TECHNICAL REVIEWERS' RATING SUMMARY

R015-C

Innovative Lithium Battery Production for Renewable Energy Storage Systems

Clean Republic LLC
Principal Investigator: Yong Hou & Michael Shope
Request for $190,000; Total Project Costs $403,000

Rating Category	Weighting Factor		Technical Reviewer 1A	1B	1C	1D	Average Weighted Score
					Rating		
1. Objectives	9		4	3	4	5	36.00
2. Achievability	9		2	2	2	4	22.50
3. Methodology	7		2	3	2	2	15.75
4. Contribution	7	2	~~1~~	3	3	3	17.50
5. Awareness	5		2	2	3	2	11.25
6. Background	5		2	3	3	3	13.75
7. Project Management	2		3	4	4	2	6.50
8. Equipment Purchase	2		5	5	4	4	9.00
9. Facilities	2		5	3	3	4	7.50
10. Budget	2		2	3	4	4	6.50
Average Weighted Score		132	~~125~~	142	149	169	**146.25**
Maximum Weighted Score							**250.00**

OVERALL RECOMMENDATION

FUND				
FUNDING MAY BE CONSIDERED	x	x	x	x
DO NOT FUND	~~x~~			

R015-C
Innovative Lithium Battery Producton for Renewable
Energy Storage Systems
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 1A (Rating: 4)
The goals are clearly stated, which is to improve the thermal management, cell balancing, and serviceability of large battery packs suitable for storage of wind energy.

Reviewer 1B (Rating: 3)
This proposal discusses a potential manufacturing operation based in North Dakota, selling renewable energy-related energy storage products. Those products also are applicable to the wind and solar projects already existing in the state. As such, the objectives and goals of the proposed project are clear and consistent with the NDIC/REC goals, including efficient, economic and environmentally sound development of renewable energy resources; jobs creation; stability and growth of the renewable energy industry; and encouraging the use of new technologies.

However, it's not clear why ND should be a center of lithium ion battery manufacturing – an industry which has seen recent bankruptcies because it is highly cost-competitive and crowded.

Reviewer 1C (Rating:4)
The key objectives of the proposal are identified. Specifically, the proposed research seeks to overcome barriers to the greater use of renewable energy by providing more cost effective energy storage options. These objectives are well aligned with the Council's goals.

Reviewer 1D (Rating:5)
The proposal aims to develop battery management system through designing novel electrical circuits, design battery pack frameworks with removable architectures, and investigate the use of phase change materials for thermal management of batteries. The study and investigations will be tested in field with wind/solar hybrid generation system.

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: 2)
None of the approaches proposed is unique or novel. In some cases, not concrete plan is described. For example, it is unclear what phase change material will be tested. Without the specifics, it is not clear whether the material can be configured to the desired form, or whether there is any environmental issue in their use. Although they have a reasonable chance to achieve the technical goals, the proposer has not provided a reasonable justification of commercial potential. For example, cell balancing is practiced in many commercial applications of Li ion batteries. How is the proposed work superior in performance and in cost?

Reviewer 1B (Rating: 2)
What is proposed is a 3-part research and development program over 2 years. In order to complete these objectives, a team of 3-4 employees will need to investigate and solve disparate mechanical, electrical, and design-for-manufacturing challenges.

In addition, in these 3 primary research tasks, there is already a rich body of other research and development in what is a crowded sector (lithium ion cell and battery manufacturing), and it's unclear from the materials provided that this team has an advantaged starting point for developing solutions that the broader research community hasn't been able to produce. It is entirely possible that this team's approach could be successful, but it also seems unlikely that they will have breakthrough advantages in all 3 areas.

And if the objective is to develop an economically viable North Dakota-based lithium ion battery manufacturing operation based upon this team's efforts, it's notable that there is little mention in this proposal of likely cost points versus competitive offerings, in a market (lithium ion batteries) that has seen very significant price-based competition over the past decade.

Reviewer 1C (Rating: 2)
The areas identified (improved battery management systems, better thermal management, and more modular battery system design) are important. However, these areas are being aggressively pursued by many organizations. It would seem that developing competitive solutions within the time and budget proposed is a difficult challenge.

Reviewer 1D (Rating:4)
The team has facility to fabricate battery pack and test battery pack. This makes the objective achievable with the time and budget framework. The team also has experience in the battery engineering.

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: 2)
Much can be done with good engineering analysis. For example, removable mechanical architecture will make sense only for packs larger than a certain size. What preliminary analysis has been done to determine this? What is the cost/benefit analysis of using phase change materials, and what are the competing technologies? Is there any effort for bench marking?

Much can be done with engineering modeling without performing experiments to minimize the cost of development. Very little is done by the proposer.

Reviewer 1B (Rating: 3)
The proposal seems well considered and acknowledges the need to evaluate available options before determining a best design to be commercialized.

However, there is also little discussion of competitive efforts being pursued or even already commercialized. This is a critical consideration if one objective is the eventual formation of a commercially-viable ND-based battery manufacturing operation. For example, there is extensive discussion of the investigation of various phase-change materials for thermal management in the assembled battery. This is an approach that has already been pursued in the marketplace and in fact there are patents published on the subject.

Again, this team may be able to improve upon work done previously in these other efforts, and to surpass the competitors already in the marketplace. But existing IP may preclude commercialization even if this is possible.

Reviewer 1C (Rating: 2)
The one caveat is that I am reviewing just this proposal. This fact notwithstanding, there are few details in the proposed research that demonstrate novel approaches to a better BMS or a superior thermal management system. It is well-known that a good battery management system is needed to equalize charge on individual cells, and a BMS is part of any lithium ion battery system. There is no indication that the proposed work will advance the technology in this area. The second thrust is in thermal management, with the key concept to use phase change material. The use of phase change material has been around for a while. The most serious drawback is that there is only a limited amount of heat that can be removed before the material has to be solidified again. For renewable energy applications where charging and discharging are nearly continuous, the limited heat removal ability is a major obstacle. This challenge is not addressed in the proposal.

Within the modular design concept, integration with the thermal management system and accounting for the axial load that is typically used with prismatic cells is not discussed. Here, the concept is not novel but ok, yet the challenges are not clearly identified and solutions proposed.

Reviewer 1D (Rating: 2)
The methodology for some of objectives is not convincing. For example, the phase change material (PCM) is an important component for investigating thermal management of battery pack. The study on the phase change materials is not clearly illustrated how the PCM will affect temperature distribution in the battery pack. It is also important to mention how to manage the hot spots of battery cell for thermal management.

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: 1)
It is unclear what the commercial viability of the proposed technology. Without a clear performance target that is also cost competitive, the chance of success in job creation or generation of new business is low.

Reviewer 1B (Rating: 3)
There is a significant research and development component to this proposal, and the objectives of this work are clearly in alignment with the NDIC/REC goals.

Above, I have suggested that it may be difficult for this team to ultimately develop a commercially competitive lithium ion battery offering given the scope of the technical challenges faced and the fact that there is already a crowded market of competitive solutions and researchers.

That said, even if that should be the eventual result, the scientific and technical work done in pursuit of this proposal could result in either a) the identification of emerging energy storage technologies that could be valuable for ND-based renewable energy project developers and owners; and/or b) the identification of alternative configurations and applications of lithium ion technologies so that existing manufacturers may be able to better bring to ND project developers and owners products that meet their needs.

Reviewer 1C (Rating: 3)
In spite of the concerns raised above, it is likely that the proposed work would help to achieve the council's goals.

Reviewer 1D (Rating: 3)
The low cost Li-ion battery with good cycling stability and safety is an emerging energy storage technique for stationary energy storage application. The energy storage system is also important to efficiently use intermittent energy source such as solar and wind energy. The proposal work will address three key issues of current Li-ion battery packs for the stationary applications paired with solar/wind energy conversion devices. The proposed work significantly addresses the goals of North Dakota Industrial Commission/Renewable Energy Council.

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)
The description of competing technologies is minimal, certainly inadequate.

Reviewer 1B (Rating: 2)
There is little mention in the proposal of the deep body of existing research into cell balancing and thermal management. Also, modular-based energy storage is well-known and

commercialized in other energy storage technologies (notably fuel cells and flow batteries), but that is not mentioned. The major existing commercialized lithium ion efforts aimed at stationary renewable energy project applications isn't explored.

It would be good to request that the Principal Investigator make contact with leading researchers in lithium ion (such as Gerd Cedar at MIT) to discuss this proposal, and make revisions if such discussions show that existing research efforts have already pushed the state of play beyond that described in this proposal.

Reviewer 1C (Rating: 3)
The PIs have demonstrated a good awareness of the present importance of the bms and thermal management. Again, more information showing that there proposed research would advance the state of the art is needed. There is a wealth of recent literature on algorithms for charge equalization, it is not clear what novelty is proposed here.

Reviewer 1D (Rating:2)
The use of phase change materials have been reported in literature for managing thermal runaway and thermal distribution issue in battery pack.

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: 2)
It is unclear whether any of the investigators has first-hand experience in battery development of manufacturing.

Reviewer 1B (Rating: 3)
This is a strong multidisciplinary team that has already successfully introduced related applications into the marketplace. They have both a technical and a commercial background, which is valuable for this effort.

Reviewer 1C (Rating: 3)
The PIs do not have a strong track record in this field. They appear to be competent engineers and scientists, but without a deep understanding of the field.

Reviewer 1D (Rating:3)
The PIs have experiences in battery manufacturing, system control, and management. The background is adequate for conduct the research for the proposed work.

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)
The management plan is simple, but the scope of the proposed work is also small. The proposed work is too preliminary for field tests or production of prototype.

Reviewer 1B (Rating: 4)
The plan is well-defined and the investigators have a process for communicating regularly. Milestones are as well-defined as they can be at this stage of what is a somewhat open-ended investigation. It does not appear that the full salary and related labor costs for a team of 3-4 researchers over two years is included in this proposal, but that is probably to be considered an unidentified in-kind contribution from the investigators.

Reviewer 1C (Rating: 4)
No concerns here.

Reviewer 1D (Rating:2)
The project management is limited. The proposal does not listed timetable with milestones.

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 major equipment purchased is requested. The scope of work does not require unusual machinery or equipment.

Reviewer 1B (Rating: 5)
The only equipment purchases appear to be necessary components and supplies for developing the prototypes.

Reviewer 1C (Rating: 4)
The only funds for equipment identified was $13k in kind from Solargy Lights for field testing. These funds are well justified.

Reviewer 1D (Rating:4)
The proposed purchase of equipment (such as cell components, BMS boards, etc) is well justified in the budget justification.

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: 5)
Since the proposed work is rather simple, it should not be difficult to have access to adequate equipment to perform the work.

Reviewer 1B (Rating: 3)
There doesn't appear to be any specialized lithium ion battery production facility being used, although some could be available via contractors (AllCell for example). Fortunately, at the prototype level lithium ion batteries are not very difficult to make. However, making them at commercial-grade and cost-competitive levels would require a very significant additional investment.

Reviewer 1C (Rating: 3)
There are not many details about the specific test equipment available that are relevant to battery testing.

Reviewer 1D (Rating:4)
The team has facilities and equipment to fabricate battery cell pack and test the performance.

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: 2)
Although the company is providing extensive cost matching, because of the low probability of commercial success, the value of the proposed budget is not high.

Reviewer 1B (Rating: 3)
Because of the low likelihood of this turning into a commercially viable manufacturing operation, at least as written up in this version of the proposal, the proposed $185k in grant support may not provide good value. This perspective can change, if upon further exploration of existing lithium ion research and competitive offerings, the investigators revise the proposal and demonstrate a viable, price-competitive commercial opportunity they can build.

The financial commitment from other sources is attractive, and probably understated in this proposal as salaries of the 3-4 team members doesn't appear to be captured and thus is potentially in-kind via the investigators and partners.

Reviewer 1C (Rating: 4)
The proposal included significant time of faculty that were used as cost share. This feature seemed to be a strong endorsement of the concept and adds value to the project.

Reviewer 1D (Rating:4)
The proposal provide high quality match fund and supported by other sources such as faculty members from UND and NDSU, and other company. The proposed budget value is high value.

[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 ***(Do Not Fund)***
In general, this proposal lacks imagination and the proposed approaches lack novelty. The investigators do not seem to be familiar with competing technologies, and cannot provide a convincing argument of the technical or economic advantages compared with competing technologies. There is a lack of bench-marking. Overall, this is a weak proposal.

Reviewer 1B ***(Funding May Be Considered)***
Large-format energy storage to firm wind and solar renewable energy projects is indeed a large opportunity. There are, however, a multitude of efforts being undertaken in pursuit of this opportunity. For reasons of high cost, it is unclear that lithium ion will be a large-scale solution to this, above things like flow batteries, compressed air energy storage, other battery formats, etc.

Even within lithium ion, there is a very stiff competitive environment and a lot of research and development underway at many of the nation's leading research institutions.

To find this proposal fundable, I would need to better understand that the investigators have tracked down many of these researchers and existing companies, examined not only what is currently commercially available but what is also being developed, and make an informed argument that this proposed effort would result in a differentiated and cost-competitive opportunity that would warrant the extremely capital-intensive effort of building out a battery manufacturing operation.

Reviewer 1C ***(Funding May Be Considered)***
It is difficult to make recommendations in a bit of vacuum having only seen one proposal and not having a track record with this process. That being said, my recommendation is not to fund the project. The principal weakness is the lack of details showing innovation in the bms development and thermal management approach.

Reviewer 1D ***(Funding May Be Considered)***

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 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 removable architectures is unique, although it is not clear how the proposed phase change materials effectively improve the performance of battery pack at different thermal conditions for better thermal management. I would recommend the proposal funded.