PROJECT RELIABLE INFRASTRUCTURE for SECURE ELECTRICITY (RISE) in Alaska

Making Electricity Storage a Reality in Alaska's Micro Grids

Total Project Cost: $1,533,628
Grant Funds requested: $749,207
Match Committed: $784,411

Proposal Submitted by

University of Alaska Fairbanks and Ambri Inc.

in response to

Alaska Energy Authority
Emerging Technology Fund
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Previous project/application title(s) and/or number(s) for grants from the REF, EETF, or DCEETG programs: None

Project Description

Reliable, *flexible* and *economical* electricity storage is key to the operation of advanced hybrid-diesel microgrids as commonly found in remote Alaska. Currently, the benefits of high contributions of variable renewable energy resources cannot be fully realized in these grids due to technical challenges with direct integration of diesel generation and the lack of clear strategies for diesel-off operation. The Alaska Center for Energy and Power (ACEP) at the University of Alaska Fairbanks (UAF) and Ambri Inc. are proposing *Project RISE in Alaska* (**R**eliable **I**nfrastructure for **S**ecure **E**lectricity), the enhancement, test and demonstration of a novel electricity storage technology to overcome current road blocks to high contribution renewable and full contribution renewable (diesel-off) operation of these microgrids.

Ambri, with technological origins at the Massachusetts Institute of Technology (MIT), has developed a liquid metal battery (LMB) which has the distinct potential to become a game changer in the electricity storage field. LMB technology is based on electrometallurgical processes as found and well understood in large industrial applications such as aluminum smelters. Research on campus was funded in part by the DOE's ARPA-E program. Ambri was founded in 2010 and is rapidly moving the LMB technology from the current **TRL 4**, with subsystems operating at Ambri's Cambridge, MA, facilities, to **TRL 6**, the desired TRL for AEA EETF projects. Ambri has mapped the projected TRL route through strategic collaborations with the Joint Base Cape Cod (a joint-use military base in Massachusetts home to the Air Force, Air National Guard, Army and Coast Guard) and other partners, and investments from Khosla Ventures, Bill Gates and the energy company Total. The company raised a Series B in May 2012 of $15 million.

Project RISE in Alaska will see an Ambri CORE™ deployed to ACEP's Power Systems Integration (PSI) Lab. At the PSI Lab, the 6.25 kW/25 kWh CORE will be integrated with a 3-phase, 480 VAC power converter to match the needs of remote Alaskan powerhouses. The CORE will undergo rigorous testing in general operation, versatility of electricity storage application from regulation services, and load following and peak shifting within the fully operational wind-diesel microgrid of the PSI lab. In the second stage of the project, a partner utility with a high contribution hybrid-diesel microgrid will be selected (e.g., TDX's Sand Point system) for the demonstration of a 25 kW / 100 kWh system (4 CORE systems combined to Ambri Energy Pod™ [AEP]). In this stage, further rigorous monitoring will reveal the viability of the AEP as a solution to high contribution renewable energy hybrid-diesel microgrids.

Project Innovation

Currently, electricity storage systems are rarely cost competitive when compared with a lowly loaded diesel generator to back-up variable renewable energy sources. The Ambri LMB has the potential to beat these economics once fully commercialized. Furthermore, in conjunction with a suitable, grid-forming inverter and an advanced control system, this electricity storage technology has the potential to provide electricity storage for diesel-off operation of hybrid-diesel microgrids reliably and economically competitive with current approaches. Since the Ambri LMB is a simple technology based on earth-abundant materials, the component and manufacturing cost for the system is very low. The modular nature of the Ambri AEP allows solutions tailored in size for the various power levels encountered in remote power systems. Megawatt-scale modules will be of interest in mitigating renewable energy integration issues on the rail-belt grid.

Project Site and Demonstration Environment

Phase 1 will be conducted at ACEP and Ambri facilities. ACEP manages and operates the Power Systems Integration (PSI) Lab at the UAF campus. The PSI Lab is a full scale hybrid-diesel microgrid that can operate at power levels as high as 500 kW, with diesel generators and a wind turbine simulator. The PSI lab is equipped with state-of-the-art control and data acquisition equipment well suited for the proposed Phase 1. **Phase 2** will seek an interested utility operating a hybrid-diesel microgrid in a remote community of Alaska. Conversations with the Alaska Village Electric Cooperative (AVEC) and TDX revealed great interest in viable electricity storage solutions to enable operation of wind farms at higher capacity factors. Selection of a power system for field demonstration will be based on data analysis from several systems to determine electricity storage needs. UAF researchers are quite familiar with the mechanisms

and processes to our collaborators to ensure site access during research projects (e.g., land and facility use agreements).

PHASE 1	PHASE 2
2014	**2015-2016**
Ambri CORE Deployment & Testing at University of Alaska Fairbanks Power Systems Integration Lab	**Ambri AEP Field Deployment with Alaskan Utility**
Winter: Ambri CORE design project complete; first Ambri CORE operational at Ambri facility **Spring:** Ambri builds and tests a 6.25 kW / 25 kWh CORE prototype system for New York site **Summer** : Ambri CORE installed in at the UAF **Fall**: Ambri Energy Pod design complete for Alaska deployment	**Winter 2015:** Go/no-go milestone; performance analysis of Ambri CORE at UAF **Spring 2015**: Ambri Energy Pod tested and validated at Ambri manufacturing facility for Alaskan site **Summer 2015**: Ambri delivers 25 kW / 100 kWh system to Alaskan site **Fall 2015**: Ambri Pilot manufacturing facility commissioned **2016**: Continued testing and use of Ambri AEP by Alaskan utility

Figure 1: Timeline for Project RISE in Alaska.

Priority

Project RISE in Alaska claims priority on account of four specific characteristics:

- Partnership with the University of Alaska Fairbanks (UAF).
- Support by in-kind contributions equivalent to >100% of the requested grant.
- Potential for widespread deployment in the state.
- Deployment of strategic electricity storage technology as defined in the requests for abstracts (RFA).

Technology Validation and Data Collection

Key Performance Metrics Phase 1: 1) operation of the LMB within an islanded hybrid-diesel laboratory microgrid; 2) load following of the LMB against adequate wind and load profiles; 3) regulation services provided by the LMB (voltage and frequency stabilization); 4) fault hardiness.
Key Performance Metrics Phase 2: 1) operation of the LMB within a utility operated hybrid-diesel microgrid; 2) increase of renewable energy capacity factor due to LMB utilization; 3) increase of overall system efficiency measured in kWh/gal diesel used due to operation of LMB; 4) availability of the LMB; 5) if applicable, successful continued and repeated diesel-off operation.
Data Collection: ACEP has access to state-of-the-art data acquisition equipment in the PSI lab. Electrical, thermal and environmental data will be collected at sufficiently high resolution to inform analysis and model development. For field deployment, ACEP has developed a mobile data acquisition system which is very robust, self-healing, and suitable for deployment and continuous operation for months at a time. Ambri will provide diagnostic data through their battery management system.

Project Schedule and Project Budget

Project RISE Alaska will take place over three years (see Figure 1). Testing of the Ambri CORE in 2014 will provide a go-no-go milestone for the project. Table 1 presents an estimated budget for Project RISE Alaska. UAF requests a total of $749,206 to cover the costs of the Ambri systems, laboratory use, partial salaries and limited travel. Ambri and ACEP will contribute a significant portion of the ancillary costs and additional days in the lab depicted below, totaling $795,798 in cost share.

Project RISE Alaska Budget

Task	Requested	Match	Total Task Funding
Phase I: CORE to University of Alaska			
Task 1.1: Project Management	$5,795	$21,938	$27,733
Task 1.2: Determine engineering requirements for installing CORE at University of Alaska	$-	$10,223	$10,223
Task 1.3: Determine product specifications for CORE deployment	$3,644	$3,101	$6,745
Task 1.4: Develop testing protocols to maximize learnings and system benefits	$8,049	$5,078	$13,127
Task 1.5: Design Ambri CORE for University of Alaska	$-	$176,670	$176,670

Task 1.6: Construct Ambri CORE for University of Alaska	$160,228	$-	$160,228
Task 1.7: Test CORE at Ambri facility	$-	$14,134	$14,134
Task 1.8: Ship CORE to University of Alaska	$10,000	$2,135	$12,135
Task 1.9: Install CORE at University of Alaska	$3,500	$61,490	$64,990
Task 1.10: Test Ambri CORE	$81,780	$66,974	$148,754
Task 1.11: Analyze Test Data	$9,686	$22,464	$32,150
Task 1.12: Report on Findings	$2,964	$10,156	$13,120
Phase I Subtotal	**$285,646**	**$394,361**	**$680,007**
Phase II: Ambri Energy Pod to Utility Customer			
Task 2.1: Project Management	$2,645	$21,938	$24,583
Task 2.2: Determine engineering requirements for installing AEP at Alaskan utility partner facility	$3,050	$-	$3,050
Task 2.3: Determine product specifications for customer	$-	$3,101	$3,101
Task 2.4: Develop testing protocols to maximize learning and system benefits	$3,050	$5,078	$8,128
Task 2.5: Design AEP for customer	$-	$176,670	$176,670
Task 2.6: Construct AEP prototype	$381,026	$-	$381,026
Task 2.7: Test AEP at Ambri facility	$-	$14,134	$14,134
Task 2.8: Ship AEP to customer in Alaska	$15,000	$2,135	$17,135
Task 2.9: Install AEP at customer facility	$3,500	$69,557	$73,057
Task 2.10: Field test AEP	$5,122	$64,818	$69,940
Task 2.11: Analyze Test Data	$5,400	$22,464	$27,864
Task 2.12: Report on Findings	$4,576	$10,156	$14,732
Phase II Subtotal	**$423,369**	**$390,049**	**$813,418**
Project Budget Subtotal	**$709,016**	**$774,118**	**$1,483,204**
Subject to UAF State of AK F&A Rate of 25%	**$160,762**	**$40,890**	**[F&A] $50,414**
Total	**$749,207**	**$784,411**	**$1,533,618**

Project Team Qualifications

The **Alaska Center for Energy and Power** is the energy research branch within the Institute of Northern Engineering at UAF. ACEP has a significant history in the collaborative development and assessment of electricity storage systems, from flow batteries to battery-inverter systems for diesel-off operation. Furthermore, ACEP is very familiar with all aspects of islanded hybrid-diesel power systems in Alaska and beyond.

ACEP Key Personnel for this project: Marc Mueller-Stoffels, Ph.D., is a Research Assistant Professor at UAF, and the lead researcher and program lead for ACEP's Power Systems Integration Program. Marc has been with ACEP since 2011 and has an extensive background in complex systems dynamics (non-linear physics), and data analysis and modeling of engineering and earth science systems. **David Light** manages the Power Systems Integration Laboratory at ACEP. Dave has extensive experience in islanded diesel microgrids through 25 years of work with NC Machinery and Alaska Power and Telephone. His expertise allows ACEP to perform research with a close focus on the needs of remote utilities and the increased requirements on reliability when it comes to the operation of equipment in remote Alaska.

Ambri is an electricity storage startup company developing an innovative grid-scale storage solution that will be low-cost, safe, and reliable. Ambri's LMB technology is well-suited to microgrid settings because it can be operated flexibly as both a power and energy resource. In addition, the LMB can operate extreme cold or hot temperatures, and is well-suited for Alaska's climate.

Project RISE in Alaska coordination will be managed by **Kristin Brief**, Ambri's Director of Corporate Development and Treasurer. Kristin brings a broad base of knowledge on the electric power sector, including wholesale market design and utility regulation to the project. Kristin's primary focus at Ambri is

on market development, and she is also in charge of finance, human resources, and marketing. Kristin will be responsible for overall management of this project – she will coordinate between the teams at Ambri, UAF, the utility partners, and AEA to ensure the smooth planning and execution of this project. She will also perform all necessary reporting for AEA's purposes. Kristin has a BA in Economics from Dartmouth College.

Individuals from Ambri's system engineering team will be intimately involved in the planning, deployment and testing of the Ambri units at Con Edison sites. This includes **Hari Nayar**, Director of Systems Engineering, **Zach Modest**, Electro-mechanical Engineer and **Nick Lekatsas**, Senior Systems Engineer. In addition, Ambri executives, **Phil Giudice**, Chief Executive Officer, **David Bradwell**, Chief Technical Officer, and **Shazad Butt**, VP of Manufacturing, will provide project input and oversight.

Discussion of Commercialization of Funded Technology

Project RISE in Alaska is a key component of Ambri's go-to-market strategy, critical both for technical and market validation. Ambri's commercialization plan will progress in three phases:

Phase 1: Delivery of Ambri Prototypes to Customers: 2014 – Ambri's first commercial deployments will be in 2014. Ambri intends to deploy one or two additional prototypes to customer sites beyond Alaska. Each prototype deployment will be tailored to unique market opportunities for electricity storage, and together, the deployments will demonstrate the value of the LMB throughout the electricity value chain. Project RISE in Alaska is critical to validating the use of electricity storage in remote micro grids, which Ambri expects will be high-value markets in the future.

Phase 2: Initial Market Entry: 2015-TBD – Ambri's Revenues from commercial battery sales will begin in 2015. Ambri will target the highest-value opportunities and expects to focus sales efforts on customer segments believed to have a high propensity to pay for electricity storage as determined by Phase 1 pilot testing. Ambri expects these opportunities will include 1) the United States Department of Defense and 2) "small grid" markets, like those in Alaska, that are currently powered predominantly with diesel generation and have the potential to convert to a generation fleet of renewable resources like wind and solar, plus electricity storage.

Phase 3: Full Commercial Operation: 2019 and beyond - Once Ambri's LMBs have been operating successfully for several years, Ambri expects that the LMB will become an accepted industry standard, enabling Ambri to sell systems to a global customer base, including organizations that exhibit high levels of risk aversion, like regulated utilities and larger end-users of electricity. Success in Phase 1 and 2 will enable Ambri to implement its global expansion strategy with partners building local manufacturing for local markets across the globe.

Project RISE in Alaska fits squarely into Phase I of Ambri's go-to-market strategy. This deployment will provide much needed market validation for the product and the data gathered would help make the case to future customers in Alaska and beyond.

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

Andrew M. Gray, Director, UAF Office of Sponsored Programs