LRC-LXIX(69)-A: "EVALUATION OF NOVEL TECHNOLOGIES FOR CO_2 CAPTURE"

Submitted by: Energy & Environmental Research Center
Request for: $50,000; Total Project Costs: $1,935,156
Project Manager: Brandon M. Pavlish
Project Duration: 16 months

RESPONSE TO REVIEWER COMMENTS

1. EXECUTIVE SUMMARY

Growing concerns about the impact of CO_2 emissions on global climate change have prompted increased research attention on the development of new technologies for CO_2 capture. Postcombustion capture, oxygen-fired combustion, and precombustion capture are among the most popular of the currently used approaches, although most of these are still in small-scale applications. In Budget Period (BP) 1 Phase 1 (funded in BP1) of Subtask 2.5 – The Partnership for CO_2 Capture (PCO_2C), the Energy & Environmental Research (EERC) proposed to conduct pilot-scale demonstration testing of selected CO_2 separation and capture technologies for fossil fuel and biomass-fired systems. PCO_2C Phase 1 was aimed at providing government and industry with key technical and economic information that can be used to examine the feasibility of technologies as a function of fuel type and system configuration. The technologies tested in the pilot-scale systems at the EERC included solvent scrubbing, solid sorbents, and oxygen-fired combustion. The overall goal of PCO_2C is to identify and help commercialize a range of CO_2 capture technology systems that can be implemented in the electric utility fleet to meet environmental emission constraints and requirements of CO_2 sequestration. In BP2, the second phase of the PCO_2C was proposed and involves continuing and new research for the promising technologies identified during Phase 1. PCO_2C Phase 2 (funded in BP2) utilizes the information gathered during Phase 1 for the development of lower-cost and more effective capture technologies and their integration into a total system that provides substantial economic and environmental benefits.

During Phase 1, several novel CO_2 capture technologies were discovered through the development of partner relationships with technology developers. These technologies do not necessarily fit within the scope of Phases 1 and 2 of PCO_2C but, rather, fit into a project that will assist in the scale-up and optimization of these technologies. These technologies are not as proven as the technologies currently being considered in Phases 1 and 2 but show greater promise for large cost reductions. Hence, the EERC is proposing to conduct a project to further develop and demonstrate these novel technologies at a scale that is appropriate for each developing technology. For BP3, the technology that has been chosen for evaluation and optimization is Neumann System Group's (NSG's) NeuStream™-C technology. The system has been proven at the bench scale to have the potential to meet or exceed the U.S. Department of Energy's (DOE's) targets for cost and efficiency of CO_2 capture. In order to get this technology ready for commercial deployment, small- and large-scale pilot studies are required not only to validate the technology, but to optimize what the technology can achieve.

The overall goal of this subtask is to evaluate technologies that have the potential to dramatically reduce the costs of CO_2 capture. The end result of the program is focused on the

development of lower-cost and more effective capture technologies and their integration into a total system that provides substantial economic and environmental benefits. Several objectives have been defined to evaluate and optimize NSG's NeuStream technology:

- Design and fabricate the NeuStream-C system (NSG)
- Perform system design verification and integration (NSG)
- Integrate and install the NeuStream-C system onto the EERC combustion test facility (CTF) (EERC)
- Perform shakedown and initial verification testing (EERC)
- Perform system baseline testing (EERC)
- Define and design system modifications for optimization based on baseline testing (EERC and NSG)
- Perform system optimization testing including testing of multiple solvents from other technology suppliers (EERC)
- Evaluate and compare baseline testing results to the current results of the EERC's conventional solvent system (EERC and NSG)
- Perform an economic analysis of the system at different points in the optimization to determine feasibility (EERC and NSG)
- Perform a sensitivity analysis to include the parameters of importance when considering scale-up (EERC and NSG)

In order to achieve these objectives, five main activities have been identified and are as follows:

1. Pilot System Design, Integration, and Installation
2. System Calibration and Baseline Testing
3. Optimization Testing
4. Systems Engineering, Analysis, and Outreach
5. Project Management and Reporting

2. ADDRESSING REVIEWER COMMENTS

Overall, the reviewers scored the proposal high but felt that there were details missing pertaining to budget and overall schedule. In order to address this concern, parts of the subtask management plan (SMP) developed for the DOE funding are included below. The SMP is discussed below and contains the details missing from the proposal. In terms of a communication plan with the subcontractor, weekly conference calls will be scheduled until the equipment is installed. After

the equipment is installed, conference calls will be scheduled on an as-needed basis. The management team may appear young on paper, but they have extensive knowledge in the development and demonstration of CO_2 capture technology. Several of the members on the management team are considered experts in the area of CO_2 capture technologies and have been invited to present at national meetings on the topic.

3. MILESTONE LOG

Milestone No.: M1
Title: Complete Design of Necessary Components
Planned Date: July 31, 2010
Verification Method: Design completed.

Milestone No.: M2
Title: Complete Construction
Planned Date: November 30, 2010
Verification Method: Construction completed.

Milestone No.: M3
Title: Complete Shakedown and Baseline Testing
Planned Date: January 31, 2011
Verification Method: Test unit will be ready for further evaluation.

Milestone No.: M4
Title: Complete Optimization Testing
Planned Date: August 31, 2011
Verification Method: Test plan will be completed, and results will be available.

Milestone No.: M5
Title: Complete Systems Analysis
Planned Date: August 31, 2011
Verification Method: Systems analysis will be completed, and the results will be available.

Milestone No.: M6
Title: Complete Economic Evaluations
Planned Date: August 31, 2011
Verification Method: Economic evaluations will be completed, and the results will be available.

4. FUNDING AND COST PROFILE

The total estimated cost for this subtask is $1,912,500, as outlined in Table 1. $1,530,000 will be provided by DOE under BP3 funding of the Strategic National Energy Security Solutions Program Area under EERC–DOE Cooperative Agreement No. DE-FC26-08NT43291. NSG will provide $164,253 of noncash cost share, and the balance of $218,247 will be provided by other

industry partners yet to be determined. The North Dakota Industrial Commission (NDIC) is requested to provide $50,000 of the cash contribution. Table 2 provides a spending plan projecting expenditure of federal funds by month; the nonfederal funds should mirror this table by percentage. Actual incurred costs and any variances will be reported on a quarterly basis.

Table 1. Subtask Funding Profile

	BP3	
	Government Funding	Cost Share
EERC	$1,530,000	
NSG – Noncash		$164,253
Nonfederal – Cash		$218,247
Total	$1,530,000	$382,500
Cost Share %	80%	20%

Table 2. Subtask Spending Plan, $K

	BP3
May 2010	5
June	10
July	300
August	200
September	100
October	100
November	60
December	40
January 2011	40
February	100
March	100
April	90
May	80
June	80
July	80
August	70
September	65
October	10
Total	**1530**

5. SUBTASK TIME LINE

The period of performance for this project is 18 months. A draft final report will be submitted to the sponsors for review by August 31, 2011. The final report will be issued by

October 31, 2011, providing that review comments from sponsors are received no later than September 30, 2011. An overview of the schedule for the subtask is shown in Figure 1.

Period of Performance: May 1, 2010 – October 31, 2011

Year	2010								2011									
Month	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**
1 – Pilot System Design, Integration, and Installation			M1 ◆				M2 ◆											
2 – System Calibration and Baseline Testing									M3 ◆									
3 – Optimization Testing																M4 ◆		
4 – Systems Engineering, Analysis, and Outreach																M5, M6 ◆		
5 – Management and Project Reporting																		
Final Report Preparation																		

◆ = Milestone

NSG Time Line: May 1, 2010 – April 30, 2011

Year	2010								2011									
Month	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**
NSG Task 1 – Demonstration Unit																		
NSG Task 2 – High Specific Surface Area Development																		
NSG Task 3 – Testing																		

Figure 1. Subtask time line.

6. TEST MATRIX

Evaluation of Novel CO_2 Capture Technologies Preliminary Test Plan				
Activity 2 System Calibration and Baseline Testing – 5 Days				
Date	Test Condition	Fuel	Technology	Description
Day 1	Shakedown of Neustream-C system	Natural gas	Neustream-C – piperazine/K_2CO_3	The system will be fired on natural gas, and the Neustream-C system will use the piperazine/K_2CO_3 solvent to develop an operating procedure and verify there are no leaks within the system.
Day 2				
Day 3	Shakedown of Neustream-C system	Natural gas	Neustream-C – piperazine/K_2CO_3	The system will be fired on natural gas. The control program will be verified, and information will be gathered to support proper start-up and shutdown of the system. Also during this period operational data will be gathered to help calibrate the model.
Day 4				
Day 5	Contingency: shakedown			A day of testing is reserved to work out any kinks that may occur during the initial shakedown of the new equipment.

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Evaluation of Novel CO_2 Capture Technologies Preliminary Test Plan (continued)				
Baseline Testing Test Period 1 – 5 to 7 Days				
Date	Test Condition	Fuel	Technology	Description
Day 1	Baseline of the Neustream-C system	TBD	Neustream-C – monoethanolamine (MEA) 30 wt%	The system will be fired on a coal TBD by the sponsors, and a solvent will be used to form a set of standards to which other technologies may be compared. Since MEA is currently considered as the best available control technology, it is suggested for evaluation in order to form a basis for comparison. If the sponsors of the project feel that there are enough data on MEA available in the literature, another solvent suggested by the group will be evaluated in place of the MEA. The data that will be gathered will include, but are not limited to, the following: 1) heat of regeneration required, 2) solvent flow rates, 3) temperatures, 4) energy consumption (fans, pumps, regeneration), 5) flue gas components (SO_x, NO_x, O_2, CO_2, Hg), 6) final CO_2 purity, 7) flue gas flow rates, 8) CO_2 capture efficiencies, and 9) impact of impurities (solvent degradation).
Day 2	Baseline of the Neustream-C system	TBD		
Day 3	Baseline of the Neustream-C system	TBD		
Day 4	Baseline of the Neustream-C system	TBD		
Day 5	Baseline of the Neustream-C system	TBD		
Day 6	Contingency: baseline			Two days of testing is reserved to work in case additional data need to be gathered to reach steady-state conditions. The need for these days will be evaluated during testing based on the expected results.
Day 7				

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Evaluation of Novel CO_2 Capture Technologies Preliminary Test Plan (continued)				
Baseline Testing Test Period 2 – 5 to 7 Days				
Date	Test Condition	Fuel	Technology	Description
Day 1	Baseline of the Neustream-C system	TBD	Neustream-C – piperazine/K_2CO_3	The system will be fired on the same coal chosen for baseline Test Period 1, which will have been chosen by the sponsors. The solvent to be evaluated will be the piperazine/K_2CO_3 blend (solvent chosen by NSG). The data that will be gathered will include, but are not limited to, the following: 1) heat of regeneration required, 2) solvent flow rates, 3) temperatures, 4) energy consumption (fans, pumps, regeneration), 5) flue gas components (SO_x, NO_x, O_2, CO_2, Hg), 6) final CO_2 purity, 7) flue gas flow rates, 8) CO_2 capture efficiencies, and 9) impact of impurities (solvent degradation).
Day 2	Baseline of the Neustream-C system	TBD		
Day 3	Baseline of the Neustream-C system	TBD		
Day 4	Baseline of the Neustream-C system	TBD		
Day 5	Baseline of the Neustream-C system	TBD		
Day 6	Contingency: baseline			Two days of testing is reserved in case additional data need to be gathered to reach steady-state conditions. The need for these days will be evaluated during testing based on the expected results.
Day 7				

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Evaluation of Novel CO_2 Capture Technologies Preliminary Test Plan (continued)				
Activity 3 – Optimization Testing				
Date	Test Condition	Fuel	Technology	Description
Day 1	Evaluation of other amines	TBD	Neustream-C – TBD	The system will be fired on a coal and other solvents (tailored, hindered, or other) to be determined by the sponsors will be evaluated. Ongoing discussions with solvent developers (Huntsman, Hitachi, and others) are taking place to secure an additional advanced amine solvent. The data that will be gathered may include, but are not limited to, the following: 1) heat of regeneration required, 2) solvent flow rates, 3) temperatures, 4) energy consumption (fans, pumps, regeneration), 5) flue gas components (SO_x, NO_x, O_2, CO_2, Hg), 6) final CO_2 purity, 7) flue gas flow rates, 8) CO_2 capture efficiencies, 9) impact of impurities (solvent degradation).
Day 2	Evaluation of other amines	TBD		
Day 3	Evaluation of other amines	TBD		
Day 4	Evaluation of other solvents	TBD		
Day 5	Evaluation of other solvents	TBD		
Day 6	Evaluation of other solvents	TBD		
Day 7	Evaluation of system integration and performance modifications	TBD	TBD	Approximately 14 days of testing is reserved for the evaluation and/or feasibility testing of integration and system performance modifications discovered during NSG bench-scale tests. The system "optimizations" will be tested to determine the percentage of increased performance in terms of cost and energy consumption.
Day 8	Evaluation of system integration and performance modifications	TBD	TBD	
Day 9	Evaluation of system integration and performance modifications	TBD	TBD	
Day 10	Evaluation of system integration and performance modifications	TBD	TBD	
Day 11	Evaluation of system integration and performance modifications	TBD	TBD	

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Evaluation of Novel CO_2 Capture Technologies Preliminary Test Plan (continued)				
Activity 3 – Optimization Testing				
Date	Test Condition	Fuel	Technology	Description
Day 12	Evaluation of system integration and performance modifications	TBD	TBD	
Day 13	Evaluation of system integration and performance modifications	TBD	TBD	
Day 14	Evaluation of system integration and performance modifications	TBD	TBD	
Day 15	Evaluation of system integration and performance modifications	TBD	TBD	
Day 16	Evaluation of system integration and performance modifications	TBD	TBD	
Day 17	Evaluation of system integration and performance modifications	TBD	TBD	
Day 18	Evaluation of system integration and performance modifications	TBD	TBD	
Day 19	Evaluation of system integration and performance modifications	TBD	TBD	
Day 20	Evaluation of system integration and performance modifications	TBD	TBD	