



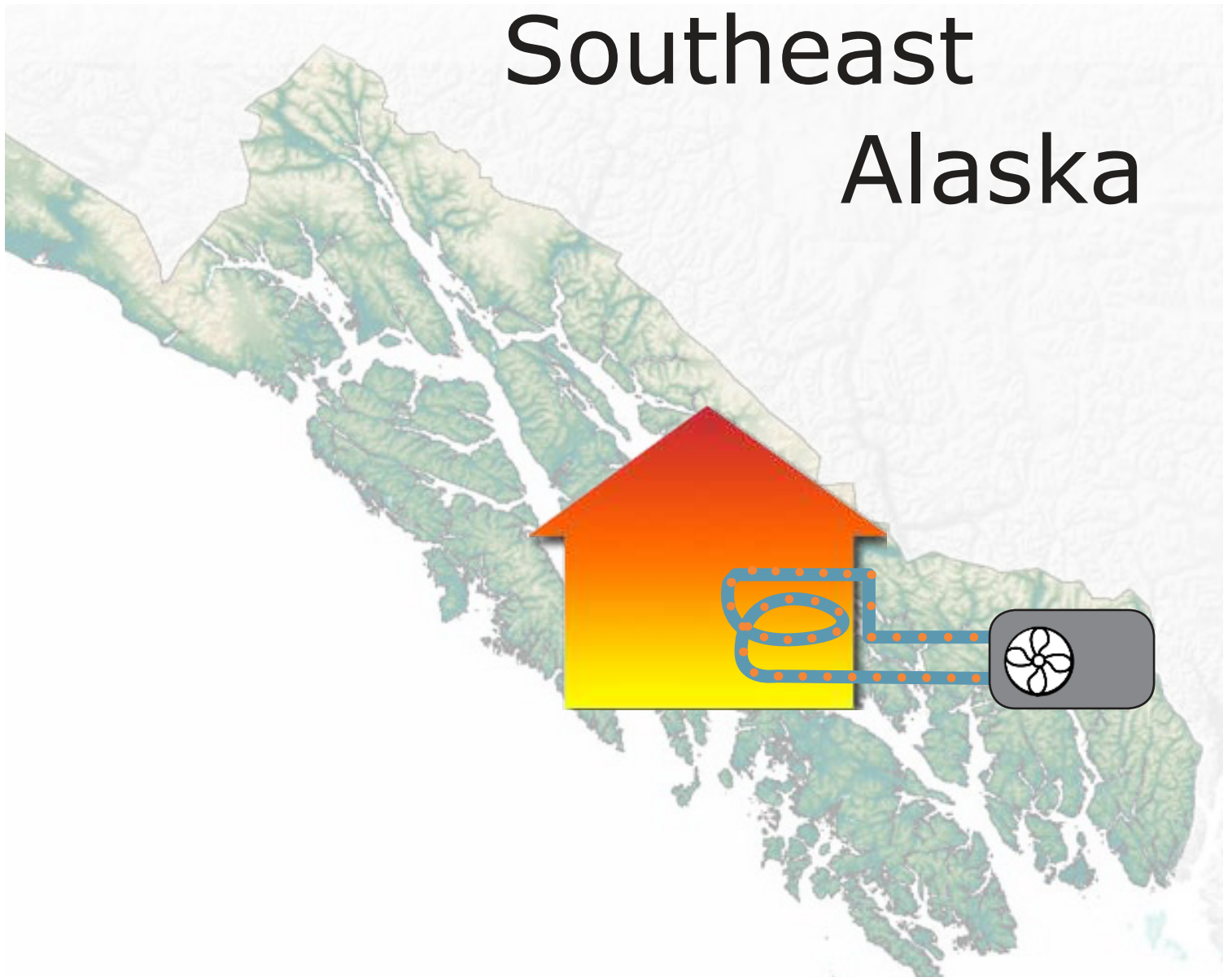
COLD CLIMATE HOUSING RESEARCH CENTER

CCHRC

Air Source Heat Pumps

in

Southeast Alaska





Air Source Heat Pumps in Southeast Alaska:

A review of the literature, a market assessment, and preliminary modeling on residential air source heat pumps in Southeast Alaska

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Disclaimer

This technology assessment provides a picture of the current use of air source heat pumps in Southeast Alaska. As such, brands and heating contractors appear in the report for informational purposes. Product and company names herein do not constitute an endorsement. Also, heating appliance selection is highly individualized to a specific building. Homeowners should speak to a contractor before choosing a heating appliance.



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List of Acronyms

AEL&P	Alaska Electric Light and Power
AFUE	Annual Fuel Utilization Efficiency
AHFC	Alaska Housing Finance Corporation
ARIS	Alaska Retrofit Information System
ASHP	Air Source Heat Pump
BEES	Building Energy Efficiency Standards
BTU	British Thermal Unit
CBS	City and Borough of Sitka
CFM	Cubic Feet per Minute
COMM	Communications
COP	Coefficient of Performance
DHP	Ductless Heat Pump
DHW	Domestic Hot Water
EER	Energy Efficiency Ratio
EF	Energy Factor
GHG	Greenhouse Gas
GSHP	Ground Source Heat Pump
HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilation, and Air-Conditioning
kWh	Kilowatt-hour
SEER	Seasonal Energy Efficiency Ratio
THRHA	Tlingit-Haida Regional Housing Authority
W	Watt



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Motivation

There has been an increase in installations of air source heat pumps (ASHPs) in Southeast Alaska over the past few years. Recent advances in technology have resulted in heat pump models that are capable of producing heat efficiently in temperatures below freezing. The milder climate of Southeast Alaska and access to affordable hydroelectricity in parts of the region has created a favorable environment for ASHP use in some communities. There are currently over 100 operating ASHPs in the region. However, there is still uncertainty about their efficiency and energy use in colder climates, and of the long-term impact on electrical utility providers.

In a larger context, fossil fuel prices are predicted to rise over time (United States Energy Information Administration, 2012). Rising energy costs provide motivation for builders, homeowners, and policy-makers to find methods of space heating that are affordable now and into the future. In Southeast Alaska, residents currently have several options for reducing the use of fossil fuels in space heating, including building and retrofitting homes to be more energy efficient and using biomass and heat pump heating appliances. This report provides information on the current use of ASHPs in Southeast Alaska without endorsing or critiquing their use in the larger context of the search for affordable energy in Southeast Alaska.

This technology assessment aims to provide policy makers, design and construction professionals, and utility operators with a baseline understanding of ASHPs, their current use in Southeast Alaska, and their potential as a space heating option for the warmer regions of Alaska. The goal is help readers better understand regional energy use and policy. While homeowners are not the intended audience, they may find the report useful for learning about ASHP technology, where ASHPs are being used, and people's experiences with them. However, it is important for anyone considering installing an ASHP to talk to a contractor about whether this technology is a good fit for their home.

This report includes four main sections, beginning with Section 1: *Air Source Heat Pump Primer* on how ASHPs work, how their performance is measured, and their advantages and disadvantages. Section 2, the *Review of Literature Research*, explores the history of ASHPs in cold climates, recent advances in technology to adapt ASHPs to cold climates, past performance studies, and current research. A survey of select ASHP products available in domestic and European markets, installers of ASHPs in Alaska, and the perspective of power utilities in regions where ASHPs are being implemented are discussed in Section 3: *Southeast Alaska Market Assessment*. The modeling research part of this technology assessment is covered in Section 4: *RETScreen and AkWarm Modeling*. Findings and research recommendations for the future are found in the *Conclusion*, which is followed by appendices for readers interested in more information.



1. Air Source Heat Pump Primer

An air source heat pump (ASHP) is a space-conditioning appliance that can provide both heating and cooling, although models exist that only provide one or the other. In heating mode, the heat pump uses electricity to extract heat from the outside air and transfers it to the home's interior. While it may seem counterintuitive that a winter atmosphere can provide heat, the outdoor air does indeed contain heat. An ASHP uses a refrigeration cycle to “step up” the heat to a temperature suitable for space heating. In cooling mode, the heat pump works like a refrigerator, removing heat from the interior of a house and moving it outside.

1.1 How it works

An air source heat pump moves heat by way of a refrigeration cycle. Heat is transferred by the refrigerant, or the fluid that moves through the refrigeration cycle. In heating mode, the refrigerant gains heat from the outdoor air as it travels through heat exchanger coils located in the outside unit. These coils are collectively called the “evaporator” because the outdoor heat causes the refrigerant to evaporate into a gas. This gas then goes to a compressor, which uses electricity to raise the temperature of the refrigerant gas until it is suitable for space heating. The gas then passes into a set of indoor heat exchanger coils (also referred to as “the condenser”) where it condenses into a liquid, releasing heat. In an air-to-air ducted heat pump, such as shown in Figure 1, a fan is used to move the heat into the room. Finally, the liquid refrigerant moves into an expansion valve, which lowers its pressure, and begins the cycle again.

ASHPs use electricity to provide power to pumps, fans, and the compressor. Because heat pumps are not converting electricity to heat, but rather using it to run a refrigeration cycle to transfer heat, ASHPs can reach efficiencies of over 100%. Basically, this means that occupants of a home receive more heat than is contained in the electricity delivered to the ASHP. The current draw of an ASHP depends on the model, but they use about the same amount of current as a refrigerator: smaller systems typically draw less than 10 amps of current, while larger systems may draw up to 20 amps.

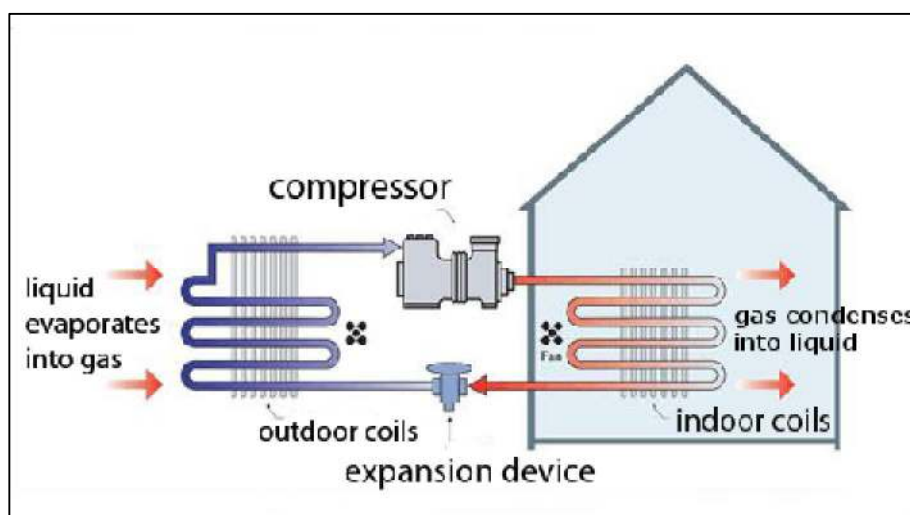


Figure 1: An ASHP refrigeration cycle in heating mode. The refrigerant transfers heat from the outdoor air into a house as it passes through a refrigeration cycle. Image courtesy of (RETScreen, 2012).



There are a few types of ASHPs on the market that use different methods for distributing heat from the ASHP throughout the home.



Figure 2: The outdoor coils for this ASHP, at HVAC, Inc. in North Pole, are contained in an outdoor unit located next to the building.

First, **in a traditional ducted ASHP system**, the heat from the refrigeration cycle is used to heat air for distribution in a forced air, or ducted, distribution system. This type of system is commonly seen in houses that use ASHPs for heating and cooling. Typically the outdoor coils and compressor are located outside the home (Figure 2), and the blower, or fan, that distributes the conditioned air throughout the house is located inside (see Figure 3).



Figure 3: This photo shows an air duct attached to the ceiling. The duct carries heated air above the door of a mechanical room and delivers it to rooms in the house.



A **mini-split ductless system**, or ductless heat pump (DHP), on the other hand, has one set of outdoor coils with piping to one or more heat exchanger coils inside. This type of system has recently gained popularity. Inside the house, each set of coils has its own small fan to provide heat to the area around it. The indoor coils and fan are packaged in a small wall-mounted unit, seen in Figure 4. One outdoor unit may provide refrigerant to several indoor units. Instead of ducts carrying heated air throughout a house, pipes connect the indoor and outdoor coils in these systems.



Figure 4: Two indoor units of a mini-split ductless heat pump system appear in two rooms of a building. The indoor units have a fan that blows air over coils containing heated refrigerant and into the room.

A third type of air source heat pump, called a **ventilation combination system**, gathers heat from the stale air being vented out of a building through a ventilation system instead of from the outdoor air. This type of heat pump, which is popular in Europe, typically has both the evaporator and the condenser located indoors, in conjunction with the ventilation system.

Finally, there are **air-to-water heat pumps**. In the three types of heat pumps discussed above, the heat pump gathers heat from outdoor or ventilation air, and transfers it to air that will be distributed through a house using ducts and/or fans. An air-to-water ASHP still gathers heat from the atmosphere, but then it is transferred to a liquid, commonly water. This type of heat pump can provide heated water for a hydronic distribution system such as baseboards, radiators, or a radiant floor. Also, an air-to-water heat pump can heat a tank of water for domestic use in showers and water faucets.



The types of ASHPs are summarized in Table 1:

Table 1: This table contains descriptions of four types of air source heat pumps.

System Names	Characteristics
Ducted system Packaged system	In a ducted system, a central indoor air-handling unit is used to provide heated air to a forced air distribution system. The heated air travels through ducts to each room of the house.
Mini-split ductless system Ductless heat pump DHP	In a DHP, one set of outdoor coils is connected by pipes to multiple condensing indoor units. In the indoor units, a fan transfers the heat from the indoor coils to the surrounding room.
Ventilation combination	A ventilation combination system combines the air source heat pump with a house ventilation system. The heat pump gathers heat from outgoing, stale air and uses it to heat a home.
Air-to-water	Air-to-water heat pumps gather heat from the outdoor air and transfer it to a liquid. They can be used with a hydronic distribution system or to heat a tank of water.

1.2 Performance measurements

There are several different metrics to measure the efficiency of an ASHP. The efficiency is the ratio of the quantity of heating or cooling delivered to a room divided by the energy (in the form of electricity) used by the heat pump.

$$\text{Heat Pump Efficiency} = \frac{\text{Quantity of heating or cooling delivered}}{\text{Electricity required by the heat pump}}$$

Typically space heating appliances have an efficiency of less than 100%. In fact, combustion appliances such as furnaces and boilers cannot attain a heating efficiency of 100% because some heat is inevitably lost “up the chimney.” A highly efficient combustion furnace or boiler might have a seasonal efficiency of 90%. Electric baseboards, furnaces, and boilers have an efficiency of exactly 100% because all of the electricity used by the appliance is converted into heat. Heat pumps, on the other hand, typically have efficiencies of over 100% because the heat energy delivered to the building is more than the energy required to run the heat pump.

Heating efficiency is indicated by the heating season performance factor (HSPF) and the coefficient of performance (COP). The HSPF is the ratio of the total space heating provided to the total electrical energy consumed by the heat pump during a heating season. The space heating is measured in British Thermal Units (BTU) and the electrical energy is measured in Watt-hours. An efficient heat pump has an HSPF of 8-10; an HSPF of at least 7 is needed to qualify for the ENERGY STAR label (United States DOE, 2012).

$$\text{HSPF} = \frac{\text{Total space heating provided by the ASHP in a heating season in BTU}}{\text{Total electrical energy consumed by the ASHP in a heating season in Watt \cdot hours}}$$



The COP is similar to the HSPF but uses different units and can be measured over shorter time periods. It is also the ratio of heat delivered to the electrical energy required. However, to calculate the COP, the electrical energy is converted into BTUs.

$$COP = \frac{\text{Space heating provided in BTU}}{\text{Electrical energy used in BTU}}$$

Since both the numerator and denominator of the COP are measured in the same unit, it can be thought of as efficiency, with a COP of 1 corresponding to an efficiency of 100%. So an ASHP with a COP of 2.5 has an efficiency of 250% - or the heat pump is using 1 unit of electricity to provide 2.5 units of heat energy to the home.

The COP can also be calculated over shorter periods of time than a heating season, or an instantaneous COP value can be found by using units of BTU/hr for components. Daily COP values can provide information on the fluctuation of the efficiency with respect to the outdoor temperature. The seasonal COP is the same as the HSPF, except for the difference in units. In fact, the seasonal COP can be calculated from the HSPF, by dividing by the conversion factor between BTU and Watt-hours.

$$\text{Seasonal COP} = \frac{\text{HSPF}}{3.413 \text{ BTU/Watt} \cdot \text{hours}}$$

Using this formula, the Energy Star criteria of HSPF of 7 can be converted to a seasonal COP of 2.05, which corresponds to an efficiency of 205% over a heating season.

Cooling efficiency is indicated by the energy efficiency ratio (EER) and the seasonal energy efficiency ratio (SEER). The EER is the ratio of the heat removed to the electrical power used to remove the heat.

$$EER = \frac{\text{Heat removed in BTU/hr}}{\text{Electrical energy used in W}}$$

For the EER, the heat removed is measured in BTU/hour and the electrical energy is measured in watts. The SEER is simply the EER calculated over the cooling season: so the ratio of the heat removed during the cooling season to the total electrical energy used. The units for SEER are thus the same as for the HSPF: the heat removed is measured in BTUs, and the electrical energy is measured in Watt-hours. Efficient ASHPs will have a SEER of between 14 and 18 (United States DOE, 2012).

It is also important to note that this section addresses appliance efficiency specifically, not the overall efficiency of heating with an ASHP. The COP, HSPF, EER, and SEER refer to “site” efficiency, or the efficiency of creating heat from electricity at the residence where the ASHP is located. Electricity comes from an “upstream” source and may or may not be created efficiently or with low carbon emissions. Thus, it is important to remember that site efficiency does not account for losses that occur at the power plant or during transmission.



1.3 Advantages and disadvantages of ASHPs

Like with any heating appliance, there are pros and cons of using an ASHP. One advantage of ASHPs is that they provide both heating and cooling. Even in colder climates with few cooling degree days, there are many situations where cooling may be desired, such as in an office environment or computer server room where the electronic equipment creates a lot of heat. For residences or commercial buildings that need cooling, the fact that one appliance can provide both is appealing in that there are only installation and maintenance costs for one appliance, instead of two. Furthermore, certain models of ASHPs can provide heating and cooling simultaneously, in effect transferring heat from the warmer area (perhaps a server room in an office building or a south-facing room with several windows letting in sunlight) to a colder zone in the building.

The cost of operating an ASHP could be an advantage or disadvantage depending on the local cost of fuel and electricity. ASHPs do not create heat by burning fuels; they use electricity to transfer heat from one place to another. They use less electricity than heating appliances that use electric resistance to generate heat, such as an electric furnace or electric baseboards. In regions with low electrical costs, the higher efficiency of an ASHP makes it an attractive choice over electric furnaces and baseboards. However, in regions with relatively high costs for electricity, operating an ASHP can be prohibitively expensive.

The maintenance requirements for ASHPs are relatively low in comparison to combustion heating appliances. Filters on ASHPs should be cleaned every few months, and a yearly maintenance check-up is typically recommended to check connections and adjust the control system (Northwest Ductless Heat Pump Project, 2013).

A region's form of electricity generation also determines the environmental impact of ASHPs. Regions with hydropower or other low emission sources result in ASHPs with very low carbon emissions. However, in regions that use fossil fuels to produce electricity, the ASHP will have a bigger carbon footprint. It is difficult to assess the environmental impact of greenhouse gas emissions relative to on-site fuel use and it varies widely by region.

A disadvantage of ASHPs is that they become less efficient at providing space heating as the outside temperature drops. For example, Figure 5 shows how the COP and heating capacity of a Mitsubishi heat pump decline as the outdoor temperature falls. While some ASHPs are designed specifically for colder climates (many are discussed in this report), potential ASHP users must decide which model to choose for their design temperature, as different models are rated for peak heat output at different temperatures. Below a certain outside temperature ASHPs simply do not work and some form of backup heating is needed. Most of the cold regions of Alaska are not a good candidate for ASHPs as the technology stands today.

Also, most systems currently available have a declining heat output rate as the outside temperatures decrease, as Figure 5 shows. At a certain cutoff temperature, all ASHPs will decline in efficiency and eventually shut off. Therefore in colder regions, it is advised to have a backup heating system for days when the ASHP model is operating at lower efficiencies or is incapable of meeting the heat load. This adds the additional cost of having to maintain a second heating system, and also poses the problem of how to implement a control system to manage the interaction between the appliances (for example, at what temperature one appliance turns on and the other turns off).

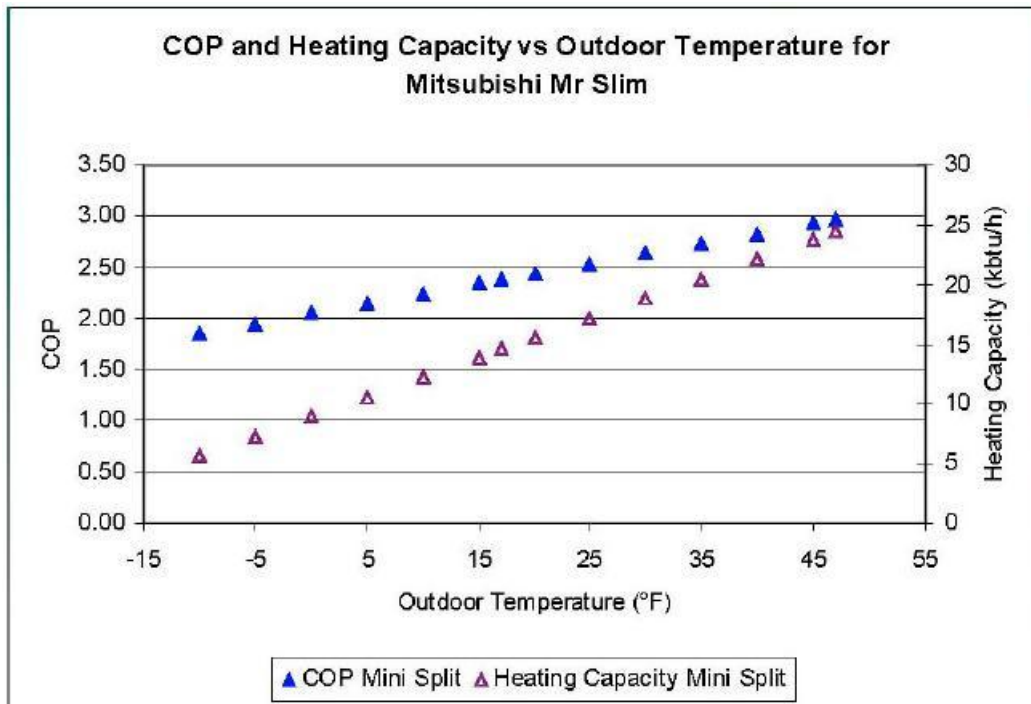


Figure 5: This graphic shows how the efficiency and heating capacity of one ASHP model follow the outdoor temperature. As the outdoor temperature decreases, the ASHP produces less heat at lower efficiency. For this reason, it is important to evaluate whether an ASHP can work throughout the winter in a given location. Reprinted from (Caneta Research Inc., 2010).



Figure 6: These two photos show the outdoor coils of a Fujitsu 12LRS heat pump. The photo on the left shows the coils just before defrost operation and the photo on the right shows the coils just after the defrost operation. Photos by Howard Cheung of Herrick Labs. Reprinted from Winkler, 2011.

An additional consideration in colder, more humid climates is that snow should be kept off the outdoor unit so air flow is not blocked and the unit does not frost up (requiring the heat pump to employ a defrost cycle, where the refrigeration cycle is reversed to melt the ice on the outdoor coils as in Figure 6). If homeowners do not want to clear snow off the unit, it can be installed with a protective roof or in a small shed with slats to allow air



flow. While humidity will not necessarily affect the instantaneous efficiency of the unit, high humidity and snow will cause frost to build up more quickly, and defrost cycles lower the seasonal efficiency.

Certain models of ASHPs, called mini-split ductless systems, are advantageous for homeowners looking to retrofit a heating appliance. These ASHPs do not require a ducted distribution system, because one or more small interior wall units (connected to one outdoor unit) can be placed throughout the home to distribute heat. However, it is important to have space to install the outdoor unit, preferably in an area where it will not become covered in snow.



2. Review of Research Literature

Air source heat pumps are used primarily in warm climates to provide cooling using a refrigeration cycle. The cycle can be reversed in the winter to provide heating as long as the outside temperatures do not get too cold. In general, colder climates in the U.S. do not use ASHPs to provide space heating because most systems are not designed to keep up with the heating demand at colder outside temperatures. However, there are a few ASHPs that can provide the necessary heating for colder climates, and technology is improving. The existing literature is broken into three broad categories: general overviews of heat pumps in cold climates, field studies, and technical prototype studies.

2.1 Heat pumps in cold climates

Bertsch, et al. laid out the four main problems that ASHPs encounter at low ambient temperatures (Bertsch, Groll, Bouffard, & Hutzler, 2005):

- There is insufficient heat output when it is needed the most;
- High compressor discharge temperature at low ambient temperature can cause the compressor to overheat, leading manufacturers to turn off the compressor at a certain temperature and rely on electric resistance heat;
- The COP decreases at low ambient temperatures;
- An ASHP designed for lower temperatures will be less efficient at higher temperatures because they cycle on and off.

Roth et al. reported on the state of ASHP technology for cold climates (2009). They summarize the recent technological advances for cold climate heat pumps:

- Sizing the heat pump for the heating load, not the cooling load, as is done in most of the U.S.;
- Variable speed compressors or the use of multiple compressors;
- Increased outdoor coil capacity;
- Using carbon dioxide as the refrigerant;
- The use of mechanical liquid subcooling in the refrigerant cycle. Mechanical subcooling refers to the cooling of the refrigerant below its condensing temperature so that only liquid refrigerant enters the expansion device;
- Optimization of the indoor and outdoor coils.

In 2009 there were two major cold climate ASHPs on the market: the Acadia and the Nyle. They both relied on two compressors operating in series to increase the cold weather performance of the system. Additionally, they relied on the use of an economizer. The units could achieve a COP of 2 at 0°F air temperature (or 200%



efficiency). When compared to gas furnaces at varying AFUE (80%-90%) the cold climate ASHP saved 19%-38% in heating costs in Chicago, New York, and Minneapolis (Roth, Dieckmann, & Brodrick, 2009). Neither ASHP in the study is in production at the time of writing, however the technology is now better understood.

There have been several studies recently commissioned by governmental organizations. The Energy Solutions Centre in Yukon completed a study reviewing new technology that could potentially make ASHP feasible in the Yukon climate (Caneta Research Inc., 2010). The study recommends a COP of at least 2 at 0°F for the Yukon and points out that the Acadia, York YZH, and Mitsubishi mini-split heat pumps all meet this criterion.

The Minnesota Division of Energy Resources also commissioned a study of ASHPs, but looked at the use of a heat pump in conjunction with supplemental electric heating. They found that going from all electric heat to an ASHP/electric hybrid system was efficient, but that temperatures below 30°F require supplemental electric heat (Franklin Energy, 2011).

The overview studies suggest a few strategies for heat pump design and installation that would benefit cold climates. Number one is to size the ASHP for the heating load rather than the cooling load, unlike most ASHP installations. This can pose a problem with short cycling at moderate loads, but that can be mitigated by using modulating or multiple compressors.

2.2 Field tests

Monitoring installed ASHPs for efficiency in-situ has been common practice since 1979. A study in Juneau that started in 1979 (Alaska Electric Light & Power Company and Ketchikan Public Utilities, 1982) monitored eight installations in Juneau and 15 installations in Ketchikan and found that ASHPs are feasible in both communities. The yearly average COP for the Ketchikan and Juneau installations was 2.05. There was some anecdotal evidence on problems with the defrost cycle on these early installations, as the units iced up and the defrost sensors had to be relocated.

A similar 1981 study in a research house in Ottawa, Canada found that an ASHP could provide 30%-40% of the heating demand of a well-insulated house (by 1980 standards). The unit had a demand defrost system that researchers found to be more efficient than a simple timed system and ideal for the “Canadian climatic conditions” (Cane, 1981).

2.2.1 Acadia studies

There are quite a few studies on the Hallowell Acadia model, also known as the Nyle Cold Climate HP (first version), and the Hallowell All Climate HP (newest version). The Acadia was designed to work more efficiently in cold weather and to perform to temperatures down to -15°F. Between 2006 and 2011 there were several monitoring field tests of the Acadia ASHP on behalf of governmental organizations and electric utilities. In general the Acadia ASHP performed well, achieving seasonal COP of 2.08 to 3.22 in a variety of colder locations across the Lower 48 (Johnson, 2010 & Johnson Research LLC., 2009). However, some studies found that the Acadia did not live up to its advertised COP (Hadley, Callanhan, & Stroh, 2006 & EnergyIdeas Clearinghouse, 2007).



The Acadia systems were installed as two units, an outdoor heat pump unit with refrigerant lines running to an inside air handler unit. The outside heat pump has four modes of operation that are engaged based on the outside temperature.

- At temperatures above 40°F the primary compressor operates on one cylinder;
- Below 40°F the second cylinder on the primary compressor runs;
- Around 20°F the booster compressor starts running;
- If the heat load of the house is not satisfied by the two compressors, an electric resistance heat system within the heat pump can provide auxiliary heat to the compressor output.

The Acadia uses a demand-driven defrost cycle. When it measures that performance has dropped it reverses the refrigerant cycle to defrost the coils and supplies electric heat to the house. The defrost cycle lowers the efficiency, however only lasts for a short time and uses minimal electricity. For example, 10 defrost cycles in one 24-hour period in a Connecticut field test took 27 minutes and used 2.7 kWh out of the 91 kWh used by the ASHP on that day (Johnson, 2010). The Nyle Cold Climate heat pump ran defrost mode about 7% of the compressor runtime (Hadley, Callanhan, & Stroh, 2006).

The Acadia systems were well studied between 2006 and 2011. Unfortunately, many of the installed Hallowell Acadia systems had mechanical problems such as compressor failures and refrigerant leakage in the air handling units, among others. The Hallowell Company went out of business in May 2011 (Russell, 2011). To date no one is manufacturing ASHPs based on the Acadia technology.

2.2.2 Mini-split or ductless heat pump studies

Mini-split or ductless heat pumps (DHPs) are used extensively in Asia and Europe and are quickly being adopted in the United States. DHPs house the compressor and outdoor coils in a unit outside, which is connected to an indoor air handler by a pair of refrigerant lines and a control wire from the outdoor unit. Instead of ducting warm air from the heat pump around the house, the heated refrigerant vapor is piped to separate ductless air handlers distributed throughout the house. The indoor units condense the vapor refrigerant, release its heat to the surrounding room, and then return the cooler liquid refrigerant to the outdoor unit.

The Bonneville Power Authority has been studying these units in residential installations in Oregon and Washington. Its initial study of 13 homes found a 40% reduction in energy use (Baylon, Geraghty, & Bedney, 2010). A separate study by the Connecticut Light and Power Company found similar savings of 43% in 96 homes in Connecticut (Swift & Meyer, 2010). Similar results were found in another Connecticut Light and Power Company study that monitored the energy use of a DHP and electric baseboard heat in a central Connecticut apartment. That study found that a DHP has the capability of saving up to 70% on energy costs when compared to electric baseboard heat (Bugbee & Swift, 2013).



Several lab tests of the DHP found that their output is temperature dependent. At 20°F outdoor air temperature, the units can provide from 10,000 to 17,000 Btu/hr at a COP of 2.5 to 3. An NREL study confirmed that the Mitsubishi and Fujitsu performed at manufacturer-stated specifications (Winkler, 2011).

2.3 Technical prototype studies

Technical improvements for the operation of ASHPs at colder temperatures continue to be developed and prototyped. A few of the technical studies that were successful at raising COP at lower temperatures are outlined below, however it is difficult to tell whether these improvements have been implemented in commercially available AHSPs.

Bertsch et al. offer several concepts for ASHPs that are well suited for colder climates. The list includes pros and cons of each system (2005):

1. Specially designed single-stage heat pumps can perform at lower temperatures but have lower COPs;
2. A two-stage heat pump with an intercooler needs measures to control temperatures at the compressor discharge, and oil movement between the compressors is critical;
3. A two-stage heat pump with an economizer (a device which controls the amount of refrigerant that enters the compressor) is a very flexible system, but is more expensive, still has oil management issues, and the defrost cycle is challenging;
4. A cascade cycle using two refrigerants is a possibility but is in need of further study;
5. Injecting an intermediate pressure refrigerant into a single-stage compressor has been studied and works well in application;
6. Cooling the oil in the compressor increases the efficiency of the compressor;
7. Mechanical subcooling of the refrigerant in a first-stage smaller cycle increases the evaporator temperature of the second cycle.

Several Chinese studies dating back to 2003 have looked at the use of a bypass refrigeration cycle that mixes high-pressure refrigerant with the regular cycle at the compressor inlet (via an economizer). The bypass cycle studies have been able to supply heat down to temperatures of -13°F (-25°C) with a COP of 1.6 (Ding, Chai, Ma, & Jiang, 2004).

Studies have found that the use of scroll compressors is more efficient than the reciprocating compressors for ASHPs (Ma & Chai, 2004). Additionally, variable speed compressors increase COP at lower temperatures over the single-stage compressors. Tian et al. (2006) were able to achieve a COP of 2 at -22°F (-30°C). These technological advances have been informing manufacturing and research. A 2008 study combined a two-stage cascading cycle with the bypass economizer loop. The prototype unit was able to achieve a COP of 2.3 at -22°F (-30°C) (Bertsch & Groll, 2008).



Other research has focused on the frosting problems of the outside units. A novel study in 2011 used a solution to extract heat from the environment and then heat the evaporator. This solution (not specified in the article) circulates around the evaporator, keeping it warm enough to prevent condensation. In this configuration frost does not develop on the evaporator and there is no need to reverse the cycle for defrost (Yongcun, Guangming, Liming, & Lihua, 2011).



3. Southeast Alaska Market Assessment

In recent years, ASHPs have been installed in areas of Alaska with relatively mild climates, especially the Southeast region. Figure 7 contains information on the number of installed ASHPs in Alaska, based on interviews with ASHP installers, homeowners, and electric utilities. Several factors have contributed to the growth in popularity of ASHPs, however, there are still uncertainties about their future applications.

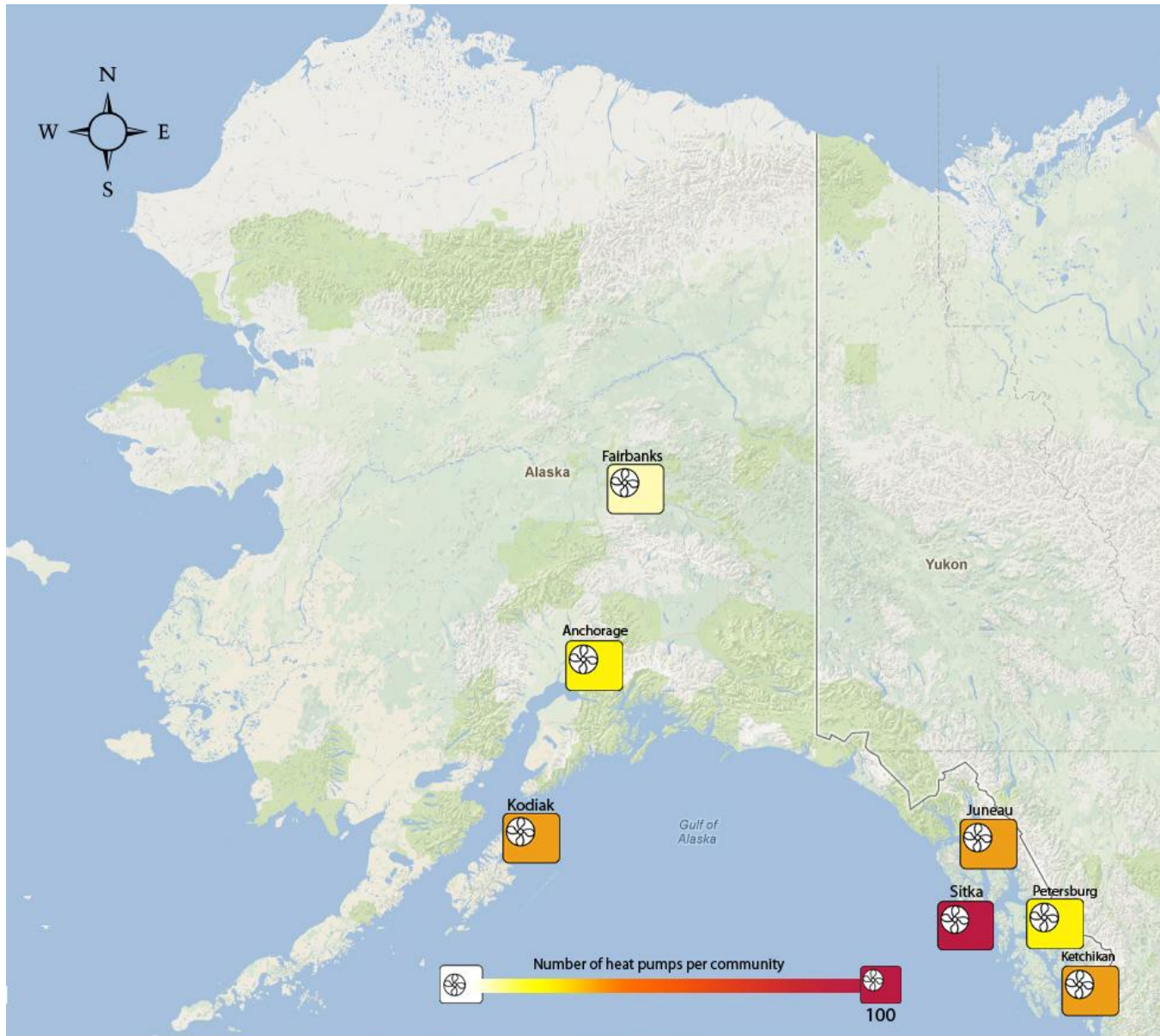


Figure 7: Current Alaska ASHP installations. ASHPs are becoming more common in Southeast communities with access to hydropower. Table 9 in Section 3.4 Inventory contains more detailed information on ASHP installations in Alaska.

3.1 Space heating in Southeast Alaska

ASHPs have been used in Southeast Alaska for decades. In fact, the Alaska Electric, Light, and Power Company (AEL&P) in Juneau commissioned a study in 1979 to examine their efficiency (Alaska Electric Light & Power



Company and Ketchikan Public Utilities, 1982). This study found that ASHPs were feasible in the region, but there was anecdotal evidence of problems with the defrost cycle on the units. These problems caused enthusiasm to wane for ASHPs. Since then, ASHPs were used sparingly in Southeast Alaska until recently. In the past few years, several installers throughout the region have reported increased interest in ASHPs and there are currently more than 100 installations in the region.

For a sampling of other heating systems in the region, researchers accessed regional data in the Alaska Retrofit Information System (ARIS). While this data is limited to homes that have had energy ratings, the 5,358 ratings found in ARIS for Southeast Alaska provided a sample of homes in the region to examine heating systems that are being used. For more information about the data used in this report, please see Appendix D.

Of the 5,358 ratings for Southeast Alaska, 4,693 were in communities with ASHP installations or interest in ASHPs: Juneau (including Douglas and Auke Bay), Ketchikan, Petersburg, Sitka, and Wrangell. The percentage of houses using each fuel type for the primary heating appliance is listed in Table 2 (the ARIS numbers are in Appendix D). In the five communities examined, fuel oil is the predominant fuel type, followed by electric resistance heat.

Table 2: Primary heating appliance fuel type. In some instances the percentages do not add up to 100% due to rounding.

	Fuel Oil	Electric Resistance	Wood	Electric (Heat Pump)	Gas
Juneau	87%	9%	2%	--	2%
Ketchikan	82%	8%	5%	--	4%
Petersburg	80%	16%	3%	--	--
Sitka	70%	20%	6%	3%	1%
Wrangell	62%	26%	7%	--	4%
Total	83%	11%	3%	1%	2%

Many homes in these communities also have secondary heating appliances. With the exception of Ketchikan, around half of the homes that had energy ratings had a backup heating appliance (see Table 3).

Table 3: Homes with secondary heating appliances of any fuel type in Southeast Alaska

Homes with secondary heating appliances	
Juneau	48%
Ketchikan	19%
Petersburg	59%
Sitka	52%
Wrangell	51%

Secondary heating appliances used a variety of fuel types (see Table 4). While wood secondary appliances were the most common, a third of the secondary appliances used electric resistance heat.



Table 4: Secondary heating appliance fuel type. In some instances the percentages do not add up to 100% due to rounding.

	Fuel Oil	Electric Resistance	Wood	Gas
Juneau	18%	33%	45%	4%
Ketchikan	20%	31%	44%	6%
Petersburg	15%	49%	31%	4%
Sitka	36%	40%	21%	2%
Wrangell	26%	19%	51%	3%
Total	20%	34%	41%	4%

3.2 Conditions for success

ASHPs are appropriate for consideration in Southeast Alaska because of recent improvements in technology, favorable climatic conditions, and relatively inexpensive electricity. Newer models of ASHPs are now capable of producing heat at temperatures below freezing. Additionally, more efficient, airtight homes have smaller heating loads that can be met with an ASHP and a back-up heating appliance for the coldest days of winter.

3.2.1 Climate

The climate in Southeast Alaska is milder than the rest of the state, with minimum temperatures that rarely drop below 0°F. Table 5 lists climate data for several towns in Southeast, with Anchorage included for a reference point. Kodiak and Homer are not in Southeast Alaska, but are included in the table because there are installed ASHPs in Kodiak, and a planned installation in Homer.

Table 5: Climate data for locations in Alaska with reports of installed ASHPs or planned installations of ASHPs (Alaska Climate Research Center, 2010). Newer cold-climate ASHP models can work at temperatures below freezing.

Location	Average annual air temperature (°F)	Annual Heating Degree Days (65°F base)	Average January minimum temperature (°F)	Average annual days with minimum temperature below 0°F
Anchorage	36.2	10470	9.3	36
Juneau	41.5	8574	20.7	6
Ketchikan	45.2	7155	28.8	0
Petersburg	42.6	8176	23.8	3
Sitka	45.0	7223	30.7	0
Wrangell	43.9	7706	25.1	1
Homer	38.1	9821	17.5	10
Kodiak	40.5	8862	24.6	1

These climate conditions are within the capabilities of DHPs designed specifically for cold climates (see Section 3.3: Technology Assessment for more details). Also, they are comparable to the climate of many places such as the northeast and northwest areas of the contiguous United States where field tests have documented installed



system performance, as discussed in Section 2.2.2. For example, Baylon et al. (2010) monitored DHPs in Washington (Moses Lake and the Seattle vicinity) and Oregon (near Portland). Similarly, Swift and Meyer (2010) present monitoring data from various locations in Connecticut, and there are anecdotal accounts of DHPs performing well generally in the Northeastern U.S. (M. Holladay, personal communication, November 7, 2012). See Table 6 for representative climate data.

Table 6: U.S. climate data is provided for locations in the northeast and northwest United States with ASHP installations (National Oceanic and Atmospheric Administration, 2005).

Location	Average temperature (°F)	Annual Heating Degree Days (65°F base)	Average January minimum temperature (°F)
Amherst, MA	47.4	6856	11.2
Hartford, CT	50.2	6104	25.7
Moses Lake, WA¹	49.0	6236	23.3
Portland, OR	53.5	4400	34.2
Seattle, WA	52.3	4797	35.9

¹ - Meteorological data from Othello, WA, the closest station to the Moses Lake monitoring location from Baylon et al. (2010).

While a backup heat source may still be required for the coldest portion of the year, cold climate heat pump models are rated to work at or near their peak rated heating capacity for much of the heating season in these climates. For retrofit systems, the residence already has a heating system that can be used as the backup. Also, while the Southeast Alaska climate does not require cooling, the fact that ASHPs can provide cooling could increase comfort level on warm days and is appealing to commercial installations that may require cooling.

The Southeast climate includes a lot of snow and rain. This environment is not optimal for ASHPs because of the potential for snow and ice accumulation on outdoor units, which need to be exposed to the outside air. The moisture can also freeze onto outdoor coils in temperatures below freezing, requiring the heat pump to deploy a defrost cycle, reversing its refrigerant to use heat from the home to melt the ice on the coils. The solution several installers have implemented is to put the ASHP in a covered “penthouse” with open grating on the sides and roof (an example is shown in Figure 8). This allows the heat pump to access the air while being protected from inclement weather. Additionally, for installations near the coast, manufacturers must use a coating on the outdoor equipment to make it less susceptible to salt air corrosion. These climatic modifications help to increase equipment lifetime.



Figure 8: Air-to-water heat pumps outside the senior center in Saxman: These heat pump units are located near the building exhaust vents to utilize any waste heat. They are also protected from precipitation. Photo courtesy of Craig Moore.

3.2.2 Electricity prices

Many communities in Southeast Alaska generate electricity with hydropower plants, with other communities (for instance, Hoonah and Angoon) using diesel oil to generate electricity. In fact, in 2011, hydropower accounted for over 95% of the electricity produced in the region, with the remainder being produced from oil (Fay, Melendez, & West, 2012). Hydropower communities in Southeast have among the lowest electricity rates in the state, which is partly because the construction of the facilities was paid for with public funds and financing, therefore the electricity price does not reflect the full cost of producing the electricity (Melendez & Fay, 2012). Some residential electric prices from 2012 are listed in Table 7 with Anchorage as a reference point¹.

¹ The rates listed in the table are average annual prices used in AkWarm, an energy rating software used in Alaska. Thus, if a region has seasonal rates that increase in the winter, using the average annual rate, as we do in this report, will underestimate the cost of space heating with electricity in that location.



Table 7: Regional electric prices for areas in Alaska with installed ASHPs or planned installations of ASHPs. Electric prices from hydropower areas in Southeast are among the lowest electric prices in the state (AkWarm (version 2.2.0.4)).

Location	Price per kilowatt-hour	Fuel surcharge per kilowatt-hour	Total price per kilowatt-hour
Anchorage	0.09856	.001683	0.100243
Juneau	0.11045	-0.0005	0.10995
Ketchikan	0.0958	0	0.0958
Petersburg	0.118	0	0.118
Sitka	0.1417	0	0.1417
Wrangell	0.126	0	0.126
Homer	0.14622	0	0.14622
Kodiak	0.138	0.0423	0.1803

In contrast to low electric rates, the price of fuel oil in the region is comparatively more expensive and rising. Table 8 shows fuel prices from 2012 for the same communities. Anchorage is included as a reference point.

Table 8: Fuel prices for communities in Alaska with reports of planned and installed ASHPs (AkWarm (version 2.2.0.4)).

Location	Price of fuel oil number 1 (\$ per gallon)
Anchorage	3.88
Juneau	4.53
Ketchikan	4.12
Petersburg	4.27
Sitka	4.35
Wrangell	4.78
Homer	4.12
Kodiak	4.26

For a simple comparison of fuel oil and electric prices, it is helpful to consider the price of a specified quantity of heat produced from oil and from electricity. One gallon of Number 1 heating oil contains approximately 132,000 BTUs of heat energy, and one kilowatt-hour of electricity contains 3,413 BTUs of heat energy. Table 9 compares the price of 1 million BTUs of heat as contained in fuel oil and electricity.

Table 9: Comparison of prices of 1 million BTUs of space heating energy using fuel oil and electricity in selected Alaskan communities.

Location	Price of 1 million BTUs from fuel oil (\$)	Price of 1 million BTUs from electricity (\$)
Anchorage	29.39	29.30
Juneau	34.32	32.21
Ketchikan	31.21	28.07
Petersburg	32.35	34.57
Sitka	32.95	41.52
Wrangell	36.21	36.92
Homer	31.21	42.84
Kodiak	32.27	52.83



Of course, it is important to consider Table 9 along with its caveats. The values in the table represent the amount of heat energy in the fuel, not the heat energy that reaches the interior of the home. Not all of the heat energy from heating oil reaches the interior of the home, because oil-fired heating appliances are less than 100% efficient (some heat is lost “up the stack”). ASHPs, on the other hand, are not converting electricity to heat but rather using electricity to transfer heat. This allows them to have efficiencies of over 100%, so in effect residents receive more heat in their home than is contained in the electricity they use to run an ASHP. The comparative pricing of electric and oil heat means that ASHPs are potentially economically attractive for residents of these communities.

3.2.3 Electric utilities and incentives

Currently, electric utilities in Southeast Alaska differ greatly in their views on heat pump technology. Some offer incentives for installing ASHPs while others provide incentives for either installing or operating ground source heat pumps (GSHP), but no utilities in the region are known to provide incentives for both at the time of writing. Many utilities are currently watching the ground-source and air-source heat pump market, however, as heat pumps may be part of the solution as oil prices rise and homeowners wish to move away from fuel oil for space heating. Additionally, utilities are observing the effect of ASHPs on utility peak loads and how some installations consist of an ASHP coupled with a backup system for heating at low temperatures.

AEL&P in Juneau offers a reduced cost of electricity via a demand rate for residential GSHPs, which is used by approximately 10 individuals (A. Mesdag, personal communication, November 29, 2012). The purpose of the incentive is to encourage the use of GSHPs in place of electric resistance heating methods such as electric boilers or electric baseboards. According to Mr. Mesdag, an energy specialist with AEL&P, the utility is slightly concerned about the long-term impact of too many people switching from oil heat to ASHPs, as additional hydroelectric facilities would be required to cover the extra electricity needed. As such, AEL&P also advocates stand-alone biomass heating and/or sizing an ASHP below peak demand with a biomass system such as a pellet stove to meet the remaining heating needs. As many homes in Juneau already have two types of heating systems, this would not be unfamiliar to homeowners in Juneau. AEL&P would like to see both biomass systems and heat pumps implemented in a way that reduces space heating costs while remaining within the capacity of its hydropower resources. AEL&P advocates for residents to focus not only on increasing efficiency of home heating systems, but also to consider converting to electric transportation, such as electric or hybrid vehicles, because this switch is a greater jump in efficiency than going from oil heat to an ASHP and better matches the power availability for the anticipated demand (A. Mesdag, personal communication, November 29, 2012).

The City and Borough of Sitka has offered a \$1,500 incentive starting in early 2012 for homeowners heating solely with electricity to switch to an ASHP (D. Hawkins, personal communication, December 10, 2012). The municipality actively promotes ASHPs as an energy efficiency measure, but not GSHPs due to the high installation cost and the lack of available land for the ground heat exchanger. Mr. Hawkins estimates that approximately 70-80 ASHPs have been installed in Sitka over the past few years, a rapid rate of implementation which he attributes to the municipal rebate program as well as the Alaska Housing Finance Corporation Home Energy Rebate program. Of these installations, approximately 90% are DHPs room heaters (i.e. one indoor unit only), which cost roughly \$3,500 (D. Hawkins, personal communication, December 10, 2012). The borough's largest remaining uncertainties over ASHPs are the efficiency at low temperatures (e.g. around 0°F).



The City of Petersburg is also promoting heat pumps as a way to reduce community energy use. The city-run Municipal Power and Light provides a \$1,500 rebate for GSHPs, but are not sufficiently confident in ASHPs to include them in the program. The utility is waiting to see how the new ASHP retrofit in the city motor pool building performs to inform its policy on ASHPs (see Section 3.4) (J. Nelson, personal communication, December 10, 2012). There are currently less than 10 ASHPs in Petersburg and probably only one GSHP (J. Nelson, personal communication, December 17, 2012).

Wrangell Municipal Light & Power began an incentive program in 2006 to give customers a reduced utility rate for heating (8 cents/kWh compared to 12 cents/kWh) if they installed a second electric meter for electric heating. Clay Hammer, the electrical superintendent, reports that about 42% of residential customers switched to electric heat, resulting in a rise in consumption of 64% (C. Hammer, personal communication, January 16, 2013). Mr. Hammer also reported that peak loads have risen from 3.5 MW in 2006 to approximately 9 MW in 2012. Thus, Wrangell Municipal Light & Power is very interested in ways to reduce electricity demand, because further increases in demand will result in large costs of expanding the diesel backup generation system. He is very interested in the potential of heat pumps to reduce electric demand (C. Hammer, personal communication, January 16, 2013).

There are also incentives for homeowners outside of utilities such as the Home Energy Rebate Program run by the Alaska Housing Finance Corporation. Homeowners must obtain an “as-is” energy rating for their home to participate in this program, but then qualify for up to a \$10,000 rebate for investing in certain energy efficiency improvements. If retrofitting a heating system with a heat pump leads to a sufficient gain in energy efficiency (measured in a “post” energy rating), then the rebate would go toward the cost of an ASHP. Lastly, another incentive available to homeowners is the federal Residential Energy Tax Credit, which provides up to 10% of the cost (up to \$500) of replacing HVAC equipment in an existing home with Energy Star-rated appliances.

3.3 Technology Assessment

There are a few products available in Southeast Alaska for ASHP installations and many more available in other cold climates throughout the world. In general, ASHP models that work at temperatures below freezing are becoming more widely available.

3.3.1 Southeast Alaska market

In Southeast Alaska, two main companies dominate the ASHP market. Mitsubishi and Fujitsu both sell cold climate ASHP models, and all interviewed installers used one of these two brands with the exception of one installation of one Daikin heat pump in Saxman (C. Moore personal communication, November 20, 2012) and another Daikin installation in Juneau (A. Mesdag, personal communication, December 31, 2012). While all of these manufacturers are providing ductless systems, the primary difference is that Daikin offers an air-to-water product for residential application, whereas Mitsubishi and Fujitsu seem to offer only ductless air-to-air systems for residential application. Installers outside of Alaska also use these ASHP models and reported that they are performing very well and meeting or exceeding manufacturer-rated heating capacity and efficiency at installations in the northeastern U.S. (M. Holladay, personal communication, November 8, 2012).

There are suppliers in Anchorage and Seattle for Mitsubishi, Fujitsu, and Daikin heat pumps. Stinebaugh & Company is the Daikin representative in Anchorage, and carries both air-to-air and air-to-water models of



ASHPs. In addition to traditional heat pumps, they also sell models that can heat and cool at the same time (for instance, cooling a server room or sunny south-facing room while heating another room). Doug Franklin, a distributor at Stinebaugh & Company, has noticed some growth in the Alaska ASHP market in the last few years as the heating efficiencies of ASHP models have gone up (D. Franklin, personal communication, February 2013). Another Anchorage supplier is Gensco, which supplies Mitsubishi heat pumps. Chris Roark at Gensco has also noticed growth in the Alaska market: he said that a few years ago there was much more skepticism about the technology, whereas now there is confidence with more communities installing them, like Sitka and Petersburg. Correspondingly, Gensco now has three Mitsubishi system trainers on staff for ASHP systems (C. Roark, personal communication, December 20, 2012).

Cold climate specific models are designed to provide heating at low outside temperatures. Some contain electric resistance coils that help heat the air when the temperature drops below the system design limit. Installers reported selling models that will work with 100% capacity at 20°F and 75% at -5°F (C. Hazel, personal communication, November 29, 2012). Another model, from Mitsubishi, has a 100% heating capacity down to 5°F (R. Murdock, personal communication, November 29, 2012). See Table 10 for manufacturer specifications of example ASHP systems.

Table 10: Example ASHP product specifications. *Assumes a hydronic supply temperature of 104°F.

Manufacturer	Model	Type	Heat output (BTU/hr)	COP	Min. outdoor temperature
Mitsubishi	Single zone, M-series "H2i"	DHP	12,500 - 21,600 at 17°F; 10,900 - 21,600 at 5°F	2.76 - 3.04 at 17°F	-13°F
	Single zone, M-series	DHP	20,800 - 22,800 at 17°F; 16,305 - 19,090 at 5°F	2.23 - 2.33 at 17°F	14
	Multi zone, City Multi "H2i"	DHP	80,000 - 216,000 from 5 to 47°F; 84% of total capacity at -13°F	Not specified	-13°F
Fujitsu	Single zone, RLS2 series	DHP	12,000 - 18,000 at 47°F	3.52 - 3.66	-5°F
	Single zone, RLS2 series	DHP	21,600 - 32,000 at 47°F	2.78 - 2.93	-5°F
Daikin	Altherma, outdoor split system	Air-to-water	19,620 - 54,600 at unspecified temp.	2.6 - 2.7 at 19°F; 2.2 - 2.3 at 5°F *	-4°F

The models with the highest reported installations are the mini-split ductless systems. A typical mini-split ductless system consists of an outside evaporator unit (Figure 10) and one or more wall- or ceiling-mounted air handling and condenser units (Figure 9). They are connected by a set of pipes for the refrigerant and a COMM cable for the control system. Typically these lines are installed in a wall or attic so they are out of sight. The systems are very quiet, and require little maintenance except to wash the indoor unit air filters every few months. Many systems are installed with control systems that can be accessed through websites or mobile phone apps that allow users to set schedules of temperatures.



Figure 9: The indoor units for a DHP are mounted on a wall or ceiling and provide heat to a room. Image courtesy of Energy Testing and Consulting.



Figure 10: The outdoor unit of a DHP is located next to the porch behind a house. Photo courtesy of Craig Moore.

There are other manufacturer options, including ductless heat pumps sold by LG and Panasonic. Some companies offer ASHPs that are more limited in their potential implementation. These include Toyotomi's single unit heating and cooling system that is placed indoors, and Monitor Product's single-zone ductless heat pump. CCHRC did not identify homeowners using any of these brands. The Hallowell Acadia was used in the past but is no longer being produced because the company went out of business. Currently, no American-made ASHPs were identified operating in Southeast Alaska. In fact, the Tlingit-Haida Regional Housing Authority (THRHA) obtained a waiver from the Department of Energy (DOE) to install a foreign ASHP in a DOE-funded senior center building, because there is no equivalent American-made heat pump available (C. Moore, personal communication, November 20, 2012).



It is generally expected that ASHP options for Alaska will continue to improve as researchers continue to develop methods of increasing low temperature efficiency. For example, the International Energy Agency currently has an Annex with the goal of improving the low ambient temperature performance of ASHPs (International Energy Agency, 2013). Also, Doug Franklin, who distributes Daikin heat pumps at the Stinebaugh Corporation, has found that new models tend to not only have higher efficiencies, but also are generally quieter and come with better control systems and features than the previous model (D. Franklin, personal communication, February 21, 2013).

3.3.2 Industry support

There is at least one organization in the United States providing industry support for ductless heat pumps. The Northwest Ductless Heat Pump Project is organized and implemented by the Northwest Energy Efficiency Alliance, a non-profit company sponsored by electric power utilities in the Northwest (<http://goingductless.com/>). The Northwest Ductless Heat Pump Project's primary purpose appears to be encouraging homeowners to switch from electric resistance heating methods to ASHPs by identifying market barriers and acting to overcome them. Its activities include demonstration projects, installer training, customer education, and working with other players in the industry. There is no industry support organization in Alaska, although basic heat pump trainings are provided in Alaska.

3.3.3 European market

In Europe, a variety of ASHPs are available that are substantially different than the systems on the U.S. market. Common heat pump systems available in northern European countries are exhaust air heat pumps and air-to-water heat pumps. While air-to-water heat pumps are conceptually very similar to the air-to-air ductless heat pumps available in the U.S., exhaust air heat pumps use the heat from the exhaust air of a ventilation system to heat ventilation supply air and domestic hot water, or in combination with an outdoor evaporator unit to provide hydronic heat. Some European companies appear in Table 11 along with a summary of their most analogous products to the ASHPs available in the U.S.



Table 11: Example ASHP systems available in Europe

Company	Country	Cold climate model	More information
Nilan	Denmark	Nilan offers an ASHP that provides ventilation, DHW, and hydronic space heating from outdoor air. It can provide up to 14,500 BTU/hr at 20°F when coupled with an outdoor unit at a COP of 2.8.	www.nilan.dk
Genvex	England	Genvex offers an exhaust air system that provides ventilation, DHW, and small capacity hydronic space heat. Its heating capacity is under 5,000 BTU/hr. If not amended by another heat source connected to its hydronic ports, the space heat appears to be from electric resistance.	www.genvex.co.uk
Viessmann	Germany	Viessmann offers a wide range of air-to-water heat pump systems. The Vitocal 300 is quoted to provide a COP of 3.9 using 35.6°F outside air and providing 95°F water. Viessmann also offers systems that provide DHW and are plumbed ready for solar thermal inputs (Vitocal 242, 222, 200). These systems can modulate output based on the space heat demand, reducing compressor short cycling. This presumably provides better partial load efficiencies, but the peak efficiency is a bit lower than the 300 series (COP of 3.5 using 35.6°F outside air and providing 95°F water).	www.viessmann.com
Nibe	Sweden	Nibe offers exhaust air heat pumps for DHW and air-to-water systems that can operate down to -4 to -13 °F, depending on the model. The Nibe F2300 comes in 48,000 BTU/hr and 68,000 BTU/hr versions, which seem to get their ratings based on the heat output provided around 35 to 40°F. At these ambient air temperatures, the rated COP is around 3 to 3.8.	www.nibe.eu
Alpha Innotec	Europe	Alpha Innotec provides air-to-water heat pumps with maximum outputs ranging from 19,100 to 105,800 BTU/hr. The specified COPs range from 3.3 to 3.8 using 35.6°F outside air and providing 95°F water.	www.alpha-innotec.de

While CCHRC is not aware of a direct performance comparison, it seems that the Viessmann, Nibe, and Alpha Innotec air-to-water ASHPs have similar manufacturer-specified COPs in comparison to the Fujitsu and Mitsubishi ASHPs studied by the National Renewable Energy Lab at ambient temperatures around 35°F (Winkler, 2011).

Given the relative lack of options for homes with hydronic heating to use DHPs, the air-to-water heat pumps would be an attractive option for ASHPs within the U.S. In contrast, GSHP systems sold in the U.S. for cold climates are widely available as hydronic and air-ducted systems. Some systems can be integrated to approximate the European products. For example, Mitsubishi offers energy recovery ventilators separately that



can be connected to the indoor units of DHPs with integrated controls, however, no complete ventilation and space heating system is offered domestically for the residential market.

3.4 Inventory

The ASHP industry in Southeast Alaska has grown considerably in the last few years. ASHPs have now been installed in many locations in Southeast Alaska, and a few other locations outside of Alaska's panhandle region.

3.4.1 Alaskan ASHP installations

Table 12 contains information gathered from interviews with homeowners, installers, and energy professionals in Alaska. It is by no means comprehensive, but it provides an idea of the minimum number of heat pumps in the region, as estimates are conservative. Also, regions outside Southeast Alaska are included to document that ASHPs have been reported in those regions, rather than to attempt an accurate tally of the ASHPs in those locations.

Table 12: Estimates of ASHPs installed in Alaska, from interviews with Alaskan residents. The estimates are conservative, and include locations outside of Southeast Alaska to document ASHP installations in those locations.

Location	Estimated number of installers	Estimated number of installed residential ASHPs (and planned installations)	Estimated number of installed commercial ASHPs (and planned installations)
Anchorage	0	10	0
Fairbanks	0	0	3
Homer	0	(1)	0
Juneau	4	25	3
Ketchikan	2	20	10
Kodiak	1	30	1
North Pole	1	0	1
Petersburg	1	10	1
Saxman	0	0	1
Sitka	2	80	10(1)
Yukon Territory	1	5	0

Many installers have installed more retrofits than new installations, mainly for people replacing oil heat (C. Hazel, personal communication, November 29, 2012; R. Murdock, November 29, 2012; & W. McDonald, December 10, 2012). Some installers also use ASHPs for cooling in commercial buildings or server rooms. In fact, all of the ASHPs identified in Fairbanks were used for cooling in commercial installations. In Anchorage, systems are being installed in condominiums because of their low installation costs in comparison to gas systems. They use a back-up heat source of electric resistance heating when the heat pump cannot meet the heat demand (S. Wisdom, personal communication, November 16, 2012). The heat pump in North Pole is used for heating during shoulder seasons (J. Palmer, personal communication, January 17, 2013).

With retrofit installations, homeowners not replacing a failed system can retain their previous heating system to serve as a back-up on days when it is too cold for the ASHP to work efficiently. If the homeowner is looking to



replacing an older or failing heating system, they must consider how to obtain additional heat on the coldest days of the year when the ASHP is operating at low efficiency. As using electric resistance heating can be problematic for electric utilities, other options may be a pellet or wood-fired stove, an oil-fired laser-vented heater, or even a second, smaller ASHP.

Information from interviews on select commercial installations in Alaska appears in Table 13. The oldest reported commercial ASHP installation is located in the Forest Service building in Sitka, where the ASHP has provided space heating for 30 years. Other installations are much more recent. The Tlingit-Haida Regional Housing Authority (THRHA) installed a heat pump in the senior center in Saxman this year as part of its goal to use 100% renewable energy for heating (C. Moore, personal communication, November 20, 2012).



Table 13: Alaska ASHP commercial installations

Location	Building	New or Retrofit?	Notes
Juneau	Centennial Hall	Unknown	There are 3 ASHPs on the roof of Centennial Hall.
Juneau	Mike's Refrigeration	Retrofit, was installed in an existing building which only received heat from adjacent building	It is a Fujitsu system with a condensing unit located in a workshop heated by a forced-air furnace. It was installed 8 years ago.
Kodiak	Alpha Appliance	Unknown	Alpha Appliance is an appliance repair company that installs ASHPs.
North Pole	HVAC, Inc.	New	HVAC, Inc. uses a Mitsubishi ASHP for cooling and shoulder-season space heating of their 18,000 ft ² building. During the coldest part of the year, they use Toyo stoves to heat the building.
Petersburg	City motor pool	Retrofit, replaced an oil-fired forced air space heater and electric resistance heat	Overall comfort improved as heat was provided to locations that were previously not heated well
Saxman	Senior center	New	The Daikin air-to-water heat pump provides DHW for a 17-unit senior center. There are plans to install another ASHP for space heating.
Sitka	Blatchley Middle School	Retrofit, replaced an oil-fired boiler	Mitsubishi ASHPs were installed in the school this year to save money.
Sitka	Forest Service Building	New	The Trane ASHP was installed 30 years ago when the building was new. It is capable of heating the building until 32°F, at which point it requires back-up heat from electric strips in the heat pump. It is also used for cooling.

There are many more commercial installations than are listed in this table, because researchers did not pursue installations where the ASHP was used only for cooling. Commercial installations require more space cooling than residences in Alaska, especially when cooling is required for a server room.

3.4.2 Installer experience

Some installers, such as Mike's Refrigeration in Juneau, have been working with ASHPs for decades (C. Spencer, personal communication, November 7, 2012). Others have only been installing them for a few years. Installers first learned about ASHPs in different ways. Rick Alton, of Cool Runnin in Juneau, first learned about them by attending a Fujitsu training in the lower 48 (R. Alton, personal communication, January 9, 2013). Charlie Hazel,



the owner of Pacific Heating in Sitka, installed one in his own home after hearing about them – he thought that that would be a good way to learn more about them (C. Hazel, personal communication, November 29, 2012). Another contractor, Rod Murdock in Kodiak, read about them in a book on refrigeration. He researched them further, and began installing them after learning that that his heating systems supplier in Anchorage also was a heat pump dealer (R. Murdock, personal communication, November 29, 2012). Finally, Wally McDonald in Petersburg, began installing them after a customer asked him if he could install one (for the customer). He agreed after doing some research himself and has since installed almost 10 more (W. McDonald, personal communication, December 10, 2012).

All installers have reported a recent surge of interest and no need to pay for advertising. Instead, they rely on word-of-mouth and discussions with homeowners looking to install a heating system to educate people about ASHPs. Many installers use ASHPs themselves and are able to share their own experience with homeowners.

Alaskan installers also discussed the cost and performance of the installed ASHP systems. Of course, there is no one value for the capital cost and efficiency of an ASHP that will apply to every installation. Each residence is different, and the capital cost depends on several factors: whether or not the system is a retrofit, the location and size of the residence, the model of heat pump, the homeowners' preferences, etc. Similarly, the efficiency of the heat pump will depend on the local climate, the design and installation of the system, how well the system is maintained, and more.

In general, people felt that ASHPs were performing at manufacturer specifications, with seasonal COPs of around 2 or 3 (see Table 7 for manufacturer COPs). Unfortunately, CCHRC was unable to locate anyone monitoring the exact performance of an ASHP system. However, some residents were monitoring fuel bills to gain a general idea if they were saving money with an ASHP. Charlie Hazel, an installer in Sitka, noticed considerable savings with an ASHP (C. Hazel, personal communication, November 29, 2012). Rick Alton in Juneau and Rod Murdock in Kodiak have also noticed savings by monitoring fuel bills (R. Alton, personal communication, January 9, 2013, & R. Murdock, November 29, 2012).

Installation costs are difficult to estimate because the cost depends on so many factors. However, in general homeowners can liken the capital cost of a small mini-split ductless ASHP to approximately that of installing an oil-fired direct vent heater such as a Toyotomi stove. For instance, the installation of an ASHP model that works at full capacity down to 20°F might cost around \$3000 for a small home of around 1,000 ft². While this is a less expensive option than models that work at colder temperatures, it would require a supplemental heat source at temperatures below 20°F (W. McDonald, personal communication, December 12, 2012). For a larger home, the installation cost will be higher because a larger unit, or multiple smaller units, may be necessary.

In Sitka, Mr. Hazel of Pacific Heating estimated that a typical installation including parts and labor might run around \$3,500 for a smaller home, or for a single zone in a larger home. This is again roughly the equivalent of installing a small oil-fired laser-vented heater such as a Toyotomi stove, an installation which includes the stove itself, the fuel tank, the labor, and the supporting plumbing equipment. In some cases, the installation of an ASHP may also include having to upgrade the electric service to the home, which would raise the price.



There were other reports of ASHP installations in Southeast costing closer to \$8000 or \$10,000 to install, especially in larger homes that required multiple indoor units for a ductless heat pump.

For comparison, the cost of the installation of the Daikin unit used for hot water in the senior center in Saxman was around \$35,000. This figure included the cost of the heat pump, which consisted of two separate units, the shipping, the plumbing, and the labor (C. Moore, personal communication, January 30, 2013). The cost of the installation of the ductless heat pump system at HVAC, Inc. in North Pole cost in the same range: \$25,000 for the 15 indoor condenser units, the outdoor unit, and copper piping. The engineers at HVAC, Inc. were able to provide their own labor, and the control system cost an additional \$1000 (J. Palmer, personal communication, January 17, 2013).



4. Modeling

Modeling analyses were performed to predict the financial and environmental impact of the use of an ASHP in a Southeastern Alaskan home, as compared to oil-fired heating appliances and electric resistance heat, two other common methods of heating in Southeast Alaska. Models were created using RETScreen and AkWarm software. Researchers used the models to compare the energy use, performance, and cost of different heating systems.

4.1 AkWarm modeling

AkWarm is a software application maintained by the Alaska Housing Finance Corporation (AHFC) that is used by builders, designers, homeowners, energy raters, and lenders to determine energy efficient design, decide on retrofits, and to determine energy ratings. It has been tested and approved by the U.S. Department of Energy and is available for download at <http://www.analysisnorth.com/AkWarm/AkWarm2download.html>.

In AkWarm, the user creates a data file with information on the shell, heating systems, appliances and other characteristics of the house that is being analyzed. Alaska-specific databases on weather, fuel, utility, and material costs are then used to calculate the energy loss and design heat load of the house. It also rates the house on a point scale and star rating system, and allows users to compare the savings from specific retrofits of energy-conservation measures.

The “house” used for the AkWarm modeling is typical of residences in the Southeast region, and conforms to the 2009 BEES² standard for the region. The parameters for the house were taken from the model used to recommend the amendments to the 2009 BEES during the update process occurring in late 2012. The model house is located in Juneau, AK and is a single family house with 4 occupants and 3 bedrooms. It has a heated area of around 2000 ft² consisting of a living space at 70°F and a garage kept at 50°F. It has a mechanical ventilation system with no heat recovery. The appliances, including the range and clothes dryer, are electric and experience average use. The house also has a storage hot water tank with an energy factor of 0.514 that is located in conditioned space and uses fuel oil number one. The house is on pilings and the garage is on-grade. For more information on how this model was created, and for the complete user inputs on the shell and other house characteristics, please see Appendix A.

Fuel prices used in the modeling (except where noted), given in Table 14, were chosen to be the average of fuel prices in locations with installed ASHPs. The electricity price and fuel oil prices are an average from the five communities identified by interviewers as having air source heat pumps, or having interest in them (Juneau, Ketchikan, Petersburg, Sitka, and Wrangell).

² The Alaska Building Energy Efficiency Standards (BEES) are established by the Alaska Housing Finance Corporation. They are Alaska-specific amendments to the building standards of the International Energy Conservation Code, and include standards for thermal resistance, air leakage, moisture protection, and ventilation.



Table 14: Average Southeast Alaska fuel prices, used in the modeling study. The fuel oil average and the electricity price are both averages of prices from communities with ASHPs.

Fuel	Cost
Fuel oil number 1	\$4.41 per gallon
Electricity	\$0.12 per kilowatt-hour

For this analysis, the prototype house was created and then different heating system scenarios were examined. Table 15 lists the characteristics of the house from the AkWarm rating that remained the same for each heating system. They are included to provide the reader with an idea of the energy use of the average Southeastern Alaska house that meets BEES.

Table 15: Southeastern AK home AkWarm results are listed for the prototype house characteristics that do not change with the heating system.

House Energy Use	
Water heating with no. 1 fuel oil	Annual use of 289 gallons
Appliances and lighting	Annual use of 7,821 kWh of electricity
Annual gross heat loss	119.5 MMBTU
Annual gross internal/internal utilization	32.0 MMBTU / 0.994
Annual gross solar/solar utilization	22.7 MMBTU / 0.775
Net annual heat load	70.2 MMBTU
Design heat load (includes garage)	38,467 BTU/hr

Eight heating systems were modeled with AkWarm software. Currently, an ASHP cannot be entered into an AkWarm house file as-is, because the user input for a primary heating system is a drop-down menu which does not include ASHPs. Instead, researchers input it as a GSHP with forced air distribution and the appropriate seasonal COP.

The heating systems are listed in Table 16 and are representative of a variety of systems that exist in Southeast Alaska. However, they do not include biomass systems, which vary greatly in usage patterns and efficiency. While biomass systems are used for primary and secondary heating systems in Southeast Alaska, this study focuses on the use of ASHPs in replacing electric or oil heating methods.



Table 16: Heating systems modeled using AkWarm software. These are representative of the variety of heating systems found in Southeast Alaska.

Heating system	Characteristics
Boiler	Improved efficiency boiler, using fuel oil no. 1, AFUE rating of 82%, hydronic distribution system
Furnace	Improved efficiency furnace, using fuel oil no. 1, AFUE rating of 82%, forced air distribution
Toyo	Direct vent efficient space heater, AFUE rating of 84%, direct to space distribution
Electric Baseboard	AFUE of 100%, direct to space distribution
ASHP, COP 3	Forced air distribution, electric input, AFUE of 300%
ASHP, COP 2	Forced air distribution, electric input, AFUE of 200%
ASHP + Toyo	In this case, the ASHP, with a COP of 2, has a back-up heating system consisting of a Toyo stove. The back-up is responsible for 10% of the space heating load.
ASHP + Baseboard	In this case, the ASHP, with a COP of 2 has a back-up heating system consisting of electric baseboard heaters. The back-up is responsible for 10% of the space heating load.

The results from the AkWarm ratings of these heating system using Southeastern average fuel prices are listed in Table 17. The AkWarm rating provides a variety of information on the home. The rating includes an Energy Rating, which is given by points and stars. Higher scores on the point scale signify greater energy efficiency, and the star rating is out of 5+ stars. A higher point/star rating means that a home is more efficient. The estimated fuel and electrical use is also given, and AkWarm uses local pricing (in this case, the average Southeastern prices) to estimate annual cost. AkWarm also provides an estimate of the carbon dioxide produced by the home.



Table 17: AkWarm ratings for an average Southeastern Alaska home with different heating systems. Each rating includes a point rating, a star rating, average fuel use, electric consumption, cost, and emissions.

	Oil Boiler	Oil Furnace	Toyo	Electric Baseboard	ASHP, COP 3	ASHP, COP 2	ASHP + Toyo	ASHP + Baseboard
Energy rating (points)	82	81.9	82.4	77.9	92.2	88.6	88.6	88.6
Energy rating (star)	4	4	4	3 +	5 +	5	5	5
Annual fuel oil use for space heating(gallons)	642	616	615	0	0	0	62	0
Annual electricity consumption for space heating (kWh)	206	1,007	576	20,555	7,455	10,730	9,715	11,713
Annual heating energy cost	\$2,854	\$2,839	\$2,781	\$2,467	\$894	\$1,287	\$1,437	\$1,405
Amount of CO₂ produced by the home (lbs per year)	19,759	19,235	19,200	6,471	6,301	6,343	7,629	6,356

AkWarm is a useful tool for comparing heating systems, because it provides information on annual fuel use, on-site emissions, and cost. Of the systems evaluated, the ASHP with a COP of 3 clearly comes out with the lowest annual operating cost, as shown in Figure 11. There is currently no monitoring to support an ASHP with a seasonal COP of 3 in Southeast Alaska; however, there is anecdotal evidence that ASHPs are performing at manufacturer specifications. The ASHP with a COP of 2 is also attractive in comparison to alternative heating systems, even with a back-up heating system installed. AkWarm does not take into account the cost of maintaining a heating system, so it is useful to remember that maintaining two heating systems will cost more than only maintaining one.



The maintenance costs of ASHPs are the same as or lower than other heating appliances. ASHPs that have forced air distribution require the homeowner to clean the filters every few months. This only costs the homeowner time, as many filters can be washed and replaced. Also, it is recommended that ASHPs, like other heating appliances, undergo an annual maintenance “check-up” by a heating technician. This typically involves a check of the control system and connections to ensure that the heat pump is operating at full efficiency. Unlike combustion appliances, ASHPs do not need a chimney sweep or burner tune-up.

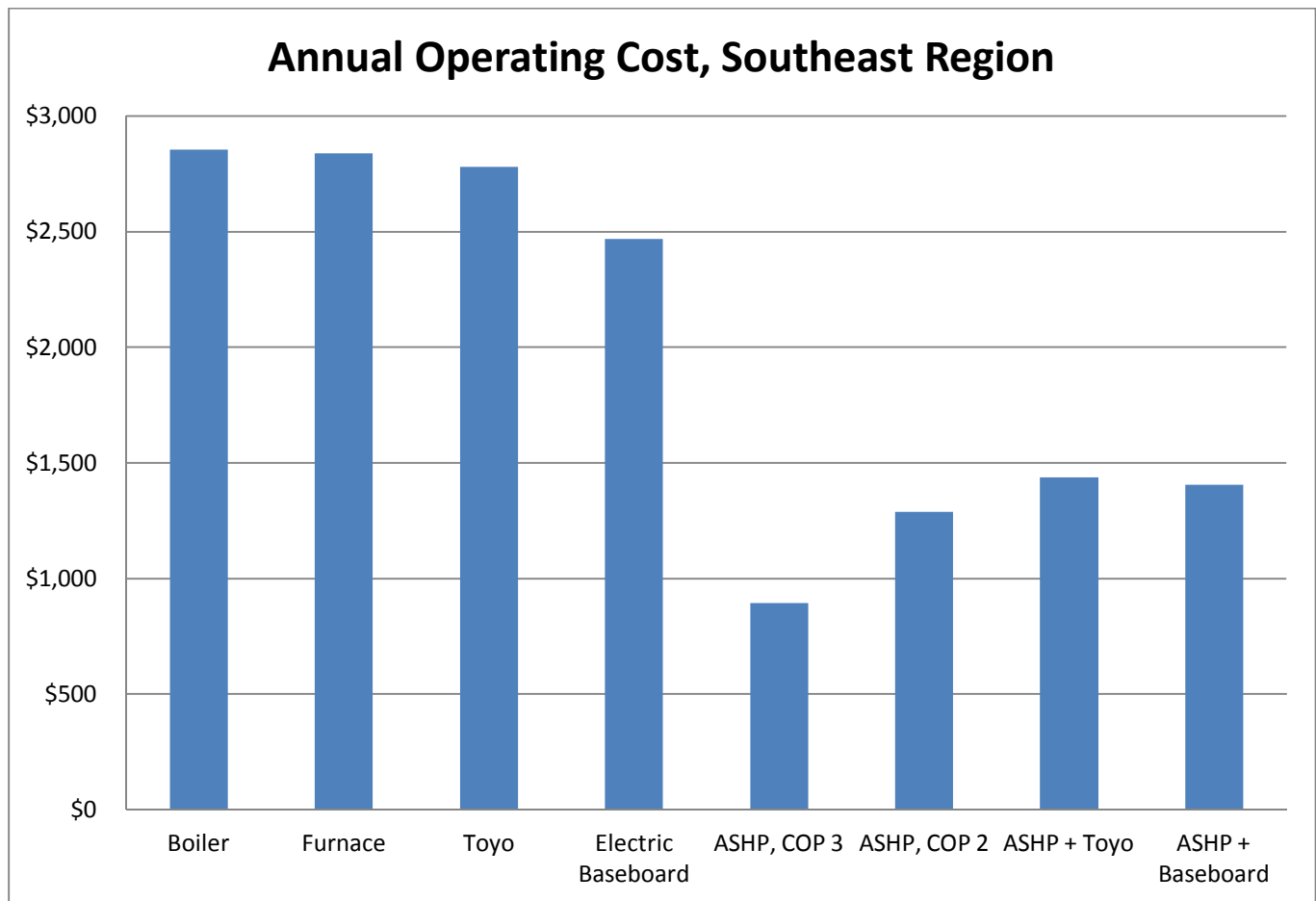


Figure 11: Annual cost is shown for several different heating systems in Southeast Alaska.

One disadvantage of ASHPs is that they use more electricity in colder weather. In order to meet peak heating demand in cold weather, some ASHPs have internal electrical resistance coils to provide supplemental heat, and all have to run defrost cycles to remove frost from the outdoor coils. This additional electrical use can strain the electrical grid. Also, in times where Southeast utilities need to use diesel generation facilities to meet electricity demand, electric heating methods will incur substantially higher costs and carbon emissions. On the other hand, ASHPs, even those with back-up systems, use considerably less electricity than sole electric baseboard heating. Figure 12 shows that an ASHP can cut electrical consumption at least in half from electric baseboard heating, but that ASHPs do use considerably more electricity than oil-fired appliances.

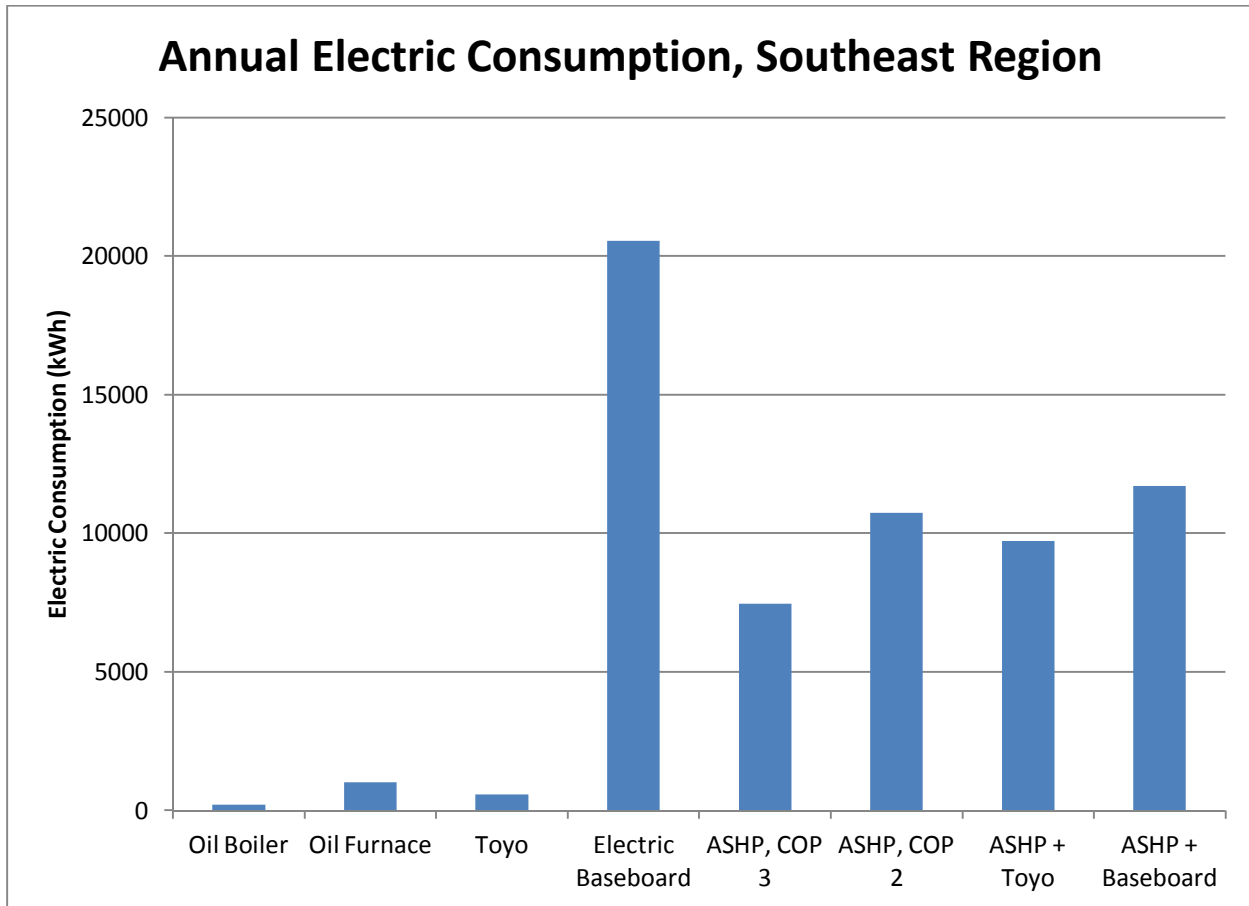


Figure 12: The annual electric consumption of a variety of heating systems used in a typical Southeast Alaska home.

AkWarm analyses were also performed for individual locations in Alaska where ASHPs are currently being installed and used as primary heating systems. These locations include Juneau, Ketchikan, Petersburg, Sitka, and Kodiak. All are in Southeast Alaska except Kodiak, which is located south of Anchorage. In these AkWarm analyses, local pricing and local climate were used. In each location, an ASHP with a seasonal COP of 2 had a lower annual operating cost than an oil furnace or electric baseboards (see Figure 13). Its annual operating cost is dependent on both the local price of electricity and the climate, as colder locations incur higher heating costs. Similar to the Southeast average results, ASHPs also had lower electrical usage than an electric baseboard for each location, and lower emissions than baseboards, furnaces, boilers, and Toyo stoves. The full results of the AkWarm analyses are located in Appendix C.

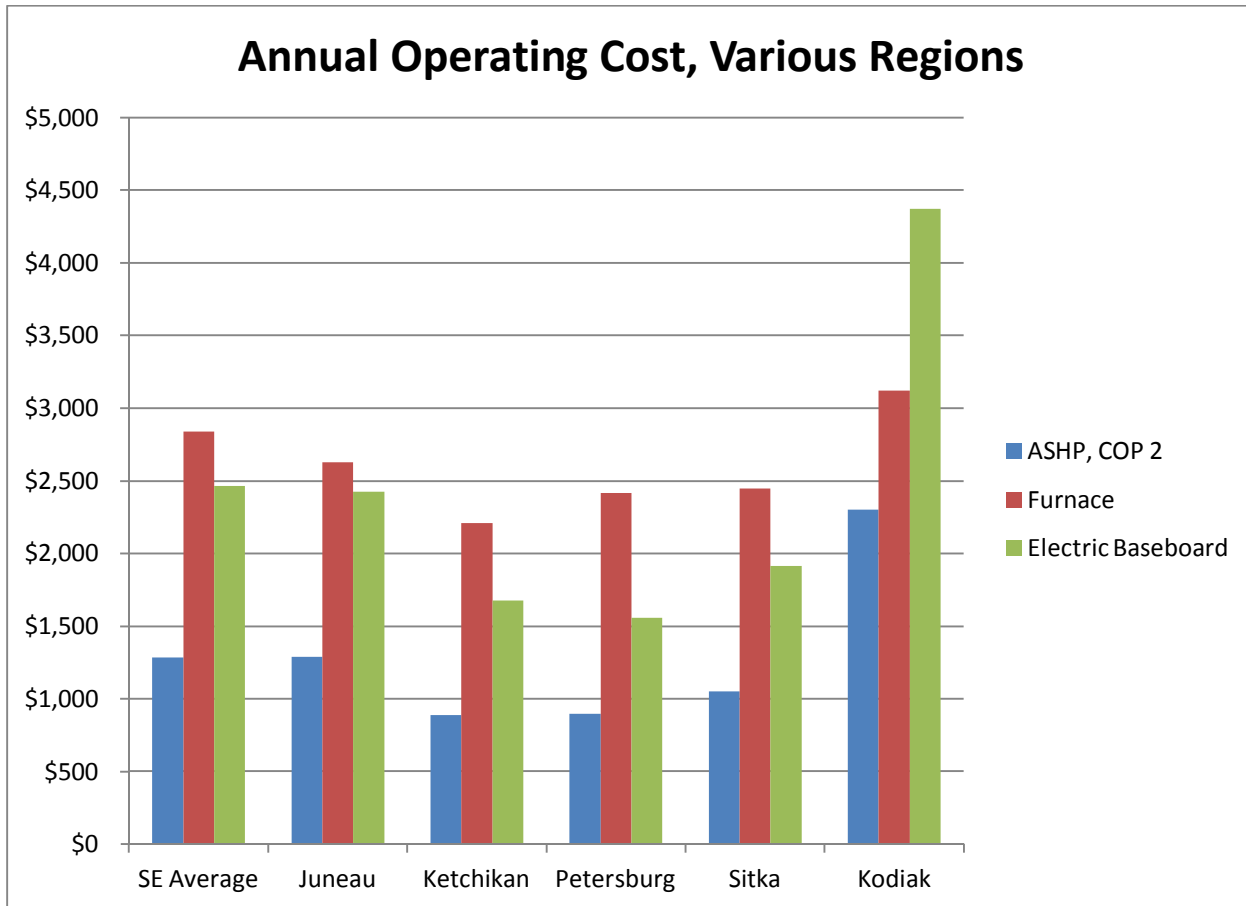


Figure 13: The annual cost of ASHPs in comparison to other heating systems, for locations in Southern Alaska.

The lower operating cost of ASHPs indicates that homeowners that install them should be able to pay for the install over time using the savings in fuel costs. As maintenance costs for ASHPs are slightly lower than maintenance costs of oil-fired appliances, and roughly equivalent to the maintenance costs for electric baseboards, the entirety of the savings in fuel costs can be applied towards paying for the installation. The use of an ASHP results in an approximately \$1000 per year savings when compared to heating with oil-fired appliances for the prototype 2000 ft² house used in this modeling. For this size house, an ASHP might cost around \$6000 (this house is double the size of the houses that installers estimated installation costs for in Section 3.4.2). As a result, residents of the model's prototype house could "pay back" their investment in an ASHP installation in about 6 years if they installed a small ASHP. As savings are smaller for people who are replacing electric baseboard heat, paybacks are longer, but still under 10 years if the capital cost of the ASHP is low. The town of Kodiak is the exception, as it has a shorter payback period for people replacing electric baseboards.

The capital cost of an ASHP will increase if it is installed together with a back-up heating source. Installing a Toyo stove back-up system will double the installation price of a smaller ASHP system, therefore resulting in double the payback period. Homes that already have a back-up heating appliance, such as a Toyo stove, wood stove, or pellet stove will significantly decrease their payback times.



4.3 RETScreen

RETScreen is a clean energy project analysis software tool. Its purpose is to help determine the technical and financial viability of renewable energy or efficiency projects. It is based on Microsoft Excel and can be downloaded, along with training material, from the RETScreen website at www.etscreen.net.

Two base case houses were created in RETScreen to compare to a proposed ASHP system. The characteristics of the base case house were chosen to be similar to the average Southeastern Alaska house used in the AkWarm modeling, and are shown in Table 18.

Table 18: The house characteristics used for RETScreen modeling were chosen to be similar to the prototype house used for AkWarm modeling.

RETScreen model house characteristics	
Building type	Single building
Heated floor area	2000 ft ²
Peak heating load	11.1 kW (38,000 BTU/hr)
Total heating load	28 MWh (95 MBTU)

The heating load for the house is calculated using the user-input values of the house total heating load, and climate data from the Juneau International Airport. Figure 14 shows that Juneau has a heating load throughout the year, although declines during the summer months to only a fraction of the heating load of the winter.

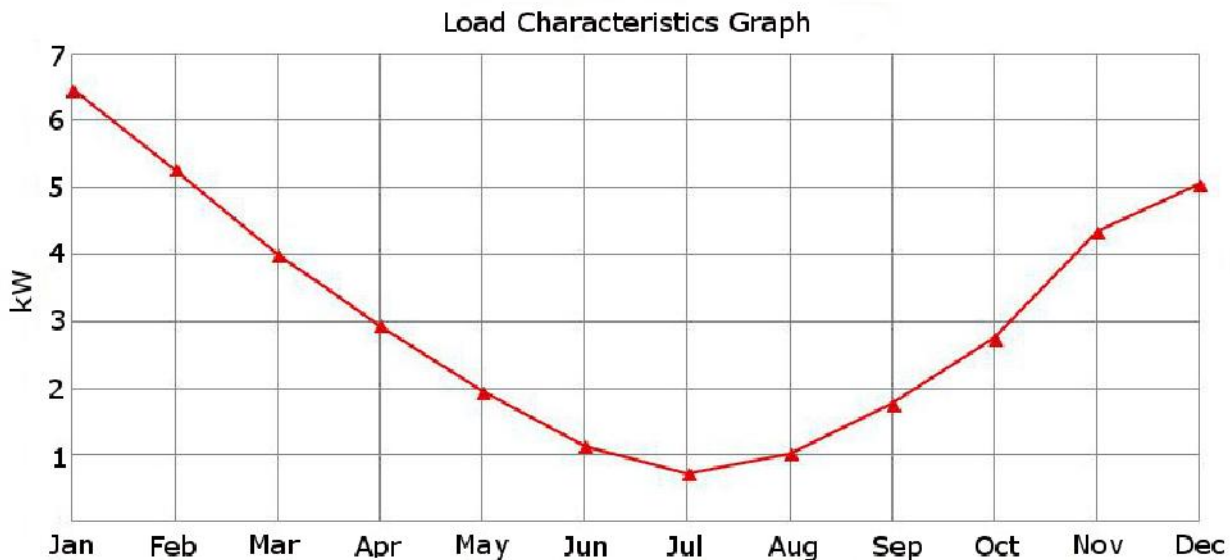


Figure 14: The annual heating load for a house in Juneau, shown by month.



The two base heating systems were chosen to be an oil-fired system with a seasonal efficiency of 82% and electric baseboards with a seasonal efficiency of 100%. The proposed system was an ASHP, with a seasonal efficiency of 200%, and an oil-fired appliance as the back-up system. The ASHP was sized to have a capacity to meet nearly 90% of the heating demand of the house. The seasonal efficiency of the back-up system was 84%, identical to that of a direct vent space heater, such as a Toyo stove (see Figure 14). Both systems together more than meet the peak demand, but it is important to have the back-up heating system for the coldest days of the year, when the ASHP functions at low efficiencies.

RETScreen then uses the heating load of the house to estimate an annual heating cost for each system. The annual heating costs for the oil-fired system came to \$3,968. The annual cost for the base case with electric baseboards is less than for the oil-fired appliance, totaling \$3,408 for the year. The annual cost estimates of the ASHP system with the back-up oil-fired appliance were the least of all the heating systems, at \$1,716.

Table 19: Annual operating costs of base and proposed cases in RETScreen modeling

Annual operating heating costs	
Base case of oil-fired system	\$3,968
Base case of electric baseboards	\$3,408
ASHP with COP of 2 and back-up Toyo stove	\$1,716

The fuel costs for the year are shown in Figure 15 for the different heating systems. These cost results agree qualitatively with those from the AkWarm modeling; the ASHP system has the lowest annual cost for Southeast Alaskan locations with inexpensive electricity. It is followed by an electric baseboard system, and then by the oil-fired furnace. The actual dollar amounts do not exactly match AkWarm results, but these differences can be attributed to the slightly different houses and different calculation methods. RETScreen does confirm that under Southeast weather and fuel price conditions, an ASHP with a back-up heating system will have lower annual operating costs than electric baseboards or an oil-fired appliance.

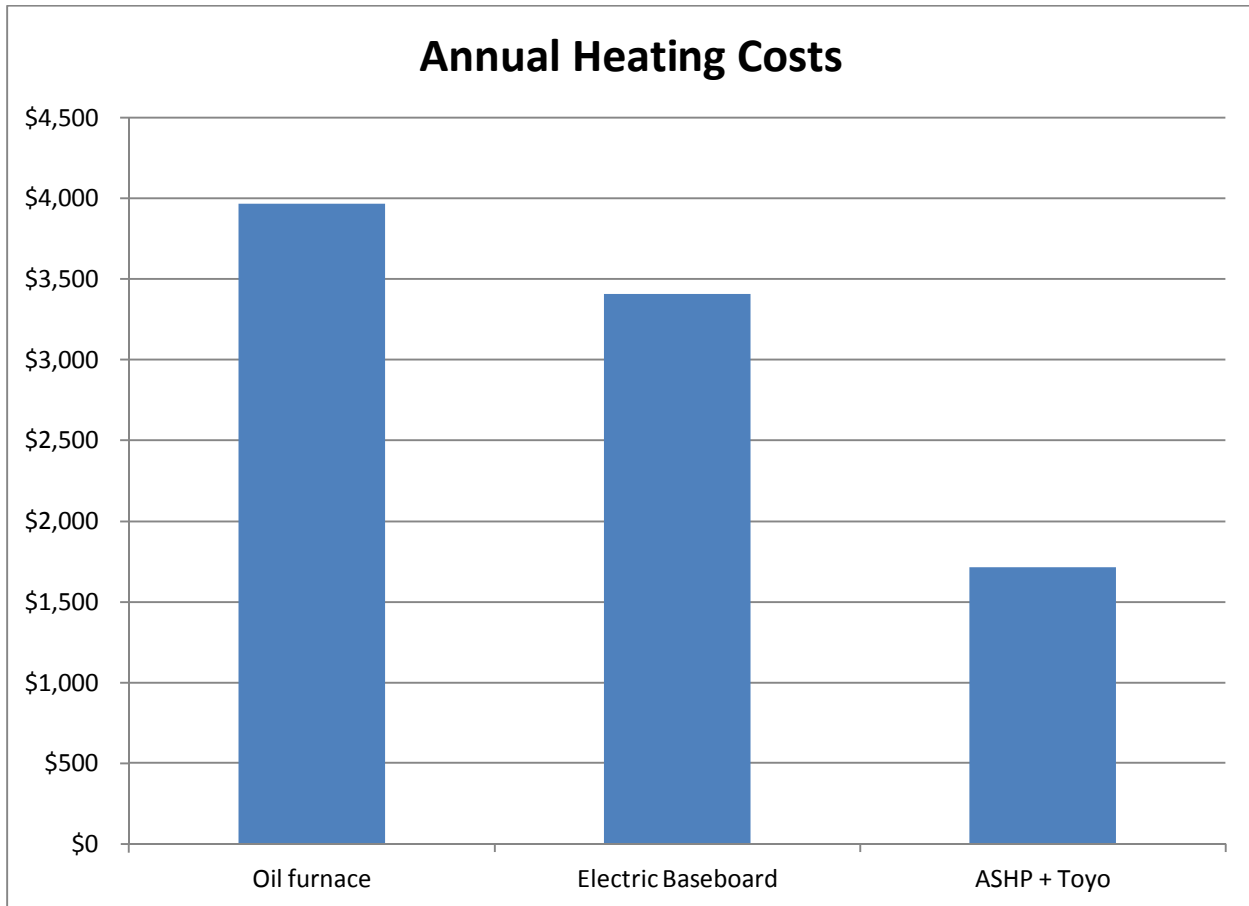


Figure 15: The annual costs from the RETScreen analysis are shown for the ASHP system and the base case scenarios of the oil-fired heating appliance and the electric baseboard heating system.

RETScreen also analyzed the emissions from different heating systems. The results of the RETScreen greenhouse gas (GHG) analysis are shown in Table 20. RETScreen uses a national scale as an input for the electricity grid. The data on the national grid emissions are stored in a database within RETScreen. The emissions analysis was performed using both the United States' national grid, and Norway's national grid. While Southeast Alaska is located in the United States, its electricity production is much more reflective of Norway's national grid. Both Southeast Alaska and Norway rely on hydropower for over 90% of their electricity, whereas the United States as a whole uses mostly coal and natural gas to produce electricity. For instance, in 2009, Norway used hydropower to produce approximately 96% of its electricity (International Energy Agency, 2013). AEL&P in Juneau obtains nearly 100% of their electricity from hydropower, except when they use back-up generation during required maintenance periods (A. Mesdag, personal communication, December 31, 2012).



Table 20: The greenhouse gas emission analysis from RETScreen shows that an ASHP produces less GHG than an oil-fired heating system in Southeast Alaska.

Electricity System	United States, with a GHG emission factor of 0.544 tCO₂/MWh and transmission losses of 5%
Base case of oil-fired heating appliance	8.8 metric tons of CO ₂ (annual)
Base case of electric baseboard	16.2 metric tons of CO ₂ (annual)
Proposed case of ASHP with oil-fired appliance back-up system	8.1 metric tons of CO ₂ (annual)
Annual GHG reduction (oil to ASHP)	0.7 metric tons of CO ₂ , or 0.1 cars not used
Annual GHG reduction (electric baseboard to ASHP)	8.1 metric tons of CO ₂ , or 1.5 cars not used
Electricity System	Norway with a GHG emission factor of 0.003 tCO₂/MWh and transmission losses of 5%
Base case of oil-fired heating appliance	8.8 metric tons of CO ₂ (annual)
Base case of electric baseboard	0.1 metric tons of CO ₂ (annual)
Proposed case of ASHP with oil-fired appliance back-up system	0.1 metric tons of CO ₂ (annual)
Annual GHG reduction (oil to ASHP)	8.7 metric tons of CO ₂ , or 1.6 cars not used
Annual GHG reduction (electric baseboard to ASHP)	0

With both the U.S. and Norwegian grids, the ASHP produces less GHG than an oil-fired system, but only for the U.S. national grid electricity does the ASHP produce measurably less GHG than electric baseboards. The results of using the Norwegian grid agree with the CO₂ production numbers estimated by AkWarm, as shown in Table 17. AkWarm also indicates that an ASHP will produce considerably less carbon dioxide than an oil-fired appliance, and that the reduction in carbon dioxide will be minimal when an electric baseboard is replaced by an ASHP with a Toyo stove back-up.

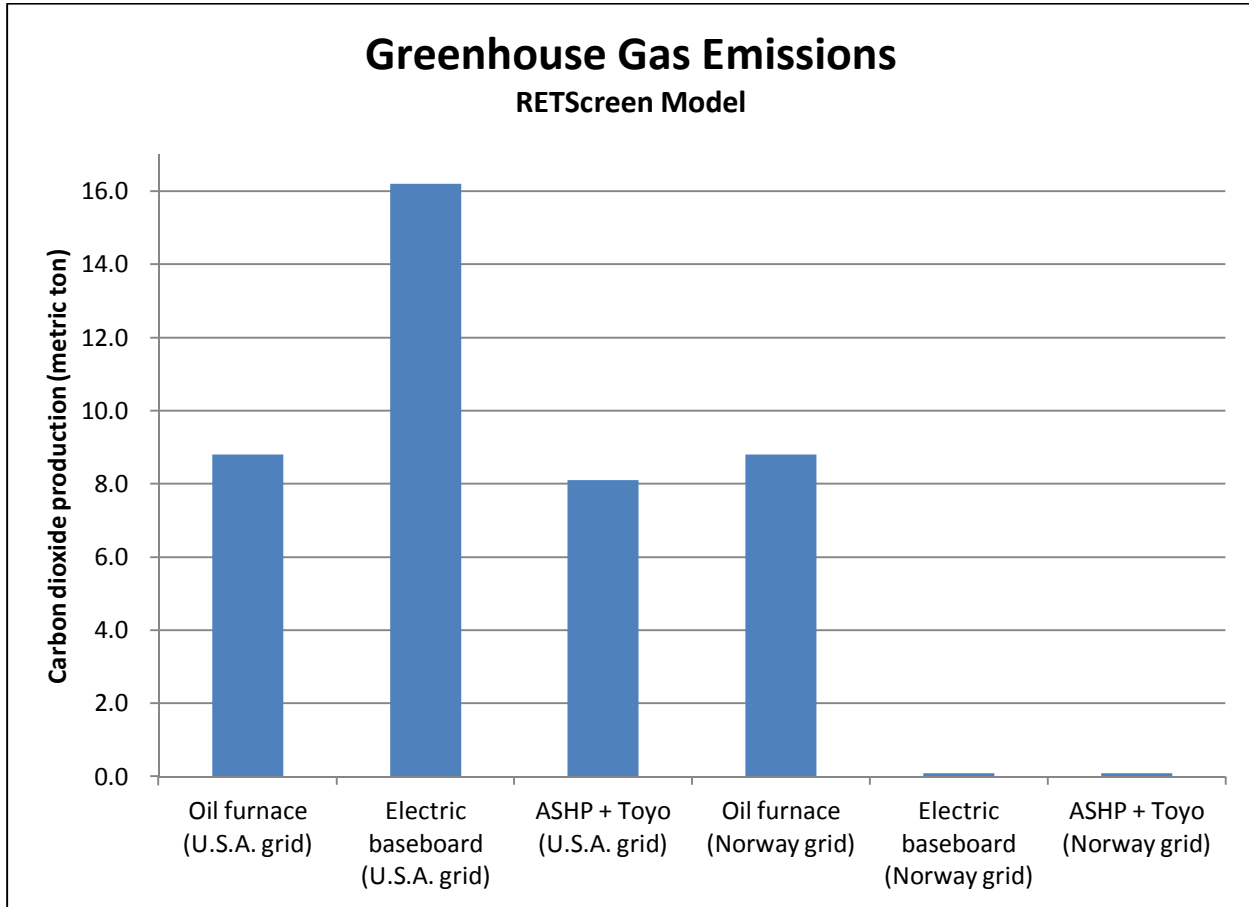


Figure 16: The GHG emissions for base and proposed case scenarios in RETScreen modeling are shown in the graph. The categories include emissions from using both the U.S. national grid and using the Norwegian grid.



Findings

ASHPs are becoming increasingly popular for heating in colder climates, in particular in the Northeast and Northwest regions of the contiguous United States. The goal of this research was to gain an understanding of the current use of ASHPs in Southeast Alaska, and to explore their potential as a space heating option for that region and other regions of Alaska with similar climatic conditions.

There are over 100 ASHPs being used as primary space heating appliances in Southeast Alaska.

ASHPs are being installed in new buildings and as retrofits. They are used in both commercial and residential buildings. The installations are concentrated in areas where hydropower is the dominant electric generation source and where a qualified installer lives: Juneau, Ketchikan, Petersburg, and Sitka. Anecdotal evidence suggests that the newly installed ASHPs are working well and are being coupled with a back-up heating system for the coldest days of winter. Usage has also been reported in other areas of the state, such as Anchorage, Kodiak and a few installations in Fairbanks.

There are no recent local studies on the performance or energy use of ASHPs.

Anecdotal evidence is that ASHPs work well in the Southeast region and take advantage of relatively low cost electricity to provide inexpensive home heating. However, without quantitative data it is difficult to gauge the effect of widespread deployment of ASHPs on the local utilities, and difficult to assess whether installed ASHP performance in Southeast communities can match manufacturer ratings at low temperatures.

It is important that systems be installed correctly if ASHPs are to be successfully implemented in the long-term. In fact, past rumors in the Southeast region about how ASHPs “don’t work” are usually attributed to bad installations or poor distribution systems (C. Spencer, personal communication, November 7, 2012). ASHPs are also being used in Canada, and the LiveSmart program, a provincial rebate program in British Columbia, is finishing an evaluation on the installed efficiency of ASHPs in the BC climate. Initial findings suggest that the installed efficiency, calculated through billing analyses, is less than expected. Potential causes include their use for cooling when there was no previous cooling load and/or poor installation (C. Frye, personal communication, November 26, 2012).

The literature review for this report identified a number of studies from the contiguous United States on both Acadia and DHP models of ASHPs. While these results are helpful, they do not address specifically the climate of Southeast Alaska. The most recent study of ASHPs in Southeast Alaska was conducted in the 1980s (Alaska Electric Light & Power Company and Ketchikan Public Utilities, 1982), and since then a number of cold climate modifications have been made to ASHPs.

Preliminary modeling analyses suggest that ASHPs are a financially attractive and environmentally preferable option for a primary heating system in Southeast Alaska.

For this report, researchers modeled a Southeast Alaskan home using both AkWarm and RETScreen software and compared the financial and environmental impact of using an ASHP as the primary heating system in place of an oil-fired appliance and electric baseboard heating. Both software modeling programs indicated that an



ASHP had a lower annual cost than the other heating systems, and produced less carbon dioxide emissions. This was true for stand-alone ASHPs, and those with back-up heating appliances used to meet peak demand periods.

The Southeast region has widely varying policies on heat pumps from electric utilities.

While all interviewed utilities were in favor of homeowners switching from sole electric heating methods to ASHPs, their public policies on ASHPs and confidence in the technology differed greatly. AEL&P in Juneau is currently providing a rate discount for GSHPs, but otherwise is focusing on biomass heating solutions and an experimental program on electric cars as preferred methods to reduce electricity demand. On the other hand, the Sitka Electric Department offers a rebate to citizens replacing an electric heating system with an ASHP, which has been popular and is anticipated to run out of funds soon. Petersburg Municipal Power and Light falls in between these two approaches by providing a rebate for installing a GSHP, but is not sufficiently confident in ASHP technology to offer a rebate. Petersburg is watching a recent installation in a city building to see if ASHPs are a good option for its customers.

While ASHPs in the Southeast region can provide heat for the majority of the heating season, they do require a back-up system for the coldest days of winter.

The need for a back-up heating system during the coldest part of winter is a prominent weak spot for ASHPs. Many homes in Alaska already have back-up heating appliances, but ASHPs do require heavy reliance or a complete switch to the back-up system on the coldest days of the year. The ASHP technology currently on the market is least efficient at low temperatures, when home heating demand is highest. Furthermore, unlike other heating systems, ASHPs have a sudden transition state from running at full capacity to stopping the refrigeration cycle once the ambient temperature falls below the system design limit. Once off, the home heat demand must be met via electric resistance backup that is integral to the ASHP or by a separate home heating appliance. The former can be relatively expensive for the homeowner, while the latter can be difficult to manage smoothly unless the back-up heating system can also provide central heating. Having fully redundant heating capacity is a greater initial cost and can lead to higher overall operating costs associated with maintaining extra heating appliances. The implementation of a control strategy to manage the interaction between two heating systems must also be addressed by homeowners with ASHPs and back-up systems.

While the need for backup heating methods is strongly a function of local climate and building design, the potential for homeowners using electric resistance backup for ASHPs is a significant concern for electric utilities. All electric utilities surveyed had some level of concern about ASHPs potentially needing electric resistance backup at low temperatures.

On the other hand, many installers reported placing retrofits in homes that were previously relying on oil-fired appliances. In these instances, the homeowners already have purchased their “back-up” system, because they can use the system the ASHP is replacing if it is in good condition and kept maintained. If the back-up appliance is an oil-fired device, it does not produce a strain on the electrical grid. Additionally, many homes in Southeast Alaska already employ a wood-fired device as a back-up system. Wood-fired devices also do not strain the electrical grid, and, if previously installed, put little financial strain on the homeowner. In these cases, the homeowner can manage the switch between the two systems, without relying on a central control system.



Recommendations

The following are preliminary considerations of possible next steps energy researchers can take to evaluate further how ASHP technology can be a part of future energy solutions in Southeast Alaska.

An energy usage analysis of retrofit installations will provide data on the performance of ASHPs in Southeast Alaska and help to inform energy policy and homeowner decisions.

There are no recent energy usage studies of ASHPs in Southeast Alaska. They have been studied in other cold climates in the United States (see Section 2), and in Southeast Alaska during the 1980s (Alaska Electric Light & Power Company and Ketchikan Public Utilities, 1982), but there has not been an analysis of Alaska installations since more cold climate-specific models became available and public interest has picked up. Retrofit studies would be most beneficial since they provide the opportunity to establish a baseline energy demand prior to retrofitting of the ASHP.

There are a number of recent retrofit installations in Southeast Alaska that could be used for an energy usage analysis. Such an analysis could take several different forms depending on the type of monitoring employed and the number of installations included. For instance, sub-meters could be used to analyze the amount of electricity ASHPs use on the coldest days and over the course of a heating season. It would also provide information on their peak power draw during cold periods, which would be useful information for electric utilities. An energy usage analysis could also include performance measurements of individual systems, and interviews with homeowners on the comfort level they experience with an ASHP. Such qualitative and quantitative information would provide evidence as to whether or not various ASHP models can match manufacturer ratings in the Alaska climate.

Another aspect of ASHP installation that could be investigated as part of an energy usage study is how houses with ASHPs heat domestic hot water. Air-to-water ASHPs can be used for both space heating and domestic hot water, but houses with air-to-air ASHPs must use another option for hot water. A survey could provide data on the energy use of houses with air-to-water ASHPs used for both space and DHW heating, as compared to houses with two separate systems. Additionally, qualitative data could be obtained on resident satisfaction with each type of system.

An investigation into the results and lessons learned from local programs on heat pump deployment can help to inform regional energy policy and increase understanding of heat pump technology in the Southeast climate.

Such an investigation would provide feedback to utilities with current rebate programs and information for other utilities in the region, and could increase the potential strategic regional planning for communities with shared power generation resources. To the knowledge of the authors, Sitka is the only location in Alaska offering a rebate program for homeowners looking to switch from electric heat to an ASHP. This rebate has been popular in the Sitka community. An investigation into this approach could reveal the impact of the program on electricity demand and homeowner satisfaction. Conversely, Petersburg offers a very similar rebate for GSHPs; however, there is probably only one installation currently in the community. An investigation could help determine if the barriers to heat pump implementation are primarily economic or due to other factors and it also could determine the effect of such rebate programs on power consumption. As several utilities in



Southeast Alaska share hydropower resources, knowing the outcomes of different policies to consumers for heat pumps could help with regional planning efforts.

Air source heat pumps should be included as a primary heating option in AkWarm.

Energy raters throughout Alaska use AkWarm software to provide energy ratings to homeowners. To create an energy rating, the user makes a file in AkWarm by entering the characteristics of the house. To enter the primary heating system, the user chooses from a dropdown menu of options. Currently, an ASHP is not listed as an option and AkWarm users must instead choose another option to represent the ASHP. In this report, researchers used a GSHP and entered in an appropriate COP as the seasonal efficiency. Other raters have instead chosen a water heater with an air handler, again entering an appropriate seasonal efficiency.

There is a spreadsheet created by Alan Mitchell of Analysis North which adjusts a manufacturer-rated HSPF to account for the colder climates of Alaskan locations. It is based on research on the affect of climate on HSPF (Fairey, Parker, Wilcox, & Lombardi, 2004). The spreadsheet includes a look-up table of Alaskan locations and a calculator where users can enter the HSPF of a heat pump, to be provided with a climate-adjusted equivalent AFUE that can be used in AkWarm. It is unknown as to how many energy raters use this spreadsheet to adjust a manufacturer HSPF before entering it into AkWarm.

The various methods of entering an ASHP into AkWarm and the inconsistencies in entering a seasonal efficiency are likely to cause some confusion and make it more difficult to document the number of ASHPs in Alaska. Additionally, the different methods of entering an ASHP into AkWarm affect the final energy rating, which creates inconsistencies across the state. There are at least 100 ASHPs being used in Alaska, and additional planned installations. This is similar or greater than the number of GSHPs installed in Alaska (Alaska Center for Energy and Power & Cold Climate Housing Research Center, 2011). By adding ASHP (both with forced air and hydronic distribution options) to AkWarm, the software could accommodate the many houses now using ASHPs in a consistent manner.



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Appendix A: BEES information

The prototype home used as the basis house in the AkWarm modeling analysis originated from data in the Alaska Retrofit Information System (ARIS). This data was used to create an average home that met the BEES requirements for the region. The ARIS database contains building characteristics gathered from the Alaska Housing Finance Corporation's rebate and weatherization programs, and other uses of the AkWarm software. The home is created using Southeastern regional averages of home characteristics in ARIS.

In order to create the prototype house, the following procedure was used:

1. Query ARIS for data on homes rated within the past 6 years that meet the latest BEES and download this data into Microsoft Excel. The data will contain these fields: location, house type, city, rating points, rating type, year built, volume, floor square feet, garage size, garage area, component type, component name, calculated size, gross area, and any additional component fields.
2. Filter data to include only the following conditions: BEES homes, AkWarm rating above 83, year built 2006 and later, single family home, and Southeast region. Components were then separated into garage and non-garage data.
3. Component averages: The averages for each component should be calculated.
4. Determine foundation type: Using distance-below-grade data, determine whether foundations were above-grade, on-grade, or below-grade. The model house contains floors with multiple foundation types, using the average area for each type. The garage components are also included.
5. The component averages and foundation type were then put in AkWarm as the prototype home.
6. R-values and characteristics of other values in the AkWarm files were assigned using prescriptive values from BEES.

The prototype home was originally used by the policy group at CCHRC in order to determine the new rating point value required to meet the 2012 BEES requirements. It has been used in this ASHP modeling analysis as a representative of an average Southeast home that met the 2009 BEES requirements.

The complete user inputs, from the Home Inputs report printed by the AkWarm file, appear below:

Client

Prototype Home
AK

Home Location

Southeast Region
Juneau, AK

Reference City: Juneau, City of
Electric Utility: AEL&P - Residential
Gas Utility: None

Rating Information

Rating Type: As-Is
Date: 7/3/2012

Rater



CCHRC

Occupancy

4 Occupants
Owner Occupied

House Type/Size

House Type: Single Family
Heated Floor Area, sq.ft.: 1,995.8
Conditioned Garage Floor Area, sq.ft.: 547.3
of Bedrooms: 3
Windshielding: Average

Actual Energy Costs

Annual Fuel Cost: \$0.00
Annual Electric Cost: \$0.00

Air

From Blower Test CFM @ 50 Pascals: 2470
ACH @ 50 Pascals: 7.00
Average Ceiling Height to Ground or Exposed Floor: 17.6
Heated Volume: 21,185.6
Ventilation System Type: Mechanical with no Heat Recovery
System has controls to operate at less than maximum flow: Yes

Heating

Thermostat Setpoint: 70
Night Setback Thermostat: None

Primary System

Fuel Type: #1 Fuel Oil
Equipment Type: Improved efficiency boiler
Flame retention burner; improved heat exchanger, vent dampers, modulating aquastat
Certified AFUE: 80
Upgrade Devices: None
Heat Distribution: Hydronic
0% in Un-conditioned Space, Not Insulated
0% in Semi-conditioned Space, Not Insulated

Secondary System

No System Installed

Cooling

Cooling System: None Present

Hot Water Heater

Fuel Type: #1 Fuel Oil
Equipment Type: High Efficiency Oil Tank
Oil storage tank post 2004
Energy Factor: 0.514
Location: Conditioned Space, > 60 deg F

Other

Dryer: Electric
Range: Electric



Misc. Electric Use: Average

Fuel Prices

Electricity, (\$/kWh): \$0.13 (Approx. Utility Price)

#1 Oil, (\$/gallons): \$4.06 (Library Price)

Shell Components

Floors - Total Area 1,475.2 sq. ft.

Above Grade Floor: AG House

Temperature: Living Space

Gross Area, Sq. Ft.: 682.6

682.60

Exposure: On Pilings

Framing Type: 2 x Lumber

Insulating Sheathing: None

Top Insulation Layer: None

Bottom Insulation Layer: R-30 Batt:FG or RW, 9.5 inches

Insulation Quality: OK

Calculated R-Value: 30.6

Below Grade Floor Perimeter: OG Garage

Temperature: Garage

Gross Area, Sq. Ft.: 136.5

Distance to Grade: On Grade

Insulation Covers Slab Perimeter: Yes

Insulation for 0' to 2' Perimeter: XPS (Blue/Pink Foam), 3 inches

Insulation for 2' to 4' Perimeter: XPS (Blue/Pink Foam), 3 inches

Insulation Quality: OK

Calculated R-Value: 24

Below Grade Floor Center: OG Garage

Temperature: Garage

Gross Area, Sq. Ft.: 163

Distance to Grade: On Grade

Center Insulation: XPS (Blue/Pink Foam), 3 inches

Insulation Quality: OK

Calculated R-Value: 52.1

Below Grade Floor Perimeter: OG House

Temperature: Living Space

Gross Area, Sq. Ft.: 141.1

Distance to Grade: On Grade

Insulation Covers Slab Perimeter: Yes

Insulation for 0' to 2' Perimeter: XPS (Blue/Pink Foam), 3 inches

Insulation for 2' to 4' Perimeter: XPS (Blue/Pink Foam), 3 inches

Insulation Quality: OK

Calculated R-Value: 24

Below Grade Floor Center: OG House

Temperature: Living Space

Gross Area, Sq. Ft.: 166.7

Distance to Grade: On Grade

Center Insulation: XPS (Blue/Pink Foam), 3 inches



Insulation Quality: OK
Calculated R-Value: 52.1

Below Grade Floor Perimeter: BG House

Temperature: Living Space
Gross Area, Sq. Ft.: 106.3
Distance to Grade: 3.86 feet below
Insulation for 0' to 2' Perimeter: XPS (Blue/Pink Foam), 3 inches
Insulation for 2' to 4' Perimeter: XPS (Blue/Pink Foam), 3 inches
Insulation Quality: OK
Calculated R-Value: 32.3

Below Grade Floor Center: BG House

Temperature: Living Space
Gross Area, Sq. Ft.: 79.1
Distance to Grade: 3.86 feet below
Center Insulation: XPS (Blue/Pink Foam), 3 inches
Insulation Quality: OK
Calculated R-Value: 60.1

Walls - Total Area 2,868.3 sq. ft.

Above Grade Wall: House

Temperature: Living Space
Gross Area, Sq. Ft.: 2,554.2
Wall Type: Single Stud
Siding Configuration: Siding and Sheathing
Insul. Sheathing: None
Structural Wall: 2 x 6, 16 inches on center
R-21 Batt:FG or RW, 5.5 inches
Window and door headers are insulated: Yes
Insulation Quality: OK
Calculated R-Value: 18.2

Above Grade Wall: Garage

Temperature: Garage
Gross Area, Sq. Ft.: 314.1
Wall Type: Single Stud
Siding Configuration: Siding and Sheathing
Insul. Sheathing: None
Structural Wall: 2 x 6, 16 inches on center
R-21 Batt:FG or RW, 5.5 inches
Window and door headers are insulated: Yes
Insulation Quality: OK
Calculated R-Value: 18.2

Doors - Total Area 116.4 sq. ft.

Exterior Door: House

Temperature: Living Space
Gross Area, Sq. Ft.: 39.6
Door Type: Entrance, Fiberglass, polyurethane core, no glass
Certified U-Value: 0.33
Storm Door: None
Calculated R-Value: 3

**Garage Door: Garage**

Temperature: Garage
Gross Area, Sq. Ft.: 76.8
Door Type: Sectional, Wood uninsulated
Certified U-Value: 0.33
Insulating Blanket: None
Calculated R-Value: 3

Windows - Total Area 333.2 sq. ft.**Window: SouthWin**

Temperature: Living Space
Gross Area, Sq. Ft.: 157.8
Orientation: South
External Shading: Little
Glass: Triple, Glass
Certified U-Value: 0.33
Solar Heat Gain Coefficient including Window Coverings: 0.41

Window: NonSouthWin

Temperature: Living Space
Gross Area, Sq. Ft.: 175.4
Orientation: Not South
External Shading: Moderate
Glass: Triple, Glass
Certified U-Value: 0.33
Solar Heat Gain Coefficient including Window Coverings: 0.41

Ceilings - Total Area 1,485.4 sq. ft.**Ceiling with Attic: House**

Temperature: Living Space
Gross Area, Sq. Ft.: 1,485.4
Framing Type: Energy Truss
Framing Spacing: 24 inches
Insulated Sheathing: None
Bottom Insulation Layer: R-38 Batt:FG or RW, 12 inches
Top Insulation Layer: None
Insulation Quality: OK
Calculated R-Value: 40.4

Design Heat Loss

Outdoor Temperature at Heating Design Conditions Option: Use Library Value
Outdoor Temperature at Heating Design Conditions Value (deg F): 1.0
Airport Wind Speed at Heating Design Conditions Option: Use Library Value
Airport Wind Speed at Heating Design Conditions Value (mph): 8.3
Lvg Mechanical Ventilation Rate, Supply Flow (cfm): 0.0
Lvg Mechanical Ventilation Rate, Exhaust Flow (cfm): 0.0
Ventilation Heat Recovery Effectiveness (%): 0.0
Main Home Heating System Distribution Efficiency Option: Use Library Value
Main Home Heating System Distribution Efficiency Value (%): 100.0
Garage Temperature (deg F): 55.0
House/Garage Uninsulated Common Area (sq feet): 0.0
Mechanical Ventilation Rate for Garage (cfm): 0.0



Garage Heating System Distribution Eff (%): 100.0

AkWarm Version Info

Application: AkWarm, Version 2.2.0.4

Calculation Engine: 2.2.0.4

Energy Library: 8/6/2012

*Filename: \\Yaranga\cchrc\Building Science Research\Projects\Southeast Air Source Heat Pump
Study\Modeling\AkWarm\Dustin SE Prototype.hm2*

Report Date: 12/20/2012



Appendix B: Interviewees

The following individuals graciously agreed to share their knowledge and perspectives with the authors of this report. Thanks to all for their time and information.

Name	Company	Location	Experience
Rick Alton	Cool Runnin	Juneau	Alton is a refrigeration contractor who installs ASHPs.
Mark Bautista	Blatchley Middle School	Sitka	Bautista works on maintaining the new ASHP at Blachley Middle School.
Cathy Cottrell	Energy Solutions Centre	Whitehorse, Yukon Territory, Canada	Cottrell is a senior energy advisor with the Energy Solutions Centre of the Yukon Government Department of Energy, Mines, and Resources.
Scott Cragun	Home Tech Home Services	Ketchikan	Cragun is an energy rater in Ketchikan. He also uses an ASHP in his home.
Doug Franklin	Stinebaugh & Company	Anchorage	Stinebaugh & Company is an Anchorage supplier of over 30 HVAC manufacturers, including Daikin heat pumps.
Chris Frye	Ministry of Energy, Mines, and Natural Gas	Vancouver, British Columbia, Canada	Frye has researched ASHPs as part of LiveSmart BC, a provincial rebate program.
Clay Hammer	Wrangell Municipal Light and Power	Wrangell	Hammer is the electrical superintendent at Wrangell Municipal Light & Power.
David Hawkins	Sitka Electric Department	Sitka	David is the T&D manager with the Sitka Electric Department.
Charlie Hazel	Pacific Heating	Sitka	Pacific Heating installs and maintains ASHPs in Sitka.



Ryan Hennessey	Energy Solutions Centre	Whitehorse, Yukon Territory, Canada	Hennessey is a senior energy advisor with the Energy Solutions Centre of the Yukon Government Department of Energy, Mines, and Resources.
Martin Holladay	GreenBuildingAdvisor.com	Newtown, Connecticut	Holladay has documented case studies of ASHP systems.
Russell Johnson	Johnson Research LLC	United States	Johnson has conducted research studies of ASHPs in cold climates.
Martin Kotol	Technical University of Denmark	Lyngby, Denmark	Martin is a PhD candidate in civil engineering focusing on heating and ventilation systems for cold climates.
Wally McDonald	Fleet Refrigeration and Heating	Petersburg	McDonald installs and maintains ASHPs in Petersburg.
Alec Mesdag	Alaska Electric Light and Power Company (AEL&P)	Juneau	Mesdag is an energy specialist with AEL&P, the electric utility company in Juneau.
Craig Moore	Tlingit Haida Regional Housing Authority (THRHA)	Juneau	Moore is the vice president of planning and development for THRHA and has installed ASHPs in THRHA buildings.
Rod Murdock	Alpha Appliance	Kodiak	Alpha Appliance installs and maintains ASHPs in Kodiak.
Joe Nelson	Petersburg Municipal Power and Light	Petersburg	Joe is the superintendent for Petersburg Municipal Power and Light.
Josh Palmer	HVAC, Inc.	North Pole	Josh is an engineer at HVAC, Inc. They use an ASHP to



			cool their building in the summer, and to provide space heating in the shoulder seasons.
Jim Rehfeldt	Alaska Energy Engineering LLC	Juneau	Alaska Energy Engineering LLC works on the design of heating systems.
Chuck Renfro	Energy Efficiency Associates	Anchorage	Renfro is the former director of the Alaska Craftsman Home Program. He also installs heating systems.
Frank Richards	Sitka Forest Service	Sitka	Richards is the building manager for the Forest Service building in Sitka, which is heated by an ASHP.
Chris Roark	Gensco	Anchorage	Chris is a sales representative for Gensco, which sells Mitsubishi heat pumps and provides training specific to those products.
Roger Schmidt	Sheldon Jackson College	Sitka	Schmidt is a campus administrator at the Sheldon Jackson College. They are installing an ASHP in the auditorium.
Chad Spencer	Mike's Refrigeration	Juneau	Spencer is the head technician at Mike's Refrigeration. Mike's Refrigeration installs and maintains ASHPs.
Margie Subers	Alaska Building Science Network	Palmer	Subers worked with the City of Petersburg on community energy use reduction.
Steve Wisdom	Wisdom & Associates, Inc.	Kenai	Wisdom is the owner of Wisdom & Associates, Inc., which provides home



inspections, energy ratings, and continuing education. He is also planning to install an ASHP at his home in Homer.

-----	Alaska Integrated Services	Juneau	Alaska Integrated Services is an engineering firm in Juneau that works mainly with control systems for heating systems.
-----	The Plumbing and Heating Company	Juneau	The Plumbing and Heating Company is a service, installation, and repair company for heating appliances.
-----	Schmolck Mechanical	Ketchikan	Schmolck Mechanical installs and maintains ASHPs in Ketchikan.



Appendix C: Local AkWarm Results

This appendix contains results from AkWarm modeling for heating systems in a prototype house for locations throughout Southern Alaska: Juneau, Sitka, Petersburg, Ketchikan, and Kodiak. These results use local climate data and prices in calculating the rating.

Juneau:

Since Juneau was the location for the regional average house, the house characteristics remain the same as reported in the modeling section. The AkWarm rating appears in the table below.

	Oil Boiler	Oil Furnace	Toyo	Electric Baseboard	ASHP, COP 3	ASHP, COP 2	ASHP + Toyo	ASHP + Baseboard
Energy rating (points)	82	81.9	82.4	77.9	92.2	88.6	88.6	88.6
Energy rating (star)	4	4	4	3+	5+	5	5	5
Annual fuel oil use for space heating(gallons)	642	616	615	0	0	0	62	0
Annual electricity consumption for space heating (kWh)	206	1,007	576	20,555	7,455	10,730	9,715	11,713
Annual heating energy cost	\$2,631	\$2,630	\$2,570	\$2,427	\$904	\$1,288	\$1,419	\$1,403
Amount of CO₂ produced by the home (lbs per year)	19,759	19,235	19,200	6,471	6,301	6,343	7,629	6,356



The energy flows for the house in Sitka:

Annual gross loss	112.6 MMBTU
Annual gross internal/internal utilization	32.0 MMBTU / 0.990
Annual gross solar/solar utilization	23.1 MMBTU / 0.738
Net annual heat load	63.9 MMBTU
Design heat load (includes garage)	27,508 BTU/hr

The AkWarm ratings for Sitka:

	Oil Boiler	Oil Furnace	Toyo	Electric Baseboard	ASHP, COP 3	ASHP, COP 2	ASHP + Toyo	ASHP + Baseboard
Energy rating (points)	82.5	82.3	82.8	78.4	92.3	88.8	88.8	88.8
Energy rating (star)	4	4	4	4	5 +	5	5	5
Annual fuel oil use for space heating(gallons)	585	562	561	0	0	0	56	0
Annual electricity consumption for space heating (kWh)	187	918	525	18,737	6,795	9,781	8,855	10,676
Annual heating energy cost	\$2,452	\$2,448	\$2,394	\$1,914	\$754	\$1,053	\$1,194	\$1,141
Amount of CO₂ produced by the home (lbs per year)	18,479	17,995	17,967	6,182	6,146	6,155	7,336	6,158



The energy flows for the house in Petersburg:

Annual gross loss	113.9 MMBTU
Annual gross internal/internal utilization	32.0 MMBTU / 0.999
Annual gross solar/solar utilization	26.8 MMBTU / 0.813
Net annual heat load	60.2 MMBTU
Design heat load (includes garage)	31,596 BTU/hr

The AkWarm ratings for Petersburg:

	Oil Boiler	Oil Furnace	Toyo	Electric Baseboard	ASHP, COP 3	ASHP, COP 2	ASHP + Toyo	ASHP + Baseboard
Energy rating (points)	83.5	83.4	83.8	79.7	92.8	89.5	89.5	89.5
Energy rating (star)	4 +	4 +	4 +	4	5 +	5	5	5
Annual fuel oil use for space heating(gallons)	550	529	527	0	0	0	53	0
Annual electricity consumption for space heating (kWh)	176	864	494	17,676	6,393	9,201	8,330	10,044
Annual heating energy cost	\$2,427	\$2,416	\$2,366	\$1,557	\$657	\$896	\$1,054	\$965
Amount of CO₂ produced by the home (lbs per year)	17,803	17,352	17,323	6,357	6,244	6,272	7,378	6,281



The energy flows for the house in Ketchikan:

Annual gross loss	109.8 MMBTU
Annual gross internal/internal utilization	32.0 MMBTU / 0.995
Annual gross solar/solar utilization	25.8 MMBTU / 0.779
Net annual heat load	57.9 MMBTU
Design heat load (includes garage)	29,895 BTU/hr

The AkWarm ratings for Ketchikan:

	Oil Boiler	Oil Furnace	Toyo	Electric Baseboard	ASHP, COP 3	ASHP, COP 2	ASHP + Toyo	ASHP + Baseboard
Energy rating (points)	82.4	82.3	82.8	78.5	92.1	88.7	88.7	88.7
Energy rating (star)	4	4	4	4	5 +	5	5	5
Annual fuel oil use for space heating(gallons)	530	509	508	0	0	0	51	0
Annual electricity consumption for space heating (kWh)	170	831	475	16,966	6,153	8,856	8,018	9,667
Annual heating energy cost	\$2,226	\$2,209	\$2,167	\$1,678	\$623	\$889	\$1,019	\$968
Amount of CO₂ produced by the home (lbs per year)	17,336	16,899	16,873	6,251	6,186	6,202	7,269	6,207



The energy flows in Kodiak:

Annual gross loss	135.3 MMBTU
Annual gross internal/internal utilization	32.0 MMBTU / 1.000
Annual gross solar/solar utilization	28.6 MMBTU / 0.858
Net annual heat load	78.8 MMBTU
Design heat load (includes garage)	32,918 BTU/hr

The AkWarm ratings for Kodiak:

	Oil Boiler	Oil Furnace	Toyo	Electric Baseboard	ASHP, COP 3	ASHP, COP 2	ASHP + Toyo	ASHP + Baseboard
Energy rating (points)	83.7	83.6	84.1	79.8	93.3	89.9	89.9	89.0
Energy rating (star)	4 +	4 +	4 +	4	5 +	5	5	5
Annual fuel oil use for space heating(gallons)	721	692	691	0	0	0	69	0
Annual electricity consumption for space heating (kWh)	231	1,131	647	23,089	8,374	12,053	10,912	13,156
Annual heating energy cost	\$3,066	\$3,123	\$3,022	\$4,370	\$1,607	\$2,301	\$2,375	\$2,508
Amount of CO2 produced by the home (lbs per year)	23,499	23,142	22,978	14,448	10,475	11,468	12,619	11,766



Appendix D: Southeast Region ARIS Data

Researchers accessed ARIS data to examine heating systems in towns across Southeast Alaska. In total, 7,818 ratings were found for the Southeast region. The ratings are from 1997 to 2012. For this analysis, the “first” ratings of duplicate rating pairs were removed. For instance, if one location had an “As-is” rating, and then a “Post” rating at a later date, the “As-is” rating was removed. This resulted in 5,358 ratings for locations throughout Southeast Alaska.

Of these ratings, 4,539 ratings were located in towns identified as having ASHP installations, or interest in ASHP installations (Juneau, Ketchikan, Petersburg, Sitka, and Wrangell). Including Auke Bay and Douglas increases the total number to 4,693.

The ratings were then sorted by primary and secondary heating fuel and counted. Fuel types from the AkWarm ratings included birch, coal, electricity, natural gas, fuel oil number 1, fuel oil number 2, propane and spruce. For the purposes of the analysis for this report, some fuel types were combined. These included fuel oil (consisting of fuel oil number 1 and fuel oil number 2), gas (consisting of natural gas and propane), and wood (consisting of birch and spruce).

The fuel type of electric included the appliances of GSHP, direct electric resistance heat (baseboards), electric furnaces, and electric boilers. It also included ASHPs, but there is no ASHP option in AkWarm, so raters must enter ASHPs as either a GSHP or a water heater. As heat pumps produce heat with a refrigeration cycle as opposed to converting electricity into heat, they were separated out from the electric category. However, the heat pump category includes both ASHPs and GSHPs as researchers did not differentiate between the two types with the current data set.

The analysis on the ARIS data was performed in Microsoft Excel. All data sorting and analysis was done using Excel tools except for the separation of electric resistance and electric heat pump heating types, which was done by hand due to the small number of systems. There is uncertainty in the analysis of the order of ± 20 ratings (out of 7,818 original ratings) which may not have been counted if they were filtered out by algorithms unintentionally.

ARIS data on primary fuel systems appears in the following table. The number of ratings with each type of primary fuel system is listed in the table by location.

	Fuel Oil	Electric Resistance	Wood	Electric (Heat Pump)	Gas	Total
Juneau	2400	238	60	12	42	2752
Ketchikan	791	79	50	4	37	961
Petersburg	243	48	10	1	2	304
Sitka	331	93	30	15	5	474
Wrangell	125	53	14	1	9	202
Total	3890	511	164	33	95	4693



ARIS data on secondary fuel systems appears in the next table. The number of ratings with each type of secondary fuel is listed in the table by location.

	Fuel Oil	Electric Resistance	Wood	Gas	Total
Juneau	232	431	594	54	1311
Ketchikan	35	55	78	11	179
Petersburg	27	88	56	7	178
Sitka	89	99	52	6	246
Wrangell	27	20	53	3	103
Total	410	693	833	81	2017