TECHNICAL REVIEWERS' RATING SUMMARY

R008-E

Development of Advanced Pretreatment Technologies for the Production of Clean Biocoal/Syncoal from Woody Biomass, Agricultural Residues, and Municipal Solid Waste

EERC
Principal Investigators:
Request for $300,000; Total Project Costs $1,432,047

Rating Category	Weighting Factor	Technical Reviewer 3A Rating	3B Rating	3C Rating	Average Weighted Score
1. Objectives	9	4	4	3	33.00
2. Achievability	9	3	3	2	24.00
3. Methodology	7	3	2	2	16.33
4. Contribution	7	4	2	2	18.67
5. Awareness	5	3	1	1	8.33
6. Background	5	4	5	4	21.67
7. Project Management	2	3	4	3	6.67
8. Equipment Purchase	2	4	4	4	8.00
9. Facilities	2	4	5	4	8.67
10. Budget	2	5	4	2	7.33
Average Weighted Score		179	155	124	**152.67**
Maximum Weighted Score					**250.00**

OVERALL RECOMMENDATION

FUND			
FUNDING MAY BE CONSIDERED	x	x	
DO NOT FUND			x

RESPONSE TO TECHNICAL REVIEWERS' RATING SUMMARY
R008-E

Development of Advanced Pretreatment Technologies for the Production of Clean Biocoal/Syncoal from Woody Biomass, Agricultural Residues, and Municipal Solid Waste

Submitted by Energy & Environmental Research Center (EERC)
Principal Investigator: Stelios Arvelakis

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

Reviewer 3A (Rating: 4)
Goals are aligned with ND ICREC. Successful completion could open new opportunities for ND board biomass.

Answer: No comment.

Reviewer 3B (Rating: 4)
The goal of this proposed work is to prepare pilot-scale test equipment and perform combustion and gasification testing of biomass/waste pretreatment for the production of biocoal/syncoal. The goal is very clear and is related to NDIC's goals.

Answer: No comment.

Reviewer 3C (Rating: 3)
The objectives of the proposed project are fairly clear to meet the goals of NDIC/REC. However, the objective to promote/demonstrate new technologies is very unclear due to lack of justification; specifically torrefaction is very unclear from the proposal content.

Answer: The proposed objectives state that the combined pretreatment technology will be used to produce clean biocoal/syncoal, which is a combustable material having handling properties that are similar to coal, making it easier to handle than straight biomass. The material is also without alkali metals, chlorine, and sulfur as well as heavy metals, which will eliminate/reduce substantially the ash-related problems as well as the emissions. This material will be produced and tested in long-term pilot-scale tests at the EERC to demonstrate its viability as a pretreatment process and as an economical fuel. The follow-on work for this project would include producing large quantities of the fuel for demonstration at a full-scale plant.

2. 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 3A (Rating: 3)
Proposed timeline is quite short for long list of objectives. It is hard to access the budget given the limited depth and experimental design provided within the proposal.

Answer: The principal investigator has broad experience in the area of biomass/coal/waste pretreatments, having worked in this area for more than 15 years. The majority of the experimental facilities are already running, which reduces substantially the time needed for installing and integrating new equipment to be used in the research project.

Reviewer 3B (Rating: 3)
This study has five objectives. However, the approaches are VERY UNCLEAR. For example, what pretreatment methods will be studied? How will the produced pellets be characterized and how will energy costs be compared to wood pellets? How will fly ash be characterized and used in cement?

Budget may be another concern. The total projected cost is over $1.4 million. Even the requested budget of $300,000 is approved from NDIC, the PIs still need to secure more than $1.1 million from other places. One of the major sources is DOE. However, whether the PIs will be able to secure funding from DOE is not sure. If such attempt fails, the entire project is likely to fail due to lack of funding. Therefore, it is reasonable to say that the success of this project will heavily depend on something unsure. I would suggest the PIs to secure cost-share fundings before they apply for funding from NDIC to reduce risk.

Answer: As mentioned in the proposal, the pretreatment approach to be studied is a combination of torrefaction and leaching pretreatment (1–6). Regarding the pellets and fly ash characterization methods, all of these are standard methods (ASTM International and others) that are well documented. Costs for the pretreatment and torrefaction technology will be estimated from the optimum process conditions, and engineering models will be used for equipment capital cost estimates for the economic evaluation.

Regarding the budget, the U.S. Department of Energy (DOE) contribution is already available through the EERC's cooperative agreement with DOE, and EERC management has given initial approval to use them as match to this project. These funds are used for projects at the discretion of the EERC management and as long as the project fulfills the overall goals of DOE; the EERC can approve their use as long as there is industrial matching funds such as requested from the ND Renewable Energy Council. Additionally, the EERC has provided several letters of commitment from other industrial partners that will also be providing matching funds for the project.

Reviewer 3C (Rating: 2)
The proposed time may be achievable for all the objectives with proper co-ordination from each investigator. Since the success of first objective will decide the completion of other objectives, it will be fairly risky to achieve all the objectives within the stipulated time frame. Budget is the

other constrain that may decide the completion depending on the success of the DOE and Industrial support.

Answer: It is expected that less than 2 months will be necessary to purchase and assemble all components for the pretreatment reactors. The torrefaction reactor to be used for this project is already in existence. Please also see answers to the previous reviewer comment regarding DOE and the industrial contributions of matching funds.

3. 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 3A (Rating: 3)
Overall concepts were provided, but very little detail. Some of this was associated with the page limits, but key parameters such as torrefaction process variables and any basic description of the pelletization process would have been very helpful.

Answer: As the reviewer mentioned, the page limit did not allow us to provide more information regarding the torrefaction process. The pelletization process is a well-documented industrial process, and so information is publicly available.

Reviewer 3B (Rating: 2)
Description of methodology is very limited in this proposal. Only some general description of activities is available. I would suggest the PIs to provide more details of their research methods.

Answer: As we mentioned before, the page limitations preclude a more comprehensive description of the methods to be used.

Reviewer 3C (Rating: 2)
The quality of methodology is below average without any clear goals for testing and demonstrating various pilot scale equipment and analytical data. No methodology for torrefaction objective and no justification for using fluidized bed torrefaction unit.

Answer: The fluidized-bed torrefaction reactor will be used for this project as this is a patented technology developed at the EERC with funding from DOE. It generated excellent results during initial proof-of-concept operation. It is the belief of the EERC that when coupled, the leaching pretreatment technology and torrefaction may be more effective than either of them individually. The goal of the project is to demonstrate at pilot scale the potential of the pretreatment processes to produce a fuel that is easier to handle than untreated biomass and has a higher level of performance in combustion and gasification equipment than untreated biomass related to ash and emission problems.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Renewable Energy Council goals will likely be:

1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 3A (Rating: 4)
Project is well aligned with scientific challenges associated w/biomass energy systems.

Answer: No comment.

Reviewer 3B (Rating: 2)
The main goal of this study is to prepare pilot scale test equipment and perform some testing on bio-coal. Although the work is practically important, its scientific or technical contribution is small. It is more important as a demonstration project than a research project.

Answer: The proposed research project will provide additional research results at the pilot-scale level that are extremely important as the technology scales up to demonstration and commercialization. The EERC has performed bench-scale work to understand some of the fundamental aspects of the process and has found some success with the processes. However, as with all nascent technologies moving from the bench to pilot scale and then commercial scale, there are unique challenges to overcome. A demonstration-phase project has already been scheduled to start by the time the pilot-scale research project is finished.

Reviewer 3C (Rating: 2)
Although the application center had good technical experience on combustion and gasification studies, lack of justifications on the proposed pretreatment technologies and inadequate methods and protocols for their processes undervalue its scientific and technical contribution to NDIC/REC goals specifically from this project.

Answer: The proposed pretreatment technologies hope to ameliorate two of the major issues when trying to utilize biomass as a fuel: handling issues due to the fibrous nature of many biomass materials and high alkali/alkaline-earth element content along with corrosive elements such as sulfur and chlorine. Removal of the elements mentioned would improve the viability of the produced fuel, giving it added value. Physically changing the material through the torrefaction process such that it can be handled in a much more efficient manner also adds value and improves the salability of the produced fuel. It is hoped that the sum of the two processes will exceed either of them separately in producing a fuel that has large market potential. The proposed pretreatment technologies are considered to be the most innovative approach today toward the elimination of the feeding, mixing, transportation, and ash and emission problems associated with biomass and waste utilization in power and fuels generation/production. The principal investigator has broad experience in the specific research area, and the EERC has patented the only torrefaction reactor proven to be able to handle a large variety of biomass and coal materials. It is hoped that the combination of expertise and available infrastructure will lead to the success of the proposed research project and the goals of NDIC/REC.

5. 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 3A (Rating: 3)
Very little background material provided. Authors suggest torrefaction at 300°C which is well outside the most economically optimal range. No mention of what range of biomass feedstock variability would be addressed.

Answer: Page 6 of the proposal lists the biomass materials to be investigated under this project, woody biomass, dried distiller's grains and solubles (DDGS), wheat straw, corn stover, switchgrass, and refuse-derived fuel (RDF). The suggested torrefaction temperature is the result of previous lab-scale torrefaction testing performed at the EERC and elsewhere by the principal investigator during the past few years.

Reviewer 3B (Rating: 1)
No reference is cited in the proposal (1–6).

Answer: As mentioned before, the page limitations of the proposal preclude the inclusion of references. The principal investigator has published a large number of articles in peer-reviewed journals and presented at conferences worldwide on this subject (1–6).

Reviewer 3C (Rating: 1)
No sign of any literature evidence related to the chosen technologies and it results in no further interpretation related to the proposal.

Answer: Please see answer to Reviewer 2.

6. 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 3A (Rating: 4)
Investigators are competent in this area of research.

Answer: No comment.

Reviewer 3B (Rating: 5)
The PIs and their affiliation (EERC) are exceptionally qualified to perform the proposal work. The proposed work is directly related to the PIs' experience, expertise, and interest.

Answer: No comment.

Reviewer 3C (Rating: 4)
Well-qualified investigators with adequate previous experience on handling pilot scale projects and testing studies. Inexperience with torrefaction and pelleting operations may be challenging to demonstrate its success.

Answer: The principal investigator is one of the leading experts worldwide in torrefaction as well as leaching pretreatment technologies. Pelletizing is a well-known industrial process, and there is nothing new that will be discovered on this subject.

7. 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 3A (Rating: 3)
Very little information is provided. No definition for metrics of completion. Very little discussion on how to manage such a large and yet short term project. Little discussion on how the 6 project staff would interact.

Answer: The project staff has worked together on a number of similar research projects and have established a successful pattern of cooperation. Page 12 of the proposal includes a paragraph in which the standards of success for the specific project are described. In addition, a timetable including activities and milestones is included on page 14 of the proposal.

Reviewer 3B (Rating: 4)
The proposal has a clear timetable and milestones.

Answer: No comment.

Reviewer 3C (Rating: 3)
Although the project management plan is fairly adequate, lack of well-defined/thought milestones doubts the successful planning and implementation of project objectives.

Answer: Please see answer to previous reviewer.

8. 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 3A (Rating: 4)
Equipment is needed to meet objectives.

Answer: No comment.

Reviewer 3B (Rating: 4)
The PIs do not budget equipment from NDIC money, however, the PIs do propose to purchase equipment ($95,000) using a to-be-secured sharing fund from DOE. These equipment and modifications are necessary to the proposed work.

Answer: No comment.

Reviewer 3C (Rating: 4)
Purchase of pelletizer requires further justification in terms of its purchase price and type of pellet mill to be purchased for pelletizing biocoal.

Answer: No comment

9. 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 3A (Rating: 4)
Many analytical and measurement labs are available.

Answer: No comment.

Reviewer 3B (Rating: 5)
The PIs have sufficient facilities and equipment to perform the proposed work. The torrefaction system, gasification system, and combustion furnace are already in place. Purchase equipment will be available for biomass pretreatment pelletization.

Answer: No comment.

Reviewer 3C (Rating: 4)
Facilities and equipment available are adequate. It was not clear why a fluidized bed torrefaction reactor was chosen for this study. No clear picture of a leaching reactor that will be built from this project.

Answer: The fluidized-bed torrefaction reactor is a patented reactor technology developed by the EERC in the 1990s with funding from DOE. It has shown excellent operational characteristics, and we are moving quickly toward its commercialization in the near future.

10. The proposed budget "value"1 **relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value (see below).**

Reviewer 3A (Rating: 5)
Great opportunity for ND to leverage funds but overall scope is quite large for a one year project.

Answer: No comment.

Reviewer 3B (Rating: 4)

The proposed work is important. If the project succeeds, and if costs of the final product can be lowered, anticipated outcomes will worth the $300k investment from NDIC.

Answer: No comment.

Reviewer 3C (Rating: 2)
Due to inadequate explanation of proposed technologies that would reduce ash related and emission problems, the outlined work is less valued and will not meet the goals of REC.

Financial commitment from industrial partners is very encouraging. However, their commitments are directly depends on the successful funding from DOE not from NDIC.

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.

Answer: The DOE funding is already available through the EERC cooperative agreement with DOE. The use of the money is contingent upon the successful acquisition of matching industrial funding. As a result, both the industrial as well as the DOE funding has been secured for this specific research project. The page limitations do not allow us to give an extensive description of the proposed technical solution, but the main advantages as well as the main characteristics of the proposed technological solution are well described. Under mild leaching conditions, the undesirable elements can be solubilized in the leaching fluid and removed from the biomass. While this process has been proven at the bench scale, it needs to be proven at the pilot scale. It is anticipated that modifications to the original process will have to be made to enable the process to be operated in an economical fashion.

Reviewer 3A ***(Funding May Be Considered)***
Overall this project addresses a key issue associate with developing a profitable and sustainable bioeconomy and if successful will certainly benefit the state of North Dakota. Positives of this project include its wide range of input feedstocks and its very strong leveraging of state dollars. Negatives include a lack of background by the investigators in the area of torrefaction and a very short timeframe for such significant work that includes several new equipment builds. I would recommend this project be considered for funding, but would suggest a required more detailed work plan with specific milestones and potential pitfalls to be addressed.

Answer: The principal investigator is one of the world's experts in torrefaction/pretreatment technology research. He has published a large number of papers in the specific research area in the last 15 years. In addition, apart from the leaching reactor and the pelletizing machine, all the other infrastructure is already available and in working mode. This reduces the complexity as well as the preparation time before the experimental work can start and guarantees the successful execution of the project.

Reviewer 3B ***(Funding May Be Considered)***

Funding to this proposal may be considered. The major merit of this study is a pilot-scale demonstration unit that shows the potential of using agricultural residues and wood for bio-coal production. Major flaws are (1) scientific or technical value of the proposed work is limited. (2) Using to-be-secured funding as a source of cost-sharing is not acceptable and risky to the proposed project. (3) It lacks an economic analysis of the proposed work. Bio-coal is not a high-value product. Pretreatment may add extra cost to the product. Justification is needed.

Answer: The proposed work addresses one of the main obstacles to the use of biomass for energy and fuels production, which is the use of the vast amounts of low-grade agricultural biomass and waste materials available domestically. One of the main issues with biomass utilization is in feeding the material into combustion systems without having to add expensive modifications to handle the material. Processing biomass to produce a consistent material that is easy to handle and can be utilized in existing systems with little or no capital improvements provides a significant motivation for utilization. Many states have already enacted threshold levels at which energy must be derived through utilization of biomass materials. Most utilities are at a loss as to how to accommodate the mandates. Providing a system that can produce a consistent fuel that is easy to handle as well as reducing any ash-related and emission problems associated with the use of these biomass and waste materials will help to create a viable and sustainable biomass industry in the Midwest that will provide jobs and assist in U.S. energy independence and security.

The DOE as well as the industrial funding for this project have already been secured as explained previously.

Biocoal is a high-value product as it will utilize agricultural residues and waste which are abundant and cheap to create a product for which there is a high demand in the United States as well as worldwide and will have the price of clean wood pellets. There is currently a huge demand in Europe for wood pellets that is being supplied in large part by Canada. Pretreatment adds cost to the biocoal product but removes the cost from the conversion pathways, including emission control, shutdowns for corrosion and deposition problems, CO_2 emissions, lower milling and handling costs, and higher efficiency compared to the original biomass.

Reviewer 3C ***(Do Not Fund)***
This project proposed to develop both leaching and torrefaction pretreatment methods for biomass to produce heat and power. Although the leaching activities are reported in the application, the procedure was not adequately explained, specifically, what type of biomass will be used in this study, what is the indicator for successful leaching process and what are the protocols used to be successful at the end of the study.

No discussion and explanation about the torrefaction technology. No justification on why do you want to build and test torrefaction technology. Other related activities that use torrefied biomass will be meaningless, if it is not produced in the project.

In overall, the proposal is not clearly written with insufficient justifications of project objectives. Additionally, detailed work plan and measurable outcomes are missing. In summary, the proposal does not meet the technical merits to recommend for funding at present condition.

Answer: The proposal states on page 6 the biomass materials that will be used in the proposed research work. It is also discussed that the leaching process removes all the alkali metals and chlorine and large amounts from the sulfur and phosphorus elements as well as heavy metals in the case of the RDF material. These are elements that have been associated with deposition problems, corrosion issues, and toxicity in ash. Removal of these elements in large part will increase the value of the fuel produced. Regarding the torrefaction technology, the proposal states that torrefaction helps to create a fuel that has qualities that make it more amenable to utilization as opposed to untreated biomass. Untreated biomass can have major issues related to getting the material to feed correctly and measurable consistency in a boiler without major capital improvements. The goal is to produce a coal substitute that will replace coal in standard power plants without mixing, corrosion, handling, and ash-related problems.

The torrefaction reactor has already been tested in other research projects and has been proven to work efficiently; as a result, there is no risk associated with its successful operation or the effect this might have on the success of the project.

The page limitations do not allow us to provide a more detailed description regarding the proposed technological solutions as well as to provide a list of publications that show the related research work being done at other universities and research centers worldwide.

A work plan is presented on page 14 of the proposal that provides information regarding the main phases and milestones in the project. In addition, the proposal outlines the measurement of success as having to show that after the pretreatment of the various biomass and waste materials, the produced fuels will have fewer ash-related as well as emission problems during combustion and gasification of the produced biocoal/syncoal. While initial bench-scale testing has shown this to be true, it remains to be seen if in scaling up there are any challenges that would reduce the impact of the pretreatment technologies and make the produced fuel less appealing.

1. Studying the Melting Behavior of Coal, Biomass, and Coal/Biomass Ash Using Viscosity and Heated Stage XRD Data
   Energy Fuels **2006**, *20*, 1329–1340
   3/15/2006
   Electronic document not available

2. Studying the Melting Behaviour of Fly Ash from the Incineration of MSW Using Viscosity and Heated Stage XRD Data
   Fuel **2008**, *87*, 2269–2280
   4/7/08
   Electronic document not available

3. Fluidized Bed Gasification of High Alkali and Chlorine Biomass: Effect of Pre-Treatments on the Agglomeration Behaviour
Presented at the 33rd International Technical Conference on Coal Utilization & Fuel Systems, Clearwater, FL, June 1–5, 2008
PDF attached – no electronic Word document available

4. Viscosity of Ashes from Energy Production and Municipal Solid Waste Handling: A Comparative Study between Two Different Experimental Setups
Energy Fuels **2008**, *22* (5), 2948–2954.
10/7/08
Electronic document not available

5. Hajicek, D.R.; Mann, M.D.; Selle, S.J. Taking Advantage of High-Reactivity Coals – Upgrading Low-Rank Fuels with the Controlled Spontaneous Reactor. In *Proceedings of the 18th International Low-Rank Fuels Symposium;* Billings, MT, June 24–26, 2003.

6. Zygarlicke, C.J.; Olson, E.S.; Sorensen, J.A.; Stepan, D.J.; Swanson, M.L.; Folkedahl, B.C.; Musich, M.A.; Schmidt, D.D. *EERC Biomass Utilization Program: Subtask 1.2 – Controlled Spontaneous Reactor for Improving Biomass Feeding for Combustion and Gasification*; Final Report for U.S. Department of Energy Cooperative Agreement No. DE-FC26-01NT41129; EERC Publication 2003-EERC-01-03; Energy & Environmental Research Center: Grand Forks, ND, Jan 2003.