

TECHNICAL REVIEWERS' COMMENTS

LRC-LXXX-E: "Carbon Capture & Utilization Using "VCCSTM Cycle" Technology - Phase I: Mineralization of Acidic Flue Gas CO₂ via Chemical Reaction with Alkaline Lignite Fly Ash + Extraction of Marketable Minerals & Other Commodities from Lignite Fly Ash"

Submitted by: Expansion Energy

Principal Investigator: David Vandor

Project Duration: 16 weeks

Request for: \$45,000; Total Project Costs: \$145,000

1. **OBJECTIVES**

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

Reviewer 17-13 (Rating: 4)

The objective of this proposal is to design and estimate the capital costs for a modular pilot plant utilizing the VCCS™ Cycle carbon capture & utilization technology. The proposal is a funding request for an engineer/design study leading to a modular pilot plant. To understand the technology it is necessary to review the research report prepared by Thomas Schuster, Ph.D.

Reviewer 17-14 (Rating: 4)

Reviewer 17-15 (Rating: 4)

The project very clearly meets the goals of the LRC.

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 17-13 (Rating: 4)

It is most likely given the proposed time and budget the design and engineer study for a modular pilot plant will be achieved.

Reviewer 17-14 (Rating: 4)

Timeline seems a bit aggressive which leads me to think that some of the proposed work has already been completed?

Reviewer 17-15 (Rating: 3)

The timeline is tight, so principals will have to be dedicated to it.

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 17-13 (Rating: 3)

It is most likely given the proposed time and budget the design and engineer study for a modular pilot plant will be achieved.

Reviewer 17-14 (Rating: 4)

Has thought been given to the use of ASPEN or ProTreat software?

Reviewer 17-15 (Rating: 4)

Process model will be transferable to ChemCAO.

4. **CONTRIBUTION**

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

Reviewer 17-13 (Rating: 3)

The scientific and technical contribution of the proposed work to specifically address NDIC LRC goals could be significant. However, based on the limited technical data in the proposal it will be difficult to apply the limited information made available.

Reviewer 17-14 (Rating: 4)

This is an interesting process that should be explored further to better determine applicability and economics. Statements about rare earth extractions are poorly founded at this point and should be explained further. The overall process, if proven to function as proposed, shows a strong potential to be beneficial to North Dakota.

Reviewer 17-15 (Rating: 4)

Phase II will be very significant if Phase I is carried out.

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 17-13 (Rating: 3)

The PIs have demonstrated an adequate awareness of scientific literature. The report by Schuster is the primary "literature" evidence of awareness. Schuster is not one of the PIs. The PIs and staff known to this reviewer are exceptional. This could be an inventive approach but is not well presented.

Reviewer 17-14 (Rating: 3)

It would have been nice to see a little more background.

Reviewer 17-15 (Rating: 4)

They all have proven track records.

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 17-13 (Rating: 4)

PIs and key staff known to this reviewer have backgrounds better than average.

Reviewer 17-14 (Rating: 4)

Background of the investigators is well demonstrated.

Reviewer 17-15 (Rating: 4)

GRE is well known for research and implementing lignite technologies.

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 17-13 (Rating: 2)

The project management plans needs to be strengthened with the addition of standard management tools.

Reviewer 17-14 (Rating: 3)

Timetable seems aggressive.

Reviewer 17-15 (Rating: 3)

Week by week schedule is provided.

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 17-13 (Rating: 5)

Reviewer 17-14 (Rating: 5)

Reviewer 17-15 (Rating: 5)

No significant equipment purchases.

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 17-13 (Rating: 4)

The engineer/design study facilities are notably good.

Reviewer 17-14 (Rating: 3)

Reviewer 17-15 (Rating: 3)

It will be critical to determine this as items are decided on for Phase II.

10. **BUDGET**

The proposed budget “value”¹ relative to the outlined work and the financial commitment from other sources² is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5- very high value.

Reviewer 17-13 (Rating: 3)

The budget value for this design study is of average value.

Reviewer 17-14 (Rating: 5)

Reviewer 17-15 (Rating: 3)

Nice to see XE will pay additional to P.C. Castello if required.

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.

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 17-13 (Rating: FUNDING TO BE CONSIDERED)

There are strong participants in the proposal. The area is of critical importance to the industry. However, the proposal lacks scientific/technical detail and project management detail. More detail could be developed to scope the possible application for ND and the lignite industry. In spite of the proposal weaknesses, the project could be considered for funding.

Reviewer 17-14 (Rating: FUND)

Even though it is felt that the timetable is aggressive it does seem to be of good value with high potential benefit to North Dakota. For the amount of funding requested it is suggested that this proposal be funded. For claims to additional benefits beyond mineralization caution is suggested.

Reviewer 17-15 (Rating: FUND)

This phase is necessary to advance the technologies capabilities. The flaw I see with it is that it is well known that CO2 will always need to be addressed, but how would implementation of this affect the markets of the proposed products? I recommend to fund.

Michael L. Jones, Ph.D.
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VIA E-MAIL ONLY

May 13, 2016

Dear Dr. Jones:

This letter is in response to the Technical Reviewers' Comments on Expansion Energy's proposal for "**Carbon Capture & Utilization Using 'VCCS Cycle'™ Technology – Phase I: Mineralization of Acidic Flue Gas CO₂ via Chemical Reaction with Alkaline Lignite Fly Ash + Extraction of Marketable Minerals & Other Commodities from Lignite Fly Ash.**" The responses are in the order in which the proposal was reviewed.

Achievability Time Line

The proposed 16-week time line for the study is relatively ambitious, particularly because the "kick-off" week will need to be somewhat flexible, responding to the availability of the team's key participants. However, because the timing of the work is not dependent on, for example, the delivery of equipment, we are confident that the study can be completed in approximately 16-weeks.

Methodology

R.C. Costello & Associates, Inc. will use CHEMCAD software for the material and energy balance simulations. It is a robust program that does as well or better than the other process simulators, particularly for chemical processes. CHEMCAD results can be "exported" into an EXCEL file.

Contribution

The rare earth extraction feature of VCCS will not be a significant portion of the proposed study. The Costello simulations will estimate the amount of recovered "liquors" that may contain rare earth elements and estimate the concentration of those elements in the recovered liquids. However, the proposed preliminary engineering of the Phase II Pilot Plant will not include a treatment/recovery methodology that separates those concentrated metals from the recovered "liquor." That work may need to be a Phase III effort (for the design of such a separation process), possibly followed by a Phase IV demonstration. In any case, recovered "liquor" can be sent to an off-site metals refining plant.

Awareness

Thomas Schuster is not part of the team because he recently passed away.

Project Management

We are open to suggestions for strengthening the management of the team.

We look forward to our presentation to the LRC on May 19th.

Best Regards,
David Vandor
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