

TECHNICAL REVIEWERS' COMMENTS

LRC-LXIX(69)-C: "WRITECoal™ Gasification Process for Low Rank Coals for Improved Integrated Gasification Combined Cycle with Carbon Capture: Phase II – Pilot-scale Demonstration"

Submitted by: Montana-Dakota Utilities Co. (MDU) and Western Research Institute (WRI)

Request for: \$549,500; Total Project Costs: \$1,970,922

Project Managers: Andrea Stomberg (MDU) and Alan E. Bland, Ph.D. (WRI)

Project Duration: 24 Months

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 10-7 (Rating: 4)

The proposed project will demonstrate 1-2 MWth pilot-scale gasification conversion technology for high-moisture lignite such as ND lignite and subbituminous coal. Small pilot-scale gasification tests will utilize a patented WRITECoal process representative of the Wilsonville transport reactor, GTI's fluidized bed and conventional and IGCC. The effort will evaluate the above three gasifiers using the WRITECoal process with respect to efficiency, air emissions, CO₂ reduction or capture. The tests will provide opportunities to capture hydrogen from syngas for potential fuel cell applications and chemicals production. Air pollutants are anticipated to be reduced (particularly mercury). In addition to Gasification, the WRITECoal process would upgrade lignite thus providing a likelihood of increased energy efficiency, thus reducing overall impact of power generation with respect to CO₂, and also provide benefits of increased efficiency and reduced air emissions of lignite-fired power plants.

Reviewer 10-8 (Rating: 2)

As discussed extensively in Section C, there is no specific discussion about whether this proposed process for drying/gasification of high moisture, low rank, low cost fuels, including North Dakota lignite, has the potential to result in a lower Cost of Electricity (COE) than any other IGCC or other power production options that meet the same environmental criteria in the same future time frame.

Reviewer 10-9 (Rating: 3)

The goal of enhancing ND's lignite industry pervades the application.

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 10-7 (Rating: 4)

Phase 1 includes detailed analyses of lignite and subbituminous coal gasification fundamental reactions followed by small pilot-scale tests gasification tests evaluating coal employing WRITECoal process the transport reactor, U-Gas gasifier and IGCC. These small-scale tests will provide detailed information separating the gasification process from downstream subsystems syngas cooling/cleaning, shift reactions. Phase II would demonstrate the WRITECoal technology at up to 5 MWth. The separate focus of gasification versus downstream subsystems should provide a separate focus on the issues leading to an IGCC plant with increased efficiency, reduced pollutants and possible chemical products. As noted above, the WRITECoal process could also benefit the lignite and subbituminous power plants with increased efficiency and reductions in air emissions.

Reviewer 10-8 (Rating: 3)

The experimental objectives are well formulated and are likely to be achieved. Estimates of COE obtained that are based at least in part on the experimental data will be much more reliable than those produced prior to the availability of that data.

Reviewer 10-9 (Rating: 3)

This piece of research is well laid out technically, with reasonable task completion estimates. Likewise the cost projection for this project appears in line with my expectations.

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 10-7 (Rating: 4)

The proposed project consists of seven well organized tasks. The experimental work would be conducted at the Energy & Environmental Research Center, Wyoming Research Institute and the Gas Technology Institute. These institutions are recognized nationally and internationally

Reviewer 10-8 (Rating: 4)

Each of the Tasks is well formulated. A preliminary task to do a speculative economic evaluation should be done initially to determine the potential for this technology to be competitive in the future, relative to other technologies likely to be available at the same time. A lot of money (~\$2 million) will be spent during this project to collect experimental data on drying and gasification, for a process that may not offer a future competitive advantage

Reviewer 10-9 (Rating: 4)

The research plan appears well formulated, with appropriate consideration for execution of all aspects of the project.

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 10-7 (Rating: 4)

The patented WRITECoal process was developed to reduce the moisture content of western lignite and subbituminous coals. The “dried upgraded coal” contains more energy, thus increasing efficiency for use in power plants and IGCC plants with both technologies realizing efficiencies gains reducing air pollutant emissions, including CO2 emissions. A WRITECoal IGCC application could utilize the syngas for power generation, production of industrial chemicals, including hydrogen for fuel cell applications. The process would provide a more efficient product (power, chemicals) with less pollutant emissions, and possible expand power generation for very high efficiency fuel cells.

Reviewer 10-8 (Rating: 3)

The data and drying and gasification of dried fuel will be significant to the scientific and engineering community. Whether it has any commercial value in terms of an improved IGCC process will not be determined until after the preliminary (not part of the proposed project) and post experimental process evaluations are completed.

Reviewer 10-9 (Rating: 3)

The goals of this project are worthy. The positive potential to ND's lignite industry is very significant. The probability of success, considering the history of lignite drying attempts, is rather limited. However, there is always the small possibility that the WRITEcoal™ process could succeed where many others heretofore have failed.

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 10-7 (Rating: 4)

The organizations have published numerous publications, including Peer Review publications, and are nationally and international recognized.

Reviewer 10-8 (Rating: 2)

There is no discussion about the other specific gasification technologies that this proposed process would have to compete with.

Reviewer 10-9 (Rating: 3)

I'm quite sure that the PI is fully aware, probably mostly through staff interaction, that a technical and positive economic future for beneficiating lignite via the WRITEcoal™ system is unlikely. However, with the huge regulatory challenges facing the lignite industry in the immediate future, the risk of investing in this research would appear prudent. I suspect this could be the line of rationale being espoused by the PI in supporting this project.

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 10-7 (Rating: 5)

The EERC, WRI and GTI organizations and research facilities are staffed with experienced research engineers that are better than average to exceptional experts addressing western lignite and subbituminous coal usage and characteristics, and are experienced research engineers familiar with power generation and gasification units. This team of professionals will combine science and engineering expertise and commercial expertise to develop a the WRITECoal concept with increased efficiency, reduced pollutants, chemical products and new generation concepts such as fuel cells.

Dr. Alan Bland (WRI) is the Principal Investigator and the Patent holder of the WRITECoal process.

Reviewer 10-8 (Rating: 4)

The individual investigators are well qualified for their specific tasks.

Reviewer 10-9 (Rating: 3)

No comments were provided by Reviewer 10-9.

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 10-7 (Rating: 2)

The project management plan was presented as an overview. Communication among the participants was not addressed. Communications of technical progress and issues was not addressed with the project sponsors.

A Ghant chart is suggested to provide more informative information for schedule, technical detail, cost, and duration of the various tasks. The project duration is 21 months. The NDIC represents 27.89 % of the total cost of \$1,970.022.

Reviewer 10-8 (Rating: 4)

The sequence of the experimental program is well done. The only mention of how the results of these various tasks will be communicated among the investigators is by means of conference calls. One or more major project meetings over the course of the project would enhance the synergy among the investigators in coming up with approaches that had the potential to reduce the COE.

Reviewer 10-9 (Rating: 4)

As mentioned earlier (above), the current research plan to test applicability of the WRITEcoal™ system appears to be well thought out in all aspects. Well done approach.

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 10-7 (Rating: 5)

No equipment purchases were identified.

Reviewer 10-8 (Rating: 5)

No major equipment items are to be purchased

Reviewer 10-9 (Rating: 3)

No comments were provided by Reviewer 10-9.

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 10-7 (Rating: 5)

The experimental activities will be conducted at three facilities: The Energy & Environmental Research Center, Wyoming Research Institute and Gas Technology Institute. The facilities and staff are knowledgeable and experienced with lignite and subbituminous characteristics and issues and with IGCC technology characteristics.

Reviewer 10-8 (Rating: 4)

All of the major equipment required from the experimental work is in place and experienced teams are available for its operation

Reviewer 10-9 (Rating: 3)

No comments were provided by Reviewer 10-9.

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 10-7 (Rating: 5)

The NDIC funding contribution represents 27.89 % of the total cost of \$1,970,022 of the overall project. The NDIC contribution is \$549,500. Industrial contribution is \$337,905. The WY state contribution is 977,617 and industrial contributions significantly exceeds the NDIC contribution. The remaining funds represents 72% of the total.

Reviewer 10-8 (Rating: 5)

NDIC is asked to contribute 27.89% of the total project cost of \$1,970,022. If the proposers can demonstrate, prior to a funding commitment, that their process has the potential to successfully compete with other approaches to power production in future IGCC plants fed with low-rank, high moisture coals, this investment will be of high value.

Reviewer 10-9 (Rating: 3)

It is surprising to note the two principal utilities who are sponsoring this research with a very low financial contribution to its success. The ‘cash’ and ‘in kind’ contributions of both MDU and Basin Electric Power Cooperative are on the verge of being ‘tokens’ only.

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 10-7 (Rating: FUND)

The proposed project will conduct a thorough characterization of ND lignite to identify chemical properties that would influence reactions consumed in gasification and combustion reactions. The characterizations would provide detailed information crucial to understand the behaviors in a combustion plants and gasification processes. The analyses would include the influence of extrinsic and intrinsic minerals that may be detrimental. The proposed bench-scale analyses would provide insight on the combustion and gasification reactions and behavior impact and similar information for gasification syngas for IGCC or fuel cells .

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.

Climate Change Legislation has a focus on CO2 emissions, causing a significant concern for coal fired power plants. The anticipated CO2 reductions could be unattainable for western coals. The promise of the WRITECoal process may provide efficiency gains both combustion and gasification processes, for production of chemical products, including hydrogen for fuel cells. If the WRITECoal process is viable and efficiencies are increased, it would benefit western coal especially lignite.

The Lignite R&D Director, Dr Michael Jones should participate in all group meetings.

| Budget: | <u>Funding</u> | | <u>Match</u> |
|-----------|-----------------|----|--------------|
| ND | \$549,500 | WY | \$977,617 |
| WRI | \$100,000 | | |
| EERC/DOE | \$300,000 | | |
| EtaEnergy | \$5,000 | | |
| FCE | \$17,905 | | |
| MDU | \$10,000 | | |
| BEPC | <u>\$10,000</u> | | |
| | \$1,970,022 | | |

Reviewer 10-8 (Rating: FUNDING MAY BE CONSIDERED)

A final decision on funding this project by NDIC should be delayed until the proposers can provide discussion that supports the premise that this combined (WRITEcoal plus low temperature gasification) technical approach has the potential to significantly reduce the COE from an IGCC plant fueled with North Dakota lignite relative to other power generation options that will be available at the same time that this technology will be ready for commercialization. The reasons for this recommendation are detailed in the following paragraphs

The proposal is very well structured in organizing a large number of participants into an effort to collect experimental data on the gasification of pre-dried PRB subbituminous coal and North Dakota lignite. In the proposed process, these fuels will be dried at <300F in the first stage of a relatively small WRITEcoal process unit to 1 or 5% moisture (both numbers appear in the proposal) In the second stage of that process, 65 or 75% (both numbers appear in the proposal) to 80% of the mercury and 25-40% of the selenium and arsenic will be liberated from the fuel at 550F. Removal of the water from the feed fuels allows the separation of the gasification reaction (to convert carbon in coal to CO) and the shift reaction to convert the CO to hydrogen. This has the potential to increase the efficiency of the IGCC process.

The treated fuels will be evaluated in two gasification applications – the fluidized bed U-GAS process of GTI and at EERC in a transport reactor that is based on the TRIG gasification process being developed by Southern Company. Both of these processes operate with a dry fuel feed at relatively low temperatures of about <1800F. The proposal states that the PRB fuels will be tested at EERC, but it is not clear whether the North Dakota based fuels will be tested at EERC. **This needs to be clarified.**

There is no discussion in the proposal about the cost of the WRITEcoal pre-treatment steps. There is a claimed increase in efficiency in Figure 4.1.1 of 3.3 points (35.4% versus 32.1%) relative to an unidentified IGCC technology. **Adding equipment to increase efficiency is not always cost effective in terms of the COE produced from the plant.**

The proposal states that previous Phase 1 of this development program showed a 5% increase in cold gas efficiency, reduced water consumption and overall IGCC efficiency increases of 4% compared to other IGCC technologies. The other technologies in this comparison are not identified. Therefore it is difficult to assess the reasonableness of these claims **More importantly, there is no discussion of the impact that these changes will have on the resulting Cost of Electricity (COE) compared to other gasification alternatives or to combustion alternatives such as Supercritical Pulverized Coal plants.**

The estimated COE is the ultimate figure of merit in comparing new technologies with estimated technologies and other technologies being developed in parallel. If there is no significant potential improvement in COE, there is no reason to invest in development of the technology. Specifically with low cost fuels, there is a diminished reduction in COE resulting from improved efficiency

Reviewer 10-9 (Rating: FUNDING MAY BE CONSIDERED)

The concept of improving the economics of utilizing ND lignite is age-old. Economically removing moisture from the lignite is the obvious means of improving its utility. However, this is (and always has been) a formidable challenge.

There appears to be nothing in the experimental approach cited in the application that would materially differentiate the WRITEcoal™ system from prior research performed in lignite drying. If there is something unique to differentiate WRITEcoal™ system from past dryers, this is not discussed.

- There is no expressed concern about volatiles being evolved from the coal at ‘drying’ conditions – nor at higher temperatures required to devolve heavy metals from the coal matrix (Hg, Se, Ar). Multiple ‘disengagement pots for tars’ are cited in the discussion; however, nothing is mentioned to address odorous, volatile compounds....
- The TRIG reactor in Wilsonville, AL was operated on ND lignite similar to that which will be provided by Basin Electric for the subject research. This test was mostly unsuccessful, due to unacceptable rate of caking in downstream separators. It was necessary to 1) reduce operating temperatures of the reactor significantly to minimize this problem (operating levels ended up well below the 1700 deg F being proposed for testing in the current research), 2) inject large quantities of dolomite in with the lignite feed; and 3) carbon conversions of 97% on lignite were never achieved due to the resulting lower operating temperatures.

It would appear unlikely, but remains to be seen whether pre-treating the coal with the WRITEcoal™ system could mitigate these issues.

- Operating the test gasifiers at 1000 PSIG will somewhat mitigate tar formation in both gasifiers, so if funding is approved, it will be instructive whether this alone would make the ND lignite gasifiable in a fluidized bed reactor.

It is this reviewer’s opinion that continued research is necessary to improve lignite’s worthiness in the United States energy market. Perhaps for that reason alone, funding should be considered for the current proposal – ‘just in case’ the WRITEcoal™ system truly can achieve a breakthrough. However, it is not apparent by studying the application that this is likely to occur.