"Snow & Ice Supported Wind Energy Powerplant (SISWEP) Prototype Test Project to Advance Technology Readiness"

Application to :
Alaska Emerging Energy Technology Fund Grant Program
AEA-12-047

Applicant :
RIC Enterprises Alaska Renewable Energy
Alaska Nonprofit Corporation # 133489
Proof of Eligibility & Certificate of Incorporation are included in Attachment 1
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Partners & Supporting Stakeholder Organizations :
Inupiat Community of the Arctic Slope - an Alaska IRA (Indian Reorganization Act) Regional Tribal Government
Ukpeagvik Inupiat Corporation, UMIAQ Barrow Science Support
North Slope Borough - Alaska's biggest Borough, larger in area than 39 states of the U.S.A.
Ilisagvik College - an Alaska Postsecondary Institution & First Federally Recognized Tribal College in Alaska
Partner & Stakeholder letters of support are included in Attachment 2

Costs :
Total Project Cost: $944,600
Grant Funds Requested: $738,000
Match Committed: $206,600
Signed match commitment is included in Attachment 8

Previous Applications: This is an updated revision of the application with the same title originally submitted to (superceded) RFA AEA-11-027

Proprietary Data subject to confidentiality requirements is not included; RIC Enterprises Intellectual Property material is included

Submission by Priority Mail, Mail Date March 2, 2012
Includes three hard copies plus two electronic copies of "SISWEP RIC Enterprises Project Proposal Abstract" and "SISWEP RIC Enterprises Project Proposal Attachments" mailed to: Alaska Energy Authority
AEA Emerging Energy Technology Grant Application AEA-12-047
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1. Project Summary

a. Project Description

The mission of this project is to perform research, development & demonstration (RD&D) on a new renewable energy harvesting system intended to harvest abundant wind energy in ice and snow covered locations in many regions of Alaska as well as Canada, Kalaallit Nunaat (Greenland), Scandinavia, Russia, Antarctica and other parts of the World. Snow and Ice Supported Wind Energy Powerplants (SISWEPs) are an innovative approach to vertical-axis wind turbine powerplants designed to cost-effectively serve residential, community, commercial, industrial and utility customer needs. Leveraging the proven technology of exemplary racing iceboats (Attachment 3, Fig. 1A) with a system of iceboat-like "windfoil modules" (Attachment 3, Fig. 1B) arranged in a closed circuit, SISWEPs can reduce fossil fuel use and mitigate global warming.

Windfoils are upwardly-projecting wings using airfoils with chord-extending flaps rather than sails, to enable higher aerodynamic lift coefficients and higher levels of wind energy harvest. Angles of attack of each windfoil will be dynamically controlled using a windfoil control rudder commanded by a control computer to optimize power harvest as the windfoil modules revolve around a closed circuit. For deployment on ice-covered surfaces such as the more than 5,000 small lakes in the North Slope Borough of Alaska, the SISWEP skate runners are mounted under pontoons. This will yield maximum power harvest in a runner-supported low-drag mode in winter while yielding moderate power in a pontoon-supported mode in the summer when power demands are lower. The closed circuit ring of windfoils will revolve at an angular velocity (RPM) targeted to optimize power extraction from the wind while avoiding reverse flow issues on the windfoils. The nominal windfoil module circumferential velocity is set at 88% of the wind speed, with a skating speed of 22 mph when the wind is blowing at 25 mph. The circular geometry ensures optimized power harvest regardless of wind direction at any given time. Plan views of a large-scale production SISWEP system and a base-scale prototype SISEWEP system are shown in Attachment 3, Fig. 2A and Fig. 2B respectively. Attachment 4, Table 1 presents summary information on key sizing parameters of the 60 kW base-scale prototype SISWEP system as compared with the 1500 kW large-scale production SISWEP system. The base-scale is approximately 35% linear scale compared to large-scale, and the prototype has a quarter the number of windfoil modules.

The base-scale prototype is a fully integrated and functional SISWEP system and will be assembled in situ and demonstrated in a very realistic, harsh climate operational environment at the Barrow Environmental Observatory (BEO) research preserve in Alaska. The key objectives of the project are to demonstrate technical and operational feasibility; to advance all facets of SISWEP design, engineering, construction & operation to technology readiness level TRL7 by the end of project testing in 2013; and to systematically identify risk mitigations along with technology & business roadmaps needed to get to TRL9 and commercial implementation of production SISWEP systems in Alaska by 2016.

b. Project Eligibility

Consistent with 3 AAC 107.715; AS 42.45.375(c)(1) and RFA AEA-12-047(sec4.2), this project meets eligibility criteria by providing a test and demonstration project for SISWEP systems, an emerging wind energy technology that can promote, enhance and expand the diversity of cost-effective available energy supply sources in Alaska, while reducing negative energy-related environmental effects such as carbon dioxide emissions. The project will advance Technology Readiness Level to TRL 7 and supports commercialization of this new class of wind power in Alaska by 2016.

c. Project Innovation

Intellectual Property (IP) for the Snow and Ice Supported Wind Energy Powerplant (SISWEP) Systems is contained in the foundational United States Patent 7,714,457 for a "Wind Energy Harvesting System on a Frozen Surface," titled to RIC Enterprises. Canadian IP is patent-pending. SISWEP systems represent a paradigm shifting innovation in renewable energy harvesting systems tailored for cold region applications and are ideally suited to many locations in Alaska. SISWEP system design is built upon sound scientific and engineering foundations established (i) by racing iceboats that very efficiently capture wind energy; (ii) by vertical axis wind turbines; (iii) by aerodynamic wing design using computational fluid dynamics (CFD); and (iv) by automatic rudder control systems. Unlike conventional horizontal axis wind turbine systems, SISWEP systems can be simply and inexpensively anchored in the ice surface of frozen lakes, and require no tall towers and associated deep foundation systems that can damage delicate environments in Arctic lakes and tundra. Target Alaska installed cost of future large-scale production 1.5 megawatt SISWEP systems is $3M which is $2M per megawatt, as compared to around $4.75M per megawatt in the recently commissioned 4.5 megawatt Pillar Mountain Wind Project in Kodiak, Alaska. With successful technology advancement to higher TRLs, production SISWEPs ranging from 240 kW base-scale production systems (using 24 prototype-proven base-scale windfoils in a ring geometry) to 1.5 MW large-scale production systems are expected to provide

lighter, cheaper, and more easily maintainable wind energy systems particularly suited for application in challenging remote Alaskan and Arctic environments such as frozen lakes and lagoons, glaciers, icefields, tundra snowfields and sea ice.

d. Priority

Consistent with AS 42.45.375(d) and RFA AEA-12-047(sec4.3), this project will advance Technology Readiness Level to TRL 7 using a combination of grant funding and matching funds, and enable accelerated low-risk commercialization of this new class of wind power in Alaska within 5 years. The Applicant is an Alaska organization (Alaska nonprofit corporation 133489), with support and participation by several Alaska entities and partnership with an Alaska postsecondary institution, Ilisagvik College. The project has potential for widespread deployment and public benefit in the state of Alaska, as will be described in detail in the Section 5. The SISWEP research, development and demonstration (RD&D) project will provide scientific and practical training on renewable energy systems to students at the Ilisagvik College, who will actively participate in the project. The project aims to provide public benefits from 2016 that align well (i) with the mission of the Alaska Energy Authority's Emerging Energy Technology Grant Program to develop emerging energy technology that has the potential of widespread deployment in Alaska and of reducing energy costs for Alaskans; and (ii) with the mission of the Denali Commission to provide critical utilities, infrastructure and economic support to distressed rural communities in Alaska.

A public benefit of pond, lake & offshore installations of SISWEPs is that they will minimize land use and damage to fragile tundra and water areas, as compared with more conventional wind energy systems. Lower windfoil blade speeds will also offer benefits in reduced noise and greatly reduced hazards to flying birds or bats. Widespread deployment of SISWEP Systems could enable Alaska to achieve aggressive renewable energy power targets and increase employment in the green energy sector of the economy. At a national and global level, the SISWEP Systems can contribute significantly to meeting CO_2 emission reduction goals while mitigating climate change and the adverse consequences of global warming such as sea level rise, polar region ice melt and decimation of the polar bear population. Worldwide markets are summarized in Attachment 4, Table 2, and a map showing high potential locations in Alaska is included in Attachment 5A. With widespread commercialization, private, community and commercial consumers of electric power should be able to benefit from reduced cost per kilowatt-hour for electricity from environmentally friendly SISWEP systems and reduced concerns with regard to price volatility and diminishing availability of many fossil fuels. SISWEPs can also help provide a national benefit to the United States of America in reducing our dependence on politically and economically volatile foreign oil sources.

2. Technology Validation and Research Methodology

a. Objectives

The current state of the art for SISWEP Systems is judged to be at Technology Readiness Level (TRL) 5 to 6. Full-scale high-performance iceboats such as the "Greenbird" (Attachment 3, Fig. 1A) are fully operational and thus by definition at TRL 9. Thus the technology risk of the windfoil and runner elements of each windfoil module of a SISWEP system are judged to be low. However, while SISWEP systems utilize several constituent technologies that have been proven in other applications to TRL 8 or 9, these technologies have not been applied to, tailored for, or proven on SISWEP systems. These constituent technologies include structural, mechanical, electrical and rudder control subsystems that exist in other applications, but that still will require a significant amount of engineering, custom fabrication and RD&D work to integrate into a robust functional SISWEP system designed to meet multiple objectives. Thus, based on this combination of different readiness levels, the overall SISWEP system technology readiness level is judged to be realistically at TRL 5 - 6, even though many subsystems when considered as separate systems for other application areas, are at TRL 8 or 9.

The key objective of this Research, Development and Demonstration (RD&D) project is to advance the state of the art of integrated SISWEP Systems from TRL 5 - 6 up to TRL 7. Supporting objectives include demonstrating structural, mechanical and electrical subsystems as well as demonstrating technologies (i) to effectively couple a series of many modules revolving around a circular loop; (ii) to individually control the plural windfoils to optimize aerodynamic and system performance including airfoil interaction effects; (iii) to engineer an optimal anchoring system that anchors the SISWEP in an ice / snow / water covered surface; and (iv) to optimally transfer power from the revolving array of windfoil modules into a rotating hub and thence to an electrical generator. Roadmaps and a product development plan will also be formulated to advance SISWEP technology to TRL 9 and to enable fully operational production systems to enter commercial service by 2016, with low risk.

b. Methodology

Methodology for technology validation; for TRL advancement; and for Research, Development & Demonstration (RD&D) of the SISWEP System includes the following elements:

- Technical, Operational and Test Requirements & Objectives (R&O) development
- Engineering studies including subsystem trade studies, engineering design & integration of the base-scale prototype SISWEP; and comparisons with base-scale & large-scale production SISWEP system designs
- Application of subsystem detailed engineering and design-to-cost methods for (i) the windfoil subsystem including design optimization using computational fluid dynamics (CFD) methods and loads and structural sizing methods; (ii) the control subsystem including windfoil rudder control algorithms and actuator selection and installation design; (iii) the windfoil support and bearing subsystem including the mast and swivel bearing system; (iv) the runner subsystem including the catamaran PontoonRunners and the connected SkateRunners; (v) the hub and spoke subsystem that transfers torque from the wind-driven windfoil modules to an electrical generator subsystem; (vi) the electrical generator subsystem; (vii) the electrical power transmission, measurement & management subsystem; (viii) the low-cost anchoring system that effectively anchors the SISWEP on the ice / snow / water covered surface; (ix) the sensor, instrumentation and measurement subsystem and (x) the test control and management subsystem
- Methods for manufacture, analysis, proof testing and evaluation of subsystems and subassemblies
- Sequenced methods for prototype module integration checks, transport of modules to test site, assembly in situ, and test
- Setup of instrumentation and sensors including wind speed and direction sensors and instrumentation on the functional prototype SISWEP system, and connection with computer means for control, diagnosis and data acquisition
- Data analysis methods with comparison of data & results with pre-test predictions and analysis of differences
- Development of project conclusions on technical and operational feasibility, along with systematic assessment on achievement of TRL7 for all facets of SISWEP design, engineering, construction & operation
- Systems engineering methodology to capture & categorize all technical and operational problems encountered in the prototype test campaign in the Barrow operational environment, and to synthesize solutions to these problems
- Roadmapping methods for synthesis of technology & business roadmaps to get to TRL9 including a sequence of critical elements needed to enable financially viable development and commercialization with low technical risk
- Synthesis of a product development plan for commercial implementation of production SISWEP systems in Alaska by 2016- including engineering, procurement, manufacturing, shipping, assembly, operational, financial, business / contractual, legal / regulatory, political, community service and environmental benefit considerations.

Subassembly fabrication will occur at RIC Enterprises managed fabrication sites and contractor fabrication sites. To control costs, subassemblies will be shipped by barge from Seattle to Barrow, and SISWEP system final assembly will take place in situ at the planned test site in the Barrow Environmental Observatory (BEO) research preserve. The specific planned test site is Cake Eater Lake, a shallow thaw lake frozen in the winter and exposed to high winds from the surrounding tundra and from the nearby Arctic Ocean to the North (see Attachment 5B). The site's strong coastal winds are representative of target markets along the coastal regions of the North Slope Borough. The site has road and power access for researchers from RIC Enterprises, UMIAQ and student support from the Ilisagvik College, as well as for any needed additional technical support personnel based in Barrow. Site control at the BEO will be provided by UMIAQ Barrow Science Support; and preliminary contact has also been made with the permitting office of the North Slope Borough. Project performance will be monitored, reported, documented and analyzed by Barrow and Seattle area personnel as outlined in the milestones in Section 3.

3. Summary of Project Schedule and Summary of Project Budget

The project schedule is shown in Attachments 6A, 6B and 6C for the pre-deployment; deployment & research; and post-deployment phases of the project. A summary of project budget is as follows:

Total Project Cost: $944,600.
Match Committed: $206,600.
Grant Funds Requested: $738,000.

The $206,600 committed project match amounts to 22.% of the estimated total project cost. The committed project match includes cash contributions from RIC Enterprises, reduced labor rates, partially unreimbursed travel expenses, partially unreimbursed general and administrative (G&A) expenses, partially unreimbursed overhead expenses, and partially unreimbursed teaching & training of Ilisagvik College students supporting the project. See Attachments 6A, 6B and 6C for EETF Budget Worksheets with milestone dates and cost estimates for the Pre-Deployment, Deployment & Research, and Post-Deployment phases of the project.

4. Project Team Qualifications

The RIC Enterprises Alaska Renewable Energy RD&D team comprises people with breadth and depth of knowledge and experience, combined with a passionate common interest in contributing to visionary progress in renewable energy systems. The RIC Enterprises direct team collectively has 180 years of professional experience, 7 postgraduate degrees, and an exceptional track record of innovation with over 60 issued patents. A strong and applicable diversity of knowledge and experience encompasses science, engineering, aerodynamics & hydrodynamics, structures, systems, manufacturing, design-to-cost, business & economics, product development, project management and prototyping. Over half of the core team members are seasoned veterans of the Boeing Company, with a distinguished history of innovation and product & technology R&D through all gated development phases from concept exploration to invention incorporation in production airplanes. Biographies of RIC Enterprises direct team member are included in Attachment 7.

RIC Enterprises has past successful experience in building and testing prototypes of renewable energy inventions, including a solar energy project that was supported by the US Department of Energy with some cost-share, and another concentrating photovoltaic solar prototype that was fully self-funded. RIC Enterprises has a credible record of technically sound, financially responsible and schedule-compliant management of prototype research, development and demonstration (RD&D) work. RIC Enterprises is also engaging in a shared equity business relationship with a for-profit Australian corporation aimed at TRL advancement, further development and commercialization of a concentrating solar power heliostat system for which RIC Enterprises holds exclusive Intellectual Property rights.

In addition to the RIC Enterprises core team, collaborative project support will be provided by several Alaska partner organizations. For this prototype project contacts have already been made with key Barrow area stakeholders, including a public presentation to the Barrow community and coordination of support from several partner and stakeholder entities including the Ukpeagvik Inupiat Corporation, the Ilisagvik College, the Inupiat Community of the Arctic Slope, and the North Slope Borough (see Attachment 2 for letters of support).

5. Discussion of Commercialization of Funded Technology

Following completion of this project to advance TRL of SISWEP systems to TRL 7, the next low-risk step towards commercialization is the development and operational deployment of initial production base-scale 240 kW SISWEP system that uses 24 windfoil modules identical in size to the 6 base-scale windfoil modules of the prototype, with any lessons learned incorporated. A combination of funding sources including one or more of (i) customer community / utility funding, (ii) additional grant funding, (iii) tribal entity financing, (iv) lending institution financing, and (v) venture capital funding, can be used to successfully finance this low-risk step. The initial production units would be followed by continued in-service tests and certification leading to series production of base-scale SISWEP systems. At this time we know of no known technical or economic reason why this could not be scaled-up within a year and a half to large-scale 1.5 megawatt production SISWEP systems. Preliminary survey of markets indicates that complementary markets exist for both base-scale 240 kW SISWEP systems and large-scale 1.5 MW SISWEP systems in a many cold weather locations as summarized in Attachment 4, Table 2. SISWEP systems, once proven, should provide a very attractive renewable energy option to serve in widespread markets in the many Alaska and Worldwide locations as outlined above, where conventional large horizontal axis wind turbines could be either infeasible or very expensive, hard to maintain and potentially damaging to fragile tundra and Arctic environments.

A successful RD&D project will enable near-term commercial applications by 2016 providing cost-effective renewable energy to remote community locations in many parts of Alaska. In the mid-term by 2019, there is enough wind potential in the coast region lakes and lagoons in the 94,763 square mile North Slope Borough to harvest 1500 megawatts or more of "green" wind energy to meet up to half of Alaska's total power needs, which could be transmitted through power lines along the Dalton Highway corridor and replace dwindling North Slope oil as an economic engine creating Alaskan jobs and revenue. This could also enable a potential three billion dollar, 1500 MW North Slope Borough SISWEP Wind Farm System to win honors as the largest wind farm in America and the World, succeeding the 781 MW Roscoe Wind Farm in Texas. In a long-term scenario, by 2030 the scope of global SISWEP systems for local, regional and utility applications could reach over 100 gigawatts of renewable power or around 0.5 % of global power needs, with monetized value potential of 200 billion dollars, even without including indirect dollarized credits for job creation and climate change mitigation.

6. Signed Applicant Certification

The signed applicant certification is provided in Attachment 8.