TECHNICAL REVIEWERS' RATING SUMMARY

R024-B

Catalytic Alcohol Condensation to Higher Alcohols

EERC
Principal Investigator: Bruce Folkedahl
Request for $250,000; Total Project Costs $500,000

Rating Category	Weighting Factor	Technical Reviewer 1B Rating	2B Rating	3B Rating	Average Weighted Score
1. Objectives	9	3	3	5	33.00
2. Achievability	9	3	3	2	24.00
3. Methodology	7	3	4	4	25.67
4. Contribution	7	3	4	5	28.00
5. Awareness	5	3	3	3	15.00
6. Background	5	3	4	5	20.00
7. Project Management	2	3	4	5	8.00
8. Equipment Purchase	2	5	5	5	10.00
9. Facilities	2	4	5	5	9.33
10. Budget	2	3	4	4	7.33
Average Weighted Score		156	181	204	**180.33**
Maximum Weighted Score					**250.00**

OVERALL RECOMMENDATION

FUND		x	x
FUNDING MAY BE CONSIDERED	x		
DO NOT FUND			

R024-B
Catalytic Alcohol Condensation to Higher Alcohols
Submitted by EERC
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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 1B (Rating: 3)
Conversion of ethanol to biobutanol, a "next generation" biofuel, does fit within NDIC/REC goals. But this project appears to be in the developmental stage, and would not impact the economy of NDak for several more years.

Reviewer 2B (Rating: 3)
They bury the lede, but once presented with the reasoning – ethanol producers are at the blend wall and need additional revenue opportunities – the alignment with NDIC goals becomes clear. It's an interesting approach, and worth pursuing: http://www.biofuelsdigest.com/bdigest/2014/04/29/make-butanol-from-ethanol-the-unspoken-rfs-work-around/.

Reviewer 3B (Rating: 5)
The goals of this project are to: 1) complete development of catalytic alcohol condensation (CAC) process to convert ethanol into higher value fuels, 2) develop a CAC process that can be bolted onto commercial ethanol plants, and 3) assess the commercial feasibility of this process.

Ethanol production in the US has hit the blend wall, and as lignocellulosic ethanol plants come on line, this situation will worsen. Several years ago the DOE and USDA shifted focus from ethanol to production of "drop-in" fuels that are infrastructure compatible. In response, several companies have worked to commercialize a biobutanol production process using microbes that convert sugars into butanol. Unfortunately the fermentation route suffers from low productivity, yield, and butanol concentrations due to the high toxicity of butanol. This results in high costs for processing and product recovery.

This proposed catalytic route provides an interesting alternative, in that it would simply bolt onto the end of existing ethanol plants, using a catalytic process to convert ethanol into butanol. This proposal fills a critical need in transforming ethanol into a more marketable fuel. The key questions are the performance and cost of this system, and whether existing ethanol plants would find a sufficient return on investment to make the change.

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 1B (Rating: 3)
I believe the tasks outlined on page 6 of the proposal are likely to be achieved. The viability of the long-term goal, an economically robust catalytic conversion process for biobutanol production that can be readily integrated into bioethanol facilities is not certain.

Reviewer 2B (Rating: 3)
I say this not with any intimate knowledge of the specifics of this particular approach, but rather with a broad understanding of having looked at other more established biofuel / green chemical players in the space – Cobalt, Green Biologics, etc. – that these things just generally take longer and more money to achieve milestones than expected. This is hard to do, simple as that, and while some of these players will hopefully be successful, from an early stage investing perspective it's been a very long haul. The specific milestones here though are reasonable, and the EERC does some perfectly positioned to be able to quickly ramp up testing and lab/pilot designs, which is a major plus.

Reviewer 3B (Rating: 2)
A main emphasis of this proposal is development of the catalyst. The team has several journal articles on their research, but failed to provide details in the proposal as to their progress. Key questions are the performance of the catalyst, the anticipated lifespan of the catalyst, and the cost of the catalyst. It is not clear how far the team is in developing catalysts. The proposal reads as if they have basically just shown proof-of-concept for the CAC and have years of work ahead of them to achieve adequate catalyst performance. This can be a lengthy and complicated process, and groups such as Pacific Northwest National Labs have been working for decades on this problem. Thus I worry that the EERC team may not be far enough along that 5 months they have assigned for process development is sufficient.

Beyond catalyst development, the team indicates that other products result during the catalytic process, but do not indicate the types of chemicals and their fate in the process. Will they poison the catalyst? Will they significantly reduce yield of the desired products? What is their potential uses and values? Answering these questions takes additional time.

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 1B (Rating: 3)
The applicants possess the pilot-scale facilities and expertise to complete Tasks 1 and 2 (per p. 6), catalyst optimization and development of a pilot-scale demonstration unit. The applicants do not provide any methodology related to Tasks 3-5.

Reviewer 2B (Rating: 4)
Getting to an initial read on the economic viability of such an approach is the most crucial aspect of this project, and it's good to see that this is a clear focus of the team. The methodology of how they actually get there is sound overall.

Reviewer 3B (Rating: 4)
The team has several years of experience in thermochemical and catalytic processes so should be well versed in appropriate methodologies.

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 1B (Rating: 3)
The capability to produce biobutanol from bioethanol is or relevance to the NDIC, per my comments to Criterion 1. Yet, since the proposal provides very little relating to the specifics of the catalytic process (e.g., preliminary data on conversions), which produces some uncertainty.

Reviewer 2B (Rating: 4)
Ethanol abundance and blend wall limitation is a real pain point, not only in ND but nationally. The technical breakthrough of being able to catalytically convert ethanol to higher value (price/margin and application) butanol could be a boon to ND.

Reviewer 3B (Rating: 5)
This project offers a technology to overcome the ethanol blend wall, while still taking advantage of the efficiencies and existing infrastructure of the ethanol industry. If this technology works and can be commercialized, it could be readily deployed throughout the Midwest to existing ethanol plants. Moreover it could be similarly applied to biomass based ethanol plants. With additional catalyst development it is possible that the system could be “tuned” to produce additional long chain carbon molecules.

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 1B (Rating: 3)
The applicants are aware of the potential value of a robust process that converts bioethanol into biobutanol. But, the reviewers are given very little information on their catalytic process, and how it compares to other related processes being developed (e.g., at the University of Bristol, UK, and Western University, London, Ontario Canada).

Reviewer 2B (Rating: 3)
A discussion of what has limited prior research into the space would be helpful, as well as a description of direct sugar to butanol approaches that are currently being commercialized. Surely there are lessons to be learned that can be applied to the lab and pilot scale approaches described here that could be beneficial.

Reviewer 3B (Rating: 3)
Strong background of the team due to their prior work. Unfortunately the proposal did not do a sufficient job in describing the current status of their catalyst work and what needs to be completed. What is the current performance versus their target levels? Can this be achieved in 5 months? Unless the catalyst work is 90% completed, it is unlikely they can achieve their goals in that short timeframe.

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 1B (Rating: 3)
The EERC possesses the expertise in catalytic technology relating to biomass. Dr. Folkdahl possesses the expertise as a project director. But the reviewers are not given any information regarding the investigators who will be evaluating the catalyst, preparing the pilot-scale facilities, nor Tasks 3-5 on p. 6. The background and role of the partnering institutes, Hankinson Renewable Energy and the National Corn Growers Association, is also not described.

Reviewer 2B (Rating: 4)
The PI's work experience with related processes will obviously be beneficial.

Reviewer 3B (Rating: 5)
The team has been working on this for some time and has good expertise.

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 1B (Rating: 3)
An adequate Project Management Plan is given on p. 14. However, for almost half of the project, months 1-5 (before completion of Milestone 2), there are no scheduled meetings of the team according to the narrative on p. 14. The identification of the team members and the expertise they would bring to the table is not clear.

Reviewer 2B (Rating: 4)
It's clear that they've done similar work before under similar time frames. The budget if very well defined, and the go/no-go decisions at the various milestones should preserve funding if overall viability is deemed to be limited.

Reviewer 3B (Rating: 5)
The EERC has decades of experience in successfully managing large projects that involve multiple participants.

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

Reviewer 2B (Rating: 5)
The existing EERC facility and capabilities are obviously one of the big pluses to this proposal.

Reviewer 3B (Rating: 5)
No equipment is requested

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 1B (Rating: 4)
The EERC has outstanding facilities needed to complete Tasks 1 and 2.

Reviewer 2B (Rating: 5)
As noted above, the EERC facility appears to be an incredibly strong fit for the necessary lab and pilot scale work that will ultimately (and should I say hopefully) lead toward an engineering design for a commercial scale facility.

Reviewer 3B (Rating: 5)
The team has been working on this for some time and has needed facilities and equipment.

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 1B (Rating: 3)
The NDIC/REC investment of $250K will pay for the labor necessary to complete Tasks 1-5, with the budget (mostly labor) appearing to be commensurate with the workload of Tasks 1-5 given on p. 6. But is it unclear if the NDIC investment will lead to a robust catalytic approach for conversion of enthanol into biobutanol.

Reviewer 2B (Rating: 4)
Labor does appear particularly high – a person by person breakdown of expectations would be helpful.

Reviewer 3B (Rating: 4)
Appropriate, but a discussion of the people involved and their time commitments would have been helpful.

[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 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.*

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 1B ***(Funding May Be Considered)***
I believe this proposal may be considered for funding, but on a lower priority level. I believe the applicants are on the right track. But, the proposal provides very little concrete proof-of-concept preliminary data and a well-crafted research plan to justify its funding at a high priority level. Moreover, the proposal reads as if it was prepared at the 11th hour.

Strengths: The notion of preparing a robust catalytic conversion process to convert bioethanol, a low-value biofuel, into biobutanol or other long-chain hydrocarbon "next-generation biofuels", is a worthy pursuit. The EERC has a strong reputation for its facilities and expertise in biomass conversion and catalytic technologies. The principal investigator has experience leading large projects.

Weaknesses: The proposal does not provide any proof-of-concept data, preliminary economic assessment, or any documentation that supports the performance of the catalytic technology for converting ethanol to butanol or other n-alkanols. Information is not given in the proposal that provides information on the co-investigators who will be performing the work for Tasks 1-5, the role of the two partnering entities, and methodology for Tasks 3-5. Are there some specific benchmarks that are to be achieved, e.g., *x%* conversion of ethanol (at what percent purity required?) into biobutanol at *y* selectivity at a *z* scale and catalytic productivity rate of *w*? Are there some economic- related benchmarks? The proposal would be strengthened if a North Dakotan ethanol producer was identified who would work with EERE to implement the catalytic unit prototype in their operation. Moreover, this project appears to be in the early development stage, and would not impact the North Dakota economy in the near term.

Reviewer 2B ***(Fund)***
No general comments provided.

Reviewer 3B ***(Fund)***
My main concern is that a one year project may not be sufficient for all the objectives. If they had the catalyst fully developed and only needed to work out a few issues at the lab scale, then there would be sufficient time for the pilot scale demonstration, economic analysis, and design of the demonstration system. Unfortunately the proposal does not clearly indicate the status of the lab scale work. If substantial catalyst development is needed, this could take several years in itself, let along also optimizing the rest of the process, including product recover and the fate of wanted or unwanted coproducts.