Project Name: Demonstration of Low Cost Airborne Wind Turbine for Remote Villages

Project Applicant:
Adam Rein, Chief Financial Officer
Altaeros Energies, Inc.
337 Summer St., Floor 0
Boston, MA 02210
adam.rein@altaerosenergies.com

Partners: Matt Metcalf, Consultant/Project Manager, Hawk Consultants LLC, Anchorage, AK
Tom Lovas, former CEO, Four Dam Pool Power Agency, Anchorage, AK
Altaeros Energies, Inc.

Total Project Cost: $1.36 million
Grant Funds Requested: $740,000
Match Committed: $620,000

Previous Projects: None

1. Project Summary

Conventional tower-mounted wind turbines have two main challenges in Alaska: Most communities lack strong enough ground winds to make projects economical; and installations are too expensive, requiring a crane and deep foundation into the permafrost.

This project will demonstrate the breakthrough Altaeros Airborne Wind Turbine (AWT) to support local infrastructure and reduce the burden of high fuel costs in rural communities. The goal is to identify the economic and technical feasibility and sustainability to develop future projects in similar communities.

The AWT uses a helium-filled inflatable shell to lift a lightweight turbine 500 to 2,000 feet high, where winds are on average five times stronger than those reached by a tower. A conductive cable attached to a trailer holds the AWT steady and sends power to the ground. The lifting technology is adapted from aerostats—tethered blimps used for decades to reliably lift up telecom and surveillance equipment for months at a time in arctic conditions. The AWT operates under existing FAA regulation and requires minimal maintenance.

Figure 1: AWT Product Model and 35-foot Prototype tested in northern Maine

Project Description - This project will fund three phases. The first is the final development and fabrication of a 30kW AWT prototype, and selection of a test site. In discussions with Alaska Village Electric Cooperatrive, initial sites to be evaluated include Shishmaref, Old Harbor (off of Kodiak Island), and Eek. Other sites that have been identified as having suitable distance from an airport are King Cove, Pitka's Point, Women's Bay, Anchor Point, Knik, Nikolaevsk, Kenny Lake, and Glennallen. The second phase will be the transport and assembly of the prototype of the AWT to a site in Alaska to validate low cost, rapid setup capability. The third phase will entail the commissioning and operation of the AWT over two years to collect test data. The goal is to validate improved capacity factor and power production, minimal maintenance, and reliable operations in arctic weather conditions. Over $100 million has been invested over the past five years in efforts to harness vast untapped high altitude winds. This proposal is for the first permanent demonstration project of a tethered wind turbine in the world.

Eligibility – This project qualifies as a demonstration project by offering a novel approach to harnessing high altitude winds with lower setup cost and reduced impact. Early research on the AWT was funded by the U.S. Department of Agriculture SBIR program, the California Energy Commission, and the 2011 ConocoPhillips Energy Award. Through this research, Altaeros has brought the technology to TRL-5 with the testing of a 35-foot long proof-of-concept prototype at the former Loring Air Force Base in northern, Maine in Jan – Feb 2012. This prototype demonstrated autonomous operations by lifting Southwest SkyStream turbine to over 300 feet altitude and producing power both at high altitude and docked on the ground. The next step is to scale up to a near-product scale prototype for extended deployment and superior power production to reach TRL 6/7.

Project Innovation – The commercial AWT will have a capacity of roughly 100 kW and will offer three main benefits compared to the Northwind 100, the leading comparable wind turbine deployed in Alaska today:

- *Increase energy production (capacity factor) by 2-3x.* Wind power density increases with the cubic factor of the wind speed, so a 2x wind speed increase leads to a roughly 8x increase in wind power. The core advantage of the AWT is that it lifts 50 to 200 stories high (500 to 2,000 feet) where winds are on average five times stronger and more consistent than those reached by the Northwind 100 tower. The AWT will be able to achieve 60-75% capacity factor at a typical site, generating 2-3x more revenue than the Northwind 100 (which has an average net capacity factor of 26% according to the latest NREL study). The AWT will allow customers to site turbines closer to existing transmission lines while still harnessing strong winds, and use the greater consistency of high altitude winds to reduce the need for backup power to deal with intermittency.

- *Decrease installed capital cost by over 40%.* According to NREL and AVEC, a typical Northwind 100 installation costs roughly $1.2 million. About 60-70% of this cost is the installation, which requires driving large pylons 40 feet underground through the permafrost and the rental and transport of a large crane. The AWT solves this problem by deploying from a single shipping container in less than 12 hours by inflating with helium to lift up without the need for a crane. The AWT is attached to a portable trailer that has virtually no underground attachment, ideal in permafrost conditions. The AWT overall sales price is estimated to be less than $700,000, offering huge savings over the Northwind 100.

Figure 2: Rapid Inflation and setup of an aerostat

- *Reduce impact.* The AWT reduces any noise or environmental impacts by operating at high altitudes where less noise reaches the ground and there is minimal avian activity. No special roads need to be built for crane access, and there is no underground foundation.

Priority

- This project team consists of Alaska organizations. Altaeros Energies was founded out of MIT in 2010, and is currently expanding operations to Alaska given the importance of the wind-diesel market. The other project partners include an Alaskan consultant, an Alaskan business, and an Alaskan electricity cooperative.
- This project also takes advantage of significant matching funds. Altaeros will be able to provide significant matching of in-kind components and labor for use in the prototype.
- This project will demonstrate widespread potential in Alaska. Alaska has roughly 175 villages far from major electrical sources, which typically use diesel generators of 150 to 300kW. Dozens of communities are not suited to tower-mounted Northwind 100 due to resistance for a 20-year project or unfavorable wind resources. The AWT will open up new village and other wind turbine project opportunities across the state.

2. Technology Validation and Research Methodology

Project Objectives

a) Perform wind assessment through to determine wind resources at up to three potential demonstration sites.
b) Initiate and complete airspace, environmental, and community permitting process.
c) Identify power off-take method and design electrical hookup to boiler, battery, or electric grid.
d) Complete project design and licensing.
e) Procure AWT equipment, balance of plant system and assemble for deployment.
f) Transport equipment to test site and install on site including electrical hookup and commissioning.
g) Operate wind turbine, monitor power output, reliability, avian impact, and maintenance needs.
h) Iterate automated controls to improve performance and reliability.
i) Complete final report.

Methodology: Project performance through the permitting, design and construction phases will be monitored and recorded in quarterly written reports. Once the AWT system is commissioned, the system performance data will be measured and recorded using an onboard sensor suite which includes wind speed and direction sensors, GPS, an inertial measurement unit and accelerometer package, turbine RPM sensor, and turbine voltage, power and

frequency measurements. Key control and performance data will be relayed from the selected test site to a central control station in Anchorage. Power output and system status records will be used to assess performance and reliability, and will form the basis of on-site maintenance scheduling. On-site observation will be used to assess impact on avian activity. Altaeros has signed a contract with TUV Sud, a top wind turbine certification firm, to conduct third party verification of Altaeros demonstration project results.

3. Summary of Project Budget

Milestone	**EETF Funds ($K)**	**Matching Funds ($K)**	**Source Matching**	**Total**
Site selection, community partnership	25	-	Altaeros	25
AWT prototype component purchase / in-kind	130	160	Altaeros	290
AWT assembly labor	-	105	Altaeros	105
Regulatory approval / Permitting	75	-	-	75
Transport prototype and team to site	40	-	-	40
Prototype assembly and commissioning	75	85	Altaeros	160
Electrical hookup / additional transmission	105	-	-	105
Test equipment	15	-	-	15
24 month operations – monitoring	100	60	Altaeros	160
Planned maintenance	110	-	-	110
Unplanned maintenance	-	100	-	100
Data collection and evaluation	40	20	Altaeros	60
Decommissioning	25	-	-	25
Project management and overhead	-	90	Altaeros	90
TOTAL	**$740**	**$620**	**-**	**$1,360**

Summary of Project Schedule

Phase I: 9/1/2012 – 8/31/2013 – Pre-Deployment Activities: Project site identified. All land use, airspace and environmental permitting completed. Prototype components designed, fabricated, assembled and pre-tested. Matching funds procured. Research and O&M plan finalized.

Phase II: 9/1/2013 – 11/31/2013 – Deployment: Technology R&D plan finalized and validated. Altaeros AWT installed at test site. Initial performance assessed. Hookup to electrical load. Commissioning to reach peak performance. Training of local maintenance staff member. Project ongoing monitoring communications validated.

Phase III: 12/1/2013 – 11/30/2015 – Post-Deployment: Ongoing testing of power performance. Testing to reduce maintenance requirement. Evaluation of wear and tear. Monitoring, reporting, and decommissioning. Development of commercialization and financing plan. Permits updated. Final performance reports.

4. Project Team Qualifications

a) Ben Glass, Chief Executive and Technical Officer, Altaeros Energies. Inventor, Altaeros Airborne Wind Turbine, with four patents filed. Research conducted at MIT on wind turbines, solar cars, and at the MIT Gas Turbine laboratory. S.M., Massachusetts Institute of Technology Aeronautical/Astronautical Engineering.

b) Tom Lovas, Independent Consultant. Contractor to National Rural Electric Cooperative Association. Former CEO, The Four Dam Pool Power Agency, AK. Manager, System Development & Corporate Planning, Chugach Electric Association, Anchorage, AK.

c) Dr. Chris Vermillion, Chief Controls Engineer, Altaeros Energies. Controls Researcher, model-based powertrain design, Toyota Technical Center. Ten publications in leading Controls journals. Two controls patents. Ph.D. & M.S., Electrical Engineering-Systems and B.S.E., University of Michigan.

d) Matt Metcalf, Project Manager, Alaska Village Electricity Coop. Four years developing and implementing renewable energy projects in Alaskan villages and other sites.

e) Adam Rein, Chief Financial Officer, Altaeros Energies. Senior Associate Consultant, Bain & Company. Business lead for two early-stage energy companies. MBA/MPA, MIT Sloan and Harvard Kennedy School.

An additional project partner to help manage electrical hookup and maintenance is being confirmed.

Altaeros Energies was formed in 2010 by alumni of MIT and Harvard University. The Altaeros Board of Advisors includes an MIT Professor and former Secretary of the U.S. Air Force, the former CEO of wind turbine manufacturer Clipper Windpower, an environmental and airspace lawyer, and a Director of NRG Energy.

5. Discussion of Commercialization of Funded Technology

Altaeros will fill a key gap in the wind market by offering a mid-sized (100kW-900kW) turbine with 2-3x higher energy production and up to 90% lower setup cost than competing tower-mounted turbines. According to the DOE, "There is a substantial market for midsize wind turbines…an estimated 220 GW of market potential for technologically improved midsize turbines." The largest market barrier to reaching this potential is the lack of economically-viable turbines available.

Altaeros will bring its first 100kW AWT to market targeting remote off-grid sites in 2014-2015. This will be followed by a larger AWT launched targeting farms, industrial sites, rural communities, and military bases. Long-term, Altaeros will scale up its product to deploy in deep water offshore wind farms. The DOE has identified many industries that have a strong demand for a better mid-sized wind turbine: foundries, metal smelting, meatpacking, food processing, feedlots, and center-pivot irrigation. Oil & gas, mining, and agricultural companies that use off-grid diesel generators face energy costs up to five times higher than grid power. The Altaeros AWT is designed to hook onto existing diesel generators, using an automated control system to provide diesel power whenever the wind is not blowing. In addition, the Department of Defense offers an attractive market segment, spending roughly $3.5 billion annually for base electricity and diesel generator fuel.

The FAA recently announced that Airborne Wind Energy Systems can be sited under the same regulation (Part §77) as tower-mounted wind turbines up to 500 feet high. The FAA also allows aerostats to operate up to 2,000 feet altitude deployment in low-population areas more than three miles from an airport, with emergency deflation safety features and night time lighting. Since AWTs are permanently moored, they pose a similar aviation risk as a radio tower, which are routinely sited at high heights. Altaeros has already received a one-year FAA exemption for the testing of its early prototype in Maine. Aerostats are extremely robust, with 10-15 year lifespans, lightning-resistant tethers, and survival in up to 100mph winds and in arctic conditions.

Figure 3: Low visibility of aerostat

Altaeros has filed four U.S. patents and one international patent on the AWT technology to date. Altaeros has received letters of interest or support from a number of key partners:

- Jon Cristiani, Renewable Energy Team Leader, U.S. Army CERDEC
- Leon Steinberg, CEO, National Wind, a U.S. community wind developer
- MA Senator John Kerry
- Matt Nordan, Vice President, Venrock, a venture capital firm

6. Signed Applicant Certification

"By signature on this application, I certify that we are complying and will comply with the amount of matching funds being offered."

Adam Rein, Chief Financial Officer, Altaeros Energies 3/7/12