APPLICATION CHECKLIST

Use this checklist as a tool to ensure that you have all of the components of the application package. Please note, this checklist is for your use only and does not need to be included in the package.

☒	Application
☒	Transmittal Letter
☒	$100 Application Fee
☒	Tax Liability Statement
☒	Letters of Support (If Applicable)
☒	Other Appendices (If Applicable)

When the package is completed, send an electronic version to Ms. Karlene Fine at kfine@nd.gov, and 2 hard copies by mail to:

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

For more information on the application process please visit:
http://www.nd.gov/ndic/renew/info/submit-grant-app.pdf

Questions can be addressed to Ms. Fine at 328-3722, or Andrea Holl Pfennig at 328-2687.

Application

Project Title:

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

Applicant:

Clean Republic LLC, Grand Forks, ND

Principal Investigator:

Yong Hou, Clean Republic LLC

Michael Shope, Clean Republic LLC

Date of Application:

January 1, 2013

Amount of Request:

$220,000

Total Amount of Proposed Project:

$443,000

Duration of Project:

2 Years

Point of Contact (POC):

Yong Hou, Ph.D.

POC Telephone:

218-791-3746

POC Email:

hou@cleanrepublic.com

Renewable Energy Program

North Dakota Industrial Commission

TABLE OF CONTENTS

Please use this table to fill in the correct corresponding page number.

ABSTRACT

Objective:

The production of wind and solar energy systems is often intermittent. This poses a major challenge to the utilization of renewable energy and its penetration into the electrical grid. Battery energy storage is one of the solutions developed to address this challenge, and it is gaining momentum in recent years. The round trip energy efficiency of Li-ion batteries typically exceeds 95%, compared with 50-70% for most other technologies such as lead-acid batteries, NiCd and NiMH cells. **The objective of this project is 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.** The new technologies to be developed are primarily targeted at the solar/wind systems for residential and small commercial (<100kw) various applications. In this project, lithium iron phosphate (LiFePO4) battery cells are selected due to their excellent safety, sustainable performance in wide range of temperature, and long lifetime. In particular, we propose "standard modules" for LiFePO4 battery packs to reduce the production and transportation costs, and enhance the scalability for applications. Besides the energy storage purpose, the technologies developed can also be used as clean replacement batteries in the large commercial market. With the success of this project, the ultimate goal is to commercialize the technologies and produce the battery packs at the manufacturing base of Clean Republic LLC in Grand Forks, ND.

Expected Results:

The results expected from this project are (1) the design of removable hierarchical modular architecture for quick assembly and disassembly of battery cells, and the development of "standard modules" of LiFePO4 batteries; (2) the development of multiple-level battery management systems with balancing technologies; (3) the development of advanced thermal management capability; and (4) measuring and logging the characteristics and performances of the new batteries by testing in a lab, as well as in a hybrid wind/solar energy system installed in the field. We are also expected to obtain testing orders from renewable energy industry.

Duration:

Two years (Suggested: April 1, 2013 – March 31, 2015)

Total Project Cost:

$220,000 requested from NDIC

$443,000 for total project cost

Participants:

Clean Republic LLC

PROJECT DESCRIPTION

Objectives:

The objective of this project is to develop standard LiFePO4 battery modules and hierarchical modular LiFePO4 battery packs for energy storage of renewable energy conversion systems, and to research the technologies related to battery management systems (BMS) and thermal management so that the low-temperature performance, reliability, service life, and cost effectiveness of LiFePO4 battery packs can be significantly improved. With the success of this project, we plan to commercialize the technologies and produce the battery products for renewable energy applications such as industrial or residential solar/wind systems, as well as other commercial battery applications.

Renewable energy installations are rapidly growing globally. Industrial, commercial and residential applications that rely on clean energy from solar, wind, hydro, tidal, geothermal energy and others are transforming our dependence on fossil fuels and reducing our impact on the environment. Just last year the U.S. passed the mark of 100,000 solar installations directly tied to the nation grid. For total PV production, the median estimate increases worldly from 5.6 GW in 2008 to 21 GW in 2012, a 4-year CAGR of 40% [1]. The estimated market growth to 2020 is 11% per year for the small-scale remote or off-grid market segment; 22% per year for the residential or on-grid segment; 48% across farm, business and small industrial segment; 26% per year for the wind/diesel segment; and 23% per year for the "small-scale" community segment. Remote, non-grid-connected power and water irrigation applications require some form of energy storage to supply consistent, grid-quality electrical service. Energy storage is currently the highest life-cycle cost component of a remote power system. Improving the cost and technical performance of electricity storage will increase the applicability of wind/solar-driven remote power systems [2]. **Battery storage is a critical component of the renewable energy systems** (Fig. 1) for various applications such as residential, oil and gas field, outdoor lighting, security, communication, and grid stabilizer due to the mix of renewable energy sources. It is particularly important for rural or remote areas such as the vast portion of North Dakota. We understand the important of these performance features and that is why we are to develop the high-quality, long cycle life and affordable battery products available to a wide range of renewable energy applications.

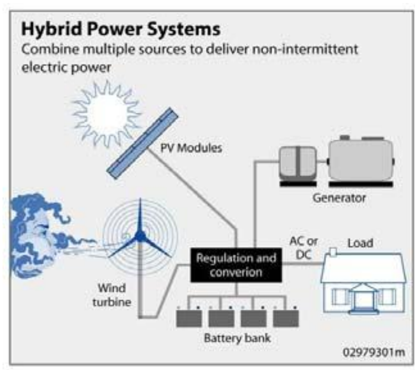


Figure 1: Battery energy storage in renewable energy systems

According to an estimation, the worldwide battery industry generates US$48 billion in sales each year with 6% annual growth [3, 4]. Lithium cells are now starting to supplant lead-acid batteries, NiCd and NiMH cells in medium-large packs for applications such as land-based electricity storage and mobile battery bank. Additionally, a new Li-ion technology, the Li-iron phosphate (Li-FePO4) cell, is rapidly becoming a prime contender for the next generation of HEV batteries, replacing existing nickel-metal hydride (Ni-MH) technology [5].However, the current medium-large packs of lithium batteries often suffer from premature failure or a reduced number of charging cycles due to improper selection of battery type, poor battery cell balancing or thermal management, especially poor low-temperature performance, poor maintainability, and high service cost due to the inflexible packaging of battery cells. We strive to overcome the challenges and offer economically viable and technically feasible solutions. As a result, the barrier of renewable energy utilization due to its nature of intermittent generation will be mitigated, the cost of energy storage will be reduced, and battery maintainability will be improved.

The lithium battery industry has changed substantially over the last few years. Small lithium batteries that are commonly used in cell phones, laptops, and other electronics are labor intensive to manufacture. There is also a considerable amount of competition in this field. This makes it unwise for new companies to venture in this direction. However, medium-large scale lithium batteries offer a far more promising market. With fewer competitors in this field the chances of success are far better. Clean Republic is well suited for this project for the following major reasons.

- Clean Republic has accumulated experience and resources in terms of lithium battery R&D, sales, and servicing over the past four years. In addition, the PI's past career in the lithium battery industry provides intimate understanding of current techniques, know-how, and insights into low cost suppliers for basic components needed for medium-large scale lithium batteries.
- North Dakota has abundant and one of the most inexpensive electricity supply in the U.S. which is critical factor to a lithium battery factory which usually suffers 20-30% on electricity expense.
- North Dakota has a good, well educated workforce that possesses good work ethics. Clean Republic has been benefiting from this workforce since 2008.
- Numerous renewable energy businesses, such as Solargy Lights and Sobear, are currently operating in North Dakota or this region. Batteries play a major role in the success or failure of these companies. Lithium battery technology offers numerous advantages over traditional lead acid, NiCd and NiMH styles; however, the huge cost difference makes it economically unviable. A company that can produce medium-large scale Lithium batteries with the capacity useful for intermittent renewable energy sources, yet capable of performing in the frigid conditions of the cold Midwest will have a considerable advantage in the market.
- Clean Republic has access to resources at both the University of North Dakota and North Dakota State University. The two research institutions present great opportunities for collaboration through their engineering and technology programs. This provides a mutually beneficial atmosphere for both company and institution. Additionally, the close relationship offers the potential for many rewarding Co-op and part-time job opportunities for students, which Clean Republic has been offering since they started operations in 2008.

Methodology:

To achieve these objectives, we plan to conduct research and development on the following key areas: (1) designing hierarchical modular structures and standard modules for $LiFePO_4$ batteries to improve the flexibility of assembly and disassembly, allow customized configuration of different battery pack size, improve the reliability and maintainability, and eliminate the transportation constraint for battery packs; (2) developing multiple-level battery management systems (BMS) for cell/module balancing to mitigate the mismatches of cells during operational life; (3) evaluating and investigating the use of phase change materials (PCMs) in thermal management of batteries, especially in cold weather conditions identifying the best possible solution; and (4) testing the battery products in a wind/solar hybrid generation system. These main R&D activities are detailed below:

1. ***Hierarchical modular structure and standard modules***

Traditionally, lithium battery producers have met the service and maintenance needs of their customers by simply replacing entire battery packs that showed decreased performance, and discarding the entire original pack though many internal cells may still have been good. This traditional service model is not desirable for larger, more valuable battery packs in alternative energy storage or other systems.

A hierarchical modular structure and standard modules for LiFePO4 battery packs would be the key for more effectively servicing and maintaining medium-large scale lithium packs. With the hierarchical modular structure, the customers only need to replace the degraded or defective standard modules from the entire battery stacking assembly (i.e., the larger battery pack). Also, with the removable structure of the standard modules, individual internal cells of large battery packs can be easily replaced. As a result, shipping and materials wastes can be significantly reduced. With these options available, revolutionary and disruptive service and maintenance business models become possible for lithium battery distributors allowing vertical integration of supply chains at very low unit volume.

Figure 2 shows the schematic of one concept of 'standard module' with mechanically removable cells, as opposed to the 'customized battery packs' which other developers are building. The traditional approach is to permanently weld the cells on the terminals of a support structure. The mechanical removable power contact has seldom been implemented in commercial lithium battery packs. Based on our extensive experience with lithium batteries, the failure of battery stacks can be often attributed to one or two cells/modules in the entire assembly, and the replacement of these failed cells/modules can bring the battery back to life. In this case, the traditional permanent type of contact makes the replacement of battery cells very difficult, if not impossible. The concept of removable cells/modules with mechanical power contact mechanisms makes maintenance and replacement easier and cheaper.

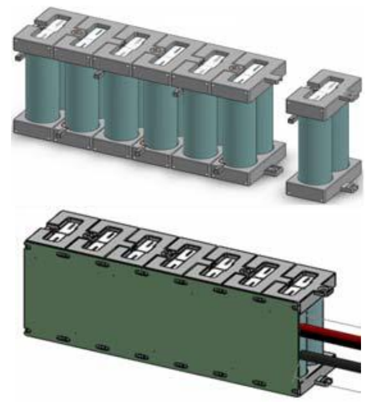


Figure 2: A removable cell structure for standard LiFePO4 battery modules, proposed by Clean Republic.

Figure 3 shows another design of 'standard module'. In this case, the geometry of the module follows the standard 5x3x2-inch case with two easy plug in and off terminals (the same features as standard 'sealed lead acid' batteries in the commercial market). We propose the 12V, 10Ah format as an energy model; and a 12V, 8Ah model for high-power shorter life applications. 24 V modules will also be produced. The aggregate lithium content of a 'standard module' qualifies for simple ground shipping regulations, as opposed to the restrictive Class 9 Hazardous Materials regulations imposed on large single-unit packs. The output style of two standard terminals makes our connecting and disconnecting job in a large battery pack assembly process very simple and reliable. Through our four years of direct marketing experience, there is not any reliability issue while it operating at 12V up to 20A, an output current exceeding the market requirements of these packs in the niches we have been exploring.

The market potential for using our 'standard module' as a standard lithium battery to replace lead acid units is huge. The possible large sales volume of the replacement/commercial market gives us big opportunity for dramatically reducing its unit price.

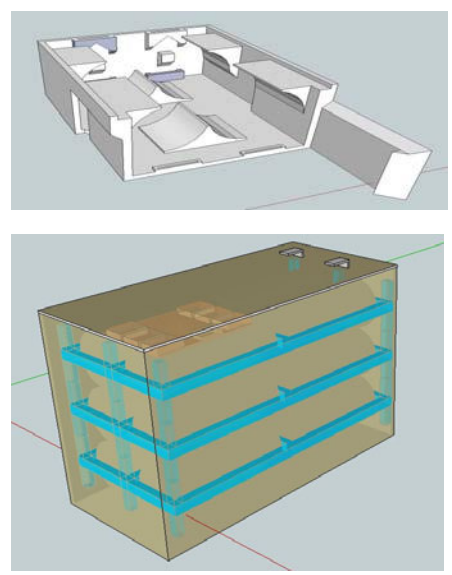


Figure 3: Another removable cell structure and battery holder for standard LiFePO4 battery modules, proposed by Clean Republic

Figure 4 shows the basic concept of battery stacking in order to assemble a larger battery pack based on the standard module proposed. It should be noted that the stacking concept is common for the industry standard Lead Acid batteries because it does not require complicated control systems for battery management. However, this has been a challenge for lithium batteries, and thus no such products are available on the market for lithium batteries.

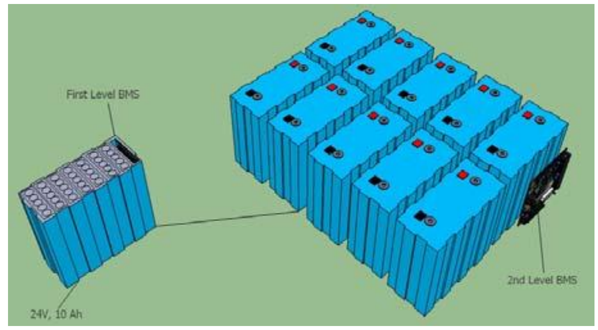


Figure 4: Hierarchical modular structure for larger battery assemblies based on the standard modules, proposed by Clean Republic

In brief, the development and research tasks in this technical area will include the following items:

- Design and prototype 'standard modules' for LiFePO4 battery as well as the stacking mechanism for larger batteries based on 'standard modules' for energy storage applications;
- Select the right materials for the structures designed;
- Test the removability of battery cells in the standard modules with and without the presence of other materials to fill the gap;
- Test the mechanical properties and performance of the structures if deemed necessary.

2. Battery Management Systems (BMS) for cell/module balancing

One advantage of a lithium battery pack is its flexibility in connecting multiple battery cells to provide various outputs. However, in the multi-cell/module battery packs, it is difficult or even impossible to find two cells/modules with identical performance. They are always different, to some extent, in terms of the state of charge, capacity, impedance, and temperature characteristics. The differences will become more significant during the life span of the battery. In this regard, an effective battery management system (BMS) to balance the cells/modules and mitigate the mismatches is of great importance. The benefits of BMS balancing include higher efficiency, overall capacity, and longer lifetime of the battery.

In general, there are two types of balancing approaches – passive balancing that is built on using power resistors to dissipate energy by discharging the cells that need to be discharged, and active balancing that uses capacitive or inductive charge shuttling to transfer charges between battery cells. Passive balancing is inexpensive and widely used in applications where cost far outweighs the battery efficiency, while active balancing is more expensive but provides higher efficiency and longer run time [6 - 9]. Existing reference solutions of BMS with passive balancing functions include the following components: Atmel (ATA6870, ATA6871), Elithion (EL01/EL02), Perkins (V series), Linear Technology (TLC 6802), Texas Instruments (bp78PL114, bp77PL900), National Semiconductor's complete BMS and Intersil (ISL9208) [10 - 13]. However, the active balancing solutions generally lack reference designs. The balancing algorithm can be based on the following three measures: (1) voltage; (2) final voltage; (3) State of Charge (SOC) history. It is our objective to explore the SOC history method as the balancing algorithm for our medium-large LFP lithium packs for renewable energy storage. Regarding the SOC history-based algorithm, an introductory technical explanation is provided in Appendix A2.

The general schematic of passive cell balancing is shown in Fig. 5. The main idea is to equalize cell voltages using the following procedure. The cell voltages are compared with the threshold value. If any cell reaches this particular value, charging will be stopped and the internal bypass to the power resistors is enabled. When the high-voltage cells hit the recovery limit, the cell balancing will stop. On the other hand, active cell balancing is more advanced, in which the balancing technology using inductors is more promising compared with that using capacitors. As indicated by Fig. 6(a), top balancing can be realized by a balancing circuit, which connects the cell with higher voltage to its secondary winding. As a result, an induced voltage will be created on the primary winding. The cell's switch is then opened and the switch of a receiving cell is closed to send the primary's energy back into its secondary winding. Energy can be transferred between cells with high efficiencies using this balancing technique. Meanwhile, bottom balancing, shown in Fig. 6(b), can also be realized which allows weaker cells to take charges from stronger cells. The circuit first uses a pulse of the battery stack voltage to energize the primary winding with all secondary switches open. Thereafter, the secondary switch for the cell to be charged is closed, and this allows the stored energy to be transferred to the particular cell.

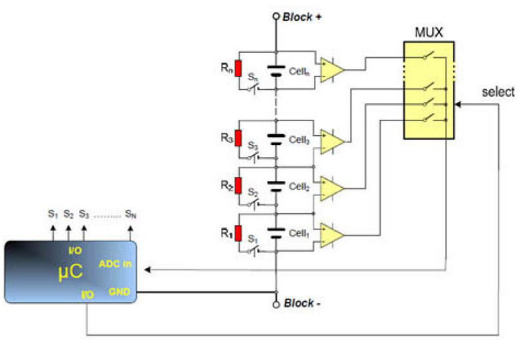
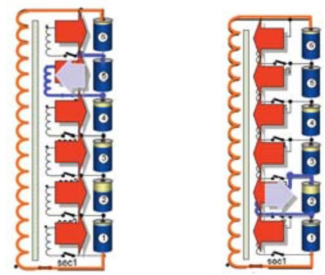


Figure 5: Schematic of passive cell balancing [6]



(a) (b)

Figure 6: Active cell balancing using inductors - (a) top balancing, and (b) bottom balancing [7]

In designing the hierarchical structure of battery packs based on the standard modules, we plan to adopt a two-layer control strategy, which is represented by the topology schematic in Figure 7. There are two possible solutions in realizing the two-layer control. The preferred solution is to implement passive or active cell balancing in each standard module, and then another central BMS unit will communicate with the local BMS units. The major advantage of this solution is the high capability of equalizing cells, while the major disadvantage is the addition of one more BMS (often more powerful and expensive). The other possible solution is to implement master/slave control for larger batteries assembled from the standard modules. In this case, the local BMS units (slaves) in the standard modules are simplified to only collect voltage, current, and temperature information and send it to a central BMS (master), while the central BMS processes the information from all standard modules and sends signals to the balancing units of the local BMS to equalize the cells monitored [14]. This solution will be more economical for larger batteries from stacking a fixed number of standard modules. However, it may not work for the purpose of using the standard modules as replacement batteries.

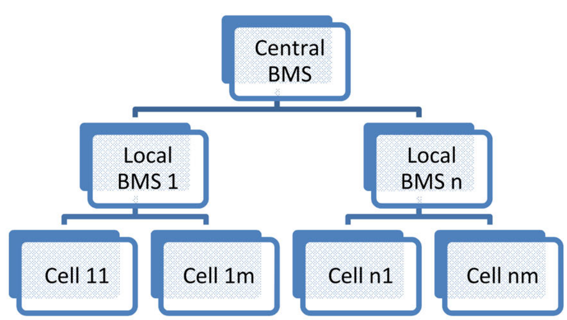


Figure 7: Schematic of two-layer BMS control

In summary, the R&D tasks on BMS development will include the following items:

- Test existing passive/active cell balancing BMS offerings and identify 1-2 products for the standard modules;
- Improve the identified solutions by exploring SOC-based algorithms in terms of
  (1) using SOC method for battery pack level and final voltage method for standard modules; or
  (2) using SOC method for standard modules but employing final voltage method for pack level;
- Develop a prototype of master/slave control strategy for multiple-module battery packs.

3. Thermal management solutions

It is also well known that the temperature of a lithium battery needs to be controlled within the optimum range. Otherwise, the electrochemical performance of lithium cell charge acceptance, power capability, reliability, lifetime, and safety will all be adversely affected. Most lithium battery cells are limited to an operating temperature of -20°C to 60°C, while their charging temperature ranges are often smaller. However, LiFePO4 is an exception, and it can operate at higher than 75 °C. Overheating poses a challenge to most lithium battery packs in which the battery cells are closely packed and the center temperature is often significantly higher. Understandably, the failure of the center cells due to high temperature will cause the failure of the entire battery pack. Generally, there are four solutions, working individually or combined, to effectively manage the thermal issues for lithium batteries. They are: BMS systems, convection air cooling, liquid cooling, and PCM temperature regulation. Often being neglected in terms of thermal management, the battery performance at low temperatures also needs to be considered, in particular for applications in the upper Midwest and other regions with low temperatures. Figure 8 shows the typical charge and discharge characteristics of LiFePO4. Our preliminary tests also indicate that LiFePO4 cells show great performance of capacity while ambient temperature is between 0-75 °C. But its capacity drops by 50% while the temperature reduces to -20 °C degree or lower. It is our belief that avoiding temperature drop is as important as, if not more important than, avoiding overheating for the LiFePO4 battery packs.

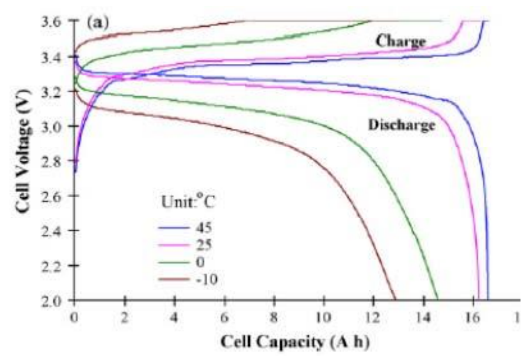


Figure 8: Typical charge and discharge characteristics of LiFePO4 [15]

BMS systems can regulate the charge and discharge rates. To ensure high-performance at low temperatures, one may develop a simple BMS-based heating solution to keep the pack above the minimum temperature by drawing energy from the charging supply. Meanwhile, though air convection is a common approach for cooling, it requires heat sinks and possibly fans. Both makes the battery packs more complicated and more difficult to maintain.

Some studies indicate that natural air convection or a forced convection cooling method is not capable of alleviating heat accumulation, especially for large-scale batteries in electric vehicles and bulky energy storage systems [16]. Based on this concern, attention has been focused on using liquids for battery thermal management. Different methods could be used, including: 1) discrete tubing around each battery module, 2) submerging modules in fluid for direct contact, 3) placing the modules on liquid cooled plates (heat sinks).The heat transfer medium could be water, glycol, oil, acetone, etc [17]. Researchers have reviewed a systematic approach for designing and evaluating battery pack thermal management systems, and the performances of liquid cooling versus air cooling, cooling and heating versus cooling only were compared [18]. It was concluded that thermal management systems using air as heat transfer are less complicated than using liquid, but liquid thermal management can achieve better thermal performance. To simulate the temperature distribution in Li-ion batteries, Wu et al. developed a two-dimensional, transient model for different heat dissipation methods [19]. In this study, two heat pipes with aluminum fins were attached to the battery for the purpose of reducing temperature rise. It indicated that the heat pipes played an important role in heat dissipation. However, liquid cooling also significantly increase the complexity and cost of the battery packs.

Using PCM (phase change materials) for battery thermal management is a relatively new idea. PCMs are materials that 'soak up heat.' They depend on chemical bonds to store energy as they change from solid state to liquid and release latent heat changing from liquid to solid. The PCMs can absorb large quantities of heat due to their high latent heat of fusion [20, 21]. The common PCMs in solar heating systems include sodium sulfate decahydrate, calcium chloride hexahydrate, and paraffin wax [22]. PCMs can be pre-formed into a cavity in which the battery cells can slide in. During discharge and charge, the heat generated could be absorbed by the PCM between the cells inside the battery pack. Basically, the PCM acts as a heat sink absorbing the heat generated by the battery. If the internal temperature exceeds the PCM melting point, the material starts to melt and the absorption of heat can prevent the battery cell from overheating. PCMs for thermal management eliminate the complicated design of traditional cooling systems. Various thermal management techniques, especially the PCM (phase change material) battery thermal management system are discussed in Rao &Wang's work [23], and the novel idea of using of PCM for battery thermal energy management was proposed for electric vehicles.

The thermal energy is stored in the PCM, in which the major proportion is latent heat due to high latent heat storage capacity. The latent energy storage acts as heat absorption to maintain constant temperature when the PCM changes its phase from solid to liquid or from liquid to gas. It has been confirmed to have better performance not only for heat dissipation but also for heating in cold environments. There are many PCMs available in a vast variety of temperature ranges. Generally, the PCM can be categorized into organic, inorganic and eutectic. A mathematical model has been created to simulate the heat-transfer process involving PCM [24]. A passive thermal management system using PCM for Li-ion batteries for electric car and scooter applications was proposed by researchers from the Illinois Institute of Technology [25]. It was found that the amount of PCM and its melting temperature had a significant effect on keeping the battery pack within a safe temperature range. About 90% of nominal battery capacity was utilized even at extreme conditions with high discharge rate and high ambient temperature. Test results again demonstrated the advantage of using the novel PCM thermal management systems over conventional cooling systems. This led to the founding of a start-up company, AllCell, which has been working with our company since 2011.

Regarding thermal management of $LiFePO_4$ batteries, we plan to develop two solutions. Both will be tested and then compared,

- One solution is to only rely on a BMS to regulate the temperature where battery cells are separated by air in standard modules. We will experiment to test the effectiveness of this solution based on application-related charge and discharge requirements. Thermocouple measurement will be carried out on a selected number of spots in battery packs.
- Our focus will be to use phase change materials (PCMs) to fill the gap of battery cells to provide an alternative thermal management solution. PCM can be used to passively regulate the temperature to avoid extreme temperature drop or increase. It should be ideal solution for $LiFePO_4$ battery due to its higher endurance to high temperatures, but increased vulnerability at lower temperatures. There are many PCMs many additive materials to be mixed in the PCMs to regulate the thermal conduction [26]. No ideal solution has been proposed for the $LiFePO_4$

battery system designed for renewable energy storage. In this regard, we will work with AllCell and NDSU/UND partners to start from the AllCell PCM composition and extend to other solutions. In this aspect, extensive experimental tests are expected.

- Since we target at low temperature performance as well, achieving good insulation of battery modules is the goal. The material selection for battery case and PCM should be considered. However, PCM mixtures usually have high conductivity, so we rely more on the case materials.
- Heat transfer simulation models (based on ANSYS or COMSOL Multiphysics) will be built to complement the experimental measurements so that the entire temperature field can be revealed and the weak points can be identified.

4. *Testing the prototype batteries*

We plan to conduct both lab and field tests for the prototype batteries produced using the proposed technologies. For lab tests, we will establish a set of apparatus to measure the characteristics of batteries. In terms of the field tests, we will work with Solargy Lights to test the performance of the batteries in conjunction with its hybrid wind/solar energy conversion systems. We have been providing consulting services to Solargy Lights, another North Dakota company, to develop street lighting solutions based on wind/solar energies (see Fig. 9). They have agreed to work with us on this project. Overall, the measurements will cover:

- Temperature monitoring profiles under various conditions;
- Charge/discharge curves at different C-rates and temperatures;
- Discharge capacity with respect to cycle number at different C-rates and different temperatures;
- Cell voltage response to current pulses for different pulse durations and temperatures;
- Electrochemical impedance spectra measured after different cycles and at different temperatures.

Figure 9: Hybrid wind/solar system (courtesy of Solargy Lights)

Anticipated Results:

The major goal of this project is to develop innovative lithium battery packaging technologies that can produce large packs of lithium batteries with improved quality, lifetime, and reliability, and reduced costs for the applications in wind/solar energy conversion systems (small or large). The same set of technologies should be suitable for the production of battery packs for other applications such as electric vehicles. The anticipated results are (1) the invention of ‘standard modules’ of LiFePo4 battery (with removable cells); (2) multiple-level BMS control for larger battery packs based on the ‘standard modules’; (3) excellent thermal management solutions based on cold weather conditions and other rigorous experimentation and simulation. We will make 5-6 prototype ‘standard modules’ for testing and benchmarking, and we will prove that the products, backed by the advanced technologies, are also economically viable. More importantly, at the end of the project, we expect to set up a low-medium volume production line that uses the developed technologies to produce high quality large LiFePO4 lithium batteries for customers in the United States and worldwide.

Facilities & Resources:

The following facilities and resources are available to Clean Republic LLC for the proposed project.

1. Clean Republic LLC has a shop space of 5,000 square feet located at 5515 University Avenue, Grand Forks, ND, for the project. The facility has PCs, measuring devices, test instruments, work benches, hand tools, and other tools for design, assembly, and test of the lithium batteries.
2. The project team has a broad spectrum of knowledge in mechanical design, electrical circuit design and testing, and battery packaging and testing.
3. The project team will, if needed, receive assistance from the leading company on battery thermal management solution, AllCell Technologies of Chicago, IL, and receive consulting services from the leading company on lithium battery BMS design, Elithion of Boulder, CO.
4. The company has an excellent collaboration history with NDSU and UND. It has the access to the talents and the necessary equipment at the two research universities.
5. Clean Republic has extensive connections with industries in the Midwest. For instance, Solargy Lights of North Dakota will provide wind/solar systems for field testing of out batteries, and Snobear USA plans to adopt the large-scale battery pack products if the project is successful.
6. The machine shops and laboratories at UND Technology School/NDSU IME Department are available for the project to make necessary prototype components.

Techniques to Be Used, Their Availability and Capability:

Hierarchical modular assembly of larger batteries based on 'standard modules' is a new idea being developed by Clean Republic LLC. The 'standard modules' also have removable structure for cells. To the best of our knowledge, no other similar products can be found on the market. The realization of this idea will require rigorous engineering and testing.

A critical component of these new packaging techniques is the battery management system (BMS) circuit board. The principles of cell balancing are not new, but the multiple-level control strategies proposed are relatively new. In particular, the realization of SOC-based algorithms in the multiple-level control has not been tried before. The development of a sound engineering solution with considerations on thermal management and cost requires significant effort and innovation.

There are a number of PCMs available for thermal energy storage, and not all are suitable for thermal management in lithium battery packaging. Identifying appropriate PCMs will require the scientific process of material selection and verification. The measurement of temperature history and the simulation of temperature fields in battery packs are also considered as the techniques available for the company or the universities that will provide services to the company on this project.

Environmental and Economic Impacts while Project is Underway:

We do not anticipate any environmental impacts when the project is underway. This is because the project does not directly involve the manufacture of individual battery cells, and furthermore we are dealing with the environmentally friendly lithium batteries instead of other types of batteries. The possible adoption of PCM materials in the battery packs does not have environmental concerns since the materials are safe and environmentally friendly.

With the success of this project, we will establish a battery packaging production line at the Grand Forks facility of Clean Republic LLC, which will provide job opportunities to this region and hire at least four additional employees in two years after the project completes. During the project certain local sub-contracting services will be employed to conduct specialized testing and consultation. Meanwhile, we expect to expand our connection with local and regional manufacturers, utility companies, and investors. With the help of this grant, we intend to spur utilization of renewable energy in North Dakota and the country by launching new, valuable products.

Ultimate Technological and Economic Impacts:

1. The battery packs manufactured using the proposed concepts will have significantly higher reliability, increased number of charging cycles, and improved maintainability.
2. The lithium battery for energy storage of wind and/or solar energy systems will stimulate the further utilization of renewable energy to protect the environment and reduce CO_2 emissions.
3. The technologies developed from this project can be scaled up to the manufacture of battery storage solutions for renewable energy generators, and applied to the manufacture of batteries for commercial applications.
4. The technologies developed will be promptly commercialized and this will contribute to the state economic development by adding jobs and tax revenue.
5. The project will also enhance local manufacturing businesses. Local manufacturing companies will have the opportunity to fabricate components for the battery packs.

Why the Project is Needed:

One pillar of North Dakota development is the energy industry. Besides the oil reserve in the western part of the state, North Dakota is also a state with abundant wind energy potential and bio-mass resources. Wind and solar generators, which do not generate carbon emissions or consume water, are environmentally-friendly forms of electrical generation. In particular, wind power could provide 20% of U.S. electricity needs by 2030, according to a U.S. DOE report of 2008 [27]. North Dakota has the most abundant wind resources among all the states in the country, according to another U.S. DOE report [28].

The biggest obstacle that keeps wind or solar energy forms from the electricity grid is their intermittent nature of power generation. Therefore, energy storage technologies for smoothing the intermittence play a pivotal role in more effectively utilizing wind and solar energy. Meanwhile, the other major advantage of energy storage is that generators can manage when to sell the electricity to maximize their profit. The available storage technologies include hydrogen production, which is electrolysis of water using the renewable energy generation; pumped storage, which uses the renewable energy generation to pump water to an elevated reservoir and release the water to drive hydraulic turbines when the renewable generation is not available; flywheel energy storage, which uses fast rotating flywheels to store excessive energy; compressed air storage, which compresses air into underground cavities and releases it to drive air motors; and battery storage, which allows charge and discharge batteries to smooth the generation [29]. Among these technologies, battery storage has the best flexibility and scalability because other technologies usually need huge investment, are developed only for very large scale renewable energy generation, and have various constraints. Battery storage can work well with not only the large scale generation, but also the small commercial and residential renewable energy conversion systems (<100kW). Just last year the U.S. passed the mark of 100,000 solar installations directly tied to the national grid, and the rate of new installations is going off the charts. The estimated market growth from 2010 to 2020 is 11% per year for the small-scale remote or off-grid market segment; and 23% per year for the "small-scale" community segment. Battery storage has been common for solar systems, and recently it has also gained momentum for wind systems [1-2, 30 – 32, also see Appendices A6-A7].

Lithium batteries, compared with other batteries such as metal-acid types, have the advantages of high energy density, deep cycles, low maintenance, good low-temperature performance, light weight, environmental friendliness, flexible battery voltages and sizes, etc. Among a variety of lithium battery types, lithium iron phosphate (LiFePO4) battery cells have been selected for this project. Table 1 shows the comparison between lead acid, NiCd, NiMH, LiFePO4, and the conventional Li-ion battery cells. The following points about LiFePO4 can be summarized [33 – 37]:

- LiFePO4 material is safer than LiCoO2 & LiMn2O4 because its stable structure can be maintained very well under continuous charging & discharging situations.
- The superior high temperature & storage performance make LiFePO4 the most suitable one for Li-ion battery positive material.
- Long cycle life (>2000) is more suitable for many applications. This is important for energy storage in that the battery packs do not need to be replaced as often.
- LiFePO4's discharge plateau is more even than the conventional Li-ion cells because its discharge voltage (3.2-3.3V) is lower than those of LiCoO2 & LiMn2O4 materials (3.6-3.7 V).
- With the abundant Fe & P resources & low cost, LiFePO4 is recognized as the appropriate material for electric power application by the Li-ion battery industry.
- Although LiFePO4 cells have lower energy density than normal Li-Ion cells, it is far more cost-effective than the normal Li-ion cells when considering the cost, cycle life, and watt hours. As such, it is most likely to be successful for applications where weight is not that critical.

Table 1. Comparison between various rechargeable battery cells

Chemistry	Voltage	Energy Density	Working Temp.	Cycle Life	Safety	Environmental	Cost based on cycle life x wh of lead acid
$LiFePO_4$	3.2V	>120 wh/kg	-0-75 °C	>2000	Safe	Good	0.15-0.25
Lead acid	2.0V	> 35wh/kg	-20 - 40°C	>200	Safe	Not good	1
NiCd	1.2V	> 40wh/kg	-20 - 50 °C	>1000	Safe	Bad	0.7
NiMH	1.2V	>80 wh/kg	-20 - 50 °C	>500	Safe	Good	1.2-1.4
$LiMn_xNi_yCo_zO_2$	3.7V	>160 wh/kg	-20 - 40 °C	>500	OK	OK	1.5-2.0
$LiCoO_2$	3.7V	>200 wh/kg	-20 - 60 °C	> 500	Unsafe	OK	1.5-2.0

In light of the promising potential of LiFePO4 battery storage for renewable energy generation and other commercial applications, new technologies need to be developed at the battery pack level to accommodate a broad range of charging and discharging rates, increase the number of charge/discharge cycles, enhance the reliability, improve the maintainability, and reduce the production cost. The major challenges faced by LiFePO4 battery packs are:

- Transportation regulations for lithium cells and batteries, as can be seen from Appendix A4, indicate that medium lithium batteries (less than 25 grams of lithium) can be shipped by motor vehicles or rail cars without Class 9 marking, labeling, and special packaging. For energy storage applications, the battery packs generally exceed the limit and thus requires special packaging.
- The current offerings of lithium battery packs for energy storage are usually of customized design, and thus they are usually very expensive. It is urgent to bring the cost down so that renewable energy systems have better and inexpensive varieties.
- The current offerings of lithium battery packs for energy storage are difficult to maintain. Customers are demanding easy-to-maintain battery packs.
- Optimal performance of LiFePO4 battery packs (and other Li-ion battery packs) has not been achieved for both rigorous low temperature and high temperature performances.

To tackle the challenges innovative research is called for, hence the proposed project and tasks.

STANDARDS OF SUCCESS

Built on the success of its electric bike business, Clean Republic LLC has expanded to a company with five full time employees within two years. Battery packaging has been a key component of this business. The company has also been developing other green energy technologies. The development of reliable battery storage systems for intermittent renewable energy sources such as wind and solar matches the strengths and focus of this company. The success will be measured from the following aspects,

- In terms of advancing battery packaging research and knowledge discovery, the success of this project will be evaluated based on the realization of the proposed technologies. It is expected that at least one patent application will be filed, and two refereed papers based on the project findings will be published.
- The LiFePO4 battery modules and packs developed will be benchmarked against the offerings available on the market to demonstrate the effectiveness of these technologies. The performance metrics are the maintainability, reliability, production cost, and overall service life.
- Although the project is targeted at battery storage solutions for wind/solar energy conversion systems, the LiFePO4 batteries standard module developed should be applicable for the battery systems in commercial products. We will find at least one such application being available in cold weather conditions within the project period.
- Also, the success will be measured by the successful delivery of new battery packs to customers at the end of the project period. We expect to establish a battery packaging production line, and grow the revenue of the battery packaging business to $1 million and add four full time employees to the company for this business within two years after the project completes.
- We will work closely with the two research universities in North Dakota – NDSU and UND, and provide training experience to at least 20 students. The outreach activities will help the students to consider staying in the state and developing a career in renewable the energy industry.

BACKGROUND/QUALIFICIATIONS

The project will provide a precious seed in the R&D budget for Clean Republic to develop a core business with huge potential. We have a track record of successful entrepreneurship, and we expect to continue it with this project. Dr. Yong Hou of Clean Republic LLC will serve as the Principle Investigator for this project. His main expertise is in the field of renewable energy technologies. He is the co-founder of Clean Republic LLC, with offices in Grand Forks, ND and Seattle, WA. The company focuses on developing alternative energy products such as rechargeable battery packs, electric bike conversion kits, and small wind turbines. Dr. Hou has a BS and an MS in Electrical Engineering, and a PhD in Management Science. He has not only published many papers in academic journals, but has personally invested and been involved in many other renewable energy projects. Dr. Hou had been working with the Neosonic Li-Polymer Energy Corporation (www.neosonic.com.cn) until he founded Clean Republic LLC with Michael Shope. Neosonic, with more than 400 employees, is a professional lithium battery manufacturer which designs and produces lithium polymer battery cells and various types of lithium battery packs. Dr. Hou was Vice President of Product Development at Neosonic.

Mr. Michael Shope will serve as the Co-Investigator for this project. Mr. Shope has extensive experience in product design and development, retail advertising and marketing, business management, and renewable energy research. Mr. Shope graduated from UND with a BS in Aeronautics, and a track in the Entrepreneurship program. He co-founded Clean Republic LLC to focus on his combined interests of product development and practical alternative energy products. He and Dr. Hou have quickly grown the successful new venture and created new jobs in North Dakota by combining a disciplined practicalitybased approach to their alternative energy product research. Mr. Shope was the recipient of the SBA Region 8 Young Entrepreneur Of The Year 2011 Award, and the Clean Republic team is the proud winner of the Innovate ND Venture Competition organized by NDIC.

Dr. Jing Shi will be the senior consultant to Clean Republic LLC. He is an Associate Professor in the Department of Industrial and Manufacturing Engineering at NDSU. He has two Ph.D. degrees, one in Materials Engineering and the other in Industrial Engineering. Dr. Shi teaches industrial automation/control, and manufacturing courses at NDSU. His current research interests include energy materials, battery packaging, energy economics, and wind forecasting. Dr. Shi serves on the editorial boards of several international energy journals as well as the international advisory committees of various energy conferences. He has authored and co-authored 100 refereed papers.

Dr. Alex Johnson will also provide necessary consulting to Clean Republic LLC on this project. He is an Assistant Professor in the Department of Technology at the University of North Dakota and also a Project Manager at Solargy Lights. He has a PhD in Education and a Master of Science in Industrial Technology from the University of North Dakota. His current research interests include metallurgy, site assessment techniques for small wind turbines, and the development of small wind turbines. He has presented extensively on these topics at national conferences and published on international journals.

In addition, Mr. Davide Andrea of Elithion Inc. will be a part of the team, and will provide consulting service on BMS design and implementation. Mr. Andrea is the world renowned expert on BMS system design for lithium batteries. He is the designer of one of the first Li-ion Battery Management systems, and the author of the book “Battery Management Systems for Large Lithium-Ion Battery Packs”.

The current primary business of Clean Republic LLC is manufacturing electric bike conversion kits. Their company developed its own lithium battery packs which are the key to the success they have enjoyed during the past three years. The track record of the two investigators in the lithium battery field has been introduced above, through the R&D experience of their V1-V4 models of lithium battery packs, as well as the most recent 40-mile battery pack. For more details about the PIs and other personnel, as well as the track record of Clean Republic LLC on battery development, please see Appendices A4-A5.

MANAGEMENT

Dr. Yong Hou of Clean Republic LLC will be the point of contact and PI for the project, and he will oversee the entire project progress. Upon the approval of the project, a team of 3-4 employees from Clean Republic LLC will be formed, with various expertise in electrical circuit analysis, mechanical design, battery assembly and testing. The team’s major responsibilities include process design, design and manufacturing of components, assembly, field tests, and report writing. A detailed schedule will be developed based on the Timetable presented below. He will also be in charge of collaboration with NDSU/UND on some technologies beyond the Company’s capability. He will ensure all action items on the schedule are carried out on time and with excellent outcomes.

Michael Shope will coordinate the consulting services provided by other companies such as AllCell, Snobear and Elithion. Whenever necessary, he will coordinate meetings and information sharing among the company team, NDSU/UND participants, and the partner companies.

Within the company, the team is expected to meet every week to discuss the progress and the plan for next week. For the potential collaboration with NDSU/UND, the company will have frequent information exchange by email and phone calls. In particular, a telephone conference will be scheduled every month between the collaborating universities and the company to check against the milestones, and address the outstanding issues, and a face-to-face meeting will happen at least once every 3 months.

Project reports will be periodically prepared by the PI(s) and submitted to NDIC for record. A final report will be prepared and submitted at the end of the project period.

TIMETABLE

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Task 1: Hierarchical modular architecture								
Design of standard modules	■	■						
Assembly structure for large batteries based on standard modules		■	■	■				
Task 1: Development of BMS for cell balancing								
Evaluate active/passive balancing solutions	■	■	■					
Develop cost-effective BMS for standard module		■	■	■	■	■		
Realize SOC algorithm based BMS for 2-layer battery assembly		■	■	■	■	■		
Task 3: Thermal management solutions								
PCM material selection and comparison		■	■					
Develop PCM based thermal management solutions		■	■	■	■	■		
Task 4: Battery testing								
Lab testing		■	■	■	■	■	■	
Field testing						■	■	■
Quarterly reports								
Write and submit reports to NDIC quarterly	■	■	■	■	■	■	■	■

BUDGET

Project Associated Expense	NDIC's Share	Applicant's Share (Cash)	Applicant's Share (In-Kind)	Other Project Sponsor's Share
Personnel				
Project management		$20,000 (Company)	$25,000 (Company)	
Standard module	$20,000	$5,000 (Company)		
Large battery assembly structure based on standard module	$20,000			
BMS development	$50,000	$40,000 (Company)		
Thermal management	$20,000	$20,000 (Company)		
System integration	$20,000			
University subcontracts on thermal management and system integration	$50,000 (NDSU/UND)			$45,000 (other)
Labor (manufacturing)		$27,000 (Company)		
Materials/components				
Components to develop lab testing apparatus	$15,000	$20,000 (Company)		
Materials for 5 prototype batteries	$25,000			
Others				$3,000 (Solargy Light – Cash)
Field installation/testing				
Property and equipment				$13,000 (Solargy L)
Labor (testing)		$3,000 (Company)		$2,000 (Solargy L)
Total	$220,000	$135,000	$25,000	$3,000 cash, $60,000 in-kind

Budget Justification:

Clean Republic LLC (the Company) requests a total amount of $220,000 for this project. The total cash matches from the company and other sources add up to $138,000, while the in-kind matches from the company, NDSU/UND professors(s), and Solargy Lights add up to $85,000. Note all matched funds are pending upon the approval of the project by NDIC.

Among the $220,000 requested from NDIC, the materials costs will be $40,000, in which the company will use $15,000 to purchase the necessary components to develop additional apparatus to test the batteries, and the company will also use $25,000 to purchase the battery cells, BMS boards, and other components for making 5 prototype battery modules to be tested with the hybrid wind/solar energy system. Meanwhile the personnel budget for technology development supported by NDIC will be $130,000, from which the company will hire an engineer (0.75FTE) paid at $40,000/year to develop the technologies, integrate components and equipment, and conduct lab testing. The total cost of this position over two years will be $80,000. Also, $25,000 from NDIC will be spent on a current company employee for the R&D efforts. The remaining $25,000 from NDIC will be spent on BMS consulting service from Elithion Inc. In addition, the company will issue a subcontract to NDSU and/or UND for the amount of $50,000 for work on key issues relating to PCM-based thermal management.

Clean Republic will invest significant resources on the project, which include $115,000 in cash for personnel salaries for project management and labor, and $20,000 for equipment and components needed for battery performance testing in a lab environment. Solargy Lights of North Dakota will provide $3,000 in cash to support this project. Also, Clean Republic will provide $25,000 of in-kind salary based on the hours contributed from its VP, Dr. Yong Hou and its CEO, Mr. Michael Shope.

The project will receive in-kind consulting services from Dr. Jing Shi of North Dakota State University during the summers for both project years. Dr. Shi is expected to invest 300 hours on this project without charge to the company, which is worth $30,000. Dr. Alex Johnson is expected to invest 150 hours on this project without charge to the company, which is worth $15,000. He is also providing the use of his fully equipped machine shop for use. As a project manager of Solargy Lights he will work closely with Clean Republic during the testing phase of this project. Meanwhile, Solargy Lights will provide two sets of wind/solar hybrid systems to test the prototype batteries developed under this project. The in-kind value is estimated to be worth $15,000.

CONFIDENTIAL INFORMATION

No confidential information is involved with this grant application.

PATENTS/RIGHTS TO TECHNICAL DATA

Clean Republic LLC reserves the right to all intellectual property developed under this project.

TAX LIABILITY STATEMENT

December 31, 2012

Clean Republic has no unpaid outstanding taxes to the State of North Dakota or its political subdivisions.

Yong Hou

Yong Hou, Vice President and Director of Product Development

December 31, 2012

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

Transmittal Letter
Lithium Battery Research Grant

Dear Ms. Karlene:

This letter is an indication of commitment from Clean Republic LLC to proceed with the proposed project – "Development of Innovative Modular Lithium Iron Phosphate Battery Packs for Energy Storage". As outlined in the proposal, there is growing demand in the renewable energy industry for lithium batteries as a medium of energy storage. However, to truly capitalize on the greatest advantages that lithium batteries can bring to this industry, key solutions must still be developed for specific challenges in troubleshooting and servicing lithium battery packs, controlling the temperature of batteries, accessing a local and reliable supply of individual battery cells, and integrating lithium batteries in small off-grid systems like remote lighting applications in simple, affordable ways.

Clean Republic has identified specific solutions (outlined in the proposal) to these challenges that will enable commercialization of new technologies and job creation if detailed testing can be performed. By collaborating with key partners in UND and NDSU and combining the resources of our research team, the academic community, and the support of the NDIC, we can a) develop a system to remove individual cells from battery packs for fast servicing and troubleshooting, b) control the internal temperature of batteries to prolong their usable life time, c) create a small-scale battery production facility in North Dakota which will create new jobs, and d) further promote the integration of lithium batteries with wind and solar systems by collaborating with ND alternative energy companies for real-world testing and product development.

Our group has a proven track record of researching and commercializing new alternative energy technologies. We are requesting $220,000 from NDIC to support this new 2-year project with testing equipment and contracted design services detailed in the proposal, which will yield more cutting-edge lithium battery solutions and accelerate alternative energy development in North Dakota. Thank you for your time and consideration in reviewing our proposal.

Sincerely,

Yong Hou

Yong Hou, PhD
Vice President and Director of Product Development

ND Office 4200 James Ray Drive #204, Grand Forks, ND 58203
Email: info@cleanrepublic.com Phone: 218 779 3136

APPENDICES

A1- References

[1] NREL, 2008 Solar Technologies Market Report, http://www1.eere.energy.gov/solar/pdfs/46025.pdf, Jan 2010

[2] Forsyth T. and Baring-Gould I., Distributed Wind Market Application, Technical Report, NREL/TP-500-39851, Nov 2007

[3] Power shift: DFJ on the lookout for more power source investment. *Draper Fisher Jurvetson*. Retrieved 20 November 2005.

[4] Buchmann, I. Battery statistics. *Battery University*. http://www.batteryuniversity.com/parttwo-55.htm

[5] Dan Ton etc., Solar Energy Grid Integration Systems – Energy Storage (SEGIS-ES), http://www1.eere.energy.gov/solar/pdfs/segis-es_concept_paper.pdf, May 2008

[6] Goldberg, L. Battery Cell Balancing for Improved Performance in EVs - Part I: Passive Balancing Technologies, Electronic Products, http://www.digikey.com/ca/en/techzone/energy-harvesting/resources/articles/battery-cell-balancing.html

[7] Goldberg, L. Battery Cell Balancing for Improved Performance in EVs - Part II: Active Balancing Technologies, http://www.digikey.com/ca/en/techzone/energy-harvesting/resources/articles/battery-cell-balancing-part-2.html

[8] Altemose, G. Achieving cell balancing for lithium-ion batteries, Electronic Products, DECEMBER 2008, pp. 21-22.

[9]]Andrea, D. Battery Management Systems for Large Lithium-ion Battery Pack, ARTECH HOUSE, ISBN-13 978-1-60807-104-3, 2010

[10] Barsukov, Y., Battery Balancing: What to Balance and How, Texas Instruments. http://focus.ti.com/download/trng/docs/seminar/Topic%202%20-%20Battery%20Cell%20Balancing%20-%20What%20to%20Balance%20and%20How.pdf

[11] Dubarry, M., Svoboda, V., Hwu, R., Liaw,B. Capacity and Power Fading Mechanism Identification from a Commercial Cell Evaluation, Journal of Power Source, 2007, 165 (2), pp. 566-572.

[12] Dubarry, M., Liaw, B. Development of a Universal Modeling Tool for Rechargeable Lithium Batteries, Journal of Power Source, 2007, 174 (2), pp.856-860.

[13] Beauregard, G. Report of investigation, Hybrids Plus Plug in Hybrid Electric Vehicle, National Rural Electron Cooperative Association, Inc. and U.S. Department of Energy, Idaho National Laboratory, ETEC, June 26, 2008

[14] Stuart, T., Fang, F., Wang, X., Ashtiani, C., Pesaran, A. A Modular Battery Management System for HEVs, National Renewable Energy Laboratory, June 2002. http://www.nrel.gov/vehiclesandfuels/energystorage/pdfs/3a_2002_01_1918.pdf

[15] Zhang, Y., Wang, C-Y., Tang, X. Cycling Degradation of an Automotive LiFePO4 Lithium-ion Battery, Journal of Power Sources, 2011, 196, pp. 1513–1520

[16] Chen, Y., Evans, J.W., Heat Transfer Phenomena in Lithium/Polymer – Electrolyte Batteries for Electric Vehicle Application, Journal of the Electrochemical Society, 1993, 196(2), pp. 793-800.

[17] Pesaran, A.A., Battery Thermal Management in EVs and HEVs: Issues and Solutions, Proceedings of Advanced automotive battery conference, February 6-8, 2011, Las Vegas, Nevada.

[18] Pesaran, A.A., Burch, S., and Keyser, M., An Approach for Designing Thermal Management Systems for Electric and Hybrid Vehicle Battery Packs, Proceedings of The Fourth Vehicle Thermal Management Systems Conference and Exhibition, May 24-27, 1999, London, UK.

[19] Wu, M.S., Liu, K.H., Wang, Y.Y., and Wan, C.C., Heat Dissipation Design for Lithium-ion Batteries, Journal of Power Sources, 2002, 109(1), pp. 160-166.

[20] Duan, X., Naterer, G. Heat Transfer in Phase Change Materials for Thermal Management of Electric Vehicle Battery Modules, International Journal of Heat and Mass Transfer, 2010, 53 (23-24), pp. 5176-5182

[21] Al-Hallaj S., Selman J.R. A Novel Thermal Management System for Electric Vehicle Batteries using Phase-Change Material, Journal of Electrochemical Society, 2000, 147 (9), pp. 3231-3236.

[22] Demirbas, F. Thermal Energy Storage and Phase Change Materials: An Overview, Energy Sources, Part B, 2006, 1, pp. 85–95.

[23] Rao, Z., Wang, S. A Review of Power Battery Thermal Energy Management, Renewable & Sustainable Energy Reviews, 2011, 15(9), pp. 4554-4571.

[24] Dutil, Y., Rousse, D. R., Salah, N. B., Lassue, S., Zalewski, L. A Review on Phase-Changing Materials: Mathematical Modeling and Simulations, Renewable & Sustainable Energy Reviews, 2011, 15(1), pp. 112-130.

[25] Al-Hallaj, S., Kizilel, R., Lateef, R., Farid, M., Selan, J.R. Novel PCM Thermal Management Makes Li-ion Batteries a Viable Option for High Power and High Temperature Applications. http://bioage.typepad.com/greencarcongress/docs/Microsunwp.pdf

[26] Demirbas, F. Thermal energy storage and phase change materials: An overview, Energy Sources, Part B, 2006, 1, pp. 85–95.

[27] U.S. Department of Energy. Energy Efficiency and Renewable Energy, 20% Wind Energy by 2030 – Increasing Wind Energy's Contribution to U.S. Electricity Supply. DOE/GO-102008-2567, May 2008.

[28] U. S. Department of Energy. Small Wind Electric System – a North Dakota Consumer's Guide. DOE/GO-102007-2406, April 2007.

[29] Della, R., Randb, D. Energy Storage — A Key Technology for Global Energy Sustainability. Journal of Power Sources, 2001, 100(1-2), pp. 2-17.

[30] Bayar, T. Batteries for Energy Storage: New Developments Promise Grid Flexibility and Stability, Renewable Energy World magazine, August 30, 2011, http://www.renewableenergyworld.com/rea/news/article/2011/08/batteries-for-energy-storage-new-developments-promise-grid-flexibility-and-stability

[31] Wald, M. L., Batteries at a Wind Farm Help Control Power Output, The New York Times, http://www.nytimes.com/2011/10/29/science/earth/batteries-on-a-wind-farm-help-control-power-output.html

[32] John, J. A Mega Wind Farm Needs Lots of Batteries, http://gigaom.com/cleantech/a-mega-wind-farm-needs-lots-of-batteries/

[33] Pasquali, M., Passerini , S., Pistoia, G. Trends in Cathode Materials for Rechargeable Batteries, Lithium Batteries: Science and Technology. Springer 2009, ISBN: 978-1-7628-2

[34] Hua, A.C.-C., Syue, B. Charge and discharge characteristics of lead-acid battery and LiFePO4 battery, 2010 International Power Electronics Conference (IPEC), 21-24 June 2010, pp. 1478 - 1483

[35] Whittingham, M. Materials Challenges Facing Electrical Energy Storage, MRS Bulletin 2008, 33(4), pp. 411-419.

[36] Qian, H., Zhang, J., Lai, J, Yu, W. A High-Efficiency Grid-Tie Battery Energy Storage System, IEEE Transactions on Power Electronics 2011, 26 (3), pp. 886 - 896

[37] Forgez, C., Do, D., Friedrich, G., Morcrette, M., Delacourt, C. Thermal modeling of a cylindrical LiFePO4/graphite lithium-ion battery. Journal of Power Sources, 2010, 195 (9), pp. 2961–2968

[38] Hartley, T., Jannette, G. A First Principles Model for Nickel Hydrogen Batteries, American Institute of Aeronautics and Astronautics' 3rd International Energy Conversion Engineering Conference, August 2005, San Francisco, CA.

[39] Annavajjula, V. K. A Failure Accommodating Battery Management System with Individual Cell Equalizers and State of Charge Observers, MS Thesis, The University of Akron, 2007

A2 – SOC-Based Algorithm for Cell Balancing

The balancing algorithm can be based on the following three areas: (1) voltage; (2) final voltage; (3) State of Charge (SOC) history. We used the voltage algorithm in our V1 and V2 model batteries developed for our e-bike and the final voltage algorithm in our V3 and V4 model batteries. Our V1 model battery has been selling in the market since 2010 with thousands units in field. The V4 model had been launched to the market in May 2012 (see Appendix A5).

It is our objective to explore the SOC history method as the balancing algorithm for our medium-large LFP lithium packs development aimed at the renewable energy storage market. We plan to test two types of systems design and compare its tech and economy performance: 1) use SOC method in pack level and keep standard module level at final voltage; or 2) use SOC method in standard module but employ final voltage for pack level.

State of charge (SOC), history-based algorithms are the most sophisticated balancing algorithms. These algorithms balance all the time and strive to match cell/module depth of discharge (DOD) based on previous history of cells/modules. One of the main objectives of a more sophisticated BMS is to balance individual cell voltages and SOC in a series-connected battery pack. Because there is no sensor that measures the SOC of a cell, the SOC has to be measured indirectly by measuring other physical parameters, and be computed by a mathematical algorithm. Current-based SOC estimation uses the basic definition of the charge $q = \int_0^t i(t)dt$ to determine the SOC of a battery. This method accumulates the current drawn in and out of the battery over time to determine the capacity of the battery. Therefore, this method is also known as *Coulomb counting*. Although coulomb counting is accurate enough for many applications, temperature, self-discharge rate and aging should be taken into account if a more accurate determination of SOC is needed.

Therefore, a mathematical model is developed that measures the SOC by correcting the SOC obtained from coulomb counting. The correction factor takes into account the effects of self-discharge, temperature and aging of the battery on SOC of the battery. The model was proposed by Hartley and Janette [33]. The battery model for lithium ion cells is a function of three state variables: the stored charge q_s, the diffused charge q_d and temperature T. Its stored charge equation is

$$\frac{dq_s(t)}{dt} = i(t) - c_1 q_s(t)\,. \tag{1}$$

The constant c1 in the equation corresponds to self-discharge. Since self-discharge is almost negligible for lithium ion cells, this constant is to set to zero [34]. So, our stored charge equation is

$$\frac{dq_s(t)}{dt} = i(t)$$

(1)

The diffused charge equation is

$$\frac{dq_d(t)}{dt} = g_1 i(t) - c_2 q_d(t) \tag{2}$$

The temperature equation is

$$\frac{dT(t)}{dt} = -c_3\left[T(t) - T_{amb}(t)\right] + g_2 i(t)^2 \tag{3}$$

Through above three equations, we developed a modified coulomb accounting as our SOC history algorithm:

$$q = \int_0^t \left[(1 + q_1)i(t) - c_2 q_d(t) - c_3\left(T(t) - T_{amb}(t)\right) + g_2 i(t)^2\right]dt \tag{4}$$

A3 – Transportation Regulation on Medium Lithium Cells and Batteries

Please see attached pages.

e-CFR Data is current as of October 12, 2011
Title 49: Transportation

PART 172—HAZARDOUS MATERIALS TABLE, SPECIAL PROVISIONS, HAZARDOUS MATERIALS COMMUNICATIONS, EMERGENCY RESPONSE INFORMATION, TRAINING REQUIREMENTS, AND SECURITY PLANS

49 CFR 172.189 *Medium lithium cells and batteries.* Effective October 1, 2008, when transported by motor vehicle or rail car, lithium cells or batteries, including cells or batteries packed with or contained in equipment, are not subject to any other requirements of this subchapter if they meet all of the following:
a. The lithium content anode of each cell, when fully charged, is not more than 5 grams.
b. The aggregate lithium content of the anode of each battery, when fully charged, is not more than 25 grams.
c. The cells or batteries are of a type proven to meet the requirements of each test in the UN Manual of Tests and Criteria (IBR; see §171.7 of this subchapter). A cell or battery and equipment containing a cell or battery that was first transported prior to January 1, 2006 and is of a type proven to meet the criteria of Class 9 by testing in accordance with the tests in the UN Manual of Tests and Criteria, Third revised edition, 1999, need not be retested.
d. Cells or batteries are separated or packaged in a manner to prevent short circuits and are packed in a strong outer packaging or are contained in equipment.
e. The outside of each package must be marked "LITHIUM BATTERIES—FORBIDDEN FOR TRANSPORT ABOARD AIRCRAFT AND VESSEL" on a background of contrasting color, in letters:
(1) At least 12 mm (0.5 inch) in height on packages having a gross weight of more than 30 kg (66 pounds); or
(2) At least 6 mm (0.25 inch) on packages having a gross weight of 30 kg (66 pounds) or less, except that smaller font may be used as necessary to fit package dimensions.
f. Except when contained in equipment, each package containing more than 24 lithium cells or 12 lithium batteries must be:
(1) Marked to indicate that it contains lithium batteries, and special procedures should be followed if the package is damaged;
(2) Accompanied by a document indicating that the package contains lithium batteries and special procedures should be followed if the package is damaged;
(3) Capable of withstanding a 1.2 meter drop test in any orientation without damage to cells or batteries contained in the package, without shifting of the contents that would allow short circuiting and without release of package contents; and
(4) Gross weight of the package may not exceed 30 kg (66 pounds). This requirement does not apply to lithium cells or batteries packed with equipment.

§ 171.8 Definitions and abbreviations.

Aggregate lithium content means the sum of the grams of lithium content or equivalent lithium content contained by the cells comprising a battery.
Equivalent lithium content means, for a lithium-ion cell, the product of the rated capacity, in ampere-hours, of a lithium-ion cell times 0.3, with the result expressed in grams. The equivalent lithium content of a battery equals the sum of the grams of equivalent lithium content contained in the component cells of the battery.

A4 – Resumes of Key Participants

Please see attached pages.

Yong Hou, Ph.D.

5515 University Avenue, Grand Forks, ND 58203 **Phone: 701.738.4805, Cell phone: 218.791.3746**

Email: hou@cleanrepublic.com

BUSINESS AND WORKING EXPERIENCE

Aug. 2008- Co-founder and Production Manger

Clean Republic LLC, Grand Forks, North Dakota

- Direct the production and logistics management
- Direct the product research and development
- Direct the import/export and outsourcing management

Aug. 2008- Assistant Professor Temporary

University of North Dakota

2007- 2008 Vice President of Product Development

Neosonic Li-Polymer Energy (Zhuhai) Corporation

- Direct the development of new style Lithium Polymer battery use for light electric vehicles
- Direct the Neosonic business department in mainland China
- Taking charge of ERP system and Testing Laboratory

2002-2007 Founder/President

Shanghai Wuling Information Technology Ltd.

- Import/export business between United States, Canada and China
- Research on projects of new battery and solar heater
- Business planning on "Our China Biofuels" project

1995-2002 Founder/General Manager

Shanghai Zhongdian International Trade Company

- Founded and managed the company into the largest wholesaler of Compaq Computers in eastern China with an annual revenue of $13 million USD
- One of the two contractors of Warehouse Supplier for Compaq (China), and took charge in its parts imp/export in eastern China
- Project leader of designing and maintaining 'Management Information System' for enterprises

1992-1995 Department Manager

Shanghai Branch Company of Chinese Electronics Group

- Supervised 7 staff in service business of computer hardware and software
- Distributor of AST and Tatun computer in Shanghai
- Supplied the imported services to customers in high-tech field

1983-1989 Electronics Engineer
Hunan Puyuan Engineering Machinery Company

- Managed a team of three to administrate an electronics parts warehouse, and reported to Department manager
- Designed the whole electrical system of new workshop and supervised installations
- Fixed and maintained the auto-controlling machine tools
- Participated in energy balancing project

EDUCATION BACKGROUND

- 2002-2007 Ph. D., Management Science
  University of Shanghai for Science and Technology
- 1989- 992 Masters of Science, Systems Engineering
  University of Shanghai for Science and Technology
- 1979-1983 Bachelors of Science, Electronics Engineering
  Hunan University of Art and Science

OTHER EDUCATION

Oct. 2004 – May. 2005 **University of North Dakota**
Visiting Scholar Program

Research Topic: Renewable Energy -- Technologies and Economics

RESEARCH EXPERIENCE

Ph. D. Dissertation

- Optimal dynamic process of investing in renewable energy as substitute for fossil energy

Master Program

- Delaminating and systems analyzing of corporation cost by his historic data.

Other research projects participated

- Technical Feasibility Analysis of Distilling Biodiesel from Cultivated Microalgae
- Our China Biofuels—An Economic Analysis of Producing Biofuels from Corn in China
- Systemic Analysis of Optimized Reduction of Greenhouse Gases with Renewable Energy
- Development of a Site Assessment Instrument for Small Wind Turbine Development in North Dakota

AWARDS

- InnovateND Venture Competition, 2010

PUBLICATIONS

1 .Yong Hou and Luke Huang, **The Present State of and a Suggested Inserting Point for Biodiesel Production Industrialization in China**: 2006 IEEE International Conference on Service Operations and Logistics, and Informatics Proceedings, June, 2006. Page 679-683, ISBN: 1-4244-0318-9 (EI Accession Number: 074610921148)

2. Yong Hou and Fuyan Xu, **The Development of Biodiesel Industrialization** (in Chinese): Commercial Research, October, 2006. ISSN: 1001-148X

3. Yong Hou, **Research on an Evaluation Model of Technique Innovation**: 2006 IEEE International Conference on Service Operations and Logistics, and Informatics Proceedings, June, 2006. Page 187-191, ISBN: 1-4244-0318-9

4. Luke Huang and Yong Hou, **Manufacturing information recognition, analysis, and simulation using Windows based programs**: The 5th Wuhan International Conference on e-Business: Integration and Innovation through Management, May, 2006, Vol. 3, pp1931-1937

5. Yong Hou, Fuyuan Xu and Wei Cheng, **A Sustainable Growth Model with the Utilization of Renewable-Energy**: 2007 IEEE International Conference on Communications, Services, Knowledge and Engineering, September 2007. Page 5012-5015, ISBN: 1-4244-1311-7

6. Yong. Hou; Y. Peng; A.L. Johnson; J. Shi (2012). **Empirical Analysis of Wind Power Potential at Multiple Heights for North Dakota Wind Observation Sites**, Energy Science and Technology ISSN 1923-8460 [Print] ISSN 1923-8479 [Online] Vol.4 No.1, August 31, 2012

7. S.M. Hanson; A.L Johnson; Yong Hou; M.D. Hellwig (2012). **Recharging Centers for Disease Control Light Trap Batteries with Solar Panel**, International Journal of Applied Science and Technology (IJAST). September 2012

Michael Shope

4200 James Ray Drive, Grand Forks ND 58203
1222 20TH Avenue East, Seattle WA 98112
Phone: (218) 779 3136 Email: mike@cleanrepublic.com

Education

- Bachelor of Science Degree in Aeronautics with an emphasis in Commercial Aviation from the University of North Dakota, Track in Entrepreneurship.
  Enrolled: September, 2000. Graduated: December, 2004.
- Cumulative GPA: 3.83
- Semester Abroad: American College of Thessaloniki, Greece. 12 credits completed.
  Enrolled: January, 2002 – June, 2002

Experience

- Business founding, marketing and communication. 2004-Present
  - Founded Clean Republic LLC with Dr. Yong Hou. See CleanRepublic.com 2008
  - Travel, production, sourcing experience in Guandong, Shanghai, Jilin, and Beijing.
  - Authored and edited two business and marketing plan documents with financials.
  - Edited and compiled: LLC registrations, bylaws, and management contracts.
- Commercial Pilot, AMEL, CFII.
- Founded Pilot Friendly Products, LLC in 2003.
  - Negotiated $15,000 seed funding from Center for Innovation.
  - Developed marketing and sales systems, and prepared invoices.
  - Created and administered company e-commerce website.
  - Sold customer base and entire inventory to an industry leader.
- Presentation and instruction experience.
  - Delivered business plan and marketing presentations for clients and customers.
  - Commercial flight instructor, JDO School of Aerospace Sciences 2004-2005
  - Prepared lesson plans and instructed single and multiple students.

Employment Experience

- Product Specialist, Aviation Supplies & Academics, Bellevue, WA
  - Invent, source production for new products. Google "ASA Tri-Lite, Hoodwink."
  - Collect market feedback for product development cycle (over 300 products).
  - Prepare reports on customer service systems for management.

  Employed: October, 2006-Jun 2008
- Non-Profit Manager, Outdoor Education Post, Garfield High School, Seattle, WA
  - Advise over 50 student staff, chair and facilitate community meetings.
  - Provide organizational and leadership reports and advice to the Board of Directors.
  - Oversee $90,000 annual budget.

  Employed: August, 2007- June 2009
- Founder and CEO – Clean Republic LLC
  - Developed new practical retail products for alternative energy industry
  - Invented solutions for universal electric bike throttle/motor control
  - Manage sales, advertising, and accounting.

  Managing: 2008 - Present

Personal Information and Honors

- Vice President of Delta Tau Delta Fraternity: 50 members, $200,000 annual budget.
  National Top 10 Awarded Chapter. November, 2002 – November, 2003
- Outward Bound leadership academy graduate July, 2003
- President's Honor Roll: University of North Dakota Spring/Fall, 2003
- Dean's List: College of Aerospace Sciences Spring/Fall 2002/2003
- Jack Wright Entrepreneurship Award
- Certified keel boat skipper
- InnovateND Venture Competition 2010
- SBA Regional Young Entrepreneur of the Year 2011

References: Available upon request.

JING SHI, Ph.D.

Associate Professor
Industrial & Manufacturing Engineering
North Dakota State University
Fargo, ND 58108, USA

Tel: 1-701-231-7119
Fax: 1-701-231-7195
Email: jing.shi@ndsu.edu

Education

2004	Ph.D., Industrial Engineering	Purdue University (West Lafayette), Indiana, USA
1998	Ph.D., Materials Engineering	University of Science and Technology Beijing, China
1992	B.E. Materials Engineering	University of Science and Technology Beijing, China

Professional Experience

2010-present	Associate Professor	Dept of Industrial & Manufacturing Engineering, North Dakota State University, Fargo, ND, USA
2004-2010	Assistant Professor	Dept of Industrial & Manufacturing Engineering, North Dakota State University, Fargo, ND, USA
2003-2003	Graduate Instructor	School of Industrial Engineering, Purdue University, Indiana, USA
1998-2002	Research Assistant/ Graduate Instructor	School of Industrial Engineering, Purdue University, Indiana, USA
1996-1997	Co-op Research Engineer	Iron and Steel Research Institute of Baosteel, Shanghai, China

Research Interests

Wind energy systems
Energy economics
Renewable energy storage technologies
Advanced energy materials and manufacturing
RFID and wireless sensor network technologies

Professional Societies

Member, Institute of Industrial Engineers (IIE)
Member, Institute of Electrical and Electronics Engineers (IEEE)
Member, American Society of Mechanical Engineers (ASME)
Member, Institute for Operations Research and the Management Sciences (INFORMS)

Honors and Awards

Alpha Pi Mu Excellence in Teaching Award, 2007
Nominated for FAG Innovation Award, 2006
Nominated for SME Young Manufacturing Engineer Award, 2006
Purdue Research Foundation Fellowship, West Lafayette, IN, 2003
Excellent Graduate/Undergraduate Scholarship, 1989-1998
Best College Graduate of Beijing City, 1992
Baosteel Fellowship, 1991

Professional Leadership Committees
Wind Energy Committee, American Society of Mechanical Engineers (ASME)
Micro/Nano Manufacturing Technical Committee, American Society of Mechanical Engineers (ASME)
International Scientific Advisory Committee, International Green Energy Conference
Symposium Organizer for ASME International Conference of Manufacturing Science and Engineering

Journal Editorial Boards
International Journal of Green Energy (to start in 2012)
International Journal of Manufacturing, Materials and Mechanical Engineering
Energy Science and Technology
The Open Renewable Energy Journal

Journal Reviews (30+ journals)
Atmospheric Research, International Journal of Green Energy, Energy, Applied Energy, Wind Energy, International Journal of Energy Research, International Journal of Electrical Power and Energy Systems, Journal of Wind Engineering & Industrial Aerodynamics, IEEE Transactions on Sustainable Energy

IEEE Transactions on Electronics Packaging Manufacturing, International Journal of Modelling and Simulation, International Journal of Applied Logistics, International Journal of Machine Tools and Manufacture, Journal of Intelligent Manufacturing, International Journal of Advanced Manufacturing Technology, Materials and Manufacturing Processes, Journal of Engineering Manufacture, Nanoscience and Nanotechnology Letters, Vacuum, International Journal of Manufacturing, Materials and Mechanical Engineering, Measurement, Scientific Research and Essays

European Journal of Operational Research, International Journal of Production Economics, IEEE Transactions on Automaton Science and Engineering, IEEE Transactions on Parallel and Distributed Systems, International Journal of RF Technologies, Advanced Engineering Informatics, Sensors, Majlesi Journal of Electrical Engineering, Knowledge-Based Systems, Current Pharmaceutical Design, Neurocomputing, IEEE Transactions on Industrial Electronics

Selected Journal Publications
[1] Yong, H., Peng, Y., Johnson A., and **Shi, J.** "Empirical analysis of wind power potential at multiple heights for North Dakota wind observation sites," *Energy Science and Technology*, 2012, 4(1), pp.1-12.
[2] Li, G., and **Shi, J.** "Agent-based modeling for trading wind power with uncertainty in the day-ahead wholesale electricity markets of single-sided auctions," *Applied Energy,* 2012, 99, pp. 13–22.
[3] **Shi, J.**, and Zeng S. "Evaluation of hybrid forecasting approaches for wind speed and power generation time series," *Renewable & Sustainable Energy Reviews*, 2012, 16 (5), pp. 3471–3480.
[4] Liu, H., Erdem, E., and **Shi, J.** "An integrated wind power forecasting methodology: Interval estimation of wind speed, operation probability of wind turbine, and conditional expected wind power output of wind farm," *International Journal of Green Energy*, accepted.
[5] Li, G., **Shi, J.**, and Qu, X. "Modeling methods for GenCo bidding strategy optimization in the liberated electricity spot market – A state-of-art review," *Energy*, 2011, 36 (8), pp. 4686-4700.
[6] Zhou, J., **Shi, J.**, and Li, G., "Fine tuning support vector machines for short-term wind speed forecasting," *Energy Conversion and Management*, 2011, 52(4), pp. 1990-1998.
[7] Li, G., and **Shi, J.**, "Applications of Bayesian methods in wind energy conversion systems," *Renewable Energy*, 2010, accepted.
[8] Erdem, E., and **Shi, J.**, "ARMA based approaches for forecasting the tuple of wind speed and direction," *Applied Energy*, 2011, 88(4), pp. 1405-1414.
[9] Liu, H., Erdem, E., and **Shi, J.**, "Comprehensive evaluation of ARMA-GARCH(-M) approaches for modeling the mean and volatility of wind speed," *Applied Energy*, 2011, 88, pp. 724–732.

[10] **Shi, J.**, Qu, X., and Zeng, S., "Short-term wind power generation forecasting: Direct versus indirect ARIMA-based approaches," *International Journal of Green Energy,* 2011, 8(1), pp. 100-112.
[11] Liu, H., **Shi, J.**, and Erdem, E., "Prediction of wind speed time series using modified Taylor Kriging method," *Energy*, 2010, 35 (12), pp. 4870-4879.
[12] **Shi, J.**, Shi, Y., and Liu, C.R., "Evaluation of three dimensional single point turning at atomistic level by molecular dynamics simulation," *International Journal of Advanced Manufacturing Technology*, 2011, 54 (1-4) pp. 161-171.
[13] **Shi, J.**, and Verma, M., "Comparing atomistic machining of monocrystalline and polycrystalline copper structures," *Materials and Manufacturing Processes*, 2011, 26, pp. 1004–1010.
[14] Li, G., and **Shi, J.**, "Bayesian adaptive combination of short-term wind speed forecasts from neural network models," *Renewable Energy*, 2011, 36(1), pp. 352-359.
[15] Zhou, J., and **Shi, J.**, "A comprehensive multi-factor analysis on RFID localization capability," *Advanced Engineering Informatics*, 2010, 25(11), pp. 32-40.
[16] Zhou, J., **Shi, J.**, and Qu, X. "Landmark placement for wireless localization in rectangular-shaped industrial facilities," *IEEE Transactions on Vehicular Technology*, 2010, 59(6), pp. 3081 – 3090.
[17] Zhou, J., and **Shi, J.**, "Error analysis of non-collaborative wireless localization in circular-shaped regions," *Computer Networks*, 2010, 54(14), pp. 2439 – 2452.
[18] Erdem, E., and **Shi, J.**, "Comparison of bivariate distribution construction approaches for analyzing wind speed and direction data," *Wind Energy*, 2011, 14(1), pp. 27 – 41.
[19] Li, G., and **Shi, J.**, "On comparing three artificial neural networks for wind speed forecasting," *Applied Energy*, 2010, 87(7), pp. 2313–2320.
[20] Qu, X., and **Shi, J.**, "Bivariate modeling of wind speed and air density distribution for long-term wind energy estimation," *International Journal of Green Energy*, 2010, 7(1), pp. 21-37.
[21] Li, G., and **Shi, J.**, "Application of Bayesian model averaging in modeling long-term wind speed distributions," *Renewable Energy*, 2010, 35(6), pp. 1192-2002.
[22] **Shi, J.**, Xu, X., Wang, J., and Li, G., "Beam damage detection using computer vision technology," *Nondestructive Testing and Evaluation*, 2010, 25(3), pp. 189-204.
[23] Zhou, J., **Shi, J.**, and Qu, X., "Statistical characteristics of landmark-based localization performance," *International Journal of Advanced Manufacturing Technology*, 2010, 46(9), pp. 1215-1227.
[24] **Shi, J.***, and Liu, C.R., "Two-step cutting as a tool for improving surface integrity and rolling contact fatigue performance of hard machined surfaces," *Materials and Manufacturing Processes*, 2010, 25(6), pp. 495 - 502.
[25] Zhou, J. and **Shi, J.** "Performance evaluation of object localization based on active radio frequency identification technology," *Computers in Industry*, 2009, 60(9), pp. 669-676.
[26] Zhou, J. and **Shi, J.** "RFID localization algorithms and applications – A review," *Journal of Intelligent Manufacturing*, 2009, 20(6), pp. 695-707.
[27] Zhou, J. and **Shi, J.** "Localisation of stationary objects using passive RFID technology," *International Journal of Computer Integrated Manufacturing*, 2009, 22 (7), pp. 717-726.
[28] **Shi, J.** and Grow, D. "Effect of double constraints on the optimization of two-component armor systems," *Composite Structures*, 2007, 79, pp. 445-453.
[29] **Shi, J.**, Wang, J.Y., and Liu, C.R. "Modelling white layer thickness based on the cutting parameters of hard machining," *Journal of Engineering Manufacture*, 2006, 220(2), pp.119-128.
[30] **Shi, J.** and Liu, C.R., "On predicting chip morphology and phase transformation in hard machining," *International Journal of Advanced Manufacturing Technology*, 2006, 27, pp. 645-654.
[31] **Shi, J.** and Liu, C.R., "On predicting softening effects in hard turned surfaces –Part I Construction of material softening model," *Journal of Manufacturing Science and Engineering*, 2005, 127(3), pp.476-483.

Alex Johnson Ph.D.
2607 South 10^{th} Street
Grand Forks, ND 58201
701-772-1766
ajohnson@business.und.edu

Educational Background

University of North Dakota, Grand Forks, ND **5/2010**
Ph.D. in Teaching & Learning
Dissertation Topic "Suitability of Bench Top Metal Lathes in Education"

University of North Dakota, Grand Forks, ND **12/2001**
M.S., Industrial Technology
Independent Study "Development of an Introductory Course on Stirling Engines for the Industrial Technology Department at the University of North Dakota"

University of North Dakota, Grand Forks, ND **12/2000**
B.S., Industrial Technology
Emphasis in manufacturing processes

Professional Experience

Solargy Lights, Grand Forks, ND **2011 – Present**
Consultant/Project Manager Part-Time

University of North Dakota, ND **2007 –Present**
Assistant Professor Department of Technology

Concrete Inc. Grand Forks, ND **2003 – 2007**
Quality Control Technician

EAPC Architects Engineers, Grand Forks, ND **2002-2003**
Mechanical Technician (Drafter)

Cirrus Design, Grand Forks, ND **1999-2000**
Manufacturing Engineer Intern

Bobcat, Gwinner, ND **1999**
Tooling Department Intern

Publications, Presentations

Johnson, A., & Yearwood, D. (2012). "Bench Top and Industrial Metal Lathes-Differences and Similarities. Technology Interface International Journal (TIIJ). Volume 12, Number 2, Spring/Summer 2012

Yearwood, D., & Johnson, A., (2012). *"Assessing the viability of bench-top versus full scale industrial lathes to teach fundamental machining concepts".* American Society for Engineering Education (ASEE). June 2012

Y. Hou; Y. Peng; A.L. Johnson; J. Shi *(2012). "Empirical Analysis of Wind Power Potential at Multiple*

Heights for North Dakota Wind Observation Sites"
Energy Science and Technology ISSN 1923-8460 [Print] ISSN 1923-8479 [Online] Vol.4 No.1, August 31, 2012

S.M. Hanson; A.L Johnson; Y. Hou; M.D. Hellwig (2012). "*Recharging Centers for Disease Control Light Trap Batteries with Solar Panel"*
International Journal of Applied Science and Technology (IJAST). September 2012

P. Johnson; A.L. Johnson (2008). "*Fighting Diabetes through a Service Learning Partnership between Turtle Mountain Community College and the University of North Dakota"* Year Two Abstract Community College National Center for Community Engagement (CCNCCE).

Professional Presentations

National
June 2012 ASEE San Antonio, TX
Presentation Topic: Assessing the viability of bench-top versus full scale industrial lathes to teach fundamental machining concepts
Presented by Dr. Alex Johnson

May 2008 Community College National Center for Community Engagement (CCNCCE) National Conference, Scottsdale, Arizona
Presentation Topic: Service Learning Saving Children Initiative: Recipes for student retention
Presented with: Peggy Johnson and Kathy Henry from Turtle Mountain Community College

March 2008 American Indian Higher Education Consortium (AIHEC) National Conference
Location: Bismarck, North Dakota
Presentation Topic: Interdisciplinary approach to service learning
Presented with: Dr. Scott Hanson, Andrew Johnson, & Peggy Johnson from Turtle Mountain Community College.

International
June 2011 Cleantech, Grand Forks, ND
Presentation Topic: Development of a Site Assessment Instrument for Small Wind Turbine Development in North Dakota
Presented with: Dr. Yong Hou-Clean Republic

Conferences Attended

American Society for Engineering Education
San Antonio, TX
June, 2012

Cleantech 2011
Grand Forks, ND
June, 2011

Association of Technology Management & Applied Engineering Annual Conference
Panama City, Fl
October 2010

Community College National Center for Community Engagement (CCNCCE) National Conference, Scottsdale, Arizona
May 2008

American Indian Higher Education Consortium (AIHEC) National Conference

Bismarck, North Dakota
March, 2008

Association of Technology Management & Applied Engineering Annual Conference
Panama City, Fl
October 2007

Grants and Contracts

Business and Public Administration & Law Funding
Title: *Development of a Site Assessment Instrument for Small Wind Turbine Development in North Dakota*
Spring 2011
Co-Investigators: Dr. Alex Johnson, Dr. Yong Hou
$4,835.00

FIDC Grant
Request for funding to travel to the 17th annual service learning conference sponsored by the Community College National Center for Community Engagement in Scottsdale, AZ
$750 funded

Consultant Activities

Solargy Lights, Grand Forks, ND **2011 –Present**
Consultant/Project Manager Part-Time

Oodles, Grand Forks, ND **2012 –Present**
Consultant/Product Design & Development

Davide Andrea

3393 Iris Ave Ste 110, Boulder, CO 80301-1956
Phone: 1-720-466-7006 x77 (Main), 1-303-413-1500 (C)

Davide Andrea is the owner of Elithion LLC, founded in August 2008 with the goal of making his Lithium Ion Battery Management System technology available to an industry searching for Li-Ion BMS solutions. He brings to Elithion an unique ability to develop all aspects of BMS and battery products (software, electronic hardware - analog, digital, power, and mechanical design) in a rapid and effective manner.

Davide is the author of the book "Battery Management Systems for Large Lithium-Ion Battery Packs , which was published Sep 30th 2010.

Previously, Davide co-founded Hybrids Plus, where, using his BMS technology, he developed Prius and Escape PHEV (Plug-in Hybrid) conversions. There, he also developed the Inverger™, a bidirectional Charger / Inverter for V2G (Vehicle To Grid) applications.

Previously, Davide offered electronic consulting services through DAVIDE, DBA.

Davide has 25 years experience in electronics design, a BS is Electrical Engineering and Computer Science (University of Colorado, 1982), and 3 years experience in the Li-Ion Battery Management System field.

Davide's other publications on Li-Ion BMS include:

- Andrea, Davide. Li-Ion Myth-Buster. Battery Power Conference 2010, Dallas, TX, October 19-20, 2010. http://liionbms.com/pdf/ElithionBatteryPower10.pdf
- Andrea, Davide. Connecting Batteries in Parallel: Unexpected Effects and Solutions. Battery Power Conference 2012, September 18-19, 2012, Denver, Colorado, http://www.batterypoweronline.com/conferences/program/conference-sessions/
- Andrea, Davide. Current Limiting Resistors for LEDs. http://www.eeweb.com/blog/davide_andrea/current-limiting-resistors-for-leds
- Andrea, Davide. Utility Assigns EE Part Numbers Automatically. http://www.eeweb.com/blog/davide_andrea/utility-assigns-ee-part-numbers-automatically

A5 – Lithium Battery Packs Developed by Clean Republic LLC

Our initial market research in 2008 showed the U.S. electric bike market was only being supplied with larger, high-voltage battery packs (36v, 48v, 72v), but there was larger demand for smaller, simpler systems that were hard to find. Our first commercialized battery research and development project was the development and launch of the below design:

NO	Item		Parameter	Remark
1	Rated Capacity		8500mAh	Discharge 0.2C
2	Nominal Voltage		25.9V	
3	Charge Voltage		29.4V±0.05V	
4	Discharge End Voltage		19.25V	
5	Charge Current	Standard Charge	1700mA 0.2C	
		Rapid Charge	4250mA 0.5C	
6	Discharge Current	Max Discharge	20A	
		Pulse Discharge	40A	
7	Operating Temperature	Charge	0℃~+45℃	
		Discharge	-20℃~+60℃	
8	Storage Temperature	1 month	-20℃~+45℃	Capacity recovery rate should be more than 80% under the shipment status
		3 month	-20℃~+35℃	
9	Internal Resistance		≤80mΩ	measured at AC 1KHz after

Figure A1: V1 model of Li battery pack for e-bike by Clean Republic LLC

For this V1 pack we chose prismatic LiMn (NCM) cells and a basic BMS board with standard protection and basic bleed resistor balancing functions. LiMn chemistry was chosen because of the low weight and small size expected in the larger bicycle industry for all components.

Later, after commercialization launch and market testing with about 1,000 units in the field, we refined the design in the below V2 model. We ruggedized the temperature monitor portion of the BMS circuitry and also improved the external packaging by adding flexible cable connections which were much more practical for larger-scale commercialization than the rigid components on our V1 models.

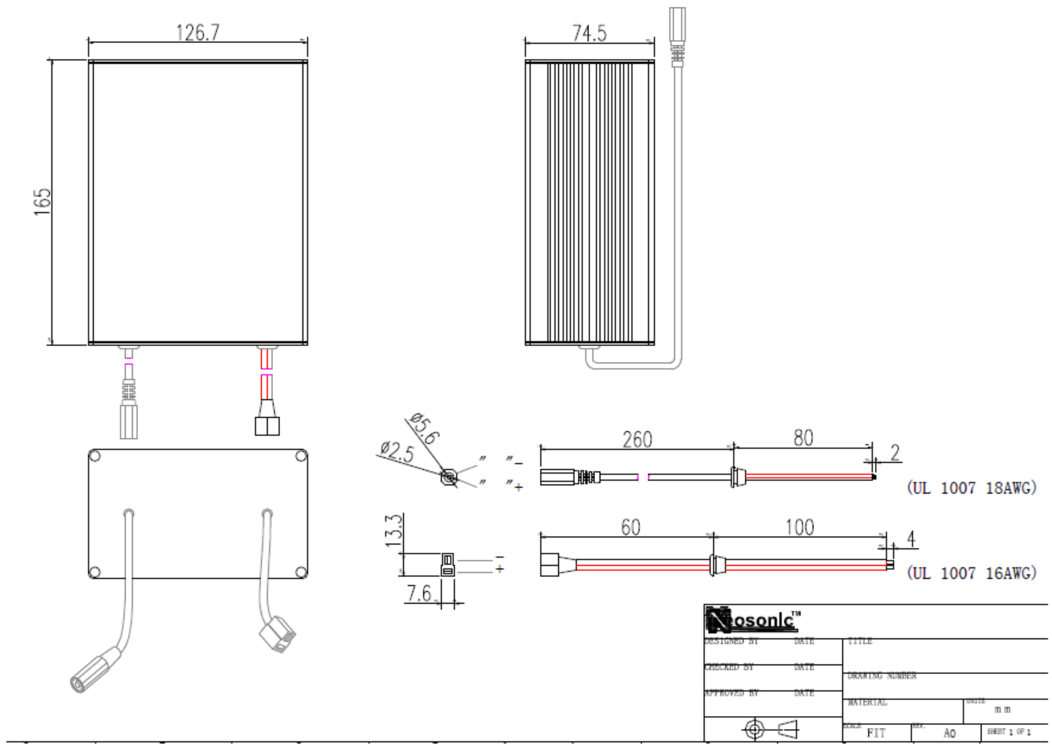


Figure A2: V2 model of Li battery pack for e-bike by Clean Republic LLC

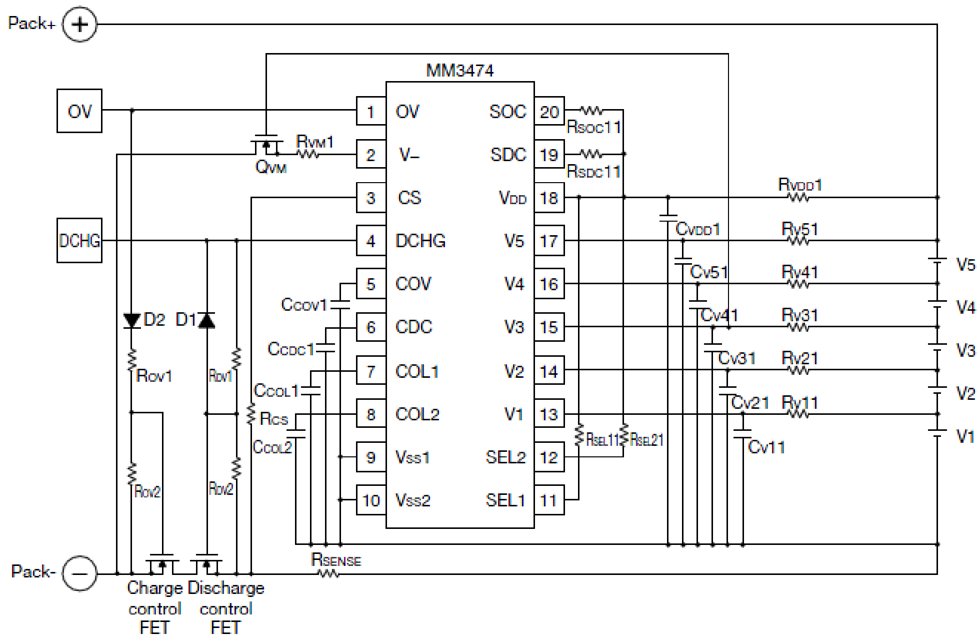
These particular design changes proved successful but we were still experiencing problems stemming from the irregular production quality of the prismatic cells (a less mature production process), and also low-quality physical manufacturing of the BMS board, as well as Integrated Circuits (IC's) in the BMS that were not matched perfectly to the parameters of our cells, allowing discharge to go about 0.15v below the optimum discharge limit for these cells.

Another problem with most electric bike packs, as well as our V1 and V2 designs was over-heating. Our V3 design work outline below aimed at correcting both the accuracy of the over-discharge voltage protection and also better thermal management. We used an updated BMS design with *two* 5-cell Mitsumi IC's better calibrated to our cells' low-voltage protection needs, and we built in physical thermal passive management concepts by adding air circulation space between the cells. We are currently running tests comparing the ability of phase change material and basic air circulation to remove heat from the cells. Both techniques are proving effective, but we need some specialized equipment and some additional expert consultation from outside our team to move much farther forward in this area.

MITSUMI 3 to 5cells Li-ion/Li-polymer battery protection IC

Application Circuit

· 5 cells protection circuit



SEL1	SEL2	mode
H	H	5Cell in series
H	L	4Cell in series (Connect V1 and VSS terminal)
L	H	3Cell in series (Connect V2,V1 and VSS terminal)

⋆ It becomes a static test mode in SEL1=SEL2=Low.

Figure A3: Improved circuit protection in model V3 model of Li battery pack by Clean Republic LLC

This improved our over-discharge issue, increasing the total life of the packs as a result of less discharge abuse, but the inconsistency of the production quality of the larger-sized prismatic cells continued to be a problem.

Production consistency of cells must be an integral part of a commercialized pack. Theoretical testing can be done on one component of a lithium battery system for optimization, but no matter how good a BMS or physical architecture design is, the commercialized battery pack will fail in the market unless the final pack is constructed with cells that can be assumed from the beginning to be reliable. Cells of the highest reliability make all the other theoretical testing and laboratory optimization work worthwhile. For these reasons we have moved away from prismatic cells for our retail electric bike packs (though are still working with medium-large scale prismatics in our research). Our first attempt to move forward with cell reliability while maintaining all other improvements we had already made was with the AllCell team, using their Molicel cells:

What we found was that although our larger prismatic cells were less reliable in their production quality, the higher-volume production cylindrical cells suffered from additional ‘voltage sag’ and impedance due to their smaller per-cell physical size. The next two graphs show the Clean Republic V2 (“CR Voltage”) battery being compared with a 7s and then an 8s pack (V3) using cylindrical cells of similar NCM chemistry (“ACT Voltage”).

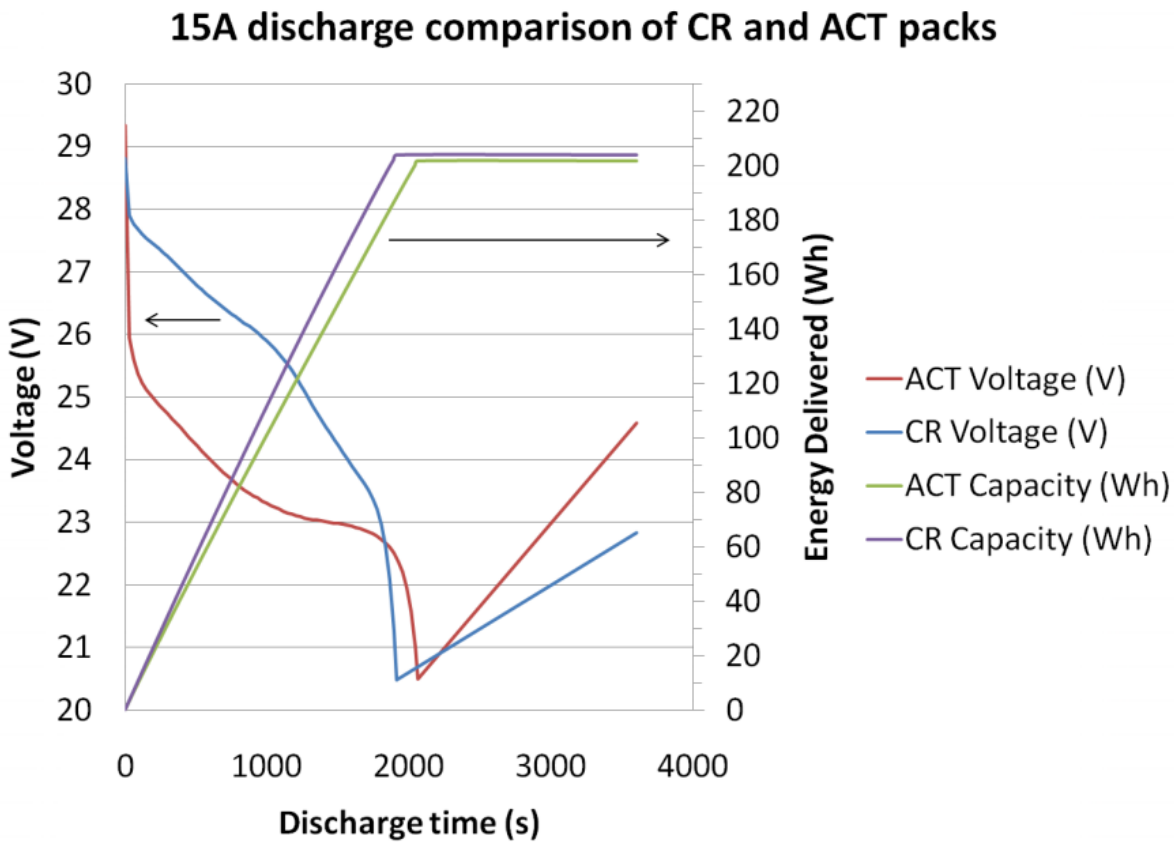
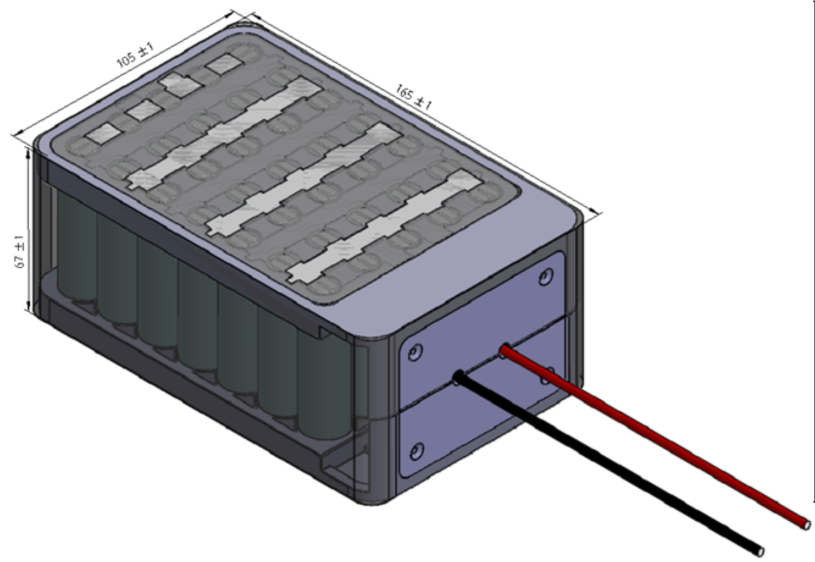


Figure A4: Performance comparison between Clean Republic V2 and V3 models of Li battery packs

After comparing all these results and considering all the commercial market issues we have learned about, we have decided to take a hands-on approach to optimizing our battery packs from here forward. During the spring of 2012 we will be replacing our current electric bike battery with a V4 model. This model uses all the previously described improvements of the other models, but improves further on the cell reliability, cost, and ease of production. We are using high-quality Samsung NCM cells directly from a registered distributor, but are setting up the supply chain for this new model so that we can easily control the production quality of the packaging, distribution, and any necessary repairs ourselves in our own North Dakota facility. This combination of factors means our performance exceeds that of our competitors, our costs are lower, and we have vastly more control over future design improvements and quality of individual components. Below is a picture of the V4 model:



Parts name	specifications	number	unit
CELL	SDI ICR18650-22P	35	PCS
PCM	RP00708B-T-556016	1	PCS
NICKEL	EZ1005 FR700-1	2	PCS
NICKEL	EZ1005 FR700-2	6	PCS
YY0705 FR700	125.2*90.8*0.3mm	2	PCS
NOMEX-3	24*16*0.2mm	10	PCS
Insulated casing	Φ5mm*40mm	2	PCS
Insulated casing	Φ3mm*15mm	6	PCS
Wire	3123#16 B=100mm	1	PCS
Wire	3123#16 R=250mm	1	PCS
Wire	3123#16 B=200mm	1	PCS
Wwire	3123#16 R=200mm	1	PCS
EVA)	150*320*1.0mm	1	PCS
EVA	90*65*1.0mm	4	PCS
Lable	40*10mm	1	pcs
Lable	40*10mm	2	PCS
Lable	65*40mm	1	pcs
PVC	175*0.15mm 1-013	15	g
Epoxy resin board	68*98*1mm	3	PCS
Epoxy resin board	155*98*1mm	2	PCS
Epoxy resin board	155*68*1mm	2	PCS

Figure A5: V4 model of Li battery pack for e-bike by Clean Republic LLC

This is a very unusual set of skills, resources, and experience for a U.S. alternative energy company, and it is the unique nature of this combination of resources that is allowing us to move out ahead of our competition in our industry niche, and develop solutions that will be commercialized outside the electric bike industry with much larger battery packs.

Finally, in working with AllCell of Chicago, we recently developed a battery pack product for customers with the need of longer distance with one full charge. It is designed to drive the Hill Topper e-bike kit from Clean Republic for 40 miles and is compatible for upgrade sales with all kits previously sold. This battery has the following specifications: 24v 20Ah, 480Wh, 7lbs, LiMn, 7s8p (56 cells), Phase Change Material thermal enhancement. The picture is shown below,

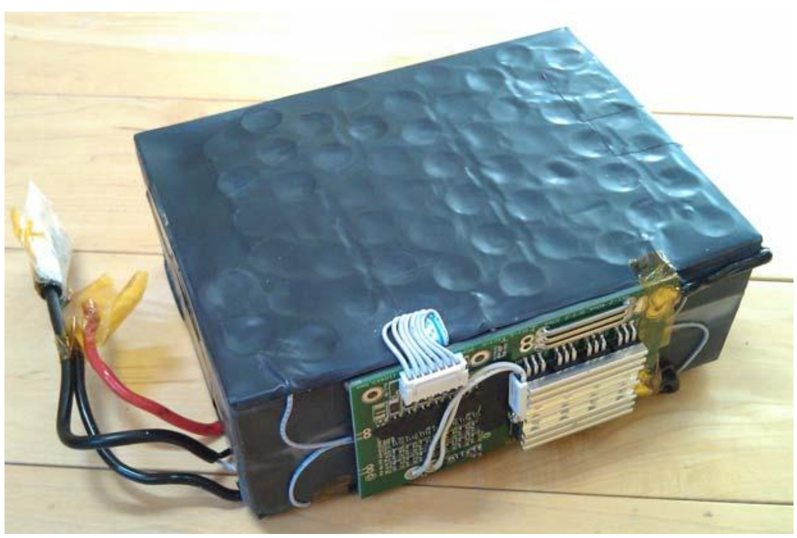


Figure A6: 40-mile Li battery pack with PCM thermal management for e-bike by Clean Republic LLC

A6 - Distributed Wind Market Applications (Summary)

Please see attached pages.

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

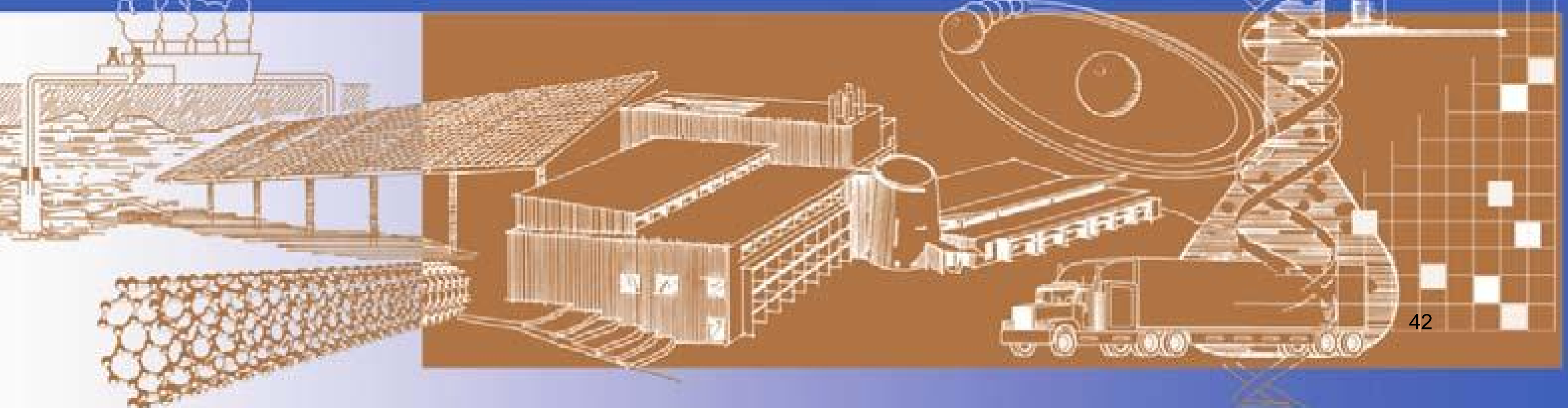
National Renewable Energy Laboratory
Innovation for Our Energy Future

Distributed Wind Market Applications

T. Forsyth and I. Baring-Gould

Technical Report
NREL/TP-500-39851
November 2007

NREL is operated by Midwest Research Institute • Battelle   Contract No. DE-AC36-99-GO10337



Chapter 1. Executive Summary

The Executive Summary will discuss the distributed wind market potential from a domestic and international perspective with greater confidence in the number of units installed for the domestic market. The market potential discussion will be followed by a summary of information provided in each chapter, including regions of market interest for both the domestic and international market, key market and technical barriers, time-critical issues for market development, technology adoption timeframe, and recommended areas of concentration.

Distributed wind energy systems provide clean, renewable power for on-site use and help relieve pressure on the power grid while providing jobs and contributing to energy security for homes, farms, schools, factories, private and public facilities, distribution utilities, and remote locations. America pioneered small wind technology in the 1920s, and it is the only renewable energy industry segment that the United States still dominates in technology, manufacturing, and world market share.

The series of analyses covered by this report were conducted to assess some of the most likely ways that advanced wind turbines could be utilized as an option to large, central station power systems. Each chapter represents a final report on specific market segments written by leading experts in each sector. As such, this document does not speak with one voice but rather a compendium of different perspectives from the U.S. distributed wind field.

For this analysis, the U.S. Department of Energy (DOE) Wind and Hydropower Technologies Program and the National Renewable Energy Laboratory's (NREL's) National Wind Technology Center (NWTC) defined distributed applications as wind turbines of any size that are installed remotely or connected to the grid but at a distribution-level voltage.

Distributed wind systems generally provide electricity on the retail side of the electric meter without need of transmission lines, offering a strong, low-cost alternative to photovoltaic (PV) power systems that are increasingly used in urban communities. Small-scale distributed wind turbines also produce electricity at lower wind speeds than large, utility-grade turbines, greatly expanding the availability of land with a harvestable wind resource. These factors, combined with increasingly high retail energy prices and demand for on-site power generation, have resulted in strong market pull for the distributed wind industry, which is poised for rapid market expansion.

Seven market segments were identified for initial investigation. These market segments, documented in this report, include small-scale remote or off-grid power; residential or on-grid power; farm, business, and small industrial wind applications; and "small-scale" community wind. A summary of the market for remote wind-diesel applications is also included in this summary, although a full report was never completed. The remaining two market segments, water pumping for large-scale irrigation and water desalination, are currently being assessed as part of other program activities and are not included at this time. While some of these market applications have existed for some time, others are just beginning to emerge as part of distributed wind power. A short introduction to each of these assessments is provided below.

- **Small-scale remote or off-grid power (residential or village):** Supplying energy to rural, off-grid applications in the developed and developing world. This market encompasses either individual homes or small community applications and is usually integrated with other components, such as storage and power converters and PV systems.

- **Residential or on-grid power:** Small wind turbines used in residential settings that are installed on the house side of the home electrical meter using net metering to supply energy directly to the home. Excess energy is sold back to the supplying utility.
- **Farm, business, and small industrial wind applications:** Supplying farms, businesses, and small industrial applications with low-cost electric power. The loads represented by this sector are larger than most residential applications, and payback must be equivalent to similar expenditures (4 to 7 years). In many cases, businesses are not eligible for net metering applications; thus the commercial loads must use most of the power from the turbine.
- **"Small-scale" community wind:** Using wind turbines to power large, grid-connected loads such as schools, public lighting, government buildings, and municipal services. Turbines can range in size from very small, several-kW turbines to small clusters of utility-scale multi-megawatt turbines. The key, defining factor is that these systems are owned by or for the community.
- **Wind/diesel power systems:** Providing power to rural communities currently supplied through diesel technology in an effort to reduce the amount of diesel fuel consumed. The rising cost of diesel fuel and increased environmental concerns regarding diesel fuel, transportation, and storage have made project economics more sensible.
- **Irrigation water pumping:** Using wind turbines to supply energy for agricultural applications. Current applications are powered by grid electricity, diesel, gasoline, propane, and particularly natural gas. Wind or hybrid systems allow farmers to offset use of high-priced fossil fuels.
- **Water desalination:** Using wind energy to directly or indirectly desalinate sea or brackish water using reverse osmosis, electrodialysis, or other desalination technologies. The economic and technical performance of wind-powered desalination depends on the configuration and placement of wind resource with regard to the impaired water and existing energy resources. Water desalination works well with the wind resource found in coastal or desert environments.

In these analyses, the DOE Wind and Hydropower Technology Program is assessing two new segments that have not historically been classified under the distributed wind banner: farm/commercial and the "small-scale" community wind market. Both of these markets struggle to find commercial turbines to meet their needs, demonstrating opportunity for the development of U.S. turbines.

These two emergent market segments combined with the existing small wind market result in three conglomerated turbine capacities. The first is the residential and smaller business sector at roughly 0 kilowatt (kW) to 100 kW capacity. The second sector is the farm/commercial market sector that includes farm, industrial, and wind/diesel from 100 kW to 500 kW. The last market sector for distributed wind is the "small-scale" community wind sector, which has been estimated to be 500 kW to 1 megawatt (MW). Although not covered specifically within this analysis, there is also likely a need to develop methodologies to lower the cost of power from large, multi-megawatt turbines that are installed in distributed community applications. Further hardware development in all of these sectors would help meet the desires of Americans to provide their own electricity, whether for a residence, farm, or business in rural America where zoning challenges are minimized.

This study identifies and describes how the distributed wind industry can overcome long-standing barriers and play an important role (in the United States and the international arena) in supplying power near the point of end use or behind the meter.

I. Summary of Market Potential

Authors were asked to conservatively assess the potential market size for the five market segments in terms of the number of units expected to be installed in 5-year increments through 2020. Additionally, authors were asked to recommend the expected turbine size that would be most applicable to meet the proposed markets. Figure E.1 shows an overview of the different market segments, the kilowatt capacity of the turbines for each market segment, and the existing turbines available within each distributed market segment.

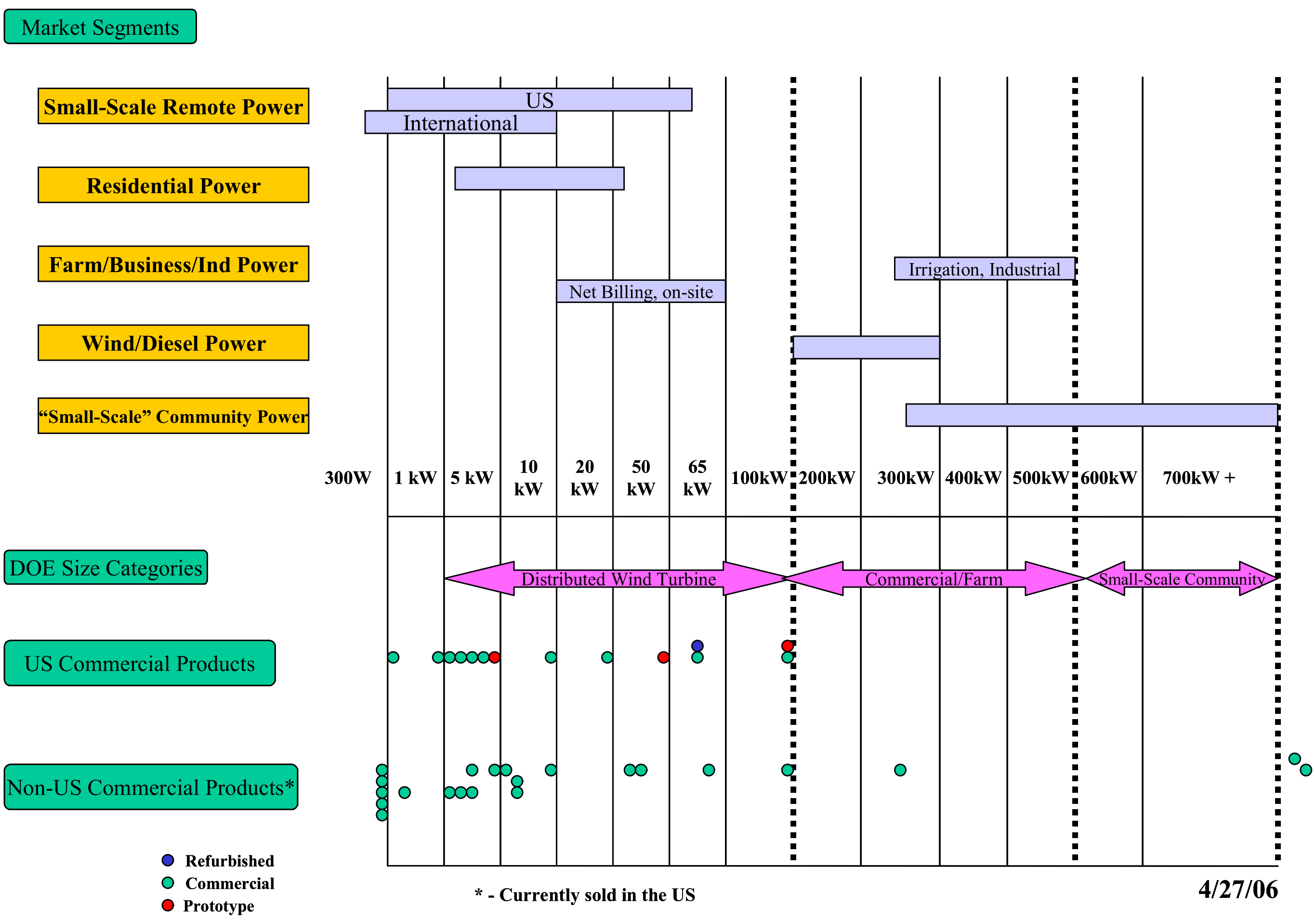


Figure E.1. Overview of market segments and commercial wind turbines

From a manufacturing perspective, the strongest market segment is turbines smaller than 10 kW in size, with 20 domestic or internationally manufactured turbines to choose from. The number of turbine choices between 20 kW and 100 kW is quite limited, and turbines between 100 kW to 1 MW are practically nonexistent.

It should be noted that the re-powering of wind farms in Europe and the United States has made available re-manufactured turbines that are being used to supply many current distributed applications. Although generally inexpensive compared to existing new turbine models, most of these are based on significantly outdated technology. Turbine design, reliability, and energy capture have been improved over the intervening time, resulting in current projects with reduced energy capture than would be expected from projects with turbines incorporating current technology and design practices.

II. Summary of Domestic Markets for Distributed Wind Technologies

Teams of technical experts with knowledge of their market segments provided the market projections summarized below. Each of these experts was asked to provide a conservative estimate to ensure the report validity in retrospect. It should be noted that NREL did not attempt to validate the expected market data from these market summary reports.

The benefits from distributed wind projects are minimized when quantified using total megawatts of installed capacity, especially for the smaller distributed turbines. However, the use of a simple number of units produced reduces the visibility of the mid-size turbines used in the farm/commercial, wind/diesel, and “small-scale” community wind segments. For this reason, the summary results are presented in terms of both the number of units and total installed capacity. It should be noted that the estimates of the number of units and thus the total installed megawatts are very rough and should only be considered in relative terms. The DOE Wind and Hydropower Program is in the process of conducting more detailed market assessments for the segments that show the most promise.

Table E.1 summarizes the cumulative number of expected domestic turbine sales over the five market segments. Note that the table also presents the turbine size for each market segment. Currently the largest sector in terms of the number of installed units is the small-scale remote or off-grid power market segment. The majority of these off-grid units have a lower capacity, with a typical turbine size in the range of a few kilowatts or less. All market segments combine to a potential total of 680,000 installed units by the end of 2020.

There are several market niches within the domestic off-grid segment, specifically in Alaska and Native American communities. An example is the Navajo Nation—approximately one-third of the 250,000 people on the reservation lack electricity.

The estimated market growth across 15 years to 2020 is 11% per year for the small-scale remote or off-grid market segment; 22% per year for the residential or on-grid segment; 48% across the farm, business, and small industrial segment; 26% per year for the wind/diesel segment; and 23% per year for the “small-scale” community segment.

Table E.1. Market Projections of Domestically Installed Units

	Off-grid	Residential	Farm, Industrial & Business	" Small Scale" Community	Wind/Diesel
Turbine size	300 W - 60 kW	1 - 25 kW	Large: 250-400 kW Net Bill: 10-60kW	100 - 1000 kW	100 - 300 kW
2005	125,700	1,800	20	150	65
2010	219,450	6,250	1,270	360	565
2015	455,450	14,000	4,270	1,010	1,565
2020	631,450	36,500	7,395	3,235	2,190

These data are shown graphically in Figure E.2. The off-grid market segment is excluded due to its dominance of the graph, which reduces the reader's ability to see the effects of other market segments. With the off-grid data removed, the residential market segments show that on a unit-production basis, residential leads the distributed market segment. From a manufacturing standpoint, in which high volume can reduce cost, the high number of units should be attractive.

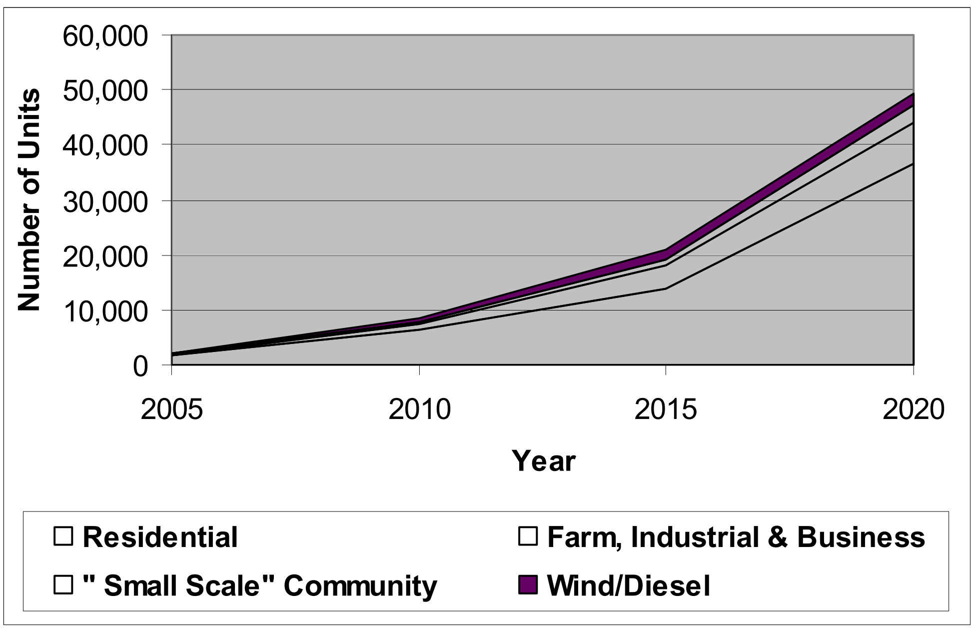


Figure E-2. Market projections using number of units installed in the United States

Table E.2 and Figure E.3 show these same data based on the expected cumulative installed domestic capacity of the turbines in these market segments. This figure provides a different view of the markets in that although fewer turbines will be installed in either the farm or community wind markets, their capacity (in terms of rated kilowatts) is much larger than the cumulative sum of the smaller residential and off-grid market segments.

It should also be understood that the "small-scale" community wind market was arbitrarily capped at a maximum turbine size of 1 MW. It is quite clear that a vibrant community wind market exists that uses turbines greater than 1 MW in size, with multiple installations reaching up to 20-MW sites. Further DOE market assessment activities will likely extend this size range of turbines to be considered to include turbines up to 1.5 MW in size.

Table E.2. Projected Domestic Installed Capacity (MW) by Sector through 2020

Year	Off-grid	Residential	Farm, Industrial & Business	" Small Scale" Community	Wind/Diesel
Turbine size	1 kW	12.5 kW	Large: 325 kW Net Bill: 30 kW	750 kW	200 kW
	Cumulative installed capacity (MW)				
2005	126	23	4	113	13
2010	219	78	260	270	113
2015	455	175	875	758	313
2020	631	456	1,516	2,426	438

Table E.2 shows the market segment with the largest installed capacity as “small-scale” community wind, followed by the farm, business, and small industrial market segment. Note that the farm, business, and small industrial market segment shares the same size turbine capacity as the wind/diesel market segment. Technological solutions would likely address both market segments. And combining the total projected market capacity of the farm, business, and small industrial segments results in approximately the same total as the “small-scale” community segment.

To date, approximately 270 MW of community wind projects are installed in the United States, representing $250 million in investment in rural communities. Of those, 110 MW would meet the “small-scale” community wind definition of 1 MW or less. At least 440 MW of new community-owned wind projects are in the advanced planning states in the United States; however, project developers expect to utilize turbines larger than 1 MW for nearly all of this future capacity (due to their better economics and availability).

Figure E.3 shows the total of all five market segments, resulting in 5.4 gigawatts (GW) of projected capacity by the end of 2020.

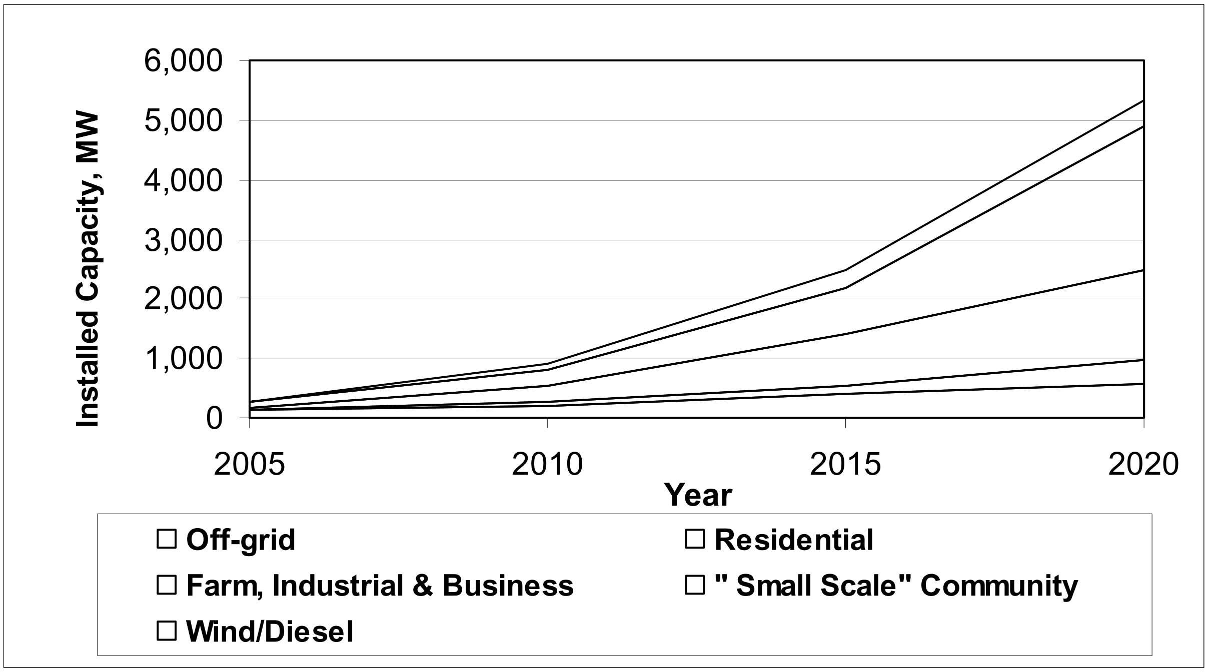


Figure E.3. Incremental domestic installed capacity by sector through 2020

A number of capacities were presented for each market segment, as shown in Tables E.1 and E.2. Each market segment chapter provides a range of market potential for 2010, 2015, and 2020 (found in each chapter's Summary Information Table). Based on those data, we evaluated the total market potential assuming *minimum* values of capacity and market potential, *likely* values of capacity and market potential (as shown in the above tables and figures), and the *maximum* value of capacity and market potential. Figure E.4 shows the bars, which represent the *likely* value of installed capacity in megawatts. The lines for each bar show the minimum and maximum for future years.

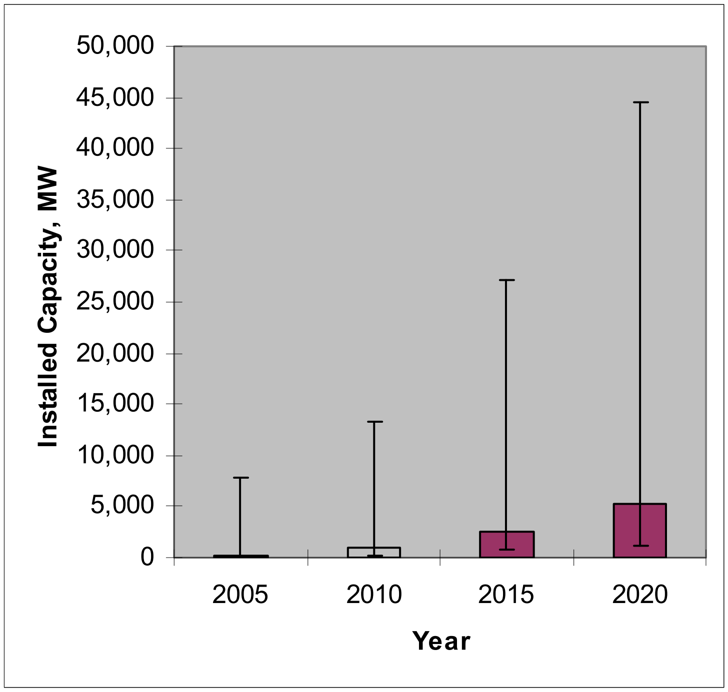


Figure E.4. Potential capacity variation for all domestic market segments

A large variation exists between the minimum and maximum value for the year 2020. This is due to several factors, including uncertainty about the optimum turbine size for each market segment, uncertainty in the removal of market barriers that are needed to propel the market forward, and uncertainty in the technology cost and the competitiveness of new products in the marketplace.

III. Summary of International Market for Distributed Wind Technologies

Although not the focus of this work, each of the market segment authors was asked to estimate the international market for distributed applications. It should be noted that international market information is notoriously difficult to measure, and the scope of these documents only allowed a cursory investigation.

The international market is of special interest because unlike the market for large wind turbines, U.S. small wind turbine manufactures currently hold a dominant market share. U.S. manufacturers of small and distributed wind turbines represent the most diverse and internationally recognized industry in this technology area.

Table E.3 provides a summary of the international market potential as identified in the market segment reports. Note that the table also presents the turbine size for each market segment. The largest sector in terms of installed megawatts is the community wind market segment. Historically, the European Union has been the leader in community wind, with about 80% of all the installed wind turbines considered community applications. This market is currently estimated to be 8.2 GW of installed units under 1 MW.

In comparison to the domestic market, three international market items stand out. First, "small-scale" community wind becomes a more dominant player in the world wind market, replacing the substantially increased off-grid market. Second, wind/diesel applications become a stronger market element. Finally, residential wind diminishes in importance. The off-grid market, although not as large as "small-scale" community wind, still offers a huge potential. Although most of this market potential is outside the developed world, China has a current installed capacity of 170,000 mini wind turbines (60 to 200 W).

Table E.3. Cumulative Installed International Capacity in MW by Sector through 2020

Year	Off-grid	Residential	Farm/Industrial/Bus	Community	Wind/Diesel
Turbine size	5 kW	12.5 kW	Large: 325 kW Net Bill: 30 kW	750 kW	200 kW
2005	2,361	14	0	8,250	10
2010	3,118	36	154	17,250	310
2015	6,275	99	410	40,125	1,810
2020	10,693	286	666	95,625	3,810

Table E.3 summarizes the cumulative capacity of expected international turbine sales over the five market segments. Note that the table also presents the turbine size for each market segment while Figure E.5 shows the expected number of installed units of each market segment, excluding the off-grid or small-system segment, which is expected to grow at more than 150,000 units per year in 2020, and distorts the impact of the other market segments. The largest sector in terms of the number of installed units is the off-grid or small-scale remote power market segment; however, the majority of these off-grid units will have a lower capacity, with a typical turbine size in the range of a few kilowatts or less. All market segments combine to a potential total of almost 1,500,000 installed units by the end of 2020. The total year-over-year international market grown is estimated at about 20%. It should be noted that due to the limited data available to support these estimates, the range between *minimum, likely,* and *maximum* values of capacity is quite large (Figure E.6).

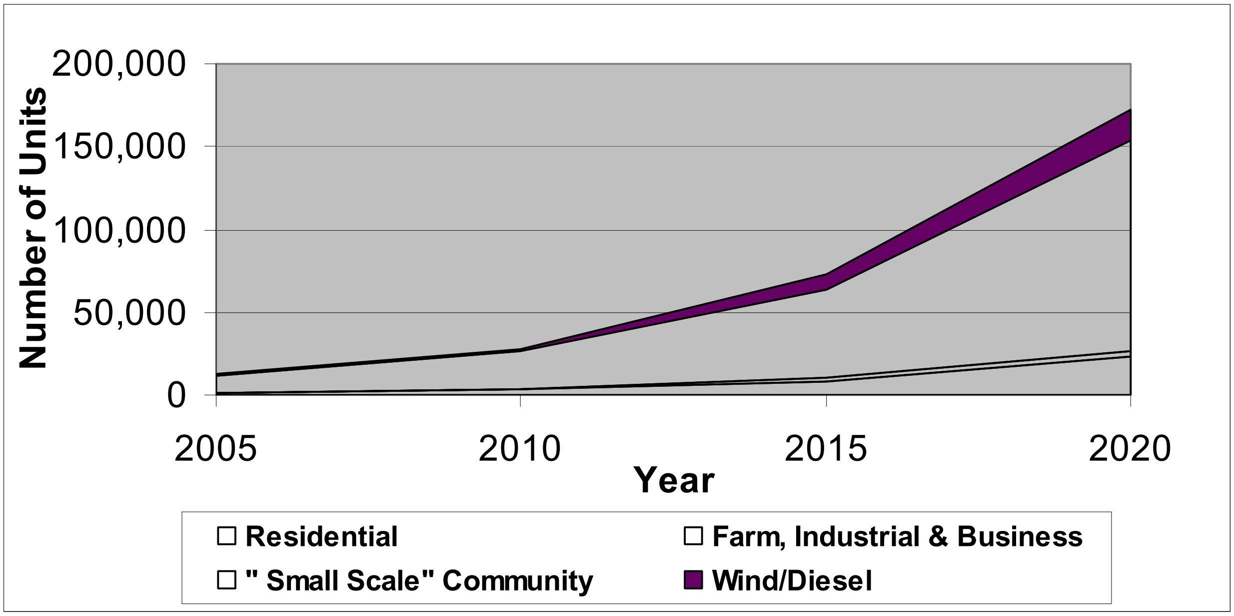


Figure E.5. Incremental international installed capacity by sector through 2020 without data for off-grid or small-system segment (which is too large to show graphically)

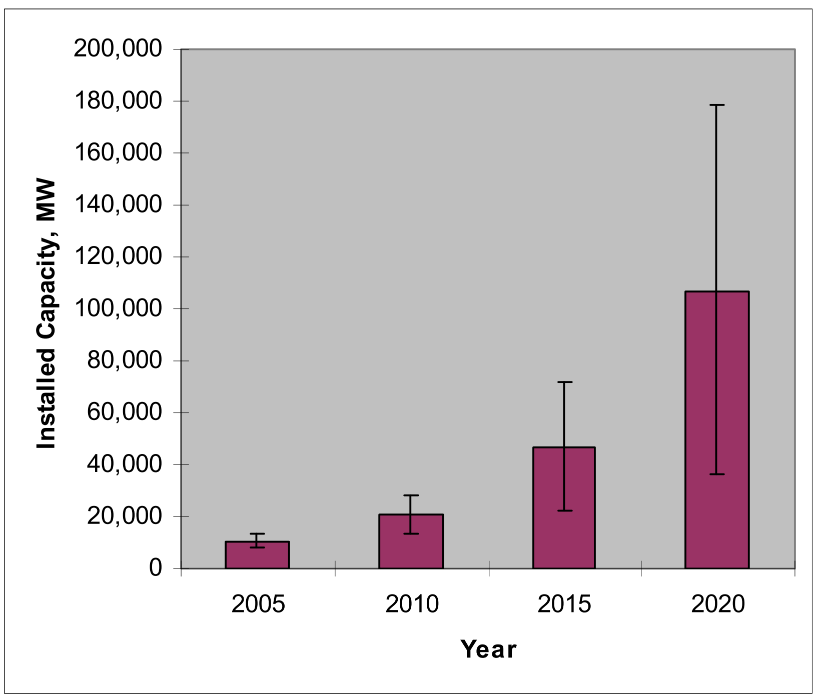


Figure E.6. Potential capacity variation for all international market segments

A robust market potential is estimated for the farm, business, and small industrial segment due to strong economic policy (for example, the German "feed in" tariffs, in which high economic value is given to the production of kilowatt-hours based in part on higher electricity rates). China also has aggressive renewable energy goals, and there is already proven use of mini turbines.

IV. Market-Based Barriers to the Distributed Wind Market

Through this market analysis, several market-based barriers were identified that hinder the development of the distributed wind applications market. Unless otherwise noted, many of the barriers, which are described in basic rank order of importance, were found to be casual factors in multiple market segments.

- **Technology not quite cost competitive:** Although markets exist in which incentive programs can be combined to give consumers 50% cost-sharing of their turbines, further cost decreases through volume manufacturing will be needed to allow appropriate payback periods for most American consumers. (Markets in which distributed wind technologies are cost effective exist in Class 3 to 4 wind resource areas and locations with high electricity costs, such as remote diesel stations.)
- **Turbine availability:** In the current market, turbines sized between 100 kW and 1 MW to serve farm, business, small industrial, wind/diesel, and small-scale community loads are not produced. There is also a shortage of turbines sized greater than 1 MW because of pre-purchases by wind developers using the Production Tax Credit. There are also opportunities for turbine development in the 5-kW to 15-kW range to meet needs in the residential market segment.
- **Zoning/permitting restrictions or complications:** Zoning remains a large issue for distributed applications, specifically for individual home or business owners seeking to install a small wind turbine on their properties in suburban America. The permitting costs and zoning requirements can greatly increase the overall cost, lead time, and complexity of installing even the smallest wind turbine. In most locations across rural America, zoning and permitting are not an issue for smaller turbines, but those locations don't typically have the incentives in place to compel the purchase of a distributed wind turbine. Model zoning ordinances for mid-size turbines currently do not exist, and there is a need for them. These ordinances should consider proper setback for sound levels and safety, as well as avian and other wildlife issues.
- **Interconnection to the grid, including standards and defined requirements:** Turbine grid interconnection is a complex issue that varies from state to state and generally from utility service provider to service provider. This creates a number of complexities, both from a technology perspective and an information outreach perspective. With such a wide range of requirements, it's almost impossible for the industry and other supporting organizations to provide informative assistance to interested homeowners.
- **Lack of consistent incentive policies across markets:** The lack of clear, consistent, and economically motivating incentives complicates and distorts markets for small wind systems. More systematic market incentives, such as "feed in" tariffs, a national investment tax credit for distributed wind applications, and state-based rebates for all distributed applications would expand the technology adoption.
- **Poor image due to past small wind experiences:** The historical performance of some distributed wind turbines has resulted in a somewhat persistent belief that small wind turbines are noisy, unsafe, and unreliable. Outreach activities addressing previous market issues and some of the largest preconceived notions of modern small wind turbines are needed.

V. Technical Barriers to the Distributed Wind Market

In addition to market barriers, technical barriers were also identified. A summary of these barriers, all of which are discussed in greater length in each of the chapters, is provided.

- **Product reliability and performance:** Turbine and system reliability, especially in distributed applications where service personal are less readily available, hinder the adoption of wind systems. Performance is typically over-predicted (usually due to a poor understanding of the wind resource, the micrositing of the turbine system, and insufficient tower heights).
- **Limited size choices using older designs:** The limited number of commercial turbines 50 kW and greater, combined with non-optimized turbine efficiency and design, result in missed market share. Many technological advances have been made on residential turbine designs and multi-megawatt turbine designs, and these technological advances could be applied to distributed turbines.
- **Availability of maintenance support:** By definition, distributed applications will not be installed in organized wind farms where field support is readily available. The lack of or additional cost of field support undermines technology acceptance.
- **Lack of performance standards, testing, and ratings:** The lack of industry-accepted standards undermines the credibility of performance estimates for wind turbines. In many cases, incentive organizations are unsure of which products to endorse and incent, limiting the available product with good economic value.
- **Technologies for low-wind regimes:** Most mid-size wind turbines used in the distributed market were designed before recent advances in low-wind-speed technology. However, a large number of sites where distributed applications will be applied are not in high-wind-speed regimes and would receive the most advantage of low-wind-speed designs.
- **Turbine noise:** Although distributed turbines are becoming quieter with each successive generation, some are still considered too noisy to be used in residential settings. Further technical advances to reduce noise will allow turbines to operate in a wider variety of settings.
- **Lightning susceptibility and grounding:** The susceptibility of distributed wind turbines to lightning and the cost of lightning protection increase the cost and technical complexity of wind systems.
- **Grid interconnection and integration:** The technical complexity and cost of interconnection of small wind systems to the electric distribution grid require further advancement, standardization, and testing. Distributing turbines through the use of more sophisticated remote-monitored controllers can allow the turbine to support the weak rural distribution systems, providing grid stability.
- **Tower options for larger wind systems:** Most towers are currently designed around wind turbines for central station wind farms. To allow for more cost-effective installation and maintenance, distributed wind turbines must be developed with towers and systems specifically designed for the distributed wind market, such as self-erecting towers or lightweight, tall towers for small turbines in rural low-wind-speed applications.
- **Energy storage for remote power systems:** Remote, non-grid-connected power and water irrigation applications require some form of energy storage to supply consistent, grid-quality electrical service. Energy storage is currently the highest life-cycle cost

component of a remote power system. Improving the cost and technical performance of energy storage will increase the applicability of wind-driven remote power systems.

VI. Acknowledgements

The following people and organizations completed the work summarized in this document:

The residential and "small-scale" community wind reports were written by a team led by Heather Rhoads-Weaver of eFormative Options LLC. The residential market team includes Amy LeGere, Brian Antonich, Johnny Holz, Steve Grover, Craig Hansen, Mick Sagrillo, Ed Kennell, Thomas Wind, Ron Lehr, Meg Gluckman, and Thom Wallace. The "small-scale" community wind team includes Brian Antonich, Lisa Daniels, Jonny Holz, Steve Grover, Craig Hansen, Mick Sagrillo, Ed Kennell, Thomas Wind, Ron Lehr, Amy LeGere, Meg Gluckman, and Thom Wallace.

The small-scale remote power report was written by Robert Foster and L. Martin Gomez Rocha from New Mexico State University – Southwest Technology Development Institute and Ken Starcher and Vaughn Nelson from West Texas A&M University – Alternative Energy Institute.

The farm, business, and small industry report was written by Ken Starcher and Vaughn Nelson from West Texas A&M University – Alternative Energy Institute and Robert Foster and Luis Estrada from New Mexico State University – Southwest Technology Development Institute.

Additional reports were completed by Dustin Gaskins, Steve Amosson, Thomas Marek, DeDe Jones, Bridget Guerrero, Lal Almas, and Fran Bretz of the Agricultural Research and Extension Center, Texas A&M University; and James Janecek, Tom Acker, Abe Springer, Jan Theron, Mark Manone, Grant Brummels, and Sean Martin of the Sustainable Water Resource Alliance and Sustainable Energy Solutions Group at Northern Arizona University. Jesse Stowell of Northern Power Systems also contributed to this report.

All of these teams have significant experience dealing with the market sector that they reported on and have provided potential market growth estimates based on their experiences. Their reports include a description of the market today, current market and technical barriers, their associated time frames, and projected market growth for the domestic and international markets.

The authors would also like to thank the U.S. DOE Wind and Hydropower Technologies Program for its support of this work.

VII. Conclusion

Distributed wind technologies provide an avenue for Americans and people from across the globe to economically take part in the determination of the world's energy future. Until recently, most of the world's population was dependent on outside forces to provide energy services, primarily through large central-station power generation. Although individuals with adequate financial resources have been able to rely on personal energy sources, such as photovoltaic panels or small fossil-fueled generators, these personal energy sources have been out of reach for many. The dramatic reduction in the cost and availability of distributed wind technologies, combined with new policy incentives in many parts of the world, has started to change this dynamic. This report documents a substantial market for distributed wind applications and, although some technical and market-based barriers exist, none of them are insurmountable. The report also indicates that there is much to be understood about this market and that further analysis will be required in areas of specific interest. As the nation moves toward a posture of energy independence using more environmentally friendly energy technologies and away from large, central-station power generation and the large transmission lines that these will require, distributed wind applications—from residential wind turbines connected to our homes to large distributed wind and wind/diesel applications—can play a greater and significant role in our energy portfolio.

A7 - 2008 Solar Technologies Market Report (Summary)

Please see attached pages.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

2008 SOLAR TECHNOLOGIES MARKET REPORT

JANUARY 2010

Executive Summary

The focus of this report is the U.S. solar electricity market, including photovoltaic (PV) and concentrating solar power (CSP) technologies. The report is organized into five chapters. Chapter 1 provides an overview of global and U.S. installation trends. Chapter 2 presents production and shipment data, material and supply chain issues, and solar industry employment trends. Chapter 3 presents cost, price, and performance trends. Chapter 4 discusses policy and market drivers such as recently passed federal legislation, state and local policies, and developments in project financing. Chapter 5 provides data on private investment trends and near-term market forecasts.

Highlights of this report include:

- **The global PV industry has seen impressive growth rates in cell/module production during the past decade, with a 10-year compound annual growth rate (CAGR) of 46% and a 5-year CAGR of 56% through 2008.** Global production reached 6.9 GW in 2008, led primarily by manufacturers in Europe, China, and Japan. China has realized very high growth rates in recent years and was tied with Europe at 27% market share in 2008. The United States ranked fifth in 2008 at 6% market share or 0.41 GW of production.

- **Thin-film PV technologies have grown faster than crystalline silicon over the past 5 years, with a 10-year CAGR of 47% and a 5-year CAGR of 87% for thin-film shipments through 2008.** Global thin-film market share increased to 14% in 2008. The United States was the global leader in thin-film production in 2008, with its top two manufacturers both thin-film producers, First Solar (CdTe) and United Solar Ovonics or Uni-Solar (a-Si). First Solar was the second-largest global PV producer in 2008.

- **Global installed PV capacity increased by 6.0 GW in 2008, a 152% increase over 2.4 GW installed in 2007.** The 2008 addition brought global cumulative installed PV capacity to 13.9 GW. Leaders in 2008 capacity additions were Spain at 2.7 GW, Germany at 1.5 GW, and the United States and Italy both at 0.34 GW. Germany maintained its lead in cumulative installed capacity in 2008 with 5.3 GW, followed by Spain at 3.4 GW, Japan at 2.1 GW, and the United States at 1.1 GW. The grid-connected market accounted for 97% of 2008 capacity additions and 94% of cumulative installed capacity in 2008.

- **The United States installed 0.34 GW of PV capacity in 2008, a 63% increase over 0.21 GW in 2007.** The 2008 addition brought U.S. cumulative installed PV capacity to 1.1 GW. California continued to dominate the market with nearly 180 MW installed in 2008, bringing cumulative installations to 530 MW or 67% of the U.S. market. New Jersey followed with 23 MW installed in 2008, bringing cumulative capacity to 70 MW or 9% of the U.S. market.

- **Global average PV module prices dropped 23% from \$4.75/W in 1998 to \$3.65/W in 2008.** Module prices rose slightly from 2002 to 2007 caused by polysilicon supply constraints, but resumed their downward trend by decreasing from \$4.07/W in 2007 to \$3.65/W in 2008. Capacity-weighted, average PV installation costs in the United States decreased 31% from $10.8/W in 1998 to $7.5/W in 2008. The cost decline of $0.3/W from 2007 to 2008 corresponds to a $0.42/W decline in module prices over the same period, whereas installation cost reductions from 1998–2005 were largely attributable to non-module costs (prices are given in real 2008$).

- **Federal legislation, including the Emergency Economic Stabilization Act of 2008 (EESA, October 2008) and the American Recovery and Reinvestment Act (ARRA, February 2009), is providing unprecedented levels of support for the U.S. solar industry.** The EESA and ARRA provide extensions and enhancements to the federal investment tax credits (ITCs), including allowing utilities to claim the ITC, a new 30% manufacturing ITC for solar and other clean energy technologies, and an option that allows grants in lieu of tax credits for taxpaying corporate entities. The $787 billion ARRA package includes additional funds for the DOE Loan Guarantee program, DOE EERE programs, and other programs and initiatives. In addition to federal support, state and local policies, incentives, rules and regulations, as well as financing developments continue to encourage deployment of solar energy technologies.

- **In 2008, global private-sector investment in solar energy technology topped $16 billion, including almost $4 billion invested in the United States.** From 2004 to 2008, global private sector investment increased more than 25-fold. Each of three major sources of new investment, venture capital and private equity, debt, and public equity, grew at a CAGR of more than 67%. Global venture capital and private equity investment in solar grew at a 4-year CAGR of 68% from $539 million in 2004 to $4.34 billion in 2008. U.S. venture capital and private equity investment increased from $61 million in 2004 to $2.3 billion in 2008, corresponding to a 4-year CAGR of 148%.

- **Solar PV market forecasts made in early 2009 anticipate global PV production and demand to increase fourfold between 2008 and 2012, reaching roughly 20 GW of production and demand by 2012.** Europe is expected to remain the largest market for solar power, but the North American market is expected to grow the fastest. Module prices are projected to decrease 34% from 2008 to 2010, and system prices are projected to decrease 31% from 2008 to 2010.

- **Globally, about 13 GW of CSP was announced or proposed through 2015, based on forecasts made in mid-2009.** Regional market shares for the 13 GW are about 51% in the United States, 33% in Spain, 8% in the Middle East and North Africa, and 8% in Australasia, Europe, and South Africa. Of the 6.5-GW project pipeline in the United States, 4.3 GW have power purchase agreements (PPAs). The PPAs comprise 41% parabolic trough, 40% power tower, and 19% dish-engine systems.

Notes

- This report includes historical price information and forecasts of future prices. Past and future prices can be provided as "current/nominal" (actual prices paid in the year stated) or "real" (indexed to a reference year and adjusted for inflation). In some cases, the report states whether prices are current/nominal or real. However, some of the published analyses from which price information is derived do not report this distinction. In practice, prices are usually considered to be current/nominal for cases in which the distinction is not stated explicitly.

- In some tables and figures, the sum of numerical components is not equal to the total sum shown due to rounding. Also, note that calculations such as growth rates were computed before numbers were rounded and reported. Standard rounding conventions were used in the report.

- Solar water heating, space heating and cooling, and lighting technologies are not covered in this report. DOE supports these technologies through its Building Technologies Program.

A8 - Support Letters

Please see attached pages.

cool by design

2321 West 41st Street
Chicago, IL 60609

January 4, 2012

North Dakota Industrial Commission
State Capitol 14th Floor
600 E. Boulevard Ave. Dept. 405
Bismarck, ND 58505

To whom this may apply:

Having heard that Clean Republic is applying for a research grant, I wanted to share a few words about them.

At AllCell Technologies, we work in this same industry. From our experience with them, it is evident that the folks at Clean Republic stand out at identifying a particular need, researching a solution, and commercializing a real product to create jobs.

Their knowledge and technical experience enables them to excel at an often overlooked art form in the Light Electric Vehicle industry. Clean Republic understands how technological advances and continuous research can improve even the newest industries and products.

I'm sure if you extended this grant to help them build a superior Battery Management System, their partners and the industry would be better off for your support.

Sincerely,

Said Al-Hallaj

Said Al-Hallaj
CEO
AllCell Technologies, Inc.

James DeSeyn

Subject: FW: Letter

From: James DeSeyn [mailto:jdes@designercare.com]
Sent: Friday, December 30, 2011 2:59 PM
To: 'yong@innovators.net'
Subject: Letter

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol-14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

RE: Clean Republic Application: Innovative Lithium Battery Production for Renewable Energy Storage Systems

Dear Ms. Fine:

Our company, Solargy Lights, LLC, is involved with providing alternative outdoor lighting solutions for various industries. These include municipalities, construction sites, sports facilities, and RV/mobile home parks.

Our hybrid street lighting system requires battery storage capacity to store the energy created by the wind turbine and the solar panel.

The Innovative Lithium Battery for Renewable Energy Storage Systems would be a nice fit to use for our battery storage pack. Dr. Yong Hou, owner of Clean Republic, is developing a battery with superior lifetime and increased reliability. Clean Republic is also engineering the batteries for optimum efficiency in cold weather conditions.

This letter is written in support of Clean Republic, and Dr. Yong Hou's efforts in developing and manufacturing the Innovative Lithium Battery Production for Renewal Storage Systems. We would like to provide two sets of wind/solar hybrid systems for Clean Republic to test as a battery prototype pilot project. Solargy Lights is willing to commit up to $3,000.00 in good faith for the purchase of Innovative Lithium Batteries for our project.

I have personally worked on a pilot street light project with Dr. Yong Hou. I have found his engineering expertise to be very valuable, along with personal qualities of ethics and honesty in our business dealings. I would highly recommend his project moving forward. Please be free to contact me at (701) 886-7684 for any reference considerations.

Warm regards,

Jim DeSeyn

Jim DeSeyn
President
Solargy Lights
474 Main Avenue
Neche ND 58265

PH: (701) 886-7684
FX: (701) 886-7797
www.solargylights.com

Snobear USA
6109 53rd Ave S
Fargo, ND 58104

Thursday, August 23rd, 2012

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol-14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

RE: Clean Republic Application
Development of Innovative Modular Lithium Iron Phosphate Battery Packs for Energy Storage

Dear Ms. Fine:

Snobear USA is currently in the process of creating the world's first production hybrid snow tracked vehicle. Snobear is a producer of modern snow track vehicles for Ice fishing and commercial use.

Once this project becomes successful we will aid the replacement of all the tracked vehicles in Yellowstone National Park and Denali National Park. With the use of technology that Clean Republic works with and will develop for our collaborative project, a dramatic reduction in winter fuel consumption within these treasured national parks will occur. This will ultimately protect these natural parks while providing tourists able means to experience them in an eco-friendly vehicle.

If Clean Republic, LLC would receive this funding to continue their passion in Lithium Battery Production for Renewable Energy Storage Systems it would be very beneficial for our unique project. This type of research, I wholeheartedly believe, is the future of many vehicle systems.

We support Clean Republic, LLC in their Innovation and continued research and development. I would encourage the State of North Dakota to support this project not only because it benefits Snobear USA but also because it is an investment in the future. The future is in alternative energy which I believe is something the State should support by helping to create new industries to augment the oil "boom", giving diversity and longevity to our state's thriving economy.

Snobear USA has found the controlling partners Michael Shoppe and Dr. Yong Hou to be passionate, knowledgeable, and professional regarding their innovative products and that is why we have created an investment of time and energy in our research work with them, and support funding for Clean Republic's research. Please feel free to contact me regarding this project at 701-610-9631.

Regards,

Michael Rocks-Macqueen
NSF Project Manager – Snobear USA

elithion
electronics for lithium-ion
Elithion Inc Electronics for Li-Ion
Phone: 1-720-466-7006 . sales@Elithion.com
3393 Iris Ave Boulder CO 80301

Support letter to Clean Republic's Lithium battery grant application

To whom it may concern,

This is a support letter to the Lithium battery grant application for the “Development of Innovative Modular Lithium Iron Phosphate Battery Packs for Energy Storage” on the part of Clean Republic LLC.

As an expert in the Li-ion industry, the designer of one of the first Li-ion Battery Management systems, and the author of the book “Battery Management Systems for Large Lithium-Ion Battery Packs”, published by Artech House September30, 2010 , I have carefully read and considered the materials presented to me by Clean Republic LLC. related to this application.

Please allow me to state with this letter my support Clean Republic LLC's Lithium battery grant application.

Respectfully,
Davide Andrea
Elithion Inc.
August 23rd 2012

August 29, 2012

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

RE: Clean Republic Application: Development of Innovative Modular Lithium Iron Phosphate Battery Packs for Energy Storage

Dear Ms. Fine,

The development of wind and solar energy systems depends on generation technology, transmission, and *increasingly* energy storage technology to solve the intermittent nature of the electrical generation. The Clean Republic team has the know-how and ability to develop adaptive lithium battery packaging technologies to meet this opportunity. They will develop a workable solution to the storage problem with lithium batteries of improved quality, longer lifetime and additional reliability (thus lower costs) for wind and solar energy applications as well as other energy storage applications. Solar and wind energy systems were growing briskly with tax credits, and now good technologies are needed to keep the industry vital. Successful results would include an innovative lithium $LiFePO_4$ battery factory at Grand Forks as well as enhanced opportunities for wind and solar energy projects around North Dakota and the nation. Batteries with these characteristics offer the best storage flexibility and scalability to allow their users to decide when to sell their electricity to maximize profit.

We know the Clean Republic team (Dr. Hou & Mr. Shope) well as they have been clients of the Center for five years. They were winners in the statewide InnovateND venture competition in 2010 judged by angel investors. In 2011 Michael Shope was the SBA Young Entrepreneur of the Year for North Dakota and the six (6) states in SBA Region VIII which includes populous states like Utah and Colorado. Dr. Yong Hou is an experienced entrepreneur growing his first company into a wholesaler of Compaq Computers with annual revenue of $13 M. He has worked on lithium battery technologies for many years. This team has a strong history of innovating and venturing.

The UND Center for Innovation Foundation provides assistance to innovators, entrepreneurs, students, and researchers to launch new ventures, commercialize new technologies, and secure access to capital from private and public sources. The Center has helped launch more than 580 ventures that employ over 5600 people and raised over $140 M in capital. We support Dr. Hou Yong's proposal to NDIC. The technologies developed from this grant will promote innovation, entrepreneurship and economic development in North Dakota.

Respectfully yours,

Bruce Gjovig
CEO & Entrepreneur Coach
Bruce@Innovators.net
701-777-3134 O

Department of Technology
Starcher Hall, Room 135
10 Cornell Street Stop 7118
Grand Forks, ND 58202-7118
701-777-2249, Phone
701-777-4320, Fax

To: North Dakota Industrial Commission

From: Dave Yearwood, Associate Professor and Chair, Department of Technology

Re: Letter of Support

Date: August 29th 2012

I am writing in support of Dr. Alex Johnson's application for an NDIC grant. Alex is an Assistant Professor in the Department of Technology and has been a valued member of the department since 2007 where he teaches manufacturing related courses. Dr. Johnson is interested in wind energy and is teaming up with Dr. Yong Hou and Mike Shope to study the feasibility of developing an innovative packaging process and thermal management solutions to increase the performance, reliability, and service life of lithium battery packs for energy storage of renewable energy conversion systems. Experience with this technology will allow Alex to expand his knowledge of wind energy systems and a viable storage unit both of which will be an asset to students in the Technology Department.

I applaud Dr. Johnson's willingness to expand his practical education knowledge of wind and storage systems. The department supports Alex's initiatives and will make lab related equipment available to support the work identified above. I hope that you will give serious consideration to Dr. Johnson's application.

DEPARTMENT OF TECHNOLOGY
STARCHER HALL ROOM 135
10 CORNELL STREET STOP 7118
GRAND FORKS ND 58202-7118
(701) 777-2249
FAX (701) 777-4320

To: North Dakota Industrial Commission
From: Alex Johnson, Assistant Professor Department of Technology
Re: Letter of Support
Date: August 28th 2012

I am writing this letter to offer my support for the grant titled "Innovative Lithium Battery Production for Renewable energy Storage Systems". I have worked with both Dr. Yong Hou and Michael Shope extensively in the past with their company, Clean Republic and know them to be both innovative and highly capable businessman. In addition, I am well aware of Dr. Hou's electrical engineering background and extensive experience with his prior company in lithium battery production. I have no doubts as to their capabilities and believe they will be successful with their mission.

As a developer of Solargy Lights, a manufacture of solar wind hybrid street lighting solutions and also with my research in North Dakota with Dr. Hou I see a need for lithium batteries sized for small wind and solar applications. Lithium batteries offer numerous advantages over conventional lead acid batteries in these systems; as well as, many other applications. Our systems currently use 24 volt 200 amp hour lead acid batteries. Batteries in this size range on the market currently cost well over $2000, which, compared with the $200 cost of an equivalent lead acid battery is more than most consumers are willing to pay. Also, currently manufactured batteries in this size range suffer from reliability issues that greatly reduce consumer interest in these products. Consequently I am very impressed by the novel solution that Dr. Hou and Mr. Shope propose that would result in increased reliability, ease of service, and reduced manufacturing costs.

By Dr. Hou's invitation, I am happy to provide summertime consulting services to Clean Republic for 300 hours.

Please don't hesitate to contact me if you have any further questions.

Sincerely,

Alex Johnson, PhD
Assistant Professor
Department of Technology, UND
701-777-2240

NDSU

NORTH DAKOTA STATE UNIVERSITY

Department of Industrial and Manufacturing Engineering

NDSU Dept. 2485
202 Civil and Industrial Engineering Building
P.O. Box 6050
Fargo, ND 58108-6050

Tel: 701-231-7119
Fax: 701-231-7195

August 30, 2012

Re: Support for NDIC grant proposal by Dr. Yong Hou

To Whom It May Concern:

I am writing this letter to support the grant application titled "Development of Innovative Modular Lithium Iron Phosphate Battery Packs for Energy Storage", an effort led by Dr. Yong Hou of Clean Republic LLC.

Wind and solar energy has been growing at an unprecedented pace in the United States and other countries. North Dakota is estimated to have the largest wind energy potential among the lower 48 states of the United States. However, the production of wind and solar energy is intermittent by nature, which affects the continuous supply of power. To explore the full potential of these renewable energy forms, energy storage is widely regarded as a viable approach, in which battery storage has been gaining popularity. With key R&D efforts, the proposed project is aimed at enhancing lithium battery packaging technologies to improve reliability and service performance, and reduce cost. I am impressed by the proposed technologies and the well-thought plan. What's more, this project will ultimately help establish a LiFePo4 battery packaging line to deliver the battery products and help the economic development.

I am regarded as an established researcher in the areas of renewable energy and energy-efficient manufacturing. I have served on a number of professional leadership committees and technical journal editorial boards, and I have published many papers in these areas. By Clean Republic's invitation, I am committed to providing complimentary consulting service to the company for 300 hours in total for the two project years.

If you have any questions, please do not hesitate to contact me.

Sincerely,

Jing Shi, PhD
Associate Professor
Industrial & Manufacturing Engineering, NDSU
Tel: 1-701-231-7119
Email: jing.shi@ndsu.edu

smart elements energy

7650 55th St. NE
Penn, ND 58362

12/15/12

December 15th, 2012
Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol -14th Floor-
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

RE: Clean Republic Application:
Development of Innovative Modular Lithium Iron Phosphate battery Packs for Energy Storage

Dear Ms. Fine,

The Lithium Batteries exists in markets such as the bike kits, power tools, electric cars, and computers. As the price of lithium batteries fall more markets will increasingly accept these great batteries. Clean Republic's development of a modular Lithium battery can help ensure that North Dakota can capture part of this expanding market.

We have been working with the Clean Republic Team for several years. Currently, We are working with Clean Republic to provide Rapala USA with a drop in replacement to the lead acid batteries that are currently used in an electric ice auger system, with plans to expand to other products. The ice auger system places extreme demands on the battery due to the extreme cold it has to operate in and the high power demands of the system. Clean Republic has delivered a great product at a great price.

Clean Republic has many things needed to become successful including expertise in the area of business they wish to grow, existing relationships to business clients, North Dakota work ethic, and North Dakota values. After looking at Clean Republic and where they want to go we feel that they will put grant money to good use to build their business and help build North Dakota in the following years.

Best Regards,

Brandon A. Pulst

Brandon Pulst

Director of New Business Development
bpulst@smartelementsenergy.com
612-547-6278