TITLE PAGE

1. PROJECT TITLE: Zeolite Refrigeration through Electro-Desorption

2. APPLICANT CONTACT INFORMATION:

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3. Technology partner

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4. Total Project Cost

Grant funds requested: $345,000
Match committed: $35,000 (10%)

5. PREVIOUS PROJECT TITLE(S) AND/OR APPLICATION NUMBER(S) FOR GRANTS FROM THE RENEWABLE ENERGY FUND OR DENALI COMMISSION EMERGING ENERGY TECHNOLOGY GRANT PROGRAM:
NONE

6. PREVIOUS PROJECT TITLE(S) FOR ABSTRACTS SUBMITTED TO THE EMERGING ENERGY TECHNOLOGY FUND:

NONE

ABSTRACT

1. PROPJECT SUMMARY and TECHNICAL SYNOPSIS

a. Project Description and b. Eligibility: The objective of this grant is to build a highly efficient refrigeration system. This invention won 2nd place in the 2009 UAF Arctic Innovation Competition with over 250 entries from around the world. Zeolite Refrigeration through Electro-Desorption (ZRED) is a patented (pending) process and will be the first R&D effort in the State of Alaska in the artificial refrigeration technology. New Hope Refrigeration has two patents pending on the technology and has partnered with the Advanced Materials Group (Alaska's only Nanotechnology and Microelectronics research center) at Institute of Northern Engineering, University of Alaska Fairbanks (UAF). The technology priority of the ZRED project is *Energy Efficiency and Conservation, and meets* AEA's priorities *to promote the expansion of energy sources available to Alaskans through demonstration projects of technologies that have a reasonable expectation to be commercially viable in the next five years.* The project is designed to test an emerging technology that will conserve energy and will focus on preserving essential food items at places where grid based electric power is not available. Funding will be used to implement a three-phase project to accomplish TRL 5-7 over a three-year project period.

c. Innovation and Scientific Concept: Zeolite Electric Refrigeration will be a significant improvement in refrigeration. It will be simple and inexpensive to build and have significantly higher energy efficiency than compressor driven units. Additionally, because it can use refrigerant that will allow high, medium and low temperature ranges, its performance will be equal to that of compressor driven units. This project will demonstrate Solar Refrigeration Patent #4,584,842 date Apr. 29, 1986, the Electro-desorption Patent # 4,038,050 date July 26, 1977, and of the zeolite electric refrigeration invention. Then it will implement aspects of combining the two patents and how zeolite electric refrigeration will be an improvement. In the proposed a very novel, and unique approach of combining both technologies - solar refrigeration using zeolites to absorb and desorb a bipolar gas by changing the temperature of the zeolites, will be used. The other is the desorption of bipolar gas using an electrical charge running through the zeolites. Combining these two patents to make a new use refrigerative by passing electricity through zeolites to cause the desorption of a refrigerant at pressures high enough to cause condensation.

d. Technology Readiness: Zeolite Electric Refrigeration will be a significant improvement in refrigeration. It will be simple and inexpensive to build and have significantly higher energy efficiency than compressor driven units. Additionally, because it can use refrigerant that will allow high, medium and low temperature ranges, its performance will be equal to that of compressor driven units. This project will give a description of the Solar Refrigeration Patent, the Electro-desorption Patent, and of the zeolite electric refrigeration invention. Then it will discuss various aspects of combining the two patents and how zeolite electric refrigeration will be an improvement. For this invention, I am combining two patents. One is solar refrigeration using zeolites to absorb and desorb a bipolar gas by changing the temperature of the zeolites. The other is the desorption of bipolar gas using an electrical charge running through the zeolites. Combining these two patents to make a new use refrigerative by passing electricity through zeolites to cause the desorption of a refrigerant at pressures high enough to cause

condensation.

2. TECHNOLOGY VALIDATION AND RESEARCH METHODOLOGY

a. Methodology: Proposed research will demonstrate zeolite-based refrigeration. **Objective #1:** Study competing and complementary technologies in the market that provides maximum pressure difference due to electro-desorption. Role of zeolite: 1) particle size, 2) distribution in producing the maximum pressure difference. Zeolites with open porous structure are capable of adsorbing large quantities of water vapor at room temperature and if the zeolites are then heated in a closed system, they desorb water vapor at considerably higher pressures, which can facilitate the replacement of the mechanical compressor usually found in refrigeration and heat-pump systems. Determine the zeolite particle size optimization for the ion exchange reaction. The pore volume and the ion-exchange capacity of zeolite estimation suitable for chemical tailoring for application-specific zeolite can be used. **Objective #2**: Detailed thermodynamic analysis of the selected zeolites for maximum pressure difference using super fast computing facility. Compare select types of zeolites and all chemicals adsorbed (refrigerants) to show amount adsorbed, energy to break molecular bond between zeolite and refrigerant, thermodynamic analysis, most efficient size of zeolite particles. Study heat capacity, evaporating and melting temperatures and pressures and provide inputs to the design stage. **Objective #3**: Detailed study of amount refrigerant adsorbed/desorbed to give potential BTU, electric energy to desorb refrigerant, the pressure that can be maintained in a closed system with one zeolite chamber desorbing refrigerant and another sorbing refrigerant to provide potential temp produced. Study of adsorptions cycles combined with refrigeration system to obtain a higher cooling efficiency. Evaluation of uptake efficiency of the adsorption bed and estimating conditions under which the compressor ceases to provide desired throughput. Determine electrode materials capable of accumulating thermal energy and releasing it in a reversible way with large pressure variations. **Objective #4:** Determination of difference in the densities of the refrigerant between the inlet and outlet, the adsorption characteristics of the adsorbed refrigerant pair and the void volume in the thermal compressor and the desorption state. Determine parameters for storing energy at different temperatures of the zeolites. The enthalpy of dehydration coupled with the high-peak temperature estimation for the refrigerant in inner channels of zeolite. Design optimization to provide low cost heat recovery with the adsorption cooling systems integrated in a manner to provide an overall stable, continuous operation.

3. PROJECT SCHEDULE: The project will follow Phases I through III over the three year period, as follows:

PHASE/ TRL	TIME-LINE	ACTIVITIES	MILESTONES
Phase I Pre-Development TRL 5	MONTHS 1-6	Completion of zeolite refrigeration validation and research plan; preliminary Commercialization plans; Project financing finalized; and site control activities completed. Activities will optimize processes and capabilities in terms of device dimensions, temperature requirements, throughput rate and layer-to-layer registration.	a) Proscoping completed; b) Final design completed; c) Financial plan finalized; d) Zeolite refrigeration validation and research plan finalized; e) Preliminary Commercialization Plan completed; f) Required reporting completed.

Phase II Deployment Activities	TRL 6 MONTHS 7-24	Pilot project, less than full scale in relevant environment; technology validation, research plan put into effect; monthly reports; update financial plan; update commercialization plan.	a) Project deployment; b) Zeolite refrigeration validation and research plan; c) Project monitoring activities; d) Project improvement activities; e) Financing Plan updated;
TRL 7	MONTHS 24-36	Full-scale non-commercial device deployed in relevant operational environment; technology validation and research plan put into effect; monthly reports; update project financing plan; update commercialization plan.	
Phase III: Post Deployment TRL 7	MONTHS 31-36	Analyze and report on technology validation and research plan results; update commercialization plan to reflect study results; decommission project, as needed.	a) Commercialization Plan complete; b) Continued performance monitoring; c) Final performance report; d) Analysis and recommendations

Site and/or Facilities: a) *Site Suitability:* Work has been outlined for UAF and New Hope refrigeration to perform project at the *University of Alaska-Fairbanks Advanced Materials Group* facility. AMG-UAF 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** zeolite refrigeration **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. *(See attached UAF letter)*

4. PROJECT TEAM CAPABILITIES

- ***Project Team:*** *New Hope Refrigeration* ***staff*** is experienced in technology development through generating patent and ideas that are relevant to the arctic. New Hope will engage AMG for the proposed technical research; AMG employs professionals for running the facility, R&D, and pilot production. Multiple opportunities for interdepartmental collaboration will offer graduate students participation in the project. The project team includes staff from New Hope, a professional grant services firm, and AMG; *CV's are attached for key staff*.
- Project Manager, *Bruce Kraft, CEO of New Hope Refrigeration, has* worked with UAF for the past two years to develop and expand the zeolite refrigeration. Bruce is the recipient of Arctic Innovation Competition 2009 second prize ($5,000), which he is committing as the matching fund for the present AEA grant proposal. Bruce has two pending US patent on the technology and has demonstrated the technology feasibility.
- Principal Investigator for Technology Validation and Research: *Shiva Hullavarad, Ph.D., Assistant Professor, Advanced Materials Group, INE – UAF*, presently heads Microelectronics

and Photonics DARPA funded program at AMG, UAF. As Principal Investigator for the technology, he will be responsible for ensuring valid scientific and economic data and other technology validation and research activities; providing the aforementioned information in the format reasonably specified by the Authority for all phases of the Project: Ph. 907-455-2017 Email: shiva.h@alaska.edu

- ***Financing Plan:*** Funding will provide support for New Hope administrative and support staff, travel to Fairbanks for meetings with AMG staff and for attending an annual industry conference; a sub-award to UAF will provide funding for salaries, the use of existing equipment, and facility use expenses. Consultant(s) will be hired by New Hope for assistance with the commercialization planning and updates based on research and testing results; Equipment maintenance, software, and clean room supplies will be needed for the AMG facility to conduct all research, and student stipends are budgeted for participation at the University. Legal expenses and U.S. Patent Office fees are budgeted for filing provisional and final patent applications, office rent, office supplies, and insurance expenses are budgeted for the project.

5. MARKET

Potential Market Defined: The proposed technology has the potential to become a breakthrough, market-disruptive new product that is energy-efficient and appropriate for decorative and safety purposes in both residential and commercial applications. Its potentially diverse applications present numerous possibilities for significant economic impact. It is expected that the product testing process will yield ideas for increased uses and its marketability, especially for commercial applications.

Potential Market Size: An electro-desorption unit will be much less expensive and simpler to build than an electric motor and compressor. The unit also should have a longer life and require less maintenance than a conventional unit. If natural zeolites can be used there will be additional cost savings. Overall, there will be significant cost savings. Electricity of 220 volts is in all houses and small businesses. Commercial plants needing large units requiring higher voltage generally have 440 volt or higher services on the premises. The electric requirements are practical.

Potential Public Benefit: The amount of the electrical energy consumed in regenerating the bed can be slightly greater than the caloric equivalent to the heat of vaporization of water removed from the bed." (Electrodesorption Patent, column 8 line 63) I'm interpreting this to mean that theoretically this is close to 100% efficient. At column 7 line 30, I believe the writer is saying that there are working units operating at 50% efficiency. These units have a diameter of 183cm (6 FT) and a height of 305cm (10FT) (column 7, line 53). This is an extremely large unit. There is good possibility that smaller sized units designed for refrigeration, not gas separation, will have much greater efficiency.

There would also be some efficiency increases in the rest of the refrigeration loop. By eliminating the compressor oil that flows through the system with the refrigerant, the evaporator and condenser efficiency would be increased by about 5%.

6. BUDGET

We are requesting funding in the amount of $345,000 for this project. Costs associated with this project include $46,800 in salaries for New Hope Refrigeration, $17,561 in travel costs including, meals, lodging and car rental to lab sites, $32,700 in commodities and supplies, and $241,791 for a subaward to be issued to the University of Alaska Fairbanks.

New Hope Refrigeration will provide $23,400 of labor costs as matching funds.

7. PROOF OF ELIGIBILITY

New Hope Refrigeration is an eligible business holding Alaska Business License, #953680, and its partner for the project is the University of Alaska Fairbanks, an Alaska postsecondary institution.

By signature on this application, I certify that we are complying, and will comply,