TECHNICAL REVIEWERS' RATING SUMMARY

R018-C

Development of Innovative Modular Lithium Iron Phosphate Battery Packs for Energy Storage

Clean Republic LLC
Principal Investigator: Yong Hou & Michael Shope
Request for $220,000; Total Project Costs $443,000

Rating Category	Weighting Factor	Technical Reviewer 3A	3B	3C	Average Weighted Score
		Rating			
1. Objectives	9	3	4	4	33.00
2. Achievability	9	3	4	2	27.00
3. Methodology	7	4	4	3	25.67
4. Contribution	7	3	5	2	23.33
5. Awareness	5	3	3	3	15.00
6. Background	5	3	3	3	15.00
7. Project Management	2	4	4	4	8.00
8. Equipment Purchase	2	5	5	5	10.00
9. Facilities	2	3	4	3	6.67
10. Budget	2	3	4	3	6.67
Average Weighted Score		163	199	149	**170.33**
Maximum Weighted Score					**250.00**

OVERALL RECOMMENDATION

If > 170	**Fund**		**x**	
130 - 170	**Funding May Be Considered**	**x**		**x**
If < 130	**Do Not Fund**			

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Development of Innovative Modular Lithium Iron Phosphate
Battery Packs for Energy Storage
Submitted by Clean Republic LLC
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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 3A (Rating: 3)
The objectives and goals are clear, and are related to improving Li ion LiFePO4 battery operation. The main purpose is to improve the packaging, cell balancing, and cooling mechanism of a battery pack. Although the proposed work is development in nature, it is relevant to the Renewable Energy Council goals.

Reviewer 3B (Rating: 4)
The project propose to develop a hierarchical modular structure for LiFePO4 battery packs for energy storage of renewable energy conversion systems, and research the battery management system (BMS) and the thermal management solutions so that the low---temperature performance, reliability, service life, and cost effectiveness of LiFePO4 battery packs can be significantly improved.

Reviewer 3C (Rating: 4)
The proposal definitely shows an adherence to the stated goals of the NDIC/REC and if successful could have a positive impact on the overall energy storage sector, specifically mid-scale lithium ion battery packs.

I do have concerns, however, about the likelihood of even a successful such result having a significantly positive impact on ND-based jobs and renewables, as noted below. In particular, the tie between this research and large-format energy storage for broadscale renewables intermittency stabilization seems a stretch.

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)
The time and budget are somewhat on the tight side, but a good portion of the proposed work should be achievable.

Reviewer 3B (Rating: 4)
The proposed approach is integrative including modular assembly, battery management and thermal management. It is mostly likely the proposed objective will be achieved.

Reviewer 3C (Rating: 2)
This is not one proposed research project, it is actually three, and if any of them falls short of expectations the anticipated availability of improved mid-sized lithium ion battery packs would be in doubt. Each of them is in actuality a fairly challenging project, at very least from the perspective of commercialization issues and other risks that are unaddressed or otherwise given short shrift in this write-up.

Specifically, IP issues are not really addressed here. And yet this is a very highly crowded sector from an intellectual property perspective. A simple Google Patents search for 'heirarchical modular "battery packs"' yields over 3,000 results. Many of these found patents won't be directly relevant, but even given that it would be shocking if the innovations being pursued by this team aren't in potential conflict with someone else's intellectual property.

Another risk is the reliance upon a partner, AllCell, that is a thinly-capitalized startup in its own right and hasn't been able to raise much capital since attempting (and it would appear unsuccessfully) a $5M equity raise two years ago. That's not to say that they're at severe risk for sure, but the thermal management side of this project is completely dependent upon AllCell's phase change materials IP and approaches, and without further information about AllCell's current financial status it's difficult to say how much of that portion of the project is at risk or not.

Yet another risk is that the rapid emergence of alternative large- to mid-format energy storage technologies will obviate the current opportunity for lithium ion to have any economic value proposition at all. There is little in this plan that goes to address the very high costs of lithium ion batteries, and it is that high cost that lends hope to entrepreneurs who are bringing forth flow batteries, aqueous hybrid batteries, compressed air storage, advanced lead acid batteries, flywheels, and many other approaches to this market segment. No one has yet successfully solved the problem and achieved large scale adoption of any of these technologies in a renewable energy context, but several are certainly revenue stage or at the point of real commercialization. It's unclear, therefore, if lithium ion batteries will have any significant role to play in a large-scale renewable energy project format five years from now.

Finally, with the stated goal of addressing large-scale energy storage, it is important to bear in mind that the company (Clean Republic) has to date largely successfully tackled only much smaller li-ion form factors. They have brought on a consultant in an unknown level of commitment from another battery manufacturer, but without suggesting that this team definitely cannot make the leap from electric bicycles to large-format stationary energy storage devices, it certainly isn't clear that they definitely can make such a leap. And thus execution remains a risk as well.

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: 4)
The proposed is based on known technology, science and engineering principles. The development research is mostly for engineering, putting the proven components together for an improved package. The proposed ideas are simple and relatively straight forward. Thus the level of innovation is limited, but the work should lead to improvement as predicted.

Reviewer 3B (Rating: 4)
The methodology is convincing and comprehensive. It includes design of both hierarchical modular structure and standard modules, design of multiple-level battery management systems to balancing the mismatches of cells during operational life; and use phase change materials for thermal management of batteries/ and field demonstration in a wind/solar hybrid system.

Reviewer 3C (Rating: 3)
From a process stand-point the methodology appears well-planned, and this is a team that has successfully introduced products to the marketplace before. They have a basis for believing their approach to product development of a system like this will be successful. I wish there were more details, however, about why this team's methodology would be successful in the face of so much other researchers and battery manufacturers in this field. I marked down for the lack of a comprehensive competitive landscape analysis.

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: 3)
The contribution is adequate. If successful, the improved packaging may lead to new products and new markets for the company. That should translate to more jobs. The proposal predicts addition of four new jobs if successful. The main unknown is the added cost and whether the improvement justifies the cost. That remains to be seen after the technology is proven.

Reviewer 3B (Rating: 5)
The proposed work is timely as safety of Li-ion battery has huge concern in publicity now. The selection of thermal stable of LiFePO4 cathode chemistry in the battery for renewable energy application is good. The electrical circuit design for battery management and thermal management will comprehensively make the battery safe and long cycling.

Reviewer 3C (Rating: 2)
For reasons stated above, it should be acknowledged that this is a risky endeavor, both from a technology development and from a successful commercialization perspective.

Even if successful, it's unclear what the contribution of this work would do to directly impact REC goals. The prime contractor is based in Seattle with a "shop space" in ND. The other major collaborating groups are based in Illinois and Colorado. It is unlikely that significant battery manufacturing based in ND would result from this effort, and it is unlikely that this particular solution would directly positively impact ND-based renewable energy production, given the availability of alternative approaches.

That said, firming windpower would be a great benefit to all major windpower generating regions including ND. And even if unsuccessful as a standalone commercialized system, there might be innovations funded here that could result in other battery manufacturers creating solutions that then end up being used in ND.

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)
The proposal indicated adequate awareness of the current commercial state of the art. Since this is a development project, the investigators opt for proven technology and not for breaking new grounds.

Reviewer 3B (Rating: 3)
There are a few ARPA-E projects that propose high-risk and high reward battery management system that PIs may be aware of it. The algorithm used in the battery management is not well stated.

Reviewer 3C (Rating: 3)
The principal investigator has clearly done some research into the topic and has tapped into a couple of knowledgeable outside consultants / partners. This gives some credibility to the effort. However, there is no discussion of likely intellectual property that may already be in place covering part of the area of investigation, nor do I see papres from well-known li-ion researchers listed (Gerd Ceder of MIT comes to mind just as an example), which suggests to me that the investigator's awareness is incomplete. I would urge that additional effort be put into a competitive landscaping both on the research and the product side, and particularly that a thorough intellectual property search is done on the three areas of investigation, to make sure that this effort doesn't result in something that cannot be commercialized due to IP conflicts or other restrictions.

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: 3)
The investigators have adequate background to conduct the proposed work. They have shown an adequate level of understanding of the issues and possible solutions.

Reviewer 3B (Rating: 3)
The PIs has less experience in the field of battery chemistry and battery diagnostic. However, as LiFePO4-graphite is relatively mature battery chemistry, the team has adequate knowledge and capability to run the project.

Reviewer 3C (Rating: 3)
It is difficult to draw conclusions here, because it is not well described to what extent they will be able to draw upon the knowledge and other resources of the key li-ion focused collaborators, AllCell and Elithion. It would appear from their CVs that the core team is not expert in lithium-ion technology, but are more systems and mechanically-oriented. So much depends upon how much they will be able to draw from these external resources to augment their skills in this area.

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: 4)
The investigators are from the same company that has been in operation and products in the market. They have worked together successfully.

Reviewer 3B (Rating: 4)
The milestone, schedule, and financial plan are well stated.

Reviewer 3C (Rating: 4)
The plan seems very well defined, and is well thought-out, from a process and collaboration/ communication standpoint.

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: 5)

Reviewer 3B (Rating: 5)
No equipment proposed to be purchased in NDIC's share.

Reviewer 3C (Rating: 5)
It would appear that no equipment is to be purchased.

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: 3)
The PIs have the necessary equipment to perform the proposed work.

Reviewer 3B (Rating: 4)
The cost share is proposed in use and purchase of equipment. The team has necessary facility for the proposed research.

Reviewer 3C (Rating: 3)
World-class lithium ion battery pack development and commercialization is typically done in a very robust setting, but that doesn't mean cleanroom standards, depending upon which components are being adapted and adjusted. The facilities are likely sufficient although I do have some concerns about the ability of these facilities to perform sufficiently rigorous research into a wide range of phase change materials -- I suspect that won't actually be necessary, however.

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: 3)
A weak point of the proposed work is the lack of cost and performance target/analysis, making it difficult to estimate the potential return on investment. How much improvement is expected and what is the cost to achieve that?

Reviewer 3B (Rating: 4)
The proposed budget is reasonable for the proposed research work.

Reviewer 3C (Rating: 3)
I would expect a similar effort by companies like A123, Boston Power, AllCell and others would probably cost in the millions of dollars, largely driven by significant investment in researchers. I expect a successful effort here will require the same inputs, I'm not sure what cost advantages or disadvantages would be found in ND in this particular sphere of innovation.

[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. <u>Financial commitment from other sources</u> – 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.

*<u>Reviewer 3A **(Funding May Be Considered)**</u>*
Overall, funding of the proposal is justifiable. The technical risk of such development project is low, but whether it translates to economic success is a large unknown. The main weakness of the proposal is lack of targets, both technical and cost, that can be used to judge whether the work is successful or not. Setting such targets also help the investigators to make choices. Perhaps these should be supplied by the investigators before funding is approved.

*<u>Reviewer 3B **(Fund)**</u>*
As low cost battery packs with good cycling stability and safety is in demand for efficient use of renewable energy storage resources, the proposal fits the need and goal of North Dakota Renewable Program. The proposed work on battery management and thermal management is timely as the safety of Li-ion battery is important to be addressed in publicity. The proposed research work address the key issues in development of battery packs for distributed stationary applications such as storage of solar/wind energy. The combination of battery management with cell discharge/charge balances, thermal management and fabrication of hierarchical modular is unique. I would recommend the proposal funded.

*<u>Reviewer 3C **(Funding May Be Considered)**</u>*
As my comments above probably make clear, I am skeptical about this effort's likelihood of success -- with success defined as a fully-commercialized lithium-ion based system that achieves widespread adoption by the ND-based windpower industry.

My skepticism is largely based upon the uber-competitiveness of this industry (by all reports, the Chinese-driven price pressures that collapsed the US-based solar panel manufacturing industry is analogous to what is expected to happen in the lithium ion battery industry); upon the relative inexperience of this team with this type of research project including specific techniques and technologies to be used; upon the rapid emergence of much cheaper alternatives to li-ion for these applications; and upon the dangers of such a crowded space having resulted in prior intellectual property that any final product may well run afoul of.

However, these are guesses on my part. And this is a team that has successful commercialized a product in the past (although it's unclear at what volumes...). They are clearly bright and innovative.

Even if the fully-wrought product is not born directly into the marketplace as a result of this investigation, it may well yield results that are additive to someone else's li-ion based solution that ends up gaining adoption in the marketplace. Given the low cost being requested to fund this investigation, and the multiple areas of investigation being pursued, it may well justify the moderate expenditure.