Commercializing Alaskan Production of Fly Ash-Based Geopolymer Cements, Transforming Power Plant & Mine Wastes into Energy Efficient Building Products

A proposal to AEA’s Emerging Energy Technology Grant Fund RFA AEA-12-047

For a project led by the

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In partnership with

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Other companies prior to the stage-2 proposal

**Total Project Cost:** $622,000
**Grant Funds Requested:** $559,000
**Match Committed:** $63,000

Previous applications
n/a
Abstract

1. Summary
   a. Description: The purpose of this project is to bring about economically viable commercial manufacturing of alkali-activated alumina-silicate cements, more commonly called geopolymers, within Alaska using Alaskan resources. Geopolymer cement is an emerging technology that is a direct replacement for Portland cement, as well as a binder for fabricating composite building products, that exhibits superior qualities in terms of energy, cost, performance, economics and environmental impact.

   High performance geopolymer cements are gaining commercial acceptance elsewhere in the world due to superior performance and cost competitiveness compared to Portland cement. In general, these cements are stronger, fireproof, and waterproof. They bond strongly to most materials, do not appreciably expand or contract, are foamable, and resistant to salts, acids and alkalis. In addition to superior performance at a cost competitive price, geopolymer cement can be made using local materials, release 80% less CO₂, and have improved life cycle cost due to improved durability and using 60% less energy to manufacture than Portland cement.

   Geopolymers are eminently applicable to local small-scale manufacturing which was recognized when CCHRC's presentation was selected as one of the top 20 finalists in the 2010 Arctic Innovation Competition. On the global scale, replacing Portland cement with geopolymers was one of 12 technological changes presented by the United Nations Environmental Program Energy Committee in 2010 as having the potential for “Transforming the global economy through 80% improvements in resource productivity.”

   Over the past four years CCHRC researched and developed geopolymer cement and this summer will use geopolymer concrete as the foundation for its 8,000 square foot building addition. Through this effort, CCHRC has formed the foundation for the commercialization of geopolymer cement in Alaska. This proposal is the pathway between CCHRC and partner's research, development, and demonstration efforts and the private sector commercialization of geopolymer cement in Alaska. This project will establish and follow a commercialization path for geopolymer cement and derivative products by accomplishing three important next tasks: 1) Expanding and organizing a consortium of interested public and private partners to help inform and advance this emerging technology to commercialization, 2) Creating a commercialization pathway and business case to aide in the transition from initial research and demonstration projects to commercialization by a private entity, and 3) Performing research, development and demonstration that is driven by the partnership described in task 1 and/or the commercialization pathway in task 2 to further ready the technology for commercialization.

   b. Eligibility: This project is designed and intended to accomplish the final steps necessary for private enterprise to successfully capitalize and commercialize geopolymer cement and concrete production and derivative product manufacturing in Alaska. CCHRC’s research and development work over the past four years has brought the material to Technology Readiness Level 6. Level 7 is imminent with CCHRC’s full-scale demonstration of geopolymer concrete for constructing an 8,000 square foot building addition beginning in April of this year. The on-going preparation project “Demonstrating Geopolymer Concrete Produced in Fairbanks” is funded by the Alaska Housing Finance Corporation (AHFC). With funding from the Fairbanks North Star Borough and Aurora Energy, LLC, CCHRC’s has also completed prefeasibility work in preparation for the business case development included as part of this proposal. Please see "Investigating 21st Century Cement Production in Interior Alaska Using Alaskan Resources" for further details. This project will take Alaskan geopolymers through Technology Readiness Level 8.

   Local production of geopolymer cement and concrete is an enabling energy technology that will increase the efficiency of coal fired electrical power generation by providing a profitable market for the fly and bottom ash that is presently wasted incurring associated disposal costs. It will also reduce the negative environmental effects of ash disposal as well as those of Portland cement, albeit currently external to Alaska, which it can competitively replace.
The needs addressed by this project range from the large scale and broad to the small and specific – From hydro-electric dam construction and substantial reduction in embodied energy and CO₂ emission to energy efficient, weather, fire, insect and rot proof building envelope components.

c. Innovation: As Alaska develops, for example to meet the demand for strategic minerals, the significance of our dependence upon Portland cement increases. Commercializing geopolymer cement in Alaska can increase the lifespan of Alaskan infrastructure while reducing capital costs due to the inherent durability of the material and cost competitive price point. This combination can positively impact life cycle costs of projects that utilize geopolymer cement. The capital investment required for a geopolymer cement bulk manufacturing plant is a few hundred thousand dollars compared to a couple hundred million dollar cost of a Portland cement plant, which in combination with our locally available materials for manufacturing such as fly ash or mine tailings make local manufacturing of cement a distinct possibility in suitable regions within Alaska. The use of fly ash or mine tailings in the manufacturing process also creates a use for a waste stream that is currently costing coal fired power plants and mineral operations in Alaska. Further, from a global perspective, replacing Portland cement with geopolymer cement can reduce energy used in manufacturing cement by 60% and the CO₂ released by 80%.

In Interior Alaska alone over 100,000 tons of ash per year from five coal-fired electrical power generation plants is wasted. This could be used to locally manufacture approximately 300,000 cubic yards of concrete per year; more if the ash were augmented with other available materials. Data collected by others indicates a high probability that ash from the Healy Clean Coal plant will also be an excellent resource when it becomes available.

d. Priority Considerations: CCHRC is an Alaskan 501(c)3 non-profit incorporated in 1999 presently employing over 30 Alaska residents in the Fairbanks area.

CCHRC needs the molecular-level testing and analytical equipment and expertise available through partnering with both the University of Alaska Fairbanks’ Advanced Materials Group (AMG) and the Advanced Instrumentation Laboratory (AIL).

On top of their high level of enthusiasm for collaborating on this project, the unique combination of expertise in nano-scale material analysis as well as entrepreneurship and business development, makes the AMG an ideal partner. Their research will demonstrate device configuration, material suitability, and address fidelity of geopolymers for market suitability. As part of the technology validation and research component, data collection (including O&M, R&R, and performance data) is included in AMG’s scope and budget for the project. The specific parameters that will be gathered and reported will be technology and project specific. Quarterly reports will be submitted as required for the project and will include all information outlined in the grant agreement.

The AIL will continue to perform component (raw) material analysis, such as X-Ray Fluorescence (XRF) and particle size distribution, services they have provided in earlier project phases. This stage of the raw material analysis will focus on determining its variability over time as it relates to commercial-scale production. Additionally they will perform Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) analysis thereby assisting in determining the impact of material and process changes on the molecular structure of the products.

CCHRC has a Memorandum of Understanding with Aurora Energy, LLC “To collaboratively work toward Commercializing Geopolymer Concrete Production in Interior Alaska.” This MOU is designed as a framework for including additional interested parties. Expanding this collaboration will necessary prior to CCHRC’s submission of a full stage-2 proposal should one be requested. While this project is focused toward the commercialization of geopolymer building products, this work is a prelude to broader applications of the material ranging from infrastructure to composite fabrication. The production of geopolymer cement as well as derivative products is readily scalable from small businesses in rural communities to bulk manufacturing where infrastructure permits and extends in scope from niche building products to widespread use in large infrastructure projects. Given the degree of leveraging and
the level of interest to date, raising at least a 10% match from external sources before stage-2 proposal submission is not expected to be difficult.

2. **Technology Validation and Research Methodology**
   a. **Objectives:** 1) Transition from research, development, and demonstration to private sector commercialization of geopolymer cement in Alaska. 2) Ensure that the prototype geopolymer products meet their performance and cost design specifications to smooth the commercialization process.
   b. **Methodology:** 1) Expand and organize a consortium of interested public and private partners to help inform and advance geopolymer cement to commercialization; 2) Create a commercialization pathway and business case to aide in the transition from initial research and demonstration projects to commercialization by a private entity; 3) Performing R&D that is driven by the partnership described in task 1 or the commercialization pathway in task 2; 4) Thoroughly document research, development, prototyping and testing procedures; 5) Rigorous material analysis, instrumentation and testing of prototypes, and market research; and 6) Interim reporting to AEA and collaborating partners.

3. **Summary of Project Schedule and Budget**
   **Phase 1:** Consortium establishment and cement and concrete commercialization plan development bringing geopolymer concrete to TRL 8. August 2012 – May 2013, $75k.
   **Phase 2:** Initial derivative geopolymer product development driven by consortium’s market considerations. August 2012 – September 2013, $291k
   **Phase 3:** Final geopolymer product prototyping and commercialization plan development and reporting bringing geopolymer products to TRL 8. September 2013 – July 2014, $256k.

4. **Project Team Qualifications**
   CCHRC is at the forefront of increasing the energy and cost efficiency of constructing and retrofitting buildings and sustainable communities in arctic environments. All CCHRC projects draw upon the diverse expertise throughout the organization as needed to ensure top quality results.

   **Cole Sonafrank,** the leader of this project, has been researching and developing alternatives to portland cement at CCHRC and his private studio since 2007. He has developed, mixed and evaluated over 700 experimental mix designs. He has thus far accumulated, organized and partially digested over 7GB of information directly related to the preparation and use of 21st century cements. In addition to cement-related work, Mr. Sonafrank has developed and managed some of CCHRC’s largest and highest priority Alaska Housing Finance Corporation (AHFC) funded projects including the Alaska Retrofit Information System (ARIS) and AkWarm Modernization, both integral to AHFC’s Home Energy Rebate and Weatherization programs. Cole joined CCHRC after a 26 year career with the University of Alaska Fairbank’s Geophysical Institute (GI). From 1995 to 2005 he managed the GI’s Computer Resource Center. From 1979 to 1995 he developed and managed the computing facilities for the Seismology and Volcanology research groups, the Alaska Earthquake Information Center and the Alaska Volcano Observatory. Cole has a BA from UAF in Economics.

   **Other key members of CCHRC’s staff contributing to this project will include:**
   **Dave Shippey** was the working foreman for building CCHRC’s Research and Testing Facility. After the building was completed on time and on budget, he was asked to stay on as the building manager. He studied electrical engineering at DeVry Institute of Technology, then earned his BA, Economics and BS, Finance from Pennsylvania State University. After college he joined the banking world until, in 1993, he bought a dump truck, backhoe and bulldozer and went into the excavation business. A few years later he went to work for Jack Hébert at Taiga Woodcraft. In the mid-1990s he built two homes as a general contractor before returning to Taiga Woodcraft as a carpenter and foreman.

   **Bruno Grunau, P.E.,** joined CCHRC in 2011 after serving as the chief engineer for a local renewable energy firm that specializes in the design and fabrication of solar and wind energy systems. His efforts in renewable energy system design, consultation, and project management have been applied to on-grid residential and commercial systems, as well as off-grid remote applications. His experience installing and troubleshooting energy systems in Alaska constantly reminds him of the importance of a
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clean, well-planned, and functional system design. His passion for sustainable technologies began when participating on Virginia Tech’s Solar Decathlon Team in 2001. As an engineer, he spent six years doing testing and analysis at a shock and vibration test laboratory.

**UAF, INE, AMG’s Shiva Hullavarad, PhD, MBA, and Nilima Hullavarad, PhD, MBA, University of Alaska-Fairbanks Advanced Materials Group** facility has the requisite infrastructure and technical resources to accomplish the project goals and objectives. AMG’s facility has the capacity to provide the needed information to prove the effectiveness of geo-polymers for the proposed market: it has a highly rated research division with a state-of-the-art clean room, materials development, and advanced level characterization facilities to carry out research and technology development for Military, Aerospace, Space and Homeland Security (MASH) applications. AMG houses over 15,000 square feet of Class 100 and Class 1000 clean room facilities. AMG leverages numerous other resources on the UAF campus, such as the centralized materials analysis lab, machine shops, and the laboratories in the electrical and mechanical engineering departments.

**UAF AIL’s Director Ken Severin, PhD,** UAF’s Advanced Instrumentation Laboratory is a multi-instrument resource for the state of Alaska. It specializes in surface and elemental analysis as well as electron microscopy. It supports and trains undergraduate and graduate students and provides technical support and facilities to researchers as well as local, state, federal, and private agencies.

**Aurora Energy, LLC**’s staff will provide the ash supply-side technical and business expertise. As stated in the MOU, their particular objectives include “Decreasing the operational costs of power plants consuming coal from the Usibelli coal mine which produce ash with significantly different characteristics than plants burning coal from other sources.”

**K & K Recycling’s Bernie Karl,** well known as one of Alaska’s preeminent entrepreneurs, has been and continues to provide significant in-kind support and interest in how CCHRC is using recycled materials such as aluminum and glass in geopolymer development. His business acumen is a great asset.

**Others** will include a Structural Engineer, either from UAF or a private firm, will be consulted on a service contract basis. Intellectual property and other legal services will be obtained on an hourly basis.

5. **Discussion of Commercialization of Funded Technology**

Work to date has included pre-feasibility manufacturing cost estimation and determined that locally produced geopolymer cement can be cost competitive with Portland cement for making concrete. A next major milestone toward geopolymer concrete commercialization is CCHRC’s full-scale, real-world building addition demonstration this spring. Work through this project will continue to advance commercialization by forming a consortium of interested public and private partners to foster and inform the process of creating a commercialization pathway. A business case for geopolymer cement and concrete will be one of AMG’s early deliverables and will involve others such as UAA’s Center for Economic Development who has previously expressed interest. The consortium and refined commercialization plan will inform the further research, development, and demonstration of geopolymer cement and associated products. These efforts will advance geopolymer cement to a position of confident standing in terms of physical properties and economic viability. Developing this level of confidence in this emerging technology is critical for the transition from current levels of research, development, and demonstration to investment and commercialization by the private sector.

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 upon submission of a stage-2 proposal under AEA’s EETF program.

Ryan Colgan, Chief Projects Officer, CCHRC

March 9, 2012