Sustainable Greenhouse for the North

Project Title: Sustainable Greenhouse for the North

Applicant Contact Information: Arctic Sun, LLC
Attn: Karl Kassel
PO Box 74798
Fairbanks, AK 99707
(907) 457-1297
Karl@arcticsun-llc.com
www.arcticsun-llc.com

Partners: UAF, School of Natural Resources and Agricultural Sciences, Department of High Latitude Agriculture

Total Project Cost:	$552,092
Grant Funds Requested	$496,883
Arctic Sun Match (11%)	$55,209

(Match will include cash, materials, and labor at a rate not to exceed Davis-Bacon)

Previous Grant Projects and/or Applications: Arctic Thermal Shutters and Doors #7310006

1. **Project Summary:**
   a. **Project Description:** Arctic Sun is partnering with the University of Alaska Fairbanks, Department of High Latitude Agriculture, and REINA construction company to create a model greenhouse that can be operated economically and sustainably for extended periods in the Far North. To accomplish this goal, extreme conservation of energy is required, compared to the typical greenhouse, plus the utilization of renewable energy wherever possible. Arctic Sun will test and quantify the performance of several individual systems, but also identify the improved efficiencies created by the synergy of combining complimentary systems. The goal is to create a greenhouse model that can operate economically enough to be a realistic source of food production across Alaska.

Alaskans only manage to produce 2% of what they eat. This creates significant concerns for the health and safety of all Alaskans if the flow of goods from Outside was substantially reduced for any amount of time. The extreme climate and short growing season present a variety of agricultural challenges for food production. The high cost of energy, and especially heat, has historically been the deal breaker for large-scale greenhouse food production. All of these issues are compounded in rural Alaska where transportation systems are more complex and energy costs are higher. The ability to produce food locally and economically is rapidly becoming a high priority across the State.

Arctic Sun and its parent company REINA construction company have long been leaders in building sustainable, high-efficiency structures, and incorporating both active and passive renewable energy systems. Our companies have recently been contacted by several villages throughout Alaska asking if we might be able to help them construct a greenhouse that could be operated economically and for a larger portion of the year than a typical greenhouse. During our research on this topic, we discovered an overwhelming absence of quality data on the majority of new greenhouse options. While several groups are experimenting with different designs, most are focused on the agricultural aspects, and not collecting any hard data on the building science and performance. None of the facilities we studied were operating at the level of performance they had hoped for.

Arctic Sun is utilizing a holistic design approach, focused on total building efficiency through the enhanced use of renewable energy and thermal storage systems, and improved conservation of energy. Our intention is to modify and combine several new cutting-edge technologies that have not been previously tested in Alaska, nor scientifically evaluated anywhere with the appropriate monitoring. Our design is a unique combination of systems that should result in dramatically reduced energy consumption and operating costs, while simultaneously extending the growing season.

The greenhouse itself will function as a large solar thermal collector, and the extra heat that is typically expelled from a standard greenhouse will be transferred via an air-based system and stored in the soil foundation. This heat will then be utilized to keep the structure warm through the night until the next heating cycle. As a by-product, this system will also help maintain the appropriate humidity levels within the greenhouse. Extremely efficient DC fans, powered primarily from solar PV panels, will move the heat and provide other ventilation as required. Part of the project analysis will be to vary the flow-rate of the air through the subterranean storage system to determine the optimum rate to maximize the amount of heat transfer per watt of fan power.

This structure will be uniquely insulated. The exterior shell of the greenhouse will be a double-wall polycarbonate frame, with the two walls separated by thirty inches of air space. Additional insulation will be created by blowing fire-suppression-style foam bubbles into this cavity when needed. As the foam dissolves, it will drain into a storage reservoir to be blown in again as needed. Anecdotal evidence from existing systems shows this approach functions well in more moderate climates and may have promise here, but there is currently no data to quantify actual R-values or performance in temperatures as extreme as Fairbanks.

The foam insulation can also be utilized to cool the greenhouse if needed. The south wall can be blown in to reduce solar gain while the north wall can remain open to dissipate heat. The opposite arrangement can also be employed to heat the greenhouse more effectively when the sun is low in the

sky. The north wall can be blown in to decrease heat loss, and to reflect additional solar radiation coming through the open south wall into the greenhouse.

Alaska is a large state encompassing many different climatic zones. No one greenhouse will be the perfect fit for all applications. Our basic design will be modified for Alaska's various regions. However, to customize and optimize the design for maximum performance requires sound scientific data which currently does not exist. This project will provide quality documentation of the greenhouse's functionality, and quantification of several technologies that are key to creating high-performance greenhouses. It will also demonstrate the advantages and synergy of integrating several renewable energies into one efficient, holistic design.

b. Project Innovation: The high cost of energy in Alaska prevents greenhouses from operating for more than a few months each year. The poor insulation value of the standard greenhouse wall makes it impossible to economically heat its typically large space when temperatures are below freezing for an extended period of time. This project's proposed wall system is predicted to have an R-value slightly over 30. This should provide a dramatic reduction in the amount of energy required to heat the structure, and allow the growing season to be extended significantly. Our expectation is that even in Fairbanks' extreme cold, the greenhouse should be a productive environment from March through October. As systems are perfected and optimized, it may be possible to extend the season even further.

For much of the growing season, the greenhouse should require almost no supplemental, non-renewable energy for heat or electricity. As the summer season changes to fall, the energy requirements will rise quickly while the solar energy input decreases. After these opposing trends cross, the greenhouse will require more supplemental heating and lighting, and at some point, the greenhouse will become uneconomical to operate. We intend to push the envelope and determine the realistic, maximum extent of the growing season to include the possibility of a year-round operation in many parts of the State.

This project will identify and quantify the energy loads, and provide the scientific data needed to accurately model and optimize greenhouse designs for the various regions of Alaska. Without actually constructing and operating a greenhouse, with all of the combined and synergistic systems operating together, it is impossible to accurately quantify the supplemental energy demands or to precisely calculate the full extent of the potential growing season.

The synergy created by the various proposed systems is multi-faceted. The cost to install each individual system is reduced when construction of that system is an integral part of another system. Also, the performance and cost-effectiveness of an individual system can be improved when it is linked to more than one system. For example, the power from the PV system becomes more efficiently utilized when linked to DC fans which, in turn, improve the efficiency of both the air-based heating system and the ventilation system.

c. **Project Site and Demonstration Environment:** We will construct this greenhouse next to our warehouse at 1050 Deere Street in Fairbanks, on land owned by REINA. This location is close to UAF and will allow us to monitor all aspects of the project at a lower cost. Its proximity will also offer us the long-term opportunity to further refine and test additional options or alterations of the basic design as ongoing research warrants.

This site is also ideal for a greenhouse as it receives almost completely unobstructed sunlight for the entire year. It sits at a low elevation, so winter temperatures will dip as low as it gets in Fairbanks. This will allows us to test the building envelope in the most extreme environment and collect data that currently does not exist. By testing the structure in the "worst environment," we will be able to more easily and reliably extrapolate the data to other milder regions of the State.

The site is completely under the jurisdiction of REINA, and will remain so for the duration of the project. The greenhouse's central location in Fairbanks will also be ideal for public visitation and demonstration to expand awareness of its potential. The produce grown during our research will be donated to the local food bank and Stone Soup Café.

d. **Priority:**
   i. Arctic Sun, LLC is a subsidiary of REINA, LLC. Both companies are wholly Alaskan owned and operated. Arctic Sun's Alaska Business License #969490.
   ii. Arctic Sun will be partnering with the UAF Department of High Latitude Agriculture. They will be assisting with the agricultural aspects of the greenhouse including plant selection, growing and harvesting, and then quantifying production. The University is also recommending design standards and criteria for lighting, temperature, humidity, ventilation, growth medium, and operational needs.
   iii. REINA and Arctic Sun have already invested significant time, money, and energy in bringing this technology to where it is today. UAF has also put significant efforts into sustainable agriculture in the north. Arctic Sun and UAF will provide a total of $55,209 match specifically for this project.
   iv. The potential for widespread deployment of this technology is tremendous. All regions of Alaska fall far short in the amount of food they can produce locally. A greenhouse that is economically viable to operate, long-term, is essential for the health and safety of all Alaskans, and especially rural residents. The data collected from this project will allow us to customize the basic design for optimal performance and use in a variety of different climatic zones across Alaska.
   v. The use of a solar-powered, air-based, heat-exchange system to capture passive solar heat and transfer it to an insulated, subterranean heat storage system will greatly reduce the need for supplemental, fuel-based heat. Because the greenhouse atrium functions as the primary solar collector, and the heat is efficiently moved by air, the initial costs and subsequent maintenance costs will be minimal. The consumption of both diesel fuel for heat and grid-supplied electricity for power will be reduced tremendously.

2. **Technology Validation and Data Collection:**
   a. **Objectives:** The objective is to field proof a sustainable greenhouse model that is capable of being economically operated for more than nine months each year in almost any region of Alaska. The goal is to collect enough quality data to be able to confidently fine-tune the basic design for the various climatic zones across the State. In the process, we will be proofing, validating, and quantifying several individual and key systems including the:
      i. Air-based heat exchange system and ventilation;
      ii. Subterranean heating and cooling system;
      iii. Blown-in foam bubble insulation system;
      iv. DC powered fans.
   b. **Data Collection:** Extensive data collection will take place on all of the greenhouse systems . Temperature and moisture sensors will be placed throughout the greenhouse atrium, and in the staging building, thermal storage bed, exterior soil, and exterior air. The DC fans, back-up oil heat system, lighting system, air-flow system, and subterranean heating and cooling system will all be monitored for energy consumption and performance. Solar irradiance will also be logged and correlated to all other system performances. Arctic Sun has consulted with the Alaska Center for Energy and Power (ACEP) on various monitoring strategies, and we will continue to work with ACEP to ensure quality and complete data collection. Trustworthy, comprehensive, scientific, and easily understood and presentable data is a primary objective of this project.

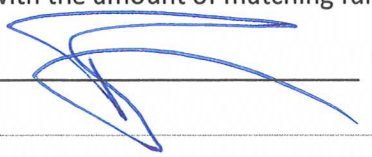
c. **Outreach:** A dedicated webpage will be created for the project, and the various sensors for measuring system performance will be streamed live. Research progress and performance reports will be updated frequently. In addition, a short 5-minute summary video and a 30-minute outreach video will be produced, outlining the project, the research, construction, function, and actual performance of the systems utilized.

3. **Summary of Project Schedule and Summary of Project Budget:**

Activity	Schedule Start	Schedule End	Budget
Complete engineering & design specifications for greenhouse structure & various systems	Feb 2014	March 2014	Grant: $36,974 Match: $4,108
Purchase & delivery of building & material supplies	April 2014	May 2014	Grant: $166,540 Match: $14,187
Construction of the greenhouse	May 2014	July 2014	Grant: $171,294 Match: $14,715
Data collection and monitoring	July 2014	Dec 2015	Grant: $56,223 Match: $6,247
Startup of extended growing season by UAF Department of High Latitude Agriculture	March 2015	October 2015	Grant: $48,996 Match: $14,079
Final analysis and performance reports; findings and video documentation published	Nov 2015	Feb 2016	Grant: $16,857 Match: $1,872

The prototype, sustainable greenhouse will be built in the spring of 2014. After all systems are installed and operational, we will optimize their performance with the measured data. Testing and monitoring will commence as soon as construction is complete, and continue beyond the end of the. In fall of 2014, we expect to have a fully equipped and operational greenhouse with all systems optimized and ready for full-scale planting in the spring. The expectation is that the renewable energy systems will have the greenhouse up to temperature, operational, and ready to plant by the beginning of March 2015. Our partners at UAF will manage, monitor, evaluate, and document the plantings and production throughout the project. Our intention is to produce a detailed report by early 2016, after the first complete growing season and a full, 4-season-year of solar gain, plant production, monitoring, and data collection.

4. **Project Team Qualifications:** The team will consist of staff at Arctic Sun and UAF, Department of High Latitude Agriculture.
   a. **Thorsten Chlupp**, Project Manager: Thorsten is the owner of Arctic Sun and is an international leader in Passive House design and construction. He has presented his research on sustainable building across the Lower 48, Canada, and around the globe.
   b. **Karl Kassel**, Project Coordinator: Karl is the General Manager of Arctic Sun and will oversee the day to day activities of the project. He previously owned and operated K2 Custom Construction and built many high-efficiency homes in Alaska.
   c. **Dr. Meriam Karlsson,** Professor of Horticulture: Dr. Karlsson will oversee the UAF staff and their coordination of the agricultural aspects of the project. Her current research interests include alternative energy sources, hydroponics, innovative use of natural and supplemental light for high latitude crop production, and development of industry partnerships in high latitude climates.
5. **Discussion of Commercialization of Funded Technology:** The ability to grow food locally, and in a feasible manner, is on everyone's mind in Alaska. High fuel costs for transportation have increased costs-of-living, especially in remote and rural areas of the State, where food and energy costs have become staggering. Additionally, food production in local greenhouses for extended seasons is cost prohibitive and simply not feasible. This project will document and showcase a new energy-efficient technology that will result in a finished, sustainable greenhouse. This model can then be scaled for a variety of applications, from smaller rural cooperatives to large-scale, commercial food production facilities in urban communities of Alaska.
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.



_____ Thorsten Chlupp, Owner/President, Arctic Sun, LLC