TECHNICAL REVIEWERS' RATING SUMMARY

R010-A

Developing a Biomass Industry in North Dakota

Submitted by ND Agricultural Experiment Station
Principal Investigator(s): F. Larry Leistritz
Request for $406,120; Total Project Costs $812,240

Rating Category	Weighting Factor	Technical Reviewer 1A Rating	1B Rating	1C Rating	Average Weighted Score
1. Objectives	9	4	5	5	42.00
2. Achievability	9	4	4	4	36.00
3. Methodology	7	3	3	5	25.67
4. Contribution	7	3	5	5	30.33
5. Awareness	5	2	4	5	18.33
6. Background	5	3	5	5	21.67
7. Project Management	2	3	5	5	8.67
8. Equipment Purchase	2	5	4	4	8.67
9. Facilities	2	4	4	5	8.67
10. Budget	2	3	5	5	8.67
Average Weighted Score		169	218	239	**208.67**
Maximum Weighted Score					**250.00**

OVERALL RECOMMENDATION

FUND		x	x
FUNDING MAY BE CONSIDERED	x		
DO NOT FUND			

R010-A
Developing a Biomass Industry in North Dakota
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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 1A (Rating: 4)
The goal of this project is to complete efforts to design a pilot scale plant for conversion of wheat straw to various biomaterials (*i.e.*, fuels, chemicals, animal feed, *etc*). Specific objectives for this project include: (1) Prototype testing of a new ammonia fiber expansion (AFEX) reactor design that is less capital intensive, (2) Prototype testing of this system for continuous ammonia reuse, and (3) Updating the commercial business plan to address (a) Deployment on a regional basis, (b) More flexible by-product potential, and (c) Updating the techno-economic analysis with a focus on regional biomass processing and rural development, and (d) updating the economic requirements for construction of a pilot scale plant. This reviewer considers the objectives/goals of the proposed project are very clear.

Reviewer 1B (Rating: 5)
The objectives of this project match very closely with several of the ND goals. In particular, this project aims to develop the information needed to model a pilot plant as based on the pretreatment process, a necessary step to full commercialization. The use of this technology for animal feeding and regional biomass processing is also considered. This tracks well with the goals based on bringing new industries to ND, increasing jobs and wealth, bringing new technologies to ND, and developing the baselines to promote further activities.

Reviewer 1C (Rating:5)
The project objectives are admirably clear and focused. They are completely consistent with the NDIC goals. Indeed, it is difficult to imagine a more clear, focused and consistent project.

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 1A (Rating: 4)
MBI has developed a new design to perform alkali pretreatment of biomass, using ammonia as the catalyst, that is anticipated to have much lower capital and operating costs over pervious Ammonia Fiber Expansion (AFEX) treatment processes. This process captures the ammonia on a new “packed bed” of biomass thereby avoiding the need for ammonia recovery and storage required in previous AFEX systems. This new treatment process has been demonstrated at bench scale (50 gram) and is called PB-AFEX. This project is to scale up the PB-AFEX process

to a three reactor semi-continuous system that operates at 4.5 kg per cycle. With data from operating this system, a pilot scale system operating at one ton per day will be able to design. The project will be completed in 15 months with $406,120 requested from the Renewable Energy Development Program. The objectives of this project are to:

1. Design and build a three reactor continuous PB-AFEX laboratory system
2. Operate the reactor system to collect mass and energy balances necessary to design a pilot plant for the process
3. Use the PB-AFEX reactor to generate sufficient quantities of AFEX-treated material for applications testing of fermentation products systems and initial animal feeding trials
4. Develop a pilot scale plan including a) Process Flow diagram; b) Proforma of anticipated capital and operating costs; and c) Plan for product development
5. Develop a proforma for regional biomass processing centers using the PB-AFEX reactor and determine rural development implications for the project.

Reviewer 1B (Rating: 4)
The largest concern regarding the completion of this project is the success of the scale-up to a 1.5kg reactor. If key pieces of this technology (for example, the successful desorption, adsorption of ammonia from one reactor to the next) prove to be more difficult than imagined, then this would increase the length of time needed for installing and shaking down the equipment, thereby decreasing time to obtain mass balances and developing the pilot plant model. However, there does appear to be sufficient time in the attached timeline to account for this. Mass and energy balances are expected to be completed by month 10, and so delays may not be critical for this proposal. Budget does not appear to be an issue.

Reviewer 1C (Rating: 4)
I have been involved in research (and life) long enough to know that nothing is "certainly achievable". However, the resources, focused objectives, quality and experience of the team, as well as the time frame for the project do put it clearly in the "most likely achievable" category.

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 1A (Rating: 3)
As indicated in the application, MBI has developed a new process for performing alkali pretreatment on wheat straw and other biomass materials. This new process is less capital intensive than previous processes and resolves the ammonia recovery and storage issue by storing the ammonia used in the process on beds of untreated biomass. The catalyst, ammonia, moves from one reactor to a second reactor eliminating the need to recover and store the ammonia for reuse. This process has been demonstrated at laboratory scale (50 gram batch). The availability of sugars from biomass after hydrolysis, using this new process is comparable with the conventional AFEX treatment processes. This new process is called Packed Bed AFEX (PB-AFEX), and the team members have filed a patent application for the process.

Reviewer 1B (Rating: 3)
The method of circulating ammonia presented in this proposal is unique and displays a great deal of promise for providing an economic ammonia pretreatment system. Likewise, the proposal lays out a clear approach to producing the proforma, including both the experimental approach and laying the groundwork for modeling the system. However, very little information is provided on the experimental section, namely the hydrolysis, fermentation, and animal feeding trials. How will these be performed? What are the benchmarks for success? Is the purpose to insure this process is no worse that batch AFEX pretreatment, or are there specific goals in mind (sugar/ethanol yield, ethanol titer, etc). Likewise, no information is provided on the animal feed, other than mentioning testing for palatability and energy. How will the energy be tested? Palatable to what livestock?

Reviewer 1C (Rating: 5)
The methodology is clear, concise and appropriate. I am not able to identify a single weakness or omission in the methodology.

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 1A (Rating: 3)
Although the scientific/technical merits of research efforts on fermentation of bio-based products, production of cellulose nanofibers, and preparation/evaluation of cellulose nanofiber bio-composites are minimum (since they have been well-studied and well-known), the exploration for developing a business entity in North Dakota to utilize its large supplies of agriculture biomass may be important economically.

Reviewer 1B (Rating: 5)
The proposal lays out with clarity the difficulty of producing a cellulosic biorefinery, which would harm ND's goal of producing energy from biomass. If this pretreatment is successfully scaled up, it would reduce the capital-intense problem of building the refinery described in the previous FEED study, and could solve logistical issues and provide a valuable alternate product in the animal feeding sector. Because the process is still unproven, the work plan laid out in this proposal is critical to scaling up the PB-AFEX process to an eventual commercial facility. The proposal lays out a strong case that it is the economic and engineering aspects that are holding back the creation of biorefineries, and so this proposal would be very useful in promoting the development of an eventual bioeconomy in North Dakota.

Reviewer 1C (Rating: 5)
The goals of the NDIC/REC include development of North Dakota's renewable energy resources, job creation based on those resources, increased economic stability and growth, promotion of new technologies, and added wealth for agriculture and landowners. All of these goals are addressed by the proposed project and potentially very large benefits might accrue to North Dakota if the project is successful. The only goal that is not directly addressed by the

proposed project is promoting public awareness. If the project is successful, I imagine that objective will also be quickly addressed.

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 1A (Rating: 2)
Fermentation of bio-based products, production of cellulose nanofibers, as well as preparation/evaluation of cellulose nanofiber bio-composites has been well-studied and well-understood. Although the details regarding research methodology are provided in the confidential portion of this application, this reviewer did not identify the substantial difference(s) with the previously reported ones (which could easily be found in published literatures). Regarding the development of a comprehensive bio-refinery, other states (such as Kansas and Pennsylvania) have conducted similar studies. A comparison of those studies to the proposed one and a clear explanation of the uniqueness and (potential) advantages of the proposed plan could help the reviewer to understand the significance of the proposed project.

Reviewer 1B (Rating:4)
Literature references were very sparse throughout the proposal, and thus it is difficult to determine the investigator's awareness of the published literature. However, the background shows a strong awareness of the economic limitations of biomass processing, and in particular the limits of the ammonia-based pretreatment discussed here. The focus of the project appears to be reducing the capital cost of the pretreatment facility and increasing biomass cofiring in electricity generation, which the authors argue are both critical for a ND bioeconomy.

Reviewer 1C (Rating: 5)
This is much more a development project than it is a research project, so I did not really expect to see much literature referenced…and that turned out to be correct. The PI is a very distinguished scholar with an excellent publication record, so I expect him to be well aware of the current literature. The MBI investigators are also among the best in their fields, and have also published extensively. So I rate this a "5".

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 1A (Rating: 3)
As addressed before, the fermentation of bio-based products, production of cellulose nanofibers, as well as preparation/evaluation of cellulose nanofiber bio-composites have been well-studied and well-known. Additionally, some efforts have been conducted regarding developing a comprehensive bio-refinery in the mid-west states. Nonetheless, the team members appear to have adequate background for the proposed work. The following are the team members:

Dr. F. Larry Leistritz, Professor, Dept. Agribusiness and Applied Economics, NDSU will serve as Principal Investigator.

Dr. Bernie Steele, Director of Operations will serve as Principal Investigator for MBI, International.

Dr. Farzaneh Teymouri, Senior Engineer, and Tim Campbell, Process Development Engineer, will direct the technical operations of MBI.

Sandra Broekema of Great River Energy will serve as industry technical consultant.

Reviewer 1B (Rating: 5)
The previous partnership between MBI and NDSU in creating a FEED study for biomass processing using AFEX pretreatment demonstrates both their ability to work together as well as their strength in process modeling. MBI's expertise with AFEX as well as general expertise in scaling up technologies should be invaluable in their attempts to scale up the PB-AFEX design. Great River Energy is an excellent partner for matters associated with biomass cofiring, and a strong consultant on other economic determinations. Given the tasks involved, this appears to be a very strong team.

Reviewer 1C (Rating: 5)
As mentioned above, these are top folks, and probably among the best in the world in this area. Furthermore, the team is well matched for capabilities, with little or no duplication and they have the added benefit of having worked together for several years so that any personality and style issues have probably been resolved.

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 1A (Rating: 3)
It is described in the application that the key project participants have been working together in efforts leading to the present undertaking for the past three years; and the project team has established a management system featuring (1) regular (generally at least weekly) e-mail communications, (2) periodic (at least quarterly) reviews of progress, and (3) publication of research findings and outreach efforts upon completion of key milestones. The application also has a timetable describing the schedule of the proposed activities, and a financial plan indicating the allocation of the requested funding. Generally speaking, it is adequate; nonetheless, it would be better if the investigators could include (1) the detailed milestones of the project and (2) more justifications for the requested budget.

Reviewer 1B (Rating: 5)
The milestone chart and schedule is clearly laid out. The work flow is clearly laid out, with proper intermediate steps and reasonable timing for each task. Likewise, the communication

among the investigators appears to be excellent. The previous work between NDSU and MBI demonstrates that a proper working relationship is already in place, and there appears to be little doubt that the two teams can work effectively. The only minor complaint is that the budget for equipment and materials is not explained in more detail. However, the rest of the budget is very well defined.

Reviewer 1C (Rating: 5)
Exceptionally clear. All of these issues have been appropriately addressed with high clarity.

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 1A (Rating: 5)
No equipment is to be purchased.

Reviewer 1B (Rating: 4)
The equipment appears to be focused on buying a bench scale AFEX reactor. Given the budget for materials provided ($32k), the cost of this reactor system to ND (the proposal stated that MBI has already committed some equipment to this project) appears to be quite small. The size appears to be small enough to keep costs low, yet large enough to provide all the data necessary to develop the proforma. Because the equipment costs were not separated from the rest of the materials, I cannot be certain that the budget is reasonable, although it certainly does seem reasonable to me. However, the need for a 3-reactor system does appear to be critical to develop the proper material and energy balances given the ammonia flow described in the proposal.

Reviewer 1C (Rating: 4)
While I do not have any problems with the equipment justification, I do not think the description of that equipment warrants the "extremely well justified" classification. I am not being critical, just trying to be objective.

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 1A (Rating: 4)
This reviewer thinks that the facility and equipment could be very good, since the key participants in this project are the North Dakota Agricultural Experiment Station (NDAES), MBI International, and Great River Energy. The lab scale reactor will be within the existing MBI facility. No new facilities are anticipated. Technology development at MBI takes place in a 120,000 square-foot, state-of-the-art R&D center, including a 20,000 square-foot pilot plant. The fully equipped facility is capable of supporting multiple projects in microbiology, molecular biology, bioprocess engineering, and materials science, and is well suited to conduct laboratory and pilot-scale research, development, and production. In addition to the laboratories and pilot

plant, support services and administrative services are integrated into the facility to coordinate project development.

Reviewer 1B (Rating: 4)
MBI's facility appears to be sufficient to operate the scaled up reactor. The integration of lab and pilot scale facilities at MBI may be useful for further development of this project as well, although that is not specifically within this proposal. The largest concern is dealing with large quantities of ammonia, a hazardous gas. However, MBI's previous research with ammonia pretreatment indicates that their facility is adequate to the task. The fact that MBI has already committed equipment to this project also shows the value of their facility.

Reviewer 1C (Rating: 5)
MBI's facilities are exceptionally good, and are probably among the best in the world in this area.

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 1A (Rating: 3)
This reviewer believes that (1) to scale up the PB-AFEX process to a three reactor semi-continuous system that operates at 4.5 kg per cycle and (2) to design a pilot scale system operating at one ton per day in the State of North Dakota may be important economically. Nonetheless, the value of the scientific/technical activities/studies in the application is limited.

Reviewer 1B (Rating: 5)
If successful, and there is a strong chance that it will be, the value of the proposal is very high. The proposed work would put this AFEX treatment plan in a strong position to be commercialized, and put the partners in a strong position to earn funding for developing a pilot facility. Thus, this work could directly lead to new jobs and new investment in creating and operating a pilot facility, and would also increase the possibility of a full scale facility, which would provide a great deal of economic value to North Dakota as outlined in the proposal. Despite the potential high value of the finished product, the budget requirements are relatively light. While there is still a great deal of work needed before this technology is ready for commercial use, the fact that this proposal is directly necessary for commercialization, and the fact that the work so far with PB-AFEX and AFEX in general has shown promising results, makes this proposal extremely valuable.

Reviewer 1C (Rating: 5)
Given the degree of cost sharing by MBI and the value of Great River Energy's involvement, this has to be rated very high value to the State of North Dakota. The State is getting a very high leveraging of its research investment.

[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.

10a. Financial commitment from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Higher priority is to be given if the application has private industry investment equal to or at least 50% or more of total cost.

The minimum 50% cash match is demonstrated.

Section C. Overall Comments and Recommendations:

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 1A ***(Fund May Be Considered)***
The goal of this project is to complete efforts to design a pilot scale plant for conversion of wheat straw to various biomaterials (*i.e.,* fuels, chemicals, animal feed, *etc*). Specific objectives for this project include: (1) Prototype testing of a new ammonia fiber expansion (AFEX) reactor design that is less capital intensive, (2) Prototype testing of this system for continuous ammonia reuse, and (3) Updating the commercial business plan to address (a) Deployment on a regional basis, (b) More flexible by-product potential, and (c) Updating the techno-economic analysis with a focus on regional biomass processing and rural development, and (d) updating the economic requirements for construction of a pilot scale plant. This reviewer believes that the team members are qualified for the proposed project, and the facility is adequate to support the project. It is noteworthy that (1) to scale up the PB-AFEX process to a three reactor semi-continuous system that operates at 4.5 kg per cycle and (2) to design a pilot scale system operating at one ton per day in the State of North Dakota may be important economically; nonetheless, the value of the scientific/technical activities/studies in the application is limited. The overall recommendation is "Funding May Be Considered".

Reviewer 1B ***(Fund)***
This is a strong proposal that can add a great deal of value to North Dakota. The emphasis here is the interest in developing a commercialized biofuel facility that can also function as a regional logistical center, provider of value-added animal feeds, and/or produce low carbohydrate biomass for electricity production. The key technology presented here has potential to vastly reduce the capital cost of ammonia pretreatment, and potentially the operating cost as well. This, coupled with its simplistic design, may allow it to be commercialized relatively rapidly despite currently proven on a larger scale.

The work plan presented details the steps needed towards developing such a facility and proposes several key steps necessary for commercialization, namely validation of the technology

and developing a proforma for pilot plant design/construction. The proposal presents a strong case for the necessity of this technology in light of the current economic situation, and the background of the two major investigating groups suggest the proper knowledge and skill to implement this proposal. On the whole, I believe this is a valuable proposal, as the technology is derisked enough to be deemed likely for commercialization, yet still requires further derisking that can be performed at a relatively low cost. The authors present a clear work plan at a relatively low cost and a strong chance of success, and the deliverable outcome has a great deal of value. Because of that, and because of the previous successes in ammonia pretreatment and evaluation of the commercialization aspect, I believe this project should be funded.

That said, there are a few areas of weakness in this proposal. In particular, the experimental approach of testing the treated material was glossed over in this proposal, with little information of how the pretreated biomass will be analyzed. Because this is not the focus of the proposal, it is not a critical issue, but it should have been addressed. Are the authors looking for specific benchmarks? Will they be attempting to tweak the reactor design based on the results of the hydrolysis/fermentation studies? Are the animal feeding studies only supplemental to the fermentation results, or will they be held in equal weight when evaluating the value of the AFEX process? Likewise, there is little mention of other pretreatments in a literature review, and the potential advantages/disadvantages this reactor system has over any other. While the case is made clearly that this is an economic improvement over the previous AFEX design, and strongly implies that it can be a viable technology with proper scale-up, more emphasis on why it is preferred over current technology would have improved the proposal.

Reviewer 1C ***(Fund)***
There are many strong reasons to believe that the cellulosic ethanol (and other biofuels) industry will grow rapidly over the next few decades. Several billion dollars have been invested in the technologies to convert biomass to fuels and the conversion technologies are developing very quickly. As the processing technologies improve, the cost and availability of feedstock will become increasingly important. This project gives North Dakota a potentially powerful “leg up” on the competition in providing abundant, low cost, pretreated biomass for biofuel production. Furthermore, the improved animal feeds that will probably arise from the PB AFEX approach will give an added income stream for farmers and help defuse the “food vs. fuel” argument against biofuels. Finally, the involvement of Great River Energy helps ensure that the residue from fermentation achieves its potential to provide a lower carbon footprint for electricity production and simultaneously improve overall fuel/electricity production economics.