TECHNICAL REVIEWERS' COMMENTS

LRC-LXXII(72)-A:
"Evaluation of CO_2 Capture from Existing Coal Fired Plants by Hybrid Sorption Using Solid Sorbents (CACHYS™)"
Submitted by: University of North Dakota (UND) Institute for Energy Studies;
Request for: $350,000; Total Project Costs: $3,690,000;
Principal Investigators: Steven A. Benson, Ph.D. (UND Institute for Energy Studies) and Srivats Srinivasachar, Ph.D. (Envergex LLC);
Project Duration: Three Years.

1. OBJECTIVES

The objectives or goals of the proposed project with respect to clarity and consistency with Industrial Commission/Lignite Research Council goals are: 1 - very unclear; 2 - unclear; 3 - clear; 4 - very clear; or 5 - exceptionally clear.

Reviewer 11-07 (Rating: 4)

The project team proposes to develop and demonstrate a hybrid solid sorbent to capture combustion flue gas CO2 via utilizing novel process chemical and contactor conditions that would minimize chemical heat of reactions yet promote fast CO2 capture and lower heat cost management A cost-effective CO2 capture and separation technology would facilitate the use of lignite for continued ND Lignite-fired plants. The proposed project is consistent with NDIC regulations.

Reviewer 11-08 (Rating: 4)

The objective is this proposal is to scale up and demonstrate the CACHYS technology. The CACHYS technology is a novel method to capture and separate CO_2 from coal combustion flue gas. The objective is consistent with NDIC/LRC goals.

Reviewer 11-09 (Rating: 3)

This project proposes to develop a new technology for post-combustion capture of CO2 from flue gas with the goal of capturing 90% of the CO2 in the flue gas as well as sequestering the CO2 at a cost increase that is less than 35% compared to a non-capture scenario. The process is named CACHYS (CO2 Capture by Hybrid Sorption using Solid Sorbents. The sorbents are a combination of support, active component, and promoter. The moisture content of the flue gas plays an important role in the absorption and regeneration processes. While the program will use desulfurized flue gas derived from combustion of North Dakota lignite, it can be used with desulfurized flue gas from combustion of any coal. Information specific to trace components contained in the experimental flue gas will provide important information of users of North Dakota lignite that are considering the installation of CO2 capture systems.

The project culminates experimentally with the operation of bench scale absorber and regenerator, although it is not clear whether these two systems will be operated in an integrated manner. The data obtained will support a comprehensive techno-economic analysis and the design of an integrated, larger pilot plant that could support continued development of this technology if initial results show sufficient promise.

2. ACHIEVABILITY

With the approach suggested and time and budget available, the objectives are: 1 - not achievable; 2 - possibly achievable; 3 - likely achievable; 4 - most likely achievable; or 5 - certainly achievable.

Reviewer 11-07 (Rating: 4)

The DOE will provide $3,690,000, requiring $350,000 matching funds. Overall funds seem to be adequate. Project duration range from Oct/31/2012 to 9/30/2014. Significant bench scale tests have identified temperatures, sorbents, chemical reactions that show promise to capture CO2, at the bench scale and potential and appropriate reactors.

Reviewer 11-08 (Rating: 4)

The objectives are most likely achievable given the suggested time and budget.

Reviewer 11-09 (Rating: 3)

The quantitative technical goals that are required in combination for each cited advantage ("reduction of energy for sorbent regeneration, utilization of novel process chemistry, contactor conditions that minimize CO2 sorbent heat of reaction and promote fast CO2 capture, low-cost method of heat management, and low-cost sorbent") to meet the overall DOE cost goal for the cost of capture and sequestration have not been specified. The combination of the required performance metrics could be combined with a maximum allowable capital cost to determine if achievement of the DOE goal were possible.

3. METHODOLOGY

The quality of the methodology displayed in the proposal is: 1 - well below average; 2 - below average; 3 - average; 4 - above average; or 5 - well above average.

Reviewer 11-07 (Rating: 5)

The proposed effort will consist of state-of-the-art EERC reactors, bench scale state-of-the-art equipment, and a diverse group of engineers and research with extensive experience, including industrial engineers experienced in combustion CO2 emissions and problems.

Reviewer 11-08 (Rating: 5)

The quality of the methodology is well above average. The proposal is typical of Dr. Benson's high quality work.

Reviewer 11-09 (Rating: 3)

The description of the process chemistry and background data is above average. The consideration of the challenges of moving circulating solids continuously between a nearly atmospheric pressure absorber and a 100 psia regenerator has not been adequately addressed. The issues are the cost of a lock hopper system or other solids pressurization/depressurization system as well as the maintenance requirements and reliability issues associated with that system.

4. CONTRIBUTION

The scientific and/or technical contribution of the proposed work to specifically address Industrial Commission/LRC goals will likely be: 1 - extremely small; 2 - small; 3 - significant; 4 - very significant; or 5 - extremely significant.

Reviewer 11-07 (Rating: 4)

Lignite coal emits more CO2 than other coals. Past and current studies are developing a Hybrid Solid Sorbent that appear capable of reducing up to 90% of lignite combustion flue gas CO2, thus reducing the higher levels of CO2. Additional pilot plant equipment will be used to verify bench-scale equipment.

Reviewer 11-08 (Rating: 4)

The scientific and technical contribution of the proposed work could be very significant. The relevance of the work to NDIC/LRC goals depends on regulatory mandates imposed by federal agencies.

Reviewer 11-09 (Rating: 4)

The development of the chemistry inherent in the CACHYS system will likely be of significant value in achieving the ultimate goal of reducing the energy requirements required to release CO2 from solid sorbents.

5. **AWARENESS**

The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 - very limited; 2 - limited; 3 - adequate; 4 - better than average; or 5 - exceptional.

Reviewer 11-07 (Rating: 5)

The EERC organization has been a prolific leader providing numerous peer reviewed publications, domestic and international research, providing testimony and to congressional leaders. The EERC researchers are exceptional, and widely acknowledged among their peers.

Reviewer 11-08 (Rating: 4)

The PIs' awareness of current research and published and unpublished literature are high. Referenced literature is not designated by footnotes in the proposal. The PIs are known to be aware of published literature and knowledgeable in the use of footnotes as used in their published articles.

Reviewer 11-09 (Rating: 2)

The proposers did an excellent job of reviewing the background literature relative to sorbent capture of CO2. However they did not provide any discussion of newer approaches to CO2 capture, primarily solvent capture systems. There are a number of post-combustion CO2 development projects involving ammonia-based systems with significant governmental/industrial support that are under way at this time. None of these are mentioned in the proposal. A comparison of the CACHYS system relative to these other systems would be valuable.

6. **BACKGROUND**

The background of the investigator(s) as related to the proposed work is: 1 - very limited; 2 - limited; 3 - adequate; 4 - better than average; or 5 - exceptional.

Reviewer 11-07 (Rating: 3)

The background of the investigators as related to the proposed work is adequate.

Reviewer 11-08 (Rating: 5)

The PIs' backgrounds in this area are exceptional. The PIs' resumes are outstanding.

Reviewer 11-09 (Rating: 4)

The investigators identified with developing an understanding of the underlying chemistry of the system are very well qualified.

7. **PROJECT MANAGEMENT**

The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any is: 1 - very inadequate; 2 - inadequate; 3 - adequate; 4 very good; or 5 - exceptionally good.

Reviewer 11-07 (Rating: 5)

The Project Management Plan has a defined schedule and financial plan. The project participants will monitor and control the project scope, project cost and schedule. Some information was too small to read.

Reviewer 11-08 (Rating: 4)

The project management is very good. The objectives, tasks, and milestones are consistent and followed logically throughout the proposal.

Reviewer 11-09 (Rating: 3)

The plan appears to be adequate for this multi-task, multi-sponsor project.

8. **EQUIPMENT PURCHASE**

The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 11-07 (Rating: 5)

No equipment is to be purchased.

Reviewer 11-08 (Rating: 5)

Note: Reviewer 11-08 provided no comments.

Reviewer 11-09 (Rating: 2)

In Year 1 of the project, $82,753 will be spent from the $350,00 total of Lignite Research Council funds for equipment. There is no discussion on the specific items to be purchased with these funds. The total equipment budget for the project is $285,015. None of the equipment purchases are specified.

9. **FACILITIES**

The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 11-07 (Rating: 5)

The EERC facility contains state-of-the-art bench-scale equipment and pilot plant equipment. **The project proposes to develop a novel sorbent-based technology that would capture up to 90% post-combustion lignite CO2.**

Reviewer 11-08 (Rating: 5)

The facilities available at UND are exceptionally good.

Reviewer 11-09 (Rating: 3)

The analytical equipment that is in place is appropriate for the tasks. The bench-scale absorber and regenerator units will have to be designed and built by the UND, which has significant experience in this area. Specialized equipment for solids heat transfer will be purchased from Solex Thermal Sciences, which is a specialist in this area.

10. **BUDGET**

The proposed budget "value" [1] relative to the outlined work and the financial commitment from other sources [2] is of: 1 - very low value; 2 - low value; 3 - average value; 4 - high value; or 5 very high value.

Reviewer 11-07 (Rating: 5)

(See below).

Reviewer 11-08 (Rating: 4)

The value of the proposed work is high. The costs of this work at other research settings would be higher. The contribution of DOE and other participants is high.

Reviewer 11-09 (Rating: 5)

The proposed total budget for this three-year project is $3,690,000 with $350,000 of that amount requested from the Lignite Research Council. By definition, that is a "very high value".

OVERALL COMMENTS AND RECOMMENDATION:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

Reviewer 11-07 (Rating: FUND)

The development of an effective tool (i.e.CACHYS technology capture of carbon, especially of high capture levels (i.e. 90%) would be especially important to the lignite industry. At present, small-scale tests of potential CO2 have been conducted and provide optimistic opportunity.

The DOE will provide will provide $3,690,000, requiring $350,000 matching funds.

[1] "Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.
[2] Financial commitment from other sources – A minimum of 50% of the total project must come from other than Industrial Commission sources to meet the program guidelines. Support greater than 50% from Industrial Commission sources should be evaluated as favorable to the application.

Reviewer 11-08 (Rating: FUND)

Strengths of this proposal include:

- The background of the PIs;
- The expertise provided by a variety of participants;
- The quality nature of the proposal;
- The highly leveraged nature of the funding, and
- The topical nature of the work.

Weaknesses of this proposal include:

- Regulatory uncertainty
- Technology development time:
    - When will the technology be commercial?
- Technology uncertainty:
    - What effect will long term operation have on attrition and efficiency?
    - What are reagent costs?
    - What are the downstream impacts?
- The use of ND lignite in the test matrix

In spite of the uncertainty, this proposal has the potential to significantly impact the costs associated with CO_2 capture. The amine and carbonate CO_2 capture technologies have reached efficiency and costs plateau. The CACHYS technology offers a unique approach and potentially a breakthrough in efficiency and costs. The strengths and potential of the proposed work exceed the perceived weaknesses. FUND

Reviewer 11-09 (Rating: FUNDING MAY BE CONSIDERED)

This project should be funded through at least through subtask 2.5 (Initial technology and economic feasibility study report) for the reasons described below. Future funding should be dependent on whether the initial results indicate that this technology has the ability to compete with other approaches to CO2 capture

The report discusses its goals in general terms, but does not provide any estimates of how the CACHYS technology will compete against alternate approaches to post-combustion CO2 capture, which are currently under development, if in fact its performance objectives can be achieved. The question is what is the relative value of "reduction of energy for sorbent regeneration, utilization of novel process chemistry, contactor conditions that minimize CO2 sorbent heat of reaction and promote fast CO2 capture, low-cost method of heat management, and low-cost sorbent" are worth in meeting the DOE goal of a less than 35% increase in the Cost of Electricity resulting from adding at least 90% CO2 capture and sequestration to electricity production.

One critical aspect of this technology, which has the potential to be a fatal flaw (in terms of economics and reliability), is the operating pressure difference between the absorber, which is described as operating at slightly above atmospheric pressure, and the regenerator, which is described as operating at about 105 psia.

The amount of solids that are to be transported is estimated at 1000 tons per hour for a 100 MW plant (or 10 tons/hr/MW). All of the solids that are transferred between the absorber and regenerator must have their pressure raised by that amount and lowered by about the same amount. The approach mentioned in the proposal for use at bench scale are lock hoppers, which are expensive systems, require energy for gas pressurization, and usually require significant maintenance. What system is proposed for commercial application?

The proposal is not clear as to whether the absorber and regenerator teat systems will be run in an integrated manner and if so, for how long? Does multi-cycle testing (Sub-task 5.3) include integrated operation of the absorber and regenerator?

Minor typo: Stream numbers 1 and 2 are not consistently labeled on pages 67 and 68 of the proposal