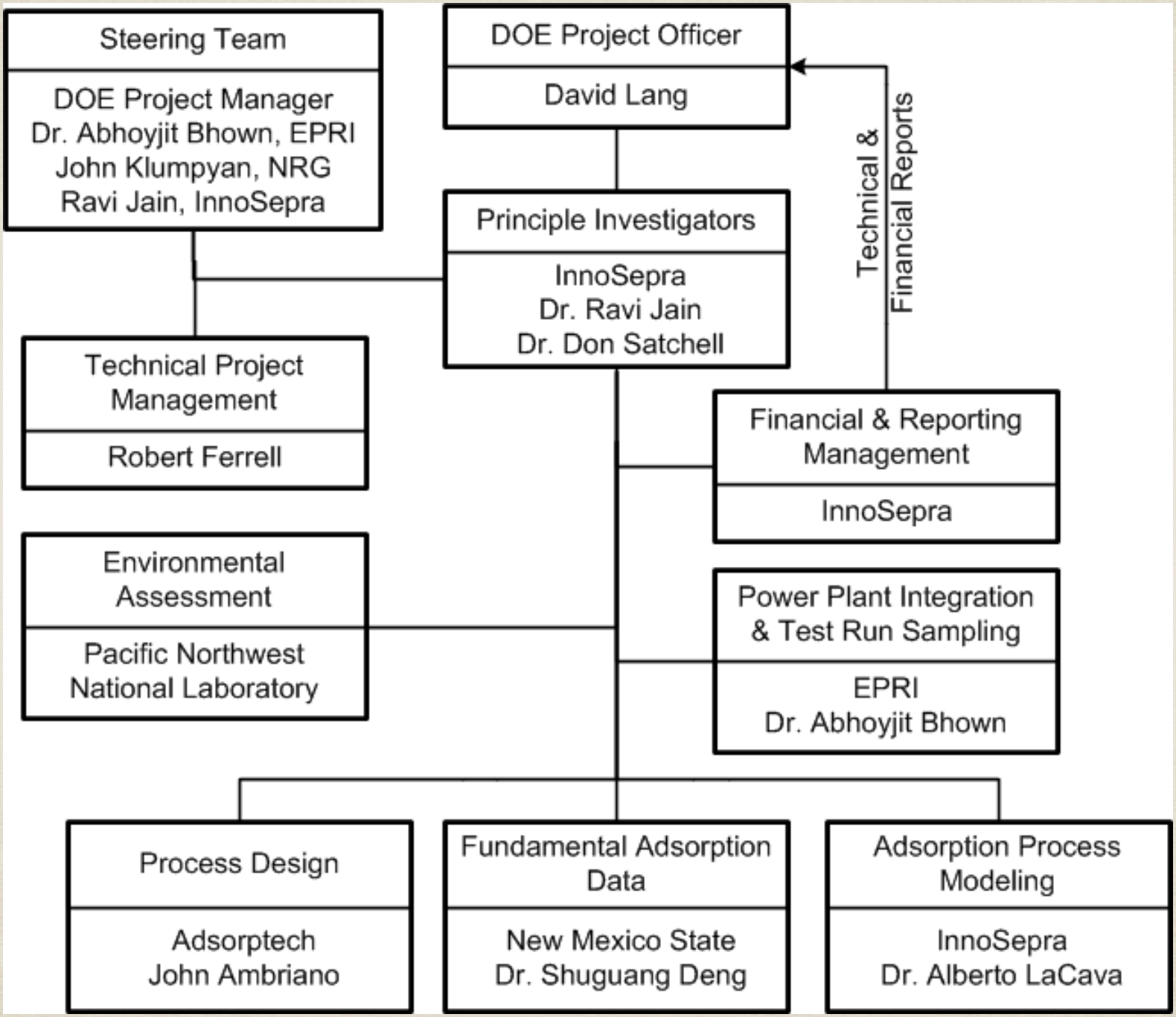
Budget Period 2

- Design and fabrication of the bench scale unit (12/7/12)
- Testing of preferred adsorbents in the bench scale unit (2/22/13)

Budget Period 3

- Commission bench scale unit at the NRG plant (5/23/13)
- Complete field testing of bench scale unit (8/30/13)
- Complete final technoeconomic study (11/1/13)

Project Organization Chart



Success Criteria at Decision Points

Decision Point	Date	Success Criteria
Go – No Go decision to build the bench scale unit	8/31/12	1. Limiting the projected increase in LCOE to below 60% based on lab scale testing and detailed technoeconomic evaluation 2. Provide a potential pathway for achieving <35% increase in LCOE
Completion of bench scale unit testing in the lab	2/28/13	1. Complete bench scale testing of preferred adsorbents in the lab and select preferred adsorbent for field testing
Project Closeout	12/31/13	1. Limiting the projected increase in LCOE to below 60% based on bench scale testing in the field and independent technoeconomic evaluation 2. Provide a potential pathway for achieving <35% increase in LCOE

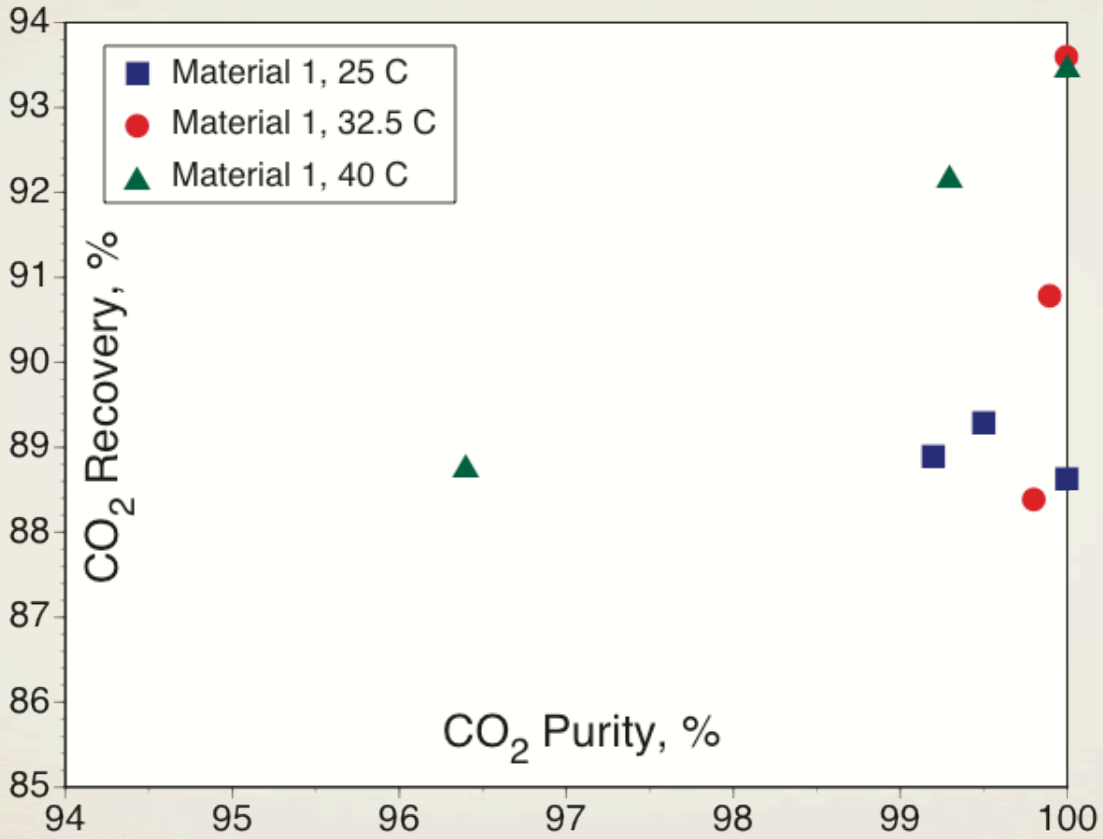
Project Risk Register

Description of Risk	Probability	Impact	Risk management
Technical Risks			
CO_2 Capture & Regeneration	Moderate	Moderate	Modify process design
Heat Transfer Design & Performance	Moderate	High	Modify heat transfer design
Moisture and Contaminants Removal	Moderate	High	Improve contaminants control steps
Technical Risks			
Project Team Availability	Low	Moderate-High	Identify backup resources
Suitability/ Availability of Sites	Low-Moderate	Low-Moderate	Identify backup sites
Component manufacturing risk	Low	Moderate	Simplify key components design, identify alternate suppliers

Technical Merit and Approach

Key Tasks

- Task 2: Laboratory testing to identify preferred adsorbents
  - Identify two adsorbents with highest productivity, CO_2 recovery, and CO_2 purity



- Task 3: Obtain heat and mass transfer data
  - Heat and mass transfer data for various process configurations

Technical Merit and Approach

- Task 5: Adsorbent Properties
  - Determine adsorbent kinetics, isotherms, and physical properties
- Task 6: Develop and Validate Process Model
  - Rigorous process simulation model incorporating adsorbent properties, heat transfer equipment, and lab scale process data
- Task 8: Complete Preliminary Technical and Economic Feasibility Study
  - Obtain CO_2 capture cost and LCOE based on lab test results and process simulation model
- Tasks 10 and 11: Design and Fabrication of Bench Scale Unit
  - Design and fabricate a bench unit capable of processing at least 1 tons per day CO_2 for lab and field testing
- Task 12: Lab Testing of Bench Scale Unit
  - Test the bench scale unit in the lab with the preferred adsorbents and synthetic flue gas (moisture-saturated, ~15% CO_2, 50-100 ppm SO_2, 50-100 ppm NO_X)

Technical Merit and Approach

- Task 13: Install and commission the bench scale unit at NRG's W.A. Parish plant
- Task 14: Testing with actual flue gas for up to 8 weeks
  - EPRI sampling to measure process performance
  - Analysis of used adsorbents to determine the effect of contaminants on adsorption capacity, and adsorbent life
- Task 16: Set commercial unit process configuration
- Task 17: Independent techno-economic analysis
  - EPRI will use a contractor for the techno-economic analysis
- Task 18: Prepare EH&S risk assessment (PNNL)

Acknowledge and Disclaimer

Acknowledgement: This presentation is based on work supported by the Department of Energy under Award Number DE-FE0007948.