United States Arctic Research Commission
Arctic Renewable Energy Working Group

Residential Heating in Remote Arctic Villages: Implementation Plan

WORKSHOP SERIES REPORT 2

A Report from the Arctic Renewable Energy Working Group

December 9, 2016

COVER PHOTO: Residential homes in Kasigluk, Alaska. *Credit: AVEC*

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About This Report

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Acronyms

AAEM .... Alaska Affordable Energy Model
AAHA .... Association of Alaska Housing Authorities
ACEP .... Alaska Center for Energy and Power
ACS .... American Community Survey
AEA .... Alaska Energy Authority
AHFC .... Alaska Housing Finance Corporation
ANTHC .... Alaska Native Tribal Health Consortium
APU .... Alaska Pacific University
AREWG .... Arctic Renewable Energy Working Group
ARIS .... Alaska Retrofit Information System
AVEC .... Alaska Village Electric Cooperative
BSNC .... Bering Strait Native Corporation
CCHRC .... Cold Climate Housing Research Center
DOE .... US Department of Energy
ISER .... Institute of Social and Economic Research at University of Alaska Anchorage
KAE .... Kotzebue Electric Association
NSF .... National Science Foundation
REAP .... Renewable Energy Alaska Project
UAF .... University of Alaska Fairbanks
USARC .... United States Arctic Research Commission
USDA-RD .... United States Department of Agriculture-Rural Development

Executive Summary

Residential heating in Alaska's remote Arctic communities is one of the most challenging and expensive essential services for utilities to provide and for consumers to afford. To better understand how renewable energy systems, energy efficiencies and education and policy initiatives might best address home heating needs for remote communities, the US Arctic Research Commission's Arctic Renewable Energy Working Group held a workshop, in January 2016, to identify data gaps and research needs regarding how heat is used in villages. In December 2016, a follow-up workshop was held to assess and identify progress, prioritize unmet data and research needs, and develop strategies to address outstanding data gaps and research needs.

Implementing research to address outstanding questions and information needs for residential heating in remote Arctic villages requires supportive funding. This poses a serious challenge given current State and federal research funding limitations. However, through incentives, collaborative approaches, partnerships and understanding the relevance of completed efforts in other Arctic countries we can continue to address the home heating needs of Alaska's Arctic rural communities.

To address outstanding research needs identified, participants from the follow-up workshop divided and prioritized specific actions into three categories: Data and Technology, Socioeconomics, and Policy and Coordination.

Data and Technology

> **Need:** Continue to develop and deploy **heating fuel meters** for individual residential homes to provide fine scale data on the volume of heating fuel used over time.

Strategy for implementation: Develop a collaborative approach between technology development entities, academic institutions, regional housing authorities and corporations to continue to develop and distribute low-cost, non-invasive heating fuel meters to collect data on individual homes in remote Arctic communities.

> **Need:** Research **heat technology case studies** from other Arctic nations to better understand the feasibility and effectiveness of converting renewable resources to electric heat in Alaska's Arctic rural communities.

Strategy for implementation: Examine the efforts and findings of heat technology research (e.g., wind-to-heat, sewage-to-heat, solar thermal, biomass, etc.) in other Arctic countries to determine and provide guidance on which technologies may be best suited to the needs of Alaska's remote Arctic communities. This work could be conducted by an academic institution (possible post-graduate project), a technology development company, or by a governmental, NGO, or private sector energy entity.

Socioeconomics

> **Need:** Develop **programs to train and retain local skilled laborers** in rural communities.

Strategy for implementation: Review other "grow-your-own" programs, such as the Health Aid and Village Public Safety Officer programs, to determine how a skilled labor program could be structured to keep trained laborers in remote communities. The possibility of sharing laborers in skilled positions across a region should also be explored. This research could be conducted by workforce development entities, tribal or state government groups, or academic institutions.

> **Need:** Understand the feasibility and potential to create **economies of scale** (or scope) for heat energy infrastructure projects (e.g., regional or multi-village projects).

Strategy for implementation: Develop a collaborative approach involving regional corporations, vendors, academic institutions, private investors, and governmental economic and energy entities to study the feasibility and effectiveness of regional infrastructure development projects that would serve multiple remote communities.

Policy and Coordination

> **Need:** Develop and implement a robust, **updated Alaska State Energy Policy** and review progress made since the 2010 Alaska State Energy Policy was issued.

Strategy for implementation: Develop a collaborative approach between academic socioeconomic institutions (e.g., UAA's Institute of Social and Economic Research) and State government energy agencies to outline a feasible strategy for effective energy policy aimed at reducing remote community dependence on diesel fuels. *Note: Since this workshop took place, the Alaska Energy Authority publicly released its Alaska Affordable Energy Strategy that provides policy recommendations related to the Alaska State Energy Policy.*

> **Need:** Improve **education and communication** of energy efficiency practices, technology and behaviors within remote communities.

Strategy for implementation: Identify and encourage community-based agencies to work with established energy education programs (e.g., Renewable Energy Alaska Project, RurAL CAP) to determine remaining needs and how collaborations could increase capacity to address those needs.

Workshop 2 Attendees

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The village of Teller, Alaska. *Credit: AVEC*

Introduction

In remote Alaskan villages, subzero temperatures, inefficient building envelopes and high heating fuel prices challenge residents' ability to adequately heat their homes. The Alaska Energy Authority (AEA) estimates that the 200+ remote communities in the state will spend approximately $186 million in residential heating costs in 2017.[1] Compared to the more populated areas of the state where natural gas is used for home heating, the primary residential heating source in remote Alaskan communities is diesel fuel oil (Figure 1). The exceptions to this are two communities in the North Slope region where local access to natural gas exists.[2]

The January 2017 Alaska Fuel Price[3] report indicated that the average retail price of heating fuel oil across 100 remote communities was $4.49/gallon but ranged both between and within regions with an average cost of $5.17/gallon in Western Alaska to $1.74/gallon in Northern Alaska where the North Slope Borough subsidizes residential heating fuel costs for its residents (Table 1). In all regions where heating fuel is not subsidized by the local government, average prices were above the national average heating fuel cost of $2.63/gallon in January 2017. In some communities, residents in the lowest income bracket spend 47% (median value) of their annual income on household energy.[4]

The high cost of diesel heating fuel in remote Alaska stems partially from the cost to transport fuel, either by air or by barge, to remote communities. The transport cost is largely responsible for the wide variation in fuel prices by region, with the more accessible communities in Southeast Alaska having lower heating fuel prices.

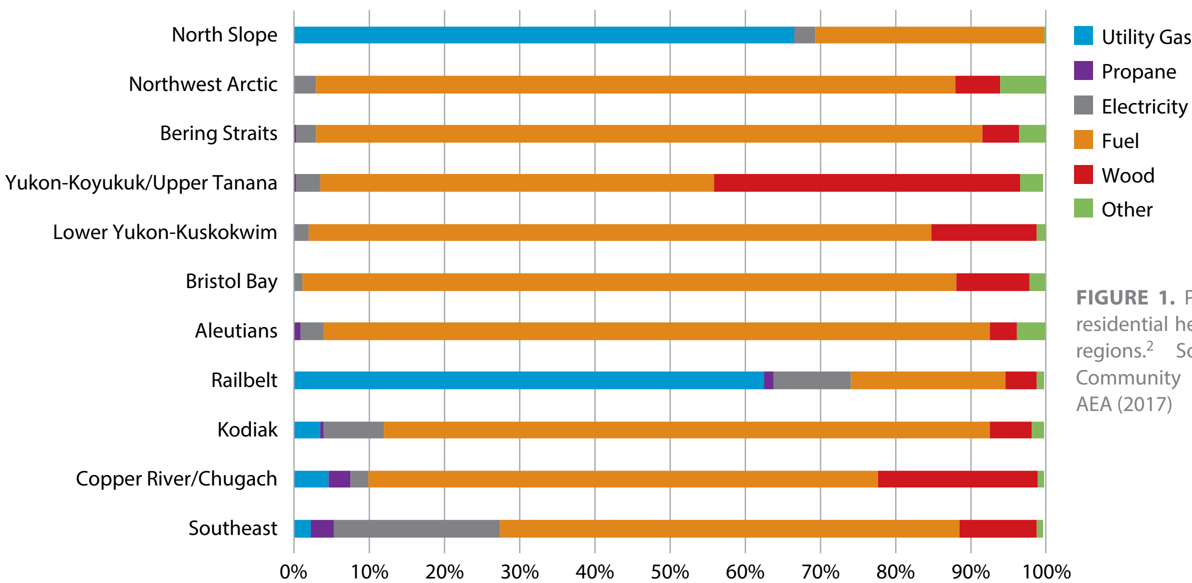


FIGURE 1. Primary source of residential heat in AEA energy regions.[2] Source: American Community Survey (2013), AEA (2017)

TABLE 1. RETAIL HEATING FUEL PRICES PER GALLON ACROSS ALASKA, JANUARY 2017.

	Gulf Coast	Interior	Northern	Northwest	Southeast	Southwest	Western
High	$6.90	$12.00	$2.50*	$7.21	$4.60	$6.85	$7.32
Low	$2.30	$2.40	$1.40*	$3.50	$2.79	$2.56	$3.95
Average	$3.48	$4.83	$1.74*	$4.92	$3.27	$4.35	$5.17

* Fuel costs in this region are subsidized by the North Slope Borough.

[1] Personal communication – Neil McMahon, Alaska Energy Authority

[2] Alaska Energy Authority. 2017. The Alaska Affordable Energy Strategy: Methodology, Finding and Recommendations. https://goo.gl/2q6vLP

[3] Alaska Fuel Price Report: Current Community Conditions, January 2016. https://goo.gl/ovN9C7

[4] Saylor, B., S. Haley, and N. Szymoniak. 2008. Estimated Household Costs for Home Energy Use. Institute of Social and Economic Research, University of Alaska Anchorage, Note 1, 10 pp. https://goo.gl/9zKwSC

Within regions, prices also vary over time and depend on accessibility. For example, some river communities that traditionally received shipments by barge are no longer able to, due to changes in the seasonal river flow which has resulted in low water levels at critical times. These communities now rely on fuel delivery by airplane, which is a significantly more expensive means of transport.

Due to their remoteness and the infrequency of fuel delivery, many communities routinely purchase and store large quantities of diesel fuel to last until the next fuel delivery season (generally, a full calendar year). As a result, fuel prices also include the operational cost of community bulk fuel storage, and are not influenced by the seasonal variability seen in other parts of the country.

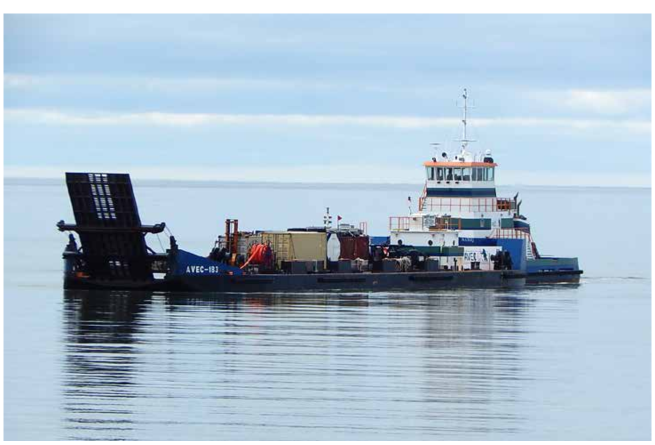
In addition, because the cost of home heating fuel is not regulated by the State of Alaska, local retailers can incorporate other expenses, such as the cost of debt for bulk fuel loans, when setting the price of heating fuel within the community. This leads to substantial variation between communities with similar geographies and logistical circumstances.

Renewable energy and energy efficiency strategies are seen as potential means of reducing residential heating costs by reducing dependence on expensive diesel fuel oil in these communities. The Arctic Renewable Energy Working Group (AREWG), coordinated by the US Arctic Research Commission (USARC), promotes research on renewable and efficient energy systems in remote Arctic communities. Formed in 2015, this working group aims to benefit rural Arctic communities by identifying and addressing critical research needs related renewable energy and energy efficiency.

Initial efforts of this working group have focused on the home heating needs of isolated Alaska villages. AREWG hosted an initial workshop (Workshop 1) in January 2016 to identify data gaps and research needs related to residential heating in remote Arctic villages. In order to better understand how renewable energy systems, energy efficiencies, as well as education and policy level efforts might best address heating needs for remote communities, a review of the status quo and identification of data gaps was the seen as a necessary first step. A report from the initial workshop is available at the following web site: https://goo.gl/5fMt84.

The second workshop (Workshop 2) of the series, held in December 2016, was convened to plan for the implementation of research needed to address data gaps and research questions related to residential heating which were identified in the initial workshop (January 2016). **The objective of the second workshop was to develop pathways and strategies to address outstanding data gaps and research needs.** A future work shop will focus on evaluation of efforts, outcomes and lesson learned (2018).

Participants in the second workshop included representatives from a wide variety of agencies and institutions (see full list on page 2).



AVEC's tugboat and barge making a fuel delivery in Shaktoolik, Alaska. *Credit: Karl Haddow*

Bulk Fuel Tank Farm in Emmonak, Alaska. *Credit: AVEC*

Matrix of Research Needs

A review of the research needs and priorities identified during Workshop 1 was provided at the outset of Workshop 2. Research needs were categorized into one of three groups—Data & Technology Needs, Socioeconomic Needs, or Policy & Collaboration Needs—to create a Research Needs Matrix (Appendix 1). This matrix was created to serve as a framework for the Workshop 2 effort.

The matrix created identifies research questions and, when possible, specific data metrics needed to answer the research questions identified during Workshop 1. It also includes a column to note progress made by various entities on these research questions since the January 2016 meeting (see Appendix 1).

Given the time interval between the two workshops, it was necessary to update participants on projects that had been completed or were currently underway which address research needs identified in Workshop 1. This information was used to populate the "Progress" column of the matrix. Three formal presentations were provided by representatives from the AEA, CCHRC and UAF/ACEP to review progress. These presentations can be accessed at https://goo.gl/PLp1AV.

Presentation 1: Development of the Alaska Affordable Energy Model (Alaska Energy Authority)

In 2014, AEA was tasked by the Alaska State Legislature to provide recommendations (by January 2017) aimed at improving the affordability of energy in the areas of the state that will not be served by a natural gas pipeline (the area broadly defined as the Railbelt Region). As part of the overall Alaska Affordable Energy Strategy (AkAES) project, the Alaska Affordable Energy Model (AAEM) was developed to help communities evaluate potential energy infrastructure projects that may reduce the cost of energy. The model is also aimed at assisting the state of Alaska in making energy policy decisions. To initialize this model, AEA conducted a large data collection effort, pulling together available information related to energy costs (both electrical and heating). This included the best available data on village level energy consumption, generation and cost for 240 separate Alaska communities. Community data was gathered from over 100 sources including US census data (2010; American Community Survey), housing data from the AHFC's Alaska Retrofit Information System (ARIS), research on potential and existing renewable energy projects, and fuel pricing data. Most of this information is housed on the Alaska Energy Data Gateway and through the Alaska Energy Data Inventory (Sidebar 1). As a model validation check, the model was used to estimate annual consumption of heating fuel for 100 communities based on available community data. These estimates were shared with the fuel supplier for these communities who provided feedback that the estimates were within 10–20% of the actual fuel amounts delivered to the communities, indicating that this model is providing reasonable estimates. While this model uses the best available data, it was noted that in the study areas (outside of the Railbelt Region), heating fuel is generally supplied by unregulated local heating oil companies. As a result, the volumes and type of heating fuel consumed at the residential household level is not precisely known and assessments must be at the community or regional level.

Sidebar 1. Alaska Energy Data Resources

The **Alaska Energy Data Inventory** (AEDI; https://goo.gl/9pZN1M) is a partnership project between the AEA, the University of Alaska's Geographic Information Network of Alaska (GINA) and the Alaska Department of Natural Resources Division of Geological and Geophysical Surveys. The main goals of the AEDI project are to a) inventory and consolidate available Alaska energy resource data suitable for electrical power generation and space heating needs and b) help identify locations or regions where the most economic energy resource or combination of energy resources can be developed to meet local needs.

The **Alaska Energy Data Gateway** (AEDG; https://goo.gl/7Um5iU) is a public resource initially funded by a grant to the University of Alaska from the Department of Energy's Experimental Program to Stimulate Competitive Research (EPSCoR) program and now supported by State funds through the Alaska Energy Authority. This resource provides the public, as well as project developers and researchers, with energy data from across the state aggregated at the community level. With this information, the public can make informed decisions about energy issues in their communities and see how similar issues are being addressed in other parts of the state.

The large data collection effort undertaken to initialize the AAEM addresses data collection gaps identified at Workshop 1, specifically as they relate to community infrastructure and building types and use. The model also assists with understanding the impact of policy on the cost of heating in rural communities, a research need raised during Workshop 1.

The CCHRC demonstration home in Anaktuvuk Pass. *Credit: USARC*

Presentation 2: Monitoring Home Energy Use (Cold Climate Housing Research Center)

The CCHRC has been working on residential home heating issues with the aim of testing, developing and vetting building and heating technologies for the North. Demonstration homes have been built in 17 Northern communities (such as Anaktuvuk Pass, Quinhagak, Atmautluak, Galena, Fairbanks and Bethel) and CCHRC has been monitoring heating fuel use at these demonstrations homes since the first one was constructed in 2008. This monitoring has shown that these energy-efficient homes use 1/5th the amount of heating fuel that typical houses use in the same community while being comfortable and socially accepted at the local level. CCHRC has also worked with the Alaska Housing Finance Corporation (AHFC) to develop, improve, and begin verifying the "AKWarm" energy modeling software, which is an effective proxy for energy use for homes which cannot be directly measured (due to high costs of automated monitoring and/or high variability in data quality when measured manually). Initial efforts to compare modeled energy use with actual energy use of select homes have indicated the AKWarm software models are within 10-15% of the actual energy use, however further verification is needed.

A second project conducted by CCHRC in association with AHFC is the 2014 Alaska Housing Assessment.[5] The Alaska Housing Assessment provides an overview of housing characteristics in Alaska so that housing authorities, policymakers, funding agencies and other interested parties can make informed decisions about resource allocation and housing program management.[6] Characteristics included in the Housing Assessment include metrics on community features, residential overcrowding and energy usage/cost, as well as housing affordability. Information is available at the state, regional (Alaska Native Claims Settlement Act region), US census area, and community level. Data for this assessment was drawn from the Alaska Retrofit Information System (ARIS), the 2011 American Community Survey (ACS), the 2009 Residential Energy Consumption Statistics from US Energy Information System, and the 2010 US Census. An updated Alaska Housing Assessment is due out in summer 2017 and will provide similar, but more current information.

One of the research questions raised during Workshop 1 was the need to understand the context of heat need for individual residences in a community. The Alaska Housing Assessment addresses this by providing a summary of the housing characteristics in a given community including summary information on the age and relative air-tightness of homes as well as the types of fuel used to provide heating.

Presentation 3: Filling Data Gaps through Collaboration (Alaska Center for Energy and Power)

In November 2016, ACEP, ISER and USARC co-sponsored the Alaska Community Data Workshop. Its purpose was to bring together users and collectors of data in Alaska to discuss what data is currently being collected, its limitations, gaps, and the potential for establishing an Alaska data portal. This data portal could be an expansion of the current Alaska Energy Data Gateway or a new data gateway that would include spatial and numerical data portals

[5] 2014 Alaska Housing Assessment. https://goo.gl/PdHhpx

[6] Wiltse, N., D. Madden, B. Valentine, and V. Stevens. 2014. *2013 Alaska Housing Assessment*. Cold Climate Housing Research Center. Prepared for: Alaska Housing Finance Corporation.

that allow communities, researchers, and agencies to access existing databases relevant to Alaska communities. This data portal would not be limited to energy data but would aim to provide a home for all community relevant data (economic, ecological, infrastructure, energy, social, cultural, health, etc.). During the workshop, commonalities in data collections among agencies and organizations were identified along with realization that data some organizations thought was missing or not being collected is actually available from other agencies. This last finding stressed the need for use of a common site (portal) that could bring together scattered data sets. Moving forward, ACEP will be pursuing support through the National Science Foundation Arctic Sciences division to facilitate Alaska community data rescue, discovery, dissemination, and coordination. Once established, this effort will address the need for a database of rural community infrastructure, buildings and homes that was identified as a research need in Workshop 1.

Following these three formal presentations, workshop participants discussed other known projects or efforts that could address research needs listed in the matrix. Additional research needs were added to the list as participants worked through the matrix.

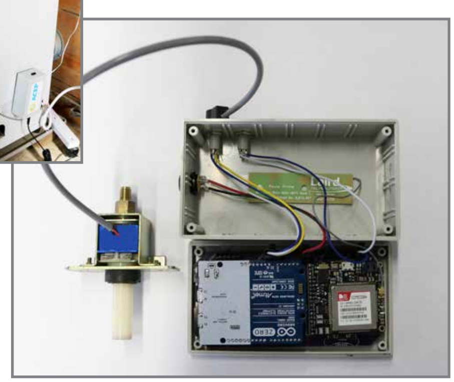
Data and Technology Research Questions and Needs

The first, and perhaps most pressing, data gap identified at the initial heat workshop in January 2016 was the need for **basic, fine temporal scale data on energy and fuel type use for residential heat** in remote arctic villages. While the 2014 Alaska Housing Assessment database mentioned above provides data on the average annual energy usage and cost for housing units in each community or region, it does not provide data at an appropriate temporal scale to answer questions that address how renewable energy systems, energy efficiencies, or education and policy level efforts might improve heating efficiency and reduce costs. Understanding how renewable systems, such wind-to-heat energy, could be implemented and what behavioral modifications would reduce fuel usage requires fine-temporal scale data on the current types, volumes and rates of fuel used. This type of data would also allow further and more detailed verification of home heating models such as the AKWarm model and allow more research to address behavioral aspects of energy usage. Obtaining this type of data has been challenging as currently available heating fuel meters, while measuring volume of fuel used, do not provide information on the rate and timing of fuel use and do not record or display information for the homeowner. Currently available heating fuel meters also tend to be very expensive and require breaching the fuel system to install. It was shared that ACEP has developed a prototype for an inexpensive, non-invasive fuel meter that provides continuous real-time data on fuel oil consumption (see Sidebar 2). These units can be easily retrofitted to fuel oil heaters, typically found in remote Arctic homes, however this device is still in the testing stages of development.

Sidebar 2. ACEP's Pump Monitoring Apparatus

The Pump Monitoring Apparatus (PuMA) has been developed by the Alaska Center for Energy and Power as a means of obtaining data on real-time diesel fuel oil consumption for individual residents. This device's installation does not require breaking into the fuel system and thus can be mounted by a residential user with basic written instructions. PuMA is able to record consumption over time and transmit the data to a central repository via SMS or MMS (cellular texting). Information and data collected and displayed by this device provides information to homeowners about their residential fuel use, including fuel remaining in the tank. This meter has been pilot tested at a few homes in the Fairbanks area but additional funds are needed to further test, refine and validate the system before it can be deployed and used in remote communities.

ACEP's PuMA fuel meter installed on residential heating stove. *Photo credit: Amanda Byrd/ACEP*



Internal components of the PuMA fuel meter. *Photo credit: Amanda Byrd/ ACEP*

Data from home heating fuel meters can provide baseline information for long-term improvements such as weatherization, allow for an understanding of the impact of behavioral changes on heating fuel use, provide insight into seasonal and diurnal heating needs, and create a data set for research and analysis that could inform policy. – G. Holdmann, ACEP

Metering of residential fuel use for heat would benefit not just academia and research needs, but would facilitate more persuasive grant applications and decrease risk when seeking public or private energy-related financing packages by providing higher quality data. If data were available to highlight the rate and volume of heating fuel used in remote communities at the scale of the individual home, it would help to bring more cost certainty to project developers when looking for feasible projects.

Additionally, this fuel use information could benefit homeowners by allowing them to see the relationship between the volume and cost of fuel used (allowing for budgeting) and how cost-saving adjustments track with behavioral changes in heat use. This has been shown to be true with the use of prepayment meter systems to monitor residential electrical use (see Sidebar 3), in several remote communities in Alaska and around the world. In communities where these meters have been installed, residents noted significant savings on their electric utility expenses immediately through the increased energy conservation behaviors activated by watching their money being spent on the in-home display of the prepayment electrical meter system.[7]

Sidebar 3. Prepayment Electrical Utility Meter Systems

Prepayment Electrical Utility Meter Systems require the residential customer to purchase a volume of electricity in advance. The meter, installed in the home, tracks actual electrical usage and removes the funds from the customers account in real-time. The meter display shows the level of electrical usage and the amount of funds remaining in the customers account. These types of systems provide specific data to the homeowner on energy usage and have assisted households in conserving energy. In Alaska there are currently two types of prepayment electrical meter system in use: "PowerStat" deployed by Precision Power, LLC and the "Ampy Meter" deployed by Marsh Creek, LLC. These prepayment systems are used in approximately 20 small villages statewide.

It was noted that when individual home metering of heating fuel usage in real time is not available, data regarding the amount of fuel purchased from suppliers at the individual residential scale would be useful to understand the overall heating fuel usage of homes and provide a baseline against which to assess improvements. This data does exist, however, it is difficult to obtain from the suppliers due to a number of concerns. Not only would extracting and sharing this type of data consume already constrained staff time, but there are high-level concerns, such as cyber security and price competition impacts, that make fuel suppliers hesitant to provide information and data publicly. The concept of data availability agreements or policies was discussed. It was shared that a model for a data agreement does exist and has been used by AHFC in their work with various entities including academic institutions, CCHRC, AEA and the Alaska Department of Health and Social Services. A key aspect of the AHFC data sharing agreement focuses on the confidentiality of the individual homeowner or building data and the use of aggregated data to insure this confidentiality. Some workshop participants felt strongly that there should be mandatory public data agreements for publicly-funded (including federal or state) energy projects/fuel suppliers with requirements for reporting energy use. It was also suggested that small grants of some kind could be used to help fuel suppliers with the personnel cost of providing this information.

[7] Personal communications – Jessie Huff, USDA-Rural Development, and Connie Fredenberg, Utility Management Assistance

Another data need identified at the initial workshop was **a database of rural community infrastructure and buildings** to include information about the number and types of buildings in each community, the size and spacing of buildings as well as the current method of heating for all buildings. While some of this data is currently available through the Alaska Retrofit Information System (ARIS), via AHFC's energy audit and weatherization programs, not all of the information listed in the Research Needs Matrix is available. Specifically, the current ARIS database does not account for non-residential (i.e., municipally or tribally-owned buildings) and in many cases the size, current method of heating and vacancy status of buildings in audited communities is not complete. The Alaska Energy Data Gateway also contains some of these data measures which AEA is utilizing in the Affordable Energy Model.

Sidebar 4. Alaska Energy Wiki

The Alaska Energy Wiki was created and powered by UAF's Alaska Center for Energy and Power. The Energy Wiki was designed to help readers learn about the state's diverse energy needs. The site provided information on raw energy resources and the technology developed to utilize those resources. The site also shared information on the challenges that these technologies and resources present. Energy related project information and energy related events were also posted to the Wiki. While still accessible (http://energy-alaska.com), the Wiki has not been updated since 2013 due to lack of funding.

Research questions related to the possible use of district heating systems for residential heating, the production of heat through small scale anaerobic digestion of sewage, food or fish waste at the residential scale, and the potential for methane as a fuel source for residential heating were also revisited. In all cases, data on residential home heat use and the geographical layout of community buildings and infrastructure are required in order to determine the needs and feasibility of an alternative energy system. Several examples of district heating systems proposed or already in use in Alaska were discussed (Chena Hot Springs, Dot Lake, Galena). It was noted that residential district heating is successfully used in several other Arctic countries such as Iceland and Russia but that success is highly dependent upon community layout which may pose a challenge for remote Alaskan villages.

A working group, led by USDA-RD, is currently being assembled to investigate the feasibility of using anaerobic digestion of sewage, food or fish waste as a way to provide net zero waste and water facilities in Alaska communities. This technique has potential, but, as of yet, is relatively unexplored in Alaska with two exceptions: a study on the use of methane gas seeps in Atqasuk, Alaska conducted by ACEP found that switching to a methane fuel for residential heating would not be economical for the community[8] and a second project, conducted by high school students in Cordova, Alaska, that investigated the use of psychrophiles (cold loving microbes) for the purpose of improving efficiency in biogas digesters for generation of cooking and heating gas for Alaska households. Results showed that residential-scale biogas digesters for cold climates are not economically viable at this time.[9]

It was noted that heat technology research is a continually evolving field with work being done around the world. Studies into the ability to turn renewable resources (hydro, wind, solar) into electrical heat, solar technology that combines waste heat from solar thermal systems to heat water, and battery storage technologies are taking place. Studies are also taking place that examine the potential for air-source heat pumps to function efficiently in cold climates. Case study write-ups for both international and Alaska-based research in heat technology would have significant value, especially if case studies incorporated "lessons learned". A repository, similar to ACEP's Energy Wiki (Sidebar 4) would be of benefit to the public but requires funding and manpower to maintain. Both AEA and AHFC have some case studies already compiled for Alaska-based projects.

Additional research questions related to building envelopes and ventilation were added to the Research Needs Matrix. Data is needed not only on the state of existing building envelopes but also for design needs of building envelopes in order to address mold avoidance and breathability. Studies have taken place in Greenland and current work with the ANTHC/CDC Air and Healthy Homes program[10] may be of use.

[8] Walter, K., D. Witmer, and G. Holdmann. 2009. Final Report: Field Exploration of Methane Seep Near Atqasuk. University of Alaska Fairbanks; DOE Award number: DE-FC26-01NT41248.

[9] Pathan, S., A. Villalobos-Melendez, and G. Fay. 2012. Cordova Psychrophiles Bio-Digester Benefit-Cost and Sensitivity Analysis, Technical Report, Institute of Social and Economic Research, University of Alaska Anchorage, prepared for the Denali Commission, 12 pages. https://goo.gl/SRFt8t

[10] Alaska Native Tribal Health Consortium Air & Healthy Homes program. https://goo.gl/i1gkqq

Socioeconomic Research Questions and Needs

The direct, high cost of fuel oil for residential heating in remote Arctic communities, as well as the potential indirect impacts of continued fossil fuel use led to many socioeconomic research questions at the initial January workshop.

An important area of socioeconomic research needed involves the **impact of energy subsidies on remote Arctic communities**. There is currently no specific State economic subsidy for home heating in remote villages in Alaska. The previously available Alaska Heating Assistance Program did not continue after FY2016 due to the reductions in the State budget. Other energy subsidies such as the federal Low Income Home Energy Assistance Program (LIHEAP) and the state's Power Cost Equalization (PCE) program provide some relief from high energy costs to home owners. In the case of PCE, residents are subsidized up to a certain threshold of electrical power usage per month. This threshold does not cover the level of electrical energy needed to make electric heat feasible. Similarly, the federal LIHEAP program helps low income households pay for heating or cooling their homes. In most states, it also helps people make sure their homes are more energy efficient by paying for certain weatherization home improvements.

When considering energy subsidies and their impact, workshop participants noted it is important to ensure policy makers understand the true cost of energy in remote communities. Often the true cost of energy production to the community or state is much higher than the cost to the consumer. The Alaska Affordable Energy Model recently developed by AEA (referred to on page 5) provides economic projections of the cost of an energy project to the community and consumer regardless of subsidies. This model will allow decision makers to have a more informed understanding of the true cost of home heating, energy consumption and cost in remote communities. Additionally, AEA's Affordable Energy Strategy report,[2] publicly released in January 2017, examines the impact of various Alaska State energy programs on energy (both electric and heat) affordability. Many of these programs focus on providing capital funds (in the form of grants or loans) to develop or improve the infrastructure and efficiency of current energy production, thus decreasing cost to the consumer. Some programs, such as AHFC Weatherization program and Home Energy Rebate program, focus directly on improvements that can be made to individual buildings to increase efficiency, thus reducing the amount of fuel needed to heat the building. While the impact of these energy programs is well described, further study is needed to gain a better understanding of the implementation process needed and potential impact of a direct subsidy for home heating in remote Arctic communities. It is currently unclear how a subsidy to an unregulated fuel supplier service would be managed to the benefit of the homeowner. Further consideration of some kind of heating energy subsidy, similar in

Snow drifts against residential homes in Wales. *Credit: AVEC* structure to the PCE program for electrical energy, would be helpful but unlikely to come to fruition given Alaska's current fiscal climate.

The concept of using subsidies to help finance renewable energy projects is of great interest as communities often do not possess the capital to implement new projects. To gain a better understanding of the true impacts of energy, and specifically heat subsides, it was suggested that information be compiled that includes all subsidies coming into any given community with updates to this information being provided each fiscal year.

One participant noted that at the base of all these socioeconomic questions is the need to understand the household level of fuel use for heat. This information forms the foundation against which various subsidy structures and policy implementations can be considered. As discussed above, this kind of household level heat use data is not readily available.

Other socioeconomic questions raised included the potential impact of multi-family housing on heating use and cost. AHFC indicated that teacher housing models in several communities are moving towards multi-family configurations to create efficiencies of scale and this may be a source of data to examine these questions in the future. However, it was also noted that the cultural acceptability of multi-family housing is variable across Alaska.

Additional questions were raised about the barriers and challenges to local implementation of renewable or energy efficiency projects. While it was agreed that lack of funding is the biggest barrier, village-level capacity is also an issue for many aspects of project implementation, including operations and maintenance, availability of certified trade positions and administrative aspects. AHFC reported that their Home Energy Rebate program was less effective in the rural communities because communities lacked the certified technicians to install modifications and also because it was expensive to purchase and ship materials required for the energy efficiency improvements out to communities. It was also noted that there are often communication and financial education barriers present (e.g., lack of communications, operations data not being used to inform financial decisions), resulting in a disconnect between the fiscal decision makers for the community and those (such as the operators) that can have an impact on the efficiency of the system.

The concept of "economies of scale" and how to achieve them when planning energy projects for rural communities was also revisited and discussed. It was noted that a common definition of the term "economies of scale" was needed in order to be able to determine if such economies of scale or scope were realistic for remote Arctic communities. It was also suggested that economies of scale could be achieved through the implementation of whole village retrofits—similar to what was carried out in Nightmute in 2008 and 2009.[11] It was noted that while this is theoretically a feasible strategy, it is often difficult to execute due to a shortage of local skilled laborers. It was also noted that these kinds of large programs require a "Project Developer" to pieces together the planning, funding and implementation of the project. Often, villages do not have a local person trained in a level of project management that would allow execution of a project in an efficient and economical way. In an attempt to address this gap, AK Department of Transportation (AK DOT), in conjunction with AHFC, recently pre-qualified a set of Project Developers[12] who are available to provide project development and energy efficiency consulting services to any entity that chooses to access and pay for their services. The services include building energy audits, general consulting, design consulting, measurement and verification analysis, energy saving reporting and building maintenance and operation staff training.

The question of how to minimize risk to investors to augment installation of renewables in remote Alaska was also raised in the initial January workshop. Since that time ACEP has develop a report on this topic based on a literature review and a series of interviews and roundtable discussions focused on energy infrastructure development in communities located outside the Railbelt Region.[13] The Alaska Affordable Energy Strategy report also explores the risk and barriers to successful energy project implementation and identifies three categories of risk: developmental, financial and operational. General risks were also identified and include a lack of resources, leadership, economics and weather or climate related events.[2]

[11] Conway, K. Nightmute Whole Village Retrofit—Then and Now. Alaska Energy Authority. https://goo.gl/MRV5Yi
[12] Pre-Qualified Project Developers program. https://goo.gl/VK758T
[13] Holdmann, G., D. Pride, J. McGlynn, A. Byrd, and S. Colt. 2016. Barriers to and Opportunities for Private Investment in Rural Alaska Energy Projects. https://goo.gl/fyBAup

Policy and Collaboration Research Questions and Needs

At the initial workshop on research needs, several questions regarding the role and impact of policies related to home heating and energy efficiency in rural communities were raised. It was noted that the current state energy policy (see Sidebar 5), passed in 2010, sets goals for energy efficiency and use of renewables. However, there has been no formal documentation of progress made since the State Energy Policy was enacted possibly due to the State of Alaska's limited financial ability to fund such a study. A report by ISER submitted to the Alaska Legislative Affairs Agency and State Senate Energy Working Group in January 2013 provided energy policy recommendations and suggested a potential heating fuel cost reduction program, similar in structure to the PCE program.[14]

Sidebar 5. State of Alaska Energy Policy

In July 2010, the State of Alaska passed House Bill 306 declaring a State Energy Policy.[15] This policy stated that it was the intent of the legislature that:

1. the state achieves a 15% energy efficiency improvement between 2010 and 2020;
2. the state receives 50% of its electrical generation from renewable and alternative energy sources by 2025;
3. the state work to ensure a reliable in-state gas supply for residents;
4. that the Power Project Fund serves as the main source of state assistance for energy projects; and
5. the state remains a leader in petroleum and natural gas production and become a leader in renewable and alternative energy development.

Another policy issue that impacts residential home heating needs is energy codes for buildings. Currently Alaska has no standard *state-wide* energy codes for buildings, although most new construction follows the Building Energy Efficiency Standards (BEES). A whitepaper, commissioned by AHFC and conducted by CCHRC, found that there are currently six different agencies that have input on building energy codes with 34 (multi-part) statutes which are not always congruent.[16] The Alaska Affordable Energy Strategy strongly recommends the establishment of residential and non-residential building energy codes for new construction and major renovations. The Alaska State Home Builders Association has also lobbied the Alaska Legislature for a state-wide building code that would level the playing field for all builders. A comprehensive statewide building code would create a minimum safety standard as well as a minimum energy efficiency standard.

From the perspective of lenders and homeowners, the minimum energy standard established by a comprehensive statewide building code would protect homeowners from skyrocketing energy costs in the winter months, decreasing the chances of defaulting on mortgage payments. The required safety standards could improve indoor air quality which will reduce health costs and lost person-days of work. – B. Grunau, CCHRC

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[14] Colt, S., G. Fay, M. Berman, and S. Pathan. 2013. Energy Policy Recommendations. https://goo.gl/ux9wYD
[15] The Alaska State Legislature. https://goo.gl/EfNLzw
[16] Davis, J., and K. Dodge. 2012. Statewide Codes White Paper. Cold Climate Housing Research Center.

Prioritization of Research Needs and Strategies for Implementation

To prioritize research needs that had not yet been addressed by efforts over the previous year and to strategize for implementation of new efforts, workshop participants divided up into separate breakout groups (Data and Technology Research Needs, Socioeconomic Research Needs, and Policy & Collaboration Research Needs) with each group focused on a specific research need category.

An AVEC lineman checks on a new Elster electronic meter being installed in Shishmaref. *Credit: AVEC*

Data and Technology Research Needs

There was general concurrence that the most pressing need in the Data and Technology category was **basic, fine temporal scale data on individual home heating fuel use**. This would include information on the volume of fuel oil used and timing of use throughout the day and year. Additional information about all other home heating appliances (e.g., wood stove) in the home, and their use (running or not) would also be needed to accurately measure heat use. Homes involved in this research would also need a concurrent (or very recently completed) energy audit to place heating fuel usage in context.

The most straightforward strategy identified for addressing this research need was to encourage the continued technology development and follow-up deployment of low-cost, non-invasive heating fuel meters on individual homes in remote Arctic communities. Academic and technology development entities would be best suited to conduct this research. Institutions such as the CCHRC can offer assistance with validation of developed heat fuel meters and act as an independent evaluator if needed. AHFC's weatherization program may be able to assist with launching a pilot study by helping to install heat fuel metering devices in communities where they are conducting weatherization projects, thus reducing some of the overhead costs of mobilizing separate work crews to deploy them. It was also suggested that students at UAF's Bristol Bay campus, could potentially assist with validation studies by installing these heating fuel meters at their homes. It was noted that involvement of UAF students in such a project may qualify for funding through the National Science Foundation's Tribal Colleges and University Program[17] (TCUP) which provides awards to tribal Colleges and Universities, Alaska Native-serving institutions, and Native Hawaiian-serving institutions to promote high quality science, technology, engineering and mathematics (STEM) education, research, and outreach. Other similar funding opportunities may also exist. Research projects to develop and test heating fuel meters for Arctic homes were also thought to be of potential interest to the Alaska Association of Housing Authorities and to community-based suppliers, and thus outreach to these groups may be beneficial in terms of financial or in-kind support.

Discussion of an implementation strategy to move ahead with development and deployment of heat fuel meters also included aspects of community involvement. Community meetings would need to be planned to explain the need, as well as the benefits to the community and to

[17] National Science Foundation's Tribal Colleges and University Program. https://goo.gl/gp1KFj

gain community acceptance of the effort. These types of community meetings may also be helpful in identifying specific homeowners interested in participating in studies to monitor heating fuel use at their residence. Some type of agreement with home owners would be necessary to cover liability issues, to gain permission to get utility information from the local utility (to examine relationship between home heat and electrical energy use), and use these data in study reports. It would also be helpful to have a specific person in the community serve as a local point of contact for the project who was trained to troubleshoot the heat fuel meters.

As an example, in the case of ACEP's PuMA project (see Sidebar 2, page 7), heating fuel meters need to be further tested and subjected to a larger scale pilot study for validation before deployment in homes in remote communities. ACEP is currently planning to deploy a limited number of meters in the Fairbanks area to test their use and specifically the data transmission system which relies on cell phone coverage in areas where the cellular signal may be relatively weak. If funding were available to deploy additional meters, pilot testing could be expanded to more rural communities (outside the Fairbanks area). Construction of the PuMA meters costs approximately $200/unit, however this construction is currently unfunded with two UAF student interns fabricating the units. Post-validation, there are funds available to deploy up to 250 heating fuel meters in remote communities as part of a NSF social science project **(**#1522836: Collaborative Research: Using Field Experiments to Understand Household Barriers to Energy Efficiency in Alaska**)** on energy use behavior changes in the fall of 2017.

While the group felt that the basic need for individual home heating fuel use data was by far the top priority, the need to **research heat technology that has been used in other Arctic environments** to assess the feasibility and effectiveness of converting renewable resources to electric heat in Alaskan rural communities was also a top priority. This could be done by examining the efforts and findings of heat technology case studies in other Arctic countries. Using lessons learned from research on heat technology such as wind-to-heat, sewage-to-heat, biomass and solar thermal systems in other areas with similar environments constraints could provide guidance regarding which technologies may be best suited to Alaska's remote communities.

Finally, **feasibility studies for residential district heating systems** in remote Alaska communities was considered a high priority. However, this task was seen as very broad, with unique challenges and solutions for individual communities given the unique physical and environmental features of each community. Investigation into the feasibility of district heating approaches as part of the relocation efforts for climate change impacted villages is warranted. Other Arctic countries are already doing these types of research and implementation of such work in the US Arctic should look to those international examples for guidance.

Socioeconomic Research Needs

Many of the socioeconomic questions raised in January 2016 are still relevant 12 months later, although projects such as the Alaska's Affordable Energy Strategy[2] (Chapter 5) and work by ISER[14] are beginning to examine the role of subsidies in home heating assistance.

The group felt many of the questions related to the barriers and challenges to local implementation of energy efficiency and renewable projects had been addressed: it is common knowledge that there is a lack of skilled labor in the rural communities to work on technical projects such as these. The group identified **resolution of this skilled labor shortage** as an important step, which could be addressed through engagement with pre-existing programs such as Alaska Rural Utility Collaborative (ARUC) and AEA's Operator Training programs, as well as through continued and increased engagement with state and regional colleges and universities. The group focused primarily on local support and encouragement of trades needed to work on energy projects by rural K-12 education and hub colleges. One means to address this would be to conduct a review of the Community Health Aid and Village Public Safety Officer programs as examples of how a potential skilled labor program could be structured to keep trained workers in rural communities. Questions were also raised about the number of skilled trade laborers (e.g., electricians, plumbers, HVC, linemen and welders) currently working in remote communities and programs in place to support continued training. The group was unaware of the answers to these questions and suspect they are also data needs. The group felt a promising way forward would be to regionalize skilled positions and encourage existing regional entities to adopt apprentice programs and grow their capacity to better accommodate the entire regions needs. *Note: Since this workshop took place the Renewable Energy Alaska Project (REAP) has initiated the Alaska Network of Energy Education and Employment (ANEEE) program.[18] The goal of the ANEEE initiative is to build a comprehensive energy network in Alaska that will inventory Alaska's energy education programs and provide a way for both education providers and consumers to see and understand what is available in the state. This program may be well-suited to explore education gaps and needs to establish a stable skilled labor force for the energy sector.*

The second priority research need identified by this group was the need to address the concept of **regional project development** in rural Alaska communities, including the creation of "project developer" positions. The group suggested examining the successes and lessons learned from project development examples both inside and outside of Alaska, focusing on project development that led to projects with business models that were based on large grant funds. A future evaluation of the rate of use and the effectiveness of AK DOT's pre-qualified Project Developers program[12] might be a first step. Exploring how this type of program could be expanded may also lead to addressing this need.

The group also raised the question of how to solve issues related to creditworthiness and limited financial knowledge. It was suggested that more collaborative projects were needed so that lenders could fund multiple homeowners as one unit to make projects bigger and more worthy of financial investment and a project developer's time. This aggregated approach would require a state, regional entity, or project developer, to organize and manage the project. Regional energy planning (Sidebar 6) was seen as a first step and a way to continue making progress addressing both the issue of economies of scale and as a means of minimizing risk to investors to augment installation of renewables in rural Alaska.

Sidebar 6: Regional Energy Planning

As defined by AEA,[19] Regional Energy Planning is a way for Alaskans to determine their energy priorities and formulate a concrete, implementable, and fundable energy plan. Each regional plan should address energy needed for electricity, heating and transportation. Each energy region can craft a specific action plan to ensure a less expensive, more reliable, efficient and sustainable energy future. Each planning effort should include regional stakeholders, document current energy resources, evaluate alternatives (both projects and strategies) for reducing energy costs and provide a prioritized action plan of projects that can be funded.

Questions related to the economic feasibility of district heating models were given lower priority by the group due to the variability of village physical layouts and because most communities already have some type of heat recovery system for utility or community/school buildings. While the concept of expanding the district heating approach or heat recovery concept to residential homes still needs development, each village will have their own set of strengths, challenges and barriers based on the layout of the community. Similarly, questions related to the use of multi-family housing as a means of increasing energy efficiency were given lower priority because individual communities need to accept the idea of multi-family housing as a solution before it gains traction. It was noted that, in some communities, current multiplex housing is not at maximum occupancy, as community members find this model unattractive and prefer having their own space/yard area.

Policy & Collaboration Research Needs

Questions related to policy and collaboration for improved residential heating in remote Arctic communities were reviewed by the third breakout group with consideration given to the previous discussion (above). It was determined that the top priority in this sector should be the **establishment of state-wide energy codes for buildings and a more robust and financially supported energy policy**. Efforts are in progress to establish standardized energy codes with specific efforts by CCHRC and AHFC. This includes commissioned research to analyze the multitude of current building codes used in the state. Additionally, AHFC, CCHRC and REAP have been providing research,

[18] Alaska Network of Energy Education and Employment (ANEEE) program. https://goo.gl/VhW9rU
[19] Alaska Energy Authority. http://www.akenergyauthority.org/Policy/RegionalPlanning

suggestions and education to various state officials in an effort to move towards a comprehensive building energy code for the entire state. This effort seems to be having an impact with a bill anticipated in the Alaska Legislature in late 2017. While movement is being made on the energy code aspect, development of a more robust and financially supported state energy policy requires more research and effort and is something that the AREWG group is considering as a potential new group objective.


Fuel tanks farm and wind turbines in Kasigluk, Alaska. *Credit: AVEC*

Another high priority identified was the need for **energy education and communication** in rural communities. REAP is working on the energy education component of this need and has developed resources for K-12 education efforts on clean energy and teacher training programs.[18] A productive next step would be to identify and encourage community-based agencies to work with the REAP program to determine what needs remain and how collaborations could be built to address those needs.

A research **review of the policies of other international Arctic communities** regarding energy and renewable energy resources was seen as an additional priority. Information on technology usage and approaches to heat utilities in other countries with remote Arctic communities would be beneficial as policies and approaches are established in Alaska. This was seen as a great opportunity for a graduate student or perhaps as a contracted study for a group such as ISER or AEA if it aligns with their research efforts. This type of international comparison research project may also be of interest to the Arctic Council.[20]

Increasing opportunities for **public-private partnerships** to develop renewable energy and energy efficiency projects and enhance residential heating options was identified as the group's final priority item. The recently released ACEP/AEA report titled "Barriers to and Opportunities for Private Investment in Rural Energy Projects"[13] outlines several approach recommendations. These include the development of a project specification process that would facilitates public-private partnerships for energy projects. The goal of this process would be to reduce the transaction costs (legal fees, permits, loan-closing fees, etc.) associated with project development for the private investor and ease the ability of the private investor to respond to opportunities that already have local community support. This report also recommends assessing how the regulatory environment could be adjusted or clarified to promote development of public-private partnerships that protect consumers. Additionally, the development of a Rural Energy Project Development Portal where potential borrowers could go to understand the available financing options, including public-private partnerships, was recommended. The Alaska Affordable Energy Strategy report[2] similarly notes that communities and investors (both public and private) lack data and data driven-support tools to identify potential infrastructure and non-infrastructure opportunities that could spur public-private partnerships. As discussed earlier in this report, community energy data is not systematically compiled making it difficult to assess the level of risk associated with a particular project in any given community. Similar to the Rural Energy Project Development Portal outlined in the ACEP report, consolidation of funding information in one accessible location is recommended in the Alaska Affordable Energy Strategy report.

Suggested funding sources to pursue these high priority items related to policy and collaboration included the regional corporations, AEA's Alternative Energy program, USDA-RD and Rural Utility Service program, and the US Department of Energy (DOE). Specifically, within DOE, the Indian Energy program may be a potential source but requires a 50% match. DOE funding is also available for policy efforts as it applies to tribes and would be available if work was done in partnership with ANTHC or housing authorities. Denali Commission may also be a funding source if future funds are received.

[20] Arctic Council Sustainable Development Working Group (SDWG). https://goo.gl/S8q4L1

Conclusion

Home heating is a critical service that can be difficult and expensive to maintain in remote Arctic communities, where winter temperatures fall well below freezing and fuel needs to be transported in via barge or air. The high cost of heating fuel and the reason behind these high costs have been well studied in Alaska.[2, 21, 22, 23] Effecting changes to mitigate these costs and implementing the use of alternative energy sources to reduce the dependence of remote communities on expensive diesel fuel for home heating continues to be a challenge.

This workshop examined the research progress made over the preceding year and developed pathways and strategies to address outstanding data gaps and research needs as they relate to residential heating in remote Arctic villages. The need for **basic, fine scale data on the volume and timing of heating fuel use for individual homes** was seen as a central research need that has yet to be addressed. Not only is this data needed for the development of technology and efficiency programs to reduce household dependence on expensive diesel fuel, but also to help inform socioeconomic and policy related questions. While efforts have begun to address this need, funding limitations have stalled progress. To reinvigorate this effort, workshop participants suggest exploring partnerships with other research and housing agencies as well as regional corporations to share the cost of the effort. Community participation and project buy-in were also seen as a key component of project success.

Implementing research to address questions and information needs for residential heating in remote Arctic villages requires funding to support the work. In the current climate of limited state and federal research funding this poses a serious challenge. While seen as an important issue in Alaska, funding for renewable energy or energy efficiency research projects is difficult to acquire. The Renewable Energy Fund, created by State Legislature in 2008 and renewed for 10 years in 2012, is a program which aims to provide financial assistance for feasibility studies, reconnaissance studies, energy resource monitoring, and work related to the design and construction of eligible facilities. In 2013, the program also established a target allocation for heat projects to compose 30 percent of the total funding recommendation. Despite the good intent of this funding program, it is subject to state appropriations and in 2016 no funding was appropriated due to other state funding priorities and a constrained state budget. Other sources of research funding for renewable energy and efficiency projects are also limited with a high level of competition for national grant and funding programs (e.g., NSF, DOE). In this funding environment, research collaboration and partnerships are increasingly important as is prioritization of research needs. Involving the private sector in the financing of renewable energy and energy efficiency projects is seen as an important step to fill the gap left by the diminished state and federal funding.[2,13] One option being explored by REAP to increase the participation of private investors, and recommended by the AkAES, is a state "Green Bank". Green banks are quasi-state institutions that work to bring private investors into deals to finance clean energy projects and have shown success in other states around the county. Building community capacity (financial, technical and managerial) and building networks between rural utilities at the regional level may also help private investors feel more comfortable investing in rural energy projects.

The Arctic Renewable Energy Working Group is focused on the continued progress and development of options for home heating that increase energy efficiency and use of renewable energy while reducing heating oil consumption in remote Arctic villages. A future workshop in 2018 will revisit the recommendations and research needs identified earlier and evaluate the success of implementation.

To learn more about the Arctic Renewable Energy Working group and access data resources and energy related publications referred to in this report, visit https://arctic.gov//arewg/index.html.

[21] Wilson, M., B. Saylor, N. Szymoniak, S. Colt, and G. Fay. 2008. Components of Delivered Fuel Prices in Alaska, June 2008. https://goo.gl/xFUPDo

[22] Szymoniak, N., G. Fay, A. Villalobos-Melendez, J. Charon, and M. Smith. 2010. Components of Alaska Fuel Costs: An Analysis of the Market Factors and Characteristics that Influence Rural Fuel Prices. University of Alaska Anchorage, Institute of Social and Economic Research. Prepared for the Alaska State Legislature, Senate Finance Committee, 77 pp.

[23] Alaska Attorney General. 2010. Rural Fuel Pricing in Alaska: A Supplement to the 2008 Attorney General's Gasoline Pricing Investigation. https://goo.gl/hz6RkF

Appendix 1.
Research Needs Matrix

Research Needs and Questions	Specific Data Needed to Answer Question	Progress to Date or Research Underway
DATA AND TECHNOLOGY NEEDS		
INDIVIDUAL HOME HEATING DATA (PER HOUSEHOLD)		
How is home heating fuel use distributed throughout out the day/night?	Fuel type(s) and use by hour	Continued need for cost-effective technology that will monitor heat fuel use at fine temporal scale for individual residences in remote communities; ACEP fuel meter development project on hold due to funding
How much of what fuel is used to heat individual homes on a seasonal basis?	Fuel type(s) and amounts by month (can be calculated from hourly data)	Data on heating fuel purchased by individual residences from fuel suppliers/retailers exists but not shared publicly; could be addressed with data from heat fuel meter (see above)
How much total heating fuel is used monthly for individual residences?	Fuel type(s) and amounts by month (can be calculated from hourly data)	Question could be addressed with data from heating fuel meter (see above)
What home heating appliances are in use?	List of heating appliances in use	AHFC's Alaska Retrofit Information System (ARIS) has this information gathered from homes that participated in AHFC's energy audit and Weatherization programs (n=17,000 homes)
Are any supplemental heating fuels used (other than oil) to heat the house? What is the "trigger" (i.e. threshold external temperature?) for use of the supplemental heat source?	Fuel type(s) and amounts by month, behavioral information	Fuel type data is in ARIS for homes that participated in AHFC's energy audit and Weatherization programs (n=17,000 homes); no known monthly fuel amounts data or behavioral information
What is the context of heat need for individual residences?	Age of home, R value of insulation of home	AHFC's Alaska Retrofit Information System (ARIS) has this information (n=17,000 homes); Data can also be found in the Alaska Housing Assessment report
HEAT FUEL USE DATA ON INDIVIDUAL HOME AND COMMERCIAL BUILDINGS		
	Fuel type(s) and amounts by hour	AHFC/ANTHC/AEA/Denali Commission/DOE village level energy audit information
DATA BASE OF RURAL COMMUNITY INFRASTRUCTURE, BUILDINGS AND HOMES (PER COMMUNITY)		
	Number of buildings and type (residential, city, tribal, business)	AHFC's Alaska Retrofit Information System (ARIS) has much of this data but does not include buildings that are municipally or tribally owed; AEA also has some of this data for some communities
	Size of buildings	Alaska Retrofit Information System (ARIS) has much of this data but does not include buildings that are municipally or tribally owed
	Spacing of buildings	No known progress/research underway
	Current heating method of each building	Alaska Retrofit Information System (ARIS) has much of this data but does not include buildings that are municipally or tribally owed
	Building use and status (vacant vs. occupied)	AEA assemble much of this data for the Alaska Affordable Energy Model for a number of communities
	Energy audit (census) data	Alaska Retrofit Information System (ARIS) has much of this data but does not include buildings that are municipally or tribally owed
	Distance to nearest community	No known progress/research underway
	Distance between communities in the region	No known progress/research underway

Research Needs and Questions	Specific Data Needed to Answer Question	Progress to Date or Research Underway
HEAT TECHNOLOGY CASE STUDIES		
Review of heat technology case studies (i.e., air-source heat pumps, biomass, waste heat and renewable energy resources to electric heat or water heat)	Feasibility data (results as compared to other methods and economics)	AEA has data on the complex economy related to the wind to electric heat model; Alaska Affordable Energy Model (https://goo.gl/Jj7BeL) also incorporates data from some of these case studies for this purpose
Solar technology that combines waste heat from solar thermal to heat water	List of past research trials and international research efforts that may apply to Alaska	There are currently several potential efforts being planned to begin addressing this question through ACEP and CCHRC
What are the opportunities for heat production through small scale anaerobic digestion of sewage, food waste or fish processing waste at the residential scale?	Fuel (input) resource information, community layout information, economic information	USDA-Rural Development has convened a working group to explore this question
What is the potential for methane as a fuel for residential heating in remote arctic villages?	Fuel (input) resource information, community layout information, economic information	Two studies have been conducted to date; both show that this is currently not an economically feasible strategy
DISTRICT HEAT		
Where are centralized district heating system possible to implement for residential heating?	Fuel resource information, community layout information, economic information	ANTHC has some of this information for community projects that may be applicable to residential applications
ENERGY STORAGE		
What are energy storage options: battery storage, ceramic block storage?	Current storage ability and type, amount/duration/timing of storage needed, economics	ACEP has developed a Research Briefing on this topic with specific research needs identified (https://goo.gl/g5cSr2)
SOCIOECONOMIC NEEDS		
IMPACT OF ENERGY SUBSIDIES		
How would a reduction or a change in structure in energy subsidies impact remote arctic communities?	Individual community and household economics (data on MHI and utility expenses, etc.)	AEA's Affordable Energy Strategy Report (https://goo.gl/2q6vLP), Chapter 5
Understanding the larger questions of subsidies (i.e., in Russia) and the possibility of using subsidies to finance projects (secure loans, etc.)	International data on subsidization and finance	ACEP is currently working on this topic with a specific focus on subsidies in Russia, Canada's North West Territories and Alaska
WHAT ARE THE SOCIAL AND BEHAVIOR BARRIERS TO IMPLEMENTATION?		
What are the challenges to local implementation of energy efficiency projects?	Capacity information, local governance information, information on technician turnover; social science research on attitudes towards EE/RE	USARC capacity assessment/improvement workshop(s)
What are the barriers to behavioral changes to implement energy efficiency efforts?	Social science research	Lister, C., and D. Ives. 2011. Recommendations for Alaska Energy Efficiency and Conservation Public Education and Outreach. https://goo.gl/pZetzT
What organizational/capacity barriers exist to implementing renewable energy projects or energy efficiency programs?	Capacity information, creditworthiness info, local governance information, social science research on attitudes towards EE/RE	AEA's Alaska's Affordable Energy Strategy report Chapter 4 (https://goo.gl/2q6vLP); ACEP's Barriers to and Opportunities for Private Investment on Rural Energy Projects report (https://goo.gl/P8ixBB); UAA Center for Economic Development report Financial Benchmarking for Rural Alaska Electrical Utilities (https://goo.gl/3kCFg3)
ECONOMIC CONSIDERATIONS		
How do we reach "economies of scale" in small remote Alaskan villages?	Individual home heating data, community infrastructure data, economic data, cost of transporting fuel/heat	AEA's Alaska Affordable Energy Strategy (https://goo.gl/Jj7BeL), Chapter 7, Recommendation C2
How do we minimize risk to investors to augment installation of renewables in remote AK?	List of risks from investors, economies of scale information, capacity information, economic information	ACEP's Barriers to and Opportunities for Private Investment on Rural Energy Projects report (https://goo.gl/P8ixBB)

Research Needs and Questions	Specific Data Needed to Answer Question	Progress to Date or Research Underway
Is district heating feasible for residential home heating in remote arctic AK?	Cost estimates, fuel resource information, community layout information, economic information	No known progress/research underway
What would be the impact of multi-family-housing on the solutions for residential heating?	Individual home heating data, community infrastructure data, economic data	Colt, S. 2015. Final Report: Benefits and Costs to Rural Alaska Households from a Carbon Fee and Dividend Program. https://goo.gl/xSpukd (This publication included a estimate of heating fuel use by home type, comparing single and multi-family homes.)
Would multi-family housing be socially acceptable to communities?	Social science research, health research	No known progress/research underway
POLICY AND COORDINATION NEEDS		
ENERGY CODES FOR ALASKA BUILDINGS		
What is the difference between state building codes/standards and community building codes/standards?	Code/standard comparison	Work by AHFC, CCHRC and REAP has been done to analyze state-wide energy building codes; Recommendations and information has been provided to AK State Officials to move forward with standardization
Are community specific building codes working in AK?	Economic data, comparison of community building code area to state building code area, individual home heating data	Alaska Housing Assessment data shows improvement over time with BEES standards; Data in ARIS could be used to investigate this question
ENERGY EDUCATION AND COMMUNICATION		
How do we provide accurate information on energy efficiency behaviors/ upgrades/programs to villages and consumers?	Additional data on communication best practices and behavioral impact	REAP's Alaska Network for Energy Education and Employment program (https://goo.gl/VhW9rU) is beginning to address this; Alaska Center for Appropriate Technology (http://acat.org) a community organization in Fairbanks, had begun an effort to develop path to net zero housing but this has stalled
How could a network of energy educators be created?	Economics/funding source, home institution availability, willingness to cooperate among regions	REAP's Alaska Network for Energy Education and Employment program (https://goo.gl/VhW9rU) is beginning to address this; CCHRC has been engaged with existing school programs; ANTHC's new collaboration with Alaska Pacific University may also provide an avenue for network enhancement
POLICY STUDIES		
What is the role of policy regarding heating in rural communities?	Additional information on relationship between policy research and policymaking with respect to heat	AEA's Affordable Energy Strategy Report, Chapter 5, January 2017
Which policies influence behavior with respect to energy efficiency?	Social science research; impact of state programs	CCHRC's Weatherization Assistance Program Outcomes (2012)
How do we approach prioritization and strategic planning to better inform renewable energy policy?	Additional information on relationship between policy research and policymaking with respect to heat	AEA's Alaska Affordable Energy Strategy Report (https://goo.gl/2q6vLP); Alaska Microgrid Partnership (https://goo.gl/usMMFk) is also starting to address this
What are the policies of other international Arctic communities regarding energy and renewable energy resources?	International policy data	No known progress/research underway
How do other Arctic communities approach administration of energy systems/services?	International data on energy system administration	No known progress/research underway
What is AK's long term vision for on renewable energy and energy efficiency? How does it compare to the federal vision?	Additional information on the current federal renewable energy vision	Current long-term vision is the 2010 Alaska Energy Policy (15% energy efficiency improvement by 2020, 50% of electrical generation from renewable energy and alternative energy sources); Comparison to federal vision has not been conducted
How do we increase opportunities for public-private partnership in the renewable energy sector in AK?	Additional information on risk/profit and community capacity	ACEP's Barriers to and Opportunities for Private Investment on Rural Energy Projects report (https://goo.gl/P8ixBB)
What new approaches to energy and maintenance management services would be effective?	Economic/cost effectiveness of regional approach	AEA's Alaska Affordable Energy Strategy Report (https://goo.gl/2q6vLP); AEA and UAA Center for Economic Development currently conducting study on ARUC-type model

BACK COVER PHOTO: Snow drifts over residential homes in Wales. *Credit: AVEC*

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