**TECHNICAL REVIEWERS' COMMENTS**

**LRC-LXXX-F: "Capture and Capture/Sequestration of Carbon Dioxide - The CEC/MTU Clearite Carbon Dioxide Capture/CO2 Production Process"**

Submitted by: Carbontec Energy Corporation/Michigan Technological University
Principal Investigator: John Simmons
Project Duration: 12 months
Request for: $48,000; Total Project Costs: $96,000

## 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 17-16 (Rating: 3 )**
*The objectives seem to align with the goals. This reviewer's understanding of the objectives includes further lab scale work to improve $CO_2$ capture, understand effects of NOx and SOx on the capture process, explore regeneration of the capture chemical producing a product $CO_2$ gas, and ultimately test this on flue gas at Great River Energy's Coal Creek station in a future phase.*

**Reviewer 17-17 (Rating: 2 )**
*This reads as a student research project and it is not at all clear how this meets NDIC/LEC goals beyond a simple solvent development program.*

**Reviewer 17-18 (Rating: 3 )**
*Solutions to CO2 are needed for existing units and this could provide a low cost option – would like to see costs evaluated using DOE methods based on data collected as a deliverable, if possible.*

## 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 17-16 (Rating: 4 )**
*It seems like 12 months is plenty of time to complete the objectives and answer early questions about the technology.*
**Reviewer 17-17 (Rating: 3 )**
*It seems the objectives can be met but there is little detail here.*

**Reviewer 17-18 (Rating: 3 )**
*Time and budget should be adequate.*

## 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 17-16 (Rating: 3 )**
*The methodology seems thoughtful and responsible focusing on improving capture, understanding impurity interactions, and finally exploring regeneration capability.*

**Reviewer 17-17 (Rating: 2 )**
*Greatly lacking detail. It is already known that Na2CO3 captures CO2. How is Clearite unique? What about solvent regeneration? Is modeling involved in the project? What are the economics of the solvent and how do they compare with other solvents?*

**Reviewer 17-18 (Rating: 3 )**
*Scope and methodology seems commensurate with the budget. However, it would be good to see: 1) economic evaluation (DOE Method); 2) evaluation of parasitic load including regeneration energy; 3) estimate of carbonate supply requirements, including expected consumption by sulfur and losses.*

## 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 17-16 (Rating: 4 )**
*One of the key goals is to find technologies that will support operation of the existing coal fleet in a CO2 emissions constrained future. The feasibility is uncertain in this reviewer's opinion, but the work is supportive of that goal.*

**Reviewer 17-17 (Rating: 2 )**
*This is just a starting solvent development request. How does this address the unique qualities of ND fuels?*

**Reviewer 17-18 (Rating: 3 )**
*These types of solutions are needed and timing is critical. Any additional focus on information related to eventual commercial application would enhance the value.*

## 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 17-16 (Rating: 3 )**
*The patent number and Michigan Technological University work references indicate that the principal investigator has knowledge in related research.*

**Reviewer 17-17 (Rating: 2 )**
*There is little to no discussion of this in the proposal.*

**Reviewer 17-18 (Rating: 2 )**
*Not much discussion about ongoing work in this area. No references to work of others using these sorbents.*

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 17-16 (Rating: 3 )**
*It seems that the principal investigator has been involved with work at Michigan Technological University for a number of years. Resumes of key personnel were not included with the proposal.*

**Reviewer 17-17 (Rating: 2 )**
*Again, more explanation is needed beyond declaring ownership of a patent.*

**Reviewer 17-18 (Rating: 2 )**
*Cannot determine because investigators are not listed (no resumes provided) although Michigan Tech is certainly 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 17-16 (Rating: 4 )**
*The budget and schedule seemed complete. It wasn't clear to this reviewer what level of involvement and communication is planned with the industry partners beyond review of the final report.*

**Reviewer 17-17 (Rating: 3 )**

**Reviewer 17-18 (Rating: 3 )**
*In general the management plan appears adequate. However, project manager needs to be identified, and solicit guidance from industry and Mike Jones.*

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 17-16 (Rating: 3 )**
*It seems nearly half of the cost is to fabricate an additional packed column and associated equipment to test further CO2 removal with two packed columns in series.*

**Reviewer 17-17 (Rating: 5 )**
*Not clear what is being purchased so it is assumed that nothing is being purchased.*

**Reviewer 17-18 (Rating: 3 )**
*No large 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 17-16 (Rating: 3 )**
*This reviewer is confident that Michigan Technological University brings valuable facilities, an independent point of view strengthening credibility, and general knowledge to the project.*

**Reviewer 17-17 (Rating: 3 )**
*Assumed adequate but it really isn't described.*

**Reviewer 17-18 (Rating: 3 )**
*Appears adequate.*

## 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 17-16 (Rating: 3 )**
*Great River Energy's commitment of $16,000 and offer to host a future pilot signals that they believe there is value in investigating this technology further.*

**Reviewer 17-17 (Rating: 3 )**
*The quality of the proposal is poor but the amount requested is low. Given what is here is seems of some value.*

**Reviewer 17-18 (Rating: 4 )**
*Appears to be a good cost for the data targeted.*

[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 17-16 (Rating: FUND )**
*This reviewer recommends funding contingent upon acquiring the full $48,000 commitment of matching industry participation. At the time the grant application was due, $16,000 was committed with $32,000 outstanding.*

*It's this reviewer's opinion that this technology is at an infancy stage of development and significant milestones must be met to prove technical feasibility.*

*Carbontech Energy Corporation is a for profit company that could benefit greatly with a successful technology development. However, as proposed, this project would be funded by industry and the state of North Dakota. Perhaps Carbontech could partially fund or better describe their contribution to the effort.*

*Concerns this reviewer has include:*
- *The expected capital, operating, and maintenance cost of this technology compared to using amines is unknown.*
- *The effects of SOx, NOx, and particulate matter may impact the process greatly and threaten technical feasibility or identify extensive additional flue gas clean up required prior to this CO2 capture system.*
- *The expected waste streams are unknown*

*With industry interest/support and financial participation secured, this technology should be further explored. This technology needs work to determine if it can survive the fatal flaws of technical feasibility and determine if it holds potential for economic feasibility and application to the existing lignite resources.*

**Reviewer 17-17 (Rating: FUNDING MAY BE CONSIDERED)**
*This proposal is more marketing document of a concept that is only at the lab scale. It doesn't show why this process should be preferred over others. Saying that, the requested amount is small, which lends the reviewer to be cautious but suggest that the proposal be considered rather than rejected outright. If the proposal is selected to be presented it is strongly urged that the presenter discuss the full story and not push a marketing plug for Clearite.*

**Reviewer 17-18 (Rating: FUNDING MAY BE CONSIDERED)**
*In addition to obtaining the reaction data, it would be desirable to get initial assessments of cost, parasitic load, and next steps toward improving commercial merit. In addition, there is some concern that when using sodium at low temperatures, any NOx can be converted to NO2 causing a plume. In the project it would be good if the researchers could address this concern. If not through testing, then through a literature search and discussions with any industry personnel with direct experience with using sodium sorbents in flue gas applications.*

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May 12, 2016

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Re: Technical Reviewer comments to Proposal LRC-LXXX-F Capture and Sequestration of Carbon Dioxide

Dear Mike:

Thanks for providing a copy of the Technical Review Comments. The reviewers raised important questions and it is very apparent that they closely reviewed our Proposal.

Objectives

We agree with Reviewer 17-16's understanding of the objectives of our proposed program.

We appreciate reviewer 17-18 thoughts that are similar to ours in that our project could provide a low cost option for $CO_2$ reduction from existing units. We also expect that the project will provide further information that will allow a basic cost comparison between the CEC/MTU $CO_2$ Technology and the Amine Process, the current best available technology (BAT).

Achievability

We are comfortable that the reviewers agreed that the projects allocated time and budget should provide objectives that are achievable.

Methodology

Again – good questions. We expect that the project will confirm and expand on the earlier and extensive research that was conducted during the development of this Technology.

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Carbonate solvents possess many advantages over the commercially available amine solvents which may make them extremely attractive. Such advantages include a lower toxicity, low volatility, non-fouling, low equipment corrosion rate, and the possibility for use as a multi pollutant capture system ($NO_x$, $SO_x$, and $CO_2$ removal).

The Process utilizes a relatively low cost carbonate solvent, a major advantage over Amines which are very expensive. Previous work has indicated that the solvent can be regenerated at 80°C (176°F), a much lower temperature than that required to regenerate Amines and a major potential cost advantage. We anticipate that further information will be obtained regarding the degree of and ideal temperature requirements of regeneration. Ideally, power plant waste heat can be used to furnish much the energy required for solvent regeneration.

Contribution

Previous research has indicated the potential for utilizing a reasonably priced solvent to obtain a reduction of $CO_2$ of more than 50% - perhaps as high as 70% or more. Additional work is needed as we move forward to commercialize the process. Previous work has also indicated that the carbonate solution will capture $SO_x$ and $NO_x$. The potential to provide a multi-pollution reduction process is a plus. However, we will also be looking for negatives that may show up. We will inject $SO_x$ and $NO_x$ into the feed gas to the scrubber and evaluate their effects during the project.

Finding a low cost solvent with an improved $CO_2$ capture rate, and a process that requires less energy to regenerate and liberate $CO_2$, is the current goal of the fossil fuel industry. The industry is not satisfied with what the current amine or advanced amine process can do. It is anticipated that this project will provide information on the laboratory level. If successful, this first stage will warrant a future, more extensive pilot phase.

The Technology has the potential to be a breakthrough for all carbon based fossil fuels and therefore duly applicable to the use of North Dakota lignite coal.

Awareness

The 180+ page Thesis of Dr. Brett Spigarelli entitled "A Novel Approach to Carbon Dioxide and Storage" was provided earlier and includes an extensive bibliography of past and current $CO_2$ related research technology.

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In further support of the principal investigator's awareness of current and previous research, I am attaching Dr. Komar Kawatra's resume. The resume describes his wide range of achievements. Dr. Kawatra is a Fulbright scholar and the recipient of many distinguished awards, including the Gaudin Award, the Frank F. Aplan Award, the Robert H. Richards Award, the Taggart Award and others. We are pleased to have the availability of Dr. Kawatra as the lead investigator for this project.

Background

Attached is a 26 page Resume of Dr. Komar Kawatra, Chairman of the Chemical Engineering Department at Michigan Technological University, one of the inventors of the Technology and the principle investigator. Also enclosed is some background information of John Simmons, also an inventor of the Technology and the Chairman of Carbontec Energy Corporation, who has been involved in several technologies that have been developed and successfully commercialized over the past 20 years. Further enclosed is information about Jay Simmons who has been directly involved with many of Carbontec's previous projects.

Project Management

John Simmons, Chairman of Carbontec Energy Corporation who has in the past closely collaborated with Dr. Komar Kawatra on the development of this CEC/MTU Carbon Capture/Storage Technology will be the project manager. Jay Simmons, Vice President, Carbontec Energy Corporation will be the assistant project manager. Dr. Komar Kawatra, as mentioned above, will be the Principal Investigator. We have had previous discussions with Mike Jones regarding this proposed project, and will also solicit his technical guidance as the project moves forward. John Weeda has advised that he will offer the technical services of Charles Bullinger to assist in the program. It is important to get end user/industry involved. We plan to solicit the assistance, as needed from interested parties, especially from industrial members that are providing the projects matching funds. Their input will be invaluable in assessing the commercial viability of this Technology and a decision to move ahead in the future, to test the process on a larger scale at Great River Energy's Coal Creek Station.

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Equipment Purchase

Equipment purchase will include the additional packed scrubber unit that will be fabricated according to the initial scrubber design that is in place at Michigan Tech. Other equipment purchases will include transfer pumps, tanks and items related to solvent regeneration and $CO_2$ release and storage.

Facilities

Michigan Technological University has adequate, high value facilities to support the proposed project:

Budget

We are comfortable that the reviewers reported an average (3) or high (4) value budget process.

Overall Comments and Recommendations

The comments of all three reviewers are well taken. Carbontec Energy has to-date invested sizable funds in its quest develop on technology that will reduce Carbon Dioxide from power plant emissions.

We have also self funded other $CO_2$ capture projects that did not make the grade, as in our judgment they were either not effective or would not be economic. The costs incurred were eventually written off. However we feel that the subject CEC/MTU $CO_2$ project will be a winner and warrants continued support. When the Process is commercialized, the coal fired power plant industry will be an initial beneficiary of the technology. Carbontec will benefit in the future. Once past expenditures have been recovered, Carbontec expects to realize a profit.

We trust that other industry members will agree to partner with us and furnish the additional $32,000 that has yet to be committed, which will enable the project, if approved, to proceed.

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I appreciate your invitation to attend the Lignite Research Council meeting. I plan to attend and will be available for further questions.

Regards, and Best Wishes,

Yours Very Truly,

John J. Simmons
Chairman
**Carbontec Energy Corporation**