Evaluation of Cold Climate Air Source Heat Pumps as an Energy Conservation Strategy

AEA Emerging Energy Technology Grant Fund Application AEA-2014-007

Applicant: Colin Craven
Cold Climate Housing Research Center
1000 Fairbanks Street
P.O. Box 82489
Fairbanks, AK 99708
(907) 457 – 3454
colin@cchrc.org

Partners: Clay Hammer
City of Wrangell Municipal Light and Power
P.O. Box 531
Wrangell, AK 99929

Dr. Tom Marsik
UAF Bristol Bay Campus
PO Box 1070
Dillingham, AK 99576

Total Project Cost: $107,191.44
Grant Funds Requested: $72,351.44
Match Committed: $34,840.00

Previous project/application title(s) and/or number(s) for grants from the Renewable Energy Fund, Emerging Energy Technology Fund, or Denali Commission Emerging Energy Technology Grant program:

1. Cold Climate Ground Source Heat Pump Demonstration: Energy Efficient Space Heating for Alaska (EETF funded project);
2. Production of Fly Ash-Based Geopolymer Cements (EETF application).

1. Project Summary

a. Project Description:

The latest air source heat pumps (ASHPs) designed for cold climates can provide an economical, low-maintenance space heating option for Alaska. As witnessed by recent implementations in Southeast communities, there is much interest in ASHPs for lowering operating costs in residential and commercial buildings. The majority of installations are air-to-air ductless heat pumps, and there are also air-to water systems available. Cold climate ASHP systems are unique relative to standard ASHP technology in that they focus on heating capacity and can operate down sub-zero outside air temperatures.

From the perspective of home and business owners, cold climate ASHPs can provide substantial savings in heating costs relative to oil and electric resistance heating methods (CCHRC, 2013); however, the perspective differs for the electrical utilities. ASHPs can represent either a power load increase or decrease for utilities, depending on whether the heat pump displaces oil or electric resistance heat. The relatively low electricity rates associated with hydropower in many Southeast communities, and the recent rise in fuel oil prices, have resulted in many electric resistance heat and electric boiler installations. One Southeast community, Wrangell, instituted a program in 2006 to incentivize electric resistance heating to provide the community an affordable alternative to heating oil. While popular with utility customers, it has resulted in a strain to the grid and the potential need for Wrangell to purchase additional diesel generation equipment.

This study will investigate several cold climate ASHP models to verify or establish their performance as installed in Alaska communities, delineate regional climatic conditions that would limit year-round ASHP operation, and estimate how much power demand ASHPs can offset by displacing electric resistance heat in residential and commercial buildings. Wrangell will be the specific case study community to test heat pump displacement of electric resistance heat as an energy conservation method for the electric utility.

Cold climate ASHPs are currently at a Technology Readiness Level (TRL) of 8 in Southeast Alaska. While they are commercially available and the ductless systems are widely deployed in the lower 48, there is still uncertainty about the ability of cold climate ASHPs to perform to specifications for efficiency and heat output at low temperatures in Alaska (CCHRC, 2013). Consequently, engineers often specify fully-redundant heating systems in building designs (Alec Mesdag, personal communication) and assessment of the potential for ASHPs to displace electric resistance heating remains speculative. Recent studies have characterized ductless ASHP performance in the lab (Winkler, 2011; Ecotope Inc., 2011) and in Northwest and Northeastern U.S. climatic conditions (Geraghty et al., 2009; Baylon et al., 2012; Swift and Meyer, 2010). These studies have provided valuable information that will be incorporated into this project, however, verification and documentation of ASHP performance in Alaskan climate conditions is anecdotal. Furthermore, air-to-water ASHPs designed for heating in cold climates have not been subject to extensive study. Upon completing the proposed study of cold climate ASHP performance in Alaska, the technology could rise to a TRL of 9.

b. Project Innovation

Cold climate ASHPs provide an energy conservation option for utilities seeking to displace demand associated with electric resistance space heating. Similar demand reduction efforts have been undertaken in the lower 48 states, with estimates ranging from 40% to 70% reduction in electricity demand per household (Geraghty et al., 2009; Swift and Meyer, 2010). The community of Sitka has experimented with a similar program, offering rebates for the replacement of appliances, water heaters and ASHP retrofits for homes with electric resistance heat (Agne, 2013). Wrangell is interested in furthering this idea by reducing electric resistance heating sufficiently to negate the need to buy additional back-up generation. However, this requires sufficient confidence in the technology to ensure that a retrofit initiative would be effective in the long term.

From the perspective of home owners and businesses in Southeast, cold climate ASHPs offer space heating at a fraction of the cost relative to electric resistance and oil heat (CCHRC, 2013). Furthermore, the simplicity of operating and maintaining heat pump systems is attractive, particularly relative to combustion heating technologies by removing complexities and risks from on-site fuel storage and handling.

c. Project Site and Demonstration Environment:

The focus of the project will be the performance characteristics of existing and future ASHPs installations in Southeast Alaska, but research will be conducted across Alaska. The first choice of monitoring locations will be in Wrangell. However, because only approximately ten to twelve ASHP installations are present in Wrangell, monitoring will also occur in communities throughout the Southeast region as necessary to cover different ASHP brands, heat delivery methods, and building types. Additionally, at least two ASHP installations will be monitored in locations with colder climates than the Southeast region: Dillingham (residential) and North Pole (commercial building). These sites will ensure that monitoring will occur at temperatures at and below the specified operational limits of the cold climate ASHPs, and will provide parties outside of Southeast with a field evaluation of heating with an ASHP for meeting partial heat loads or for a fraction of the heating season.

Specific demonstration sites will be in Wrangell public buildings: in City Hall in Wrangell and/or the Municipal Light & Power (ML&P) administrative building. Both are high-traffic areas with ample public interaction. Specifically, the ML&P building is where applicants go for electrical permits, and City Hall receives the public for routine items ranging from paying of utility bills to borough assembly and several commission meetings. Operation, maintenance and site control will be managed by the City of Wrangell.

d. Priority:

This project will be led by CCHRC, a 501(c)(3) non-profit research center based in Fairbanks, in partnership with Wrangell ML&P and Dr. Tom Marsik of the University of Alaska Fairbanks (UAF) Bristol Bay Campus. CCHRC will provide $15,000 in matching grant funds for the project, and Wrangell ML&P will provide $19,840 in matching funds via in-kind services.

Many Southeast communities are interested in the proposed project and the potential for ASHPs as a heating option for residential and commercial buildings:

- The City and Borough of Sitka Electric Department will assist in establishing monitoring locations within their customer base;
- Tlingit-Haida Regional Housing Authority will participate in the monitoring of an air-to-water ASHP at their Saxman senior home;
- Alaska Electric Light & Power Company has expressed interest in the study findings; and
- The Southeast Conference will help coordinate with other communities in the region.

Interest in cold climate ASHP technology extends beyond the Southeast region. Several installations have been documented in Kodiak (CCHRC, 2013). Wisdom & Associates has been experimenting with ASHP systems on the Kenai Peninsula, has noted several installations in the Anchorage area, and now offers classes covering heat pump technology. HVAC, Inc. in North Pole uses ASHPs to heat their offices and shop area in the shoulder seasons, and has volunteered to allow for monitoring on systems.

This proposal addresses the priority of heating efficiency because ASHPs greatly extend the value of electricity relative to resistance heating methods. Furthermore, ASHPs are on par with efficiencies from combustion appliances when evaluated at the source energy level while maintaining low operating costs. Cold climate ASHPs offer building owners the opportunity to provide space heating at high efficiency and low cost while, when displacing electric resistance heating, serve to reduce peak and seasonal demand for electric utilities.

2. Technology Validation and Data Collection

a. Objectives:

The project objectives are as follows:

1. Characterize installed cold climate ASHP performance in Alaskan climate regions.
    a. Determine whether models installed in Alaska climates perform to manufacturer specifications and research findings from other installation locations for efficiency and heat output.
    b. Characterize building owner satisfaction with ASHPs focusing on occupant comfort, maintenance requirements, and perceptions of operation costs by surveying occupant attitudes in buildings retrofitted with ASHPs.
    c. Establish where regional climatic conditions constrain year-round operation due low-temperature limits by system monitoring and surveying building occupants.
2. Quantify how much power and energy demand ASHPs can offset by displacing electric resistance heat as an energy conservation measure.
    a. Determine the effect of replacing electric resistance heat with an ASHP on the peak winter power loads.
    b. Establish the effect on total winter electrical energy demand.
    c. Evaluate whether a program to displace electric resistance heat in Wrangell will be a cost-effective and practical strategy to avoid purchasing additional power generation equipment.

One successful outcome would be Wrangell determining that an ASHP implementation program has the potential to offset 2 MW of winter electricity demand to avoid the purchase of $1 million in diesel generation equipment; this outcome could inform the policies of other utilities. Another successful outcome would be providing sufficient technical information on the performance of cold climate ASHPs in Alaska regional climate zones to guide informed decisions on heating equipment selection for residential and commercial buildings.

b. Data Collection

Data collection will vary by the type of monitoring locations, which will be classified in two categories:

1) **General operational conditions.** Consisting of monthly electrical usage, peak daily power demand, a description of the monitoring location, and a survey to determine occupant satisfaction.
2) **Detailed operational parameters**. Consisting of instantaneous and total heating season efficiency, low-temperature system cut out, heat output as a function of ambient air temperature, monthly electrical usage, a description of the monitoring location, and a survey to determine occupant satisfaction.

CCHRC will target monitoring up to 30 installations for general operational conditions and up to three installations for detailed operational parameters. For all systems, operation and maintenance of the ASHP will be the responsibility of the building owner.

3. Project Schedule and Project Budget

The project will consist of several tasks separated into the following phases:

- **Pre-implementation planning** (Spring - Summer 2014). This phase will consist of reviewing past ASHP studies to guide future monitoring, identification of monitoring locations and site access, development of a data management plan, instrumentation purchasing, and survey development.
- **Monitoring period** (Fall 2014 - Spring 2015). This phase will entail deployment of monitoring systems, refinement of data collection procedures, several monitoring system verifications, and surveying of building occupants. During this phase, the project team will engage several other Southeast electric utilities to learn from the latest results of their regional incentive programs.
- **Data analysis and reporting** (Summer - Fall 2015). This phase will include analysis of data from ASHP monitoring and survey results. This analysis will be detailed in a report that will document the study methodology, compare results to prior research results, and state how the findings influenced Wrangell's decisions on energy conservation measures.

The project budget summarized below includes costs for the applicant and project partners, including equipment and instrumentation associated with heat pump performance monitoring.

Project phase	EETF Grant Funds	Matching Funds	Totals
Pre-implementation	$32,361.80	$12,480.00	$44,841.80
Monitoring	$12,602.53	$10,220.00	$22,822.53
Data analysis and reporting	$27,387.12	$12,140.00	$39,527.12
Totals	**$72,351.44**	**$34,840.00**	**$107,191.44**

4. **Project Team Qualifications**

Vanessa Stevens, MS, will have overall responsibility for the project. She will be responsible for creating a monitoring plan and data standards, installing monitoring equipment in locations not covered by project partners, and reporting. Ms. Stevens has technical experience from several past energy monitoring projects. She has served as project manager for several projects, including the recent project assessing the current state of ASHP technology for cold climates (CCHRC, 2013).

Robbin Garber-Slaght, PE, will assist with instrumentation for ASHP monitoring, data management plan development, and will provide technical support as needed. Colin Craven will assist with coordination amongst project partners, reviews of prior research findings, analysis of monitoring data, and project reporting.

Clay Hammer is the Electrical Superintendent for the City and Borough of Wrangell and is in charge of all electrical inspections as well as approving all new electric work done within the borough. Mr. Hammer will be responsible for hosting the primary technology demonstrate site in Wrangell and for developing the future direction of Wrangell ML&P's energy conservation initiatives.

Dr. Tom Marsik will assist in the development of instrumentation for monitoring ASHP systems and hosting one of installations for detailed monitoring in Dillingham. He has expertise in heat pump technology and monitoring of mechanical systems. Dr. Marsik earned his PhD in engineering from the University of Alaska Fairbanks (UAF), and is currently an assistant professor of sustainable energy at UAF Bristol Bay's Campus where he leads the Sustainable Energy program.

5. Discussion of Commercialization of Funded Technology

ASHPs are a well-established technology in moderate climates, where they are used for both heating and cooling. Recently, several manufacturers, such as Mitsubishi, Fujitsu, and Daikin, have begun offering cold climate models of ASHPs that are capable of proving space heating at sub-zero temperatures. The proposed project will assist the commercialization of these cold climate ASHPs in Alaska by rigorously documenting their performance and limitations in several climate regions, thus providing confidence in the technology to utilities, designers, home owners, businesses, facility managers.

The available market for cold climate ASHPs is broad in Southeast Alaska. Because ductless ASHPs provide modular capacity for interior zones and outdoor units for heat output expansion, they can scale from single-zone residential buildings to large commercial buildings. Additionally, air-to-water ASHPs provide low-temperature hydronic space heating and hot water service for buildings. Market potential also exists for cold climate ASHPs in colder regions of Alaska where they can provide heating in shoulder seasons in addition to cooling during the summer. This option has been implemented as far north as the Fairbanks vicinity, where ductless ASHPs provide heat in the fall, early winter and spring for a commercial building in North Pole.

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.

9/5/13